

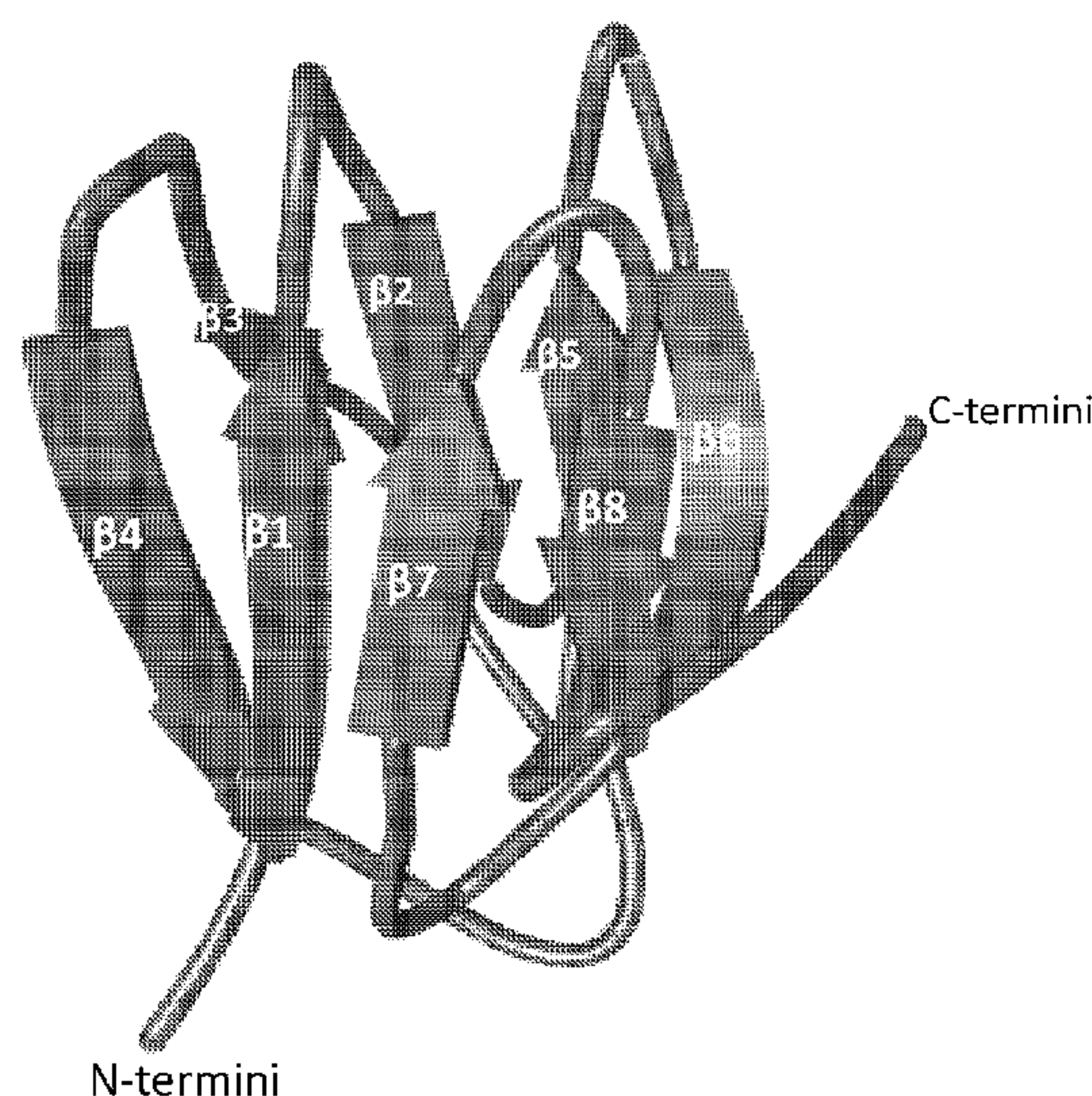


(86) Date de dépôt PCT/PCT Filing Date: 2016/03/03
(87) Date publication PCT/PCT Publication Date: 2016/09/15
(85) Entrée phase nationale/National Entry: 2017/08/28
(86) N° demande PCT/PCT Application No.: US 2016/020634
(87) N° publication PCT/PCT Publication No.: 2016/144686
(30) Priorité/Priority: 2015/03/11 (US62/131,491)

(51) Cl.Int./Int.Cl. *C12N 15/82* (2006.01),
A01N 65/00 (2009.01), *C07K 14/21* (2006.01),
C07K 14/415 (2006.01)
(71) Demandeur/Applicant:
PIONEER HI-BRED INTERNATIONAL, INC., US
(72) Inventeurs/Inventors:
LIU, LU, US;
ORAL, JARRED KENNETH, US;
POLAND, BRAD, US;
SCHELLENBERGER, UTE, US
(74) Agent: TORYS LLP

(54) Titre : METHODES BASEES SUR LA STRUCTURE, POUR MODIFIER LES POLYPEPTIDES PIP-72, ET
POLYPEPTIDES PIP-72 AINSI OBTENUS
(54) Title: STRUCTURE BASED METHODS FOR MODIFICATION OF PIP-72 POLYPEPTIDES AND PIP-72
POLYPEPTIDES DERIVED THEREFROM

Fig. 1



(57) **Abrégé/Abstract:**

Compositions and methods for controlling pests are provided. The methods involve transforming organisms with a nucleic acid sequence encoding an insecticidal protein. In particular, the nucleic acid sequences are useful for preparing plants and microorganisms that possess insecticidal activity. Thus, transformed bacteria, plants, plant cells, plant tissues and seeds are provided. Compositions are insecticidal nucleic acids and proteins of bacterial species. The sequences find use in the construction of expression vectors for subsequent transformation into organisms of interest including plants, as probes for the isolation of other homologous (or partially homologous) genes. The pesticidal proteins find use in controlling, inhibiting growth or killing Lepidopteran, Coleopteran, Dipteran, fungal, Hemipteran and nematode pest populations and for producing compositions with insecticidal activity. Structure based methods for engineering insecticidal proteins of the disclosure to have modified physical properties are provided.

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property
Organization
International Bureau(43) International Publication Date
15 September 2016 (15.09.2016)

WIPO | PCT

(10) International Publication Number
WO 2016/144686 A1

(51) International Patent Classification:

C12N 15/82 (2006.01) C07K 14/21 (2006.01)
C07K 14/415 (2006.01) A01N 65/00 (2009.01)

(21) International Application Number:

PCT/US2016/020634

(22) International Filing Date:

3 March 2016 (03.03.2016)

(25) Filing Language:

English

(26) Publication Language:

English

(30) Priority Data:

62/131,491 11 March 2015 (11.03.2015) US

(71) Applicant: PIONEER HI-BRED INTERNATIONAL, INC. [US/US]; 7100 N.W. 62nd Avenue, P.O. Box 1014, Johnston, Iowa 50131 (US).

(72) Inventors: LIU, Lu; 7250 NW 62nd Ave, PO Box 552, Johnston, Iowa 50131-0552 (US). ORAL, Jarred Kenneth; 7250 NW 62nd Ave, PO Box 552, Johnston, Iowa 50131-0552 (US). POLAND, Brad; 7250 NW 62nd Ave, PO Box 552, Johnston, Iowa 50131-0552 (US). SCHELLENBERGER, Ute; 914 Moreno Avenue, Palo Alto, California 94303 (US).

(74) Agent: BAUER, S. Christopher; PIONEER HI-BRED INTERNATIONAL, INC., 7100 N.W. 62nd Avenue, P.O. Box 1014, Johnston, Iowa 50131 (US).

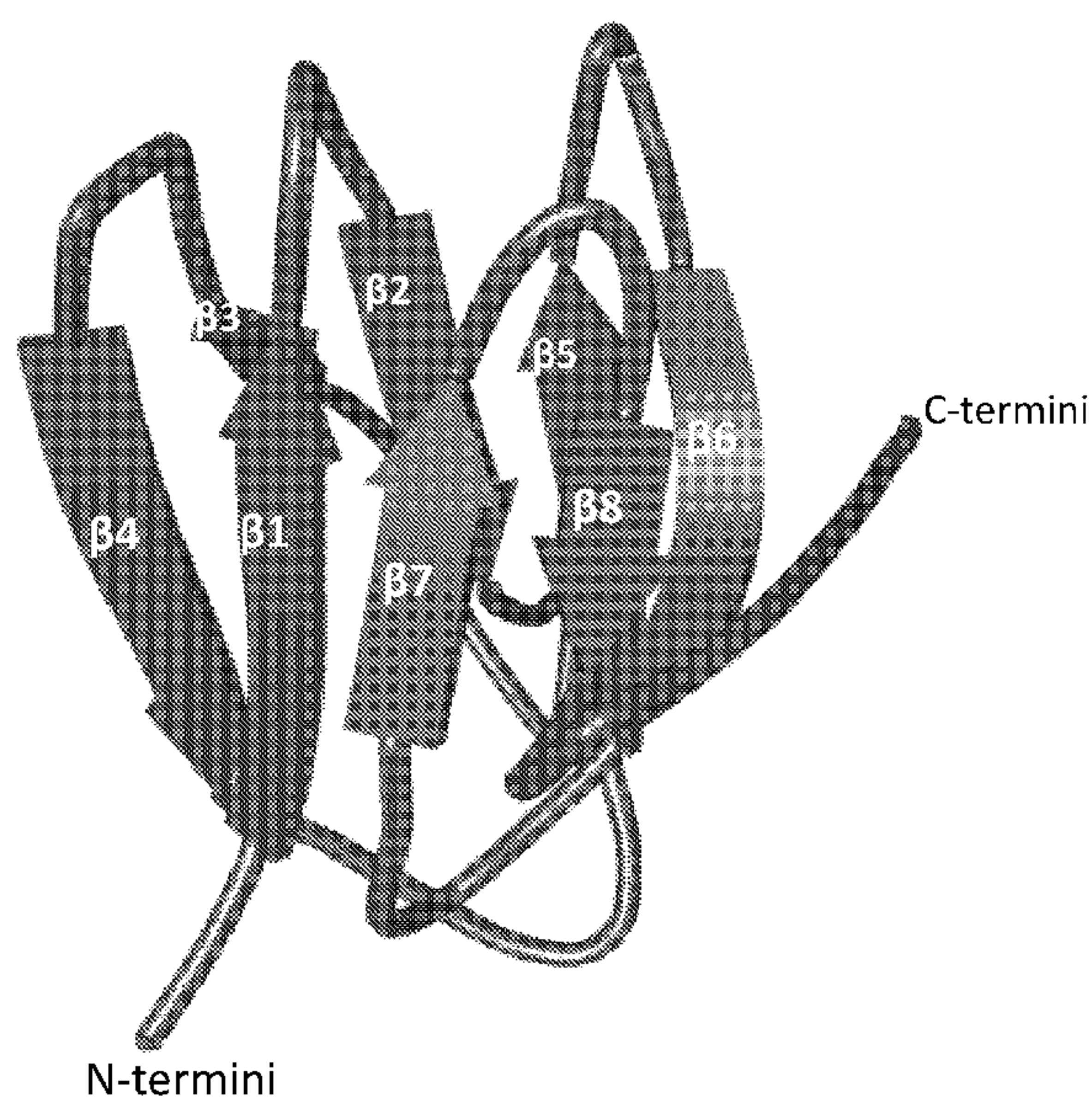
(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

[Continued on next page]

(54) Title: STRUCTURE BASED METHODS FOR MODIFICATION OF PIP-72 POLYPEPTIDES AND PIP-72 POLYPEPTIDES DERIVED THEREFROM

Fig. 1



(57) Abstract: Compositions and methods for controlling pests are provided. The methods involve transforming organisms with a nucleic acid sequence encoding an insecticidal protein. In particular, the nucleic acid sequences are useful for preparing plants and microorganisms that possess insecticidal activity. Thus, transformed bacteria, plants, plant cells, plant tissues and seeds are provided. Compositions are insecticidal nucleic acids and proteins of bacterial species. The sequences find use in the construction of expression vectors for subsequent transformation into organisms of interest including plants, as probes for the isolation of other homologous (or partially homologous) genes. The pesticidal proteins find use in controlling, inhibiting growth or killing Lepidopteran, Coleopteran, Dipteran, fungal, Hemipteran and nematode pest populations and for producing compositions with insecticidal activity. Structure based methods for engineering insecticidal proteins of the disclosure to have modified physical properties are provided.

WO 2016/144686 A1

Published:

- *with international search report (Art. 21(3))*
- *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments (Rule 48.2(h))*
- *with sequence listing part of description (Rule 5.2(a))*

STRUCTURE BASED METHODS FOR MODIFICATION OF PIP-72 POLYPEPTIDES AND PIP-72 POLYPEPTIDES DERIVED THEREFROM

REFERENCE TO SEQUENCE LISTING SUBMITTED ELECTRONICALLY

5 A sequence listing having the file name "6787-WO-PCT_sequence_listing.txt" created on February 16, 2016, and having a size of 580 kilobytes is filed in computer readable form concurrently with the specification. The sequence listing is part of the specification and is herein incorporated by reference in its entirety.

10 FIELD OF THE INVENTION

This disclosure relates to the field of molecular biology. Provided are novel genes that encode pesticidal proteins. These pesticidal proteins and the nucleic acid sequences that encode them are useful in preparing pesticidal formulations and in the production of transgenic pest-resistant plants.

15

BACKGROUND OF THE INVENTION

Biological control of insect pests of agricultural significance using a microbial agent, such as fungi, bacteria or another species of insect affords an environmentally friendly and commercially attractive alternative to synthetic chemical pesticides. Generally speaking, the use of biopesticides presents a lower risk of pollution and environmental hazards and biopesticides provide greater target specificity than is characteristic of traditional broad-spectrum chemical insecticides. In addition, biopesticides often cost less to produce and thus improve economic yield for a wide variety of crops.

25 Certain species of microorganisms of the genus *Bacillus* are known to possess pesticidal activity against a range of insect pests including Lepidoptera, Diptera, Coleoptera, Hemiptera and others. *Bacillus thuringiensis* (*Bt*) and *Bacillus popilliae* are among the most successful biocontrol agents discovered to date. Insect pathogenicity has also been attributed to strains of *B. larvae*, *B. lentimorbus*, *B. sphaericus* and *B. cereus*. Microbial insecticides, particularly those obtained from *Bacillus* strains, have played an important role in agriculture as alternatives to chemical pest control.

30 Crop plants have been developed with enhanced insect resistance by genetically engineering crop plants to produce pesticidal proteins from *Bacillus*. For example, corn and cotton plants have been genetically engineered to produce pesticidal proteins isolated from strains of *Bt*. These genetically engineered crops are now widely used in agriculture and have provided the farmer with an environmentally friendly alternative to

traditional insect-control methods. While they have proven to be very successful commercially, these genetically engineered, insect-resistant crop plants provide resistance to only a narrow range of the economically important insect pests. In some cases, insects can develop resistance to different insecticidal compounds, which raises the need to identify alternative biological control agents for pest control.

Accordingly, there remains a need for new pesticidal proteins with different ranges of insecticidal activity against insect pests, e.g., insecticidal proteins which are active against a variety of insects in the order Lepidoptera and the order Coleoptera including but not limited to insect pests that have developed resistance to existing insecticides.

SUMMARY OF THE INVENTION

Compositions and methods for conferring pesticidal activity to bacteria, plants, plant cells, tissues and seeds are provided. Compositions include nucleic acid molecules encoding sequences for pesticidal and insecticidal polypeptides, vectors comprising those nucleic acid molecules, and host cells comprising the vectors. Compositions also include the pesticidal polypeptide sequences and antibodies to those polypeptides. The nucleic acid sequences can be used in DNA constructs or expression cassettes for transformation and expression in organisms, including microorganisms and plants. The nucleotide or amino acid sequences may be synthetic sequences that have been designed for expression in an organism including, but not limited to, a microorganism or a plant. Compositions also comprise transformed bacteria, plants, plant cells, tissues and seeds.

In particular, isolated or recombinant nucleic acid molecules are provided encoding *Pseudomonas* Insecticidal Protein-72 (PIP-72) polypeptides comprising a hydrophobic interface surface, including amino acid substitutions, deletions, insertions, and fragments thereof, and combinations thereof. Additionally, amino acid sequences corresponding to the PIP-72 polypeptides comprising a hydrophobic interface surface are encompassed. Provided are isolated or recombinant nucleic acid molecules capable of encoding a PIP-72 polypeptide having at least 50% identity to the amino acid sequence of SEQ ID NO: 849 and comprising a hydrophobic interface surface, as well as amino acid substitutions, deletions, insertions, fragments thereof and combinations thereof. Nucleic acid sequences that are complementary to a nucleic acid sequence of the embodiments or that hybridize to a sequence of the embodiments are also encompassed.

Methods are provided for producing the polypeptides and for using those polypeptides for controlling or killing a Lepidopteran, Coleopteran, nematode, fungi, and/or Dipteran pests. The transgenic plants of the embodiments express one or more of the pesticidal sequences disclosed herein. In various embodiments, the transgenic plant

further comprises one or more additional genes for insect resistance, for example, one or more additional genes for controlling Coleopteran, Lepidopteran, Hemipteran or nematode pests. It will be understood by one of skill in the art that the transgenic plant may comprise any gene imparting an agronomic trait of interest.

5 Methods for detecting the nucleic acids and polypeptides of the embodiments in a sample are also included. A kit for detecting the presence of a PIP-72 polypeptide or detecting the presence of a nucleotide sequence encoding a PIP-72 polypeptide in a sample is provided. The kit may be provided along with all reagents and control samples necessary for carrying out a method for detecting the intended agent, as well as
10 instructions for use.

The compositions and methods of the embodiments are useful for the production of organisms with enhanced pest resistance or tolerance. These organisms and compositions comprising the organisms are desirable for agricultural purposes. The compositions of the embodiments are also useful for generating altered or improved
15 proteins that have pesticidal activity or for detecting the presence of PIP-72 polypeptides or nucleic acids in products or organisms

Methods of identifying regions of PIP-72 polypeptide through rational protein design with a secondary, tertiary or quaternary structure of the PIP-72 polypeptide to modified physical properties of the PIP-72 polypeptide are provided. Methods of
20 engineering a PIP-72 polypeptide to have a modified physical property by employing rational protein design with a secondary, tertiary or quaternary structure of the PIP-72 polypeptide are provided. Methods are provided to identify regions of PIP-72 polypeptides, including but not limited to loops between structural elements, which are involved in insect specificity. Methods are provided to identify regions of PIP-72
25 polypeptides, including but not limited to a hydrophobic interface surface, which is involved in dimer interaction.

BRIEF DESCRIPTION OF THE FIGURES

Figure 1 shows a schematic ribbon representation of the PIP-72Aa (SEQ ID NO: 2)
30 solution structure viewed from β -sheet 1, with the β -strands of the β -sandwich identified.

Figure 2 shows a schematic ribbon representation of the PIP-72Aa (SEQ ID NO: 2)
solution structure viewed from β -sheet 2, with the β -strands of the β -sandwich identified.

Figure 3 represents the molecular surface of PIP-72Aa (SEQ ID NO: 2) colored by hydrophobicity, blue is hydrophilic, white-brown is hydrophobic and shows the predominately hydrophobic area of sheet 2 (white-brown).

- 5 Figure 4 represents the molecular surface of PIP-72Aa (SEQ ID NO: 2) colored by hydrophobicity, blue is hydrophilic, white-brown is hydrophobic and shows the predominately hydrophilic area of sheet 1 (purple-blue).

Figure 5 show a schematic ribbon representation of the dimer model based on the NMR solution structure.

- 10 Figure 6 shows an amino acid sequence alignment of PIP-72Aa (SEQ ID NO: 2), PIP-72Ba (SEQ ID NO: 4); PIP-72Ca (SEQ ID NO: 6); PIP-72Cb (SEQ ID NO: 8); PIP-72Da (SEQ ID NO: 10); PIP-72Db (SEQ ID NO: 12); PIP-72Dc (SEQ ID NO: 14); PIP-72Ea (SEQ ID NO: 16), PIP-72Fa (SEQ ID NO: 18); GBP_A3175 (SEQ ID NO: 20), SRBS_294080 (SEQ ID NO: 22); JG43047 (SEQ ID NO: 24); SwiRh_4910 (SEQ ID NO: 26); PIP-72Ff (SEQ ID NO: 28), PFL_6283 (SEQ ID NO: 30); PIP-72Gb (SEQ ID NO: 32); XBJ1_1078 (SEQ ID NO: 34); plu2373 (SEQ ID NO: 36); and PIP-72Ge (SEQ ID NO: 38). The sequence diversity is highlighted. Amino acids 37-51 (Motif 1) relative to PIP-72Aa (SEQ ID NO: 2) are underlined.

20

DETAILED DESCRIPTION

It is to be understood that this disclosure is not limited to the particular methodology, protocols, cell lines, genera, and reagents described, as such may vary. It is also to be understood that the terminology used herein is for the purpose of describing particular embodiments only, and is not intended to limit the scope of the present disclosure.

25 As used herein the singular forms "a", "and", and "the" include plural referents unless the context clearly dictates otherwise. Thus, for example, reference to "a cell" includes a plurality of such cells and reference to "the protein" includes reference to one or more proteins and equivalents thereof known to those skilled in the art, and so forth. All technical and scientific terms used herein have the same meaning as commonly understood to one of ordinary skill in the art to which this disclosure belongs unless clearly indicated otherwise.

30 The present disclosure is drawn to compositions and methods for controlling pests. The methods involve transforming organisms with nucleic acid sequences encoding a PIP-72 polypeptide. In particular, the nucleic acid sequences of the

35

embodiments are useful for preparing plants and microorganisms that possess pesticidal activity. Thus, transformed bacteria, plants, plant cells, plant tissues and seeds are provided. The compositions are pesticidal nucleic acids and proteins of bacterial species. The nucleic acid sequences find use in the construction of expression vectors for subsequent transformation into organisms of interest, as probes for the isolation of other homologous (or partially homologous) genes, and for the generation of altered PIP-72 polypeptides by methods known in the art, such as site-directed mutagenesis, domain swapping or DNA shuffling. The PIP-72 polypeptides find use in controlling or killing Lepidopteran, Coleopteran, Dipteran, fungal, Hemipteran and nematode pest populations and for producing compositions with pesticidal activity. Insect pests of interest include, but are not limited to, Lepidoptera species including but not limited to: diamond-back moth, e.g., *Helicoverpa zea* Boddie; soybean looper, e.g., *Pseudoplusia includens* Walker; and velvet bean caterpillar e.g., *Anticarsia gemmatilis* Hübner and Coleoptera species including but not limited to Western corn rootworm (*Diabrotica virgifera*) - WCRW, Southern corn rootworm (*Diabrotica undecimpunctata howardi*) – SCRW, and Northern corn rootworm (*Diabrotica barberi*) - NCRW.

In some embodiments the PIP-72 polypeptides include amino acid sequences deduced from the full-length nucleic acid sequences disclosed herein and amino acid sequences that are shorter than the full-length sequences, either due to the use of an alternate downstream start site or due to processing that produces a shorter protein having pesticidal activity. Processing may occur in the organism the protein is expressed in or in the pest after ingestion of the protein.

Thus, provided herein are novel isolated or recombinant nucleic acid sequences that confer pesticidal activity. Also provided are the amino acid sequences of PIP-72 polypeptides. The protein resulting from translation of these PIP-72 polypeptide genes allows cells to control or kill pests that ingest it.

Nucleic Acid Molecules, and Variants and Fragments Thereof

One aspect pertains to isolated or recombinant nucleic acid molecules comprising nucleic acid sequences encoding PIP-72 polypeptides having a hydrophobic interface surface or biologically active portions thereof, as well as nucleic acid molecules sufficient for use as hybridization probes to identify nucleic acid molecules encoding proteins with regions of sequence homology. As used herein, the term “nucleic acid molecule” refers to DNA molecules (e.g., recombinant DNA, cDNA, genomic DNA, plastid DNA, mitochondrial DNA) and RNA molecules (e.g., mRNA) and analogs of the DNA or RNA generated using

nucleotide analogs. The nucleic acid molecule can be single-stranded or double-stranded, but preferably is double-stranded DNA.

An “isolated” nucleic acid molecule (or DNA) is used herein to refer to a nucleic acid sequence (or DNA) that is no longer in its natural environment, for example in vitro.

5 A “recombinant” nucleic acid molecule (or DNA) is used herein to refer to a nucleic acid sequence (or DNA) that is in a recombinant bacterial or plant host cell. In some embodiments, an “isolated” or “recombinant” nucleic acid is free of sequences (preferably protein encoding sequences) that naturally flank the nucleic acid (i.e., sequences located at the 5' and 3' ends of the nucleic acid) in the genomic DNA of the organism from which
10 the nucleic acid is derived. For purposes of the disclosure, “isolated” or “recombinant” when used to refer to nucleic acid molecules excludes isolated chromosomes. For example, in various embodiments, the recombinant nucleic acid molecule encoding a PIP-72 polypeptide can contain less than about 5 kb, 4 kb, 3 kb, 2 kb, 1 kb, 0.5 kb or 0.1 kb of nucleic acid sequences that naturally flank the nucleic acid molecule in genomic DNA of
15 the cell from which the nucleic acid is derived.

In some embodiments an isolated nucleic acid molecule encoding a PIP-72 polypeptide has one or more change in the nucleic acid sequence compared to the native or genomic nucleic acid sequence. In some embodiments the change in the native or genomic nucleic acid sequence includes but is not limited to: changes in the nucleic acid
20 sequence due to the degeneracy of the genetic code; changes in the nucleic acid sequence due to the amino acid substitution, insertion, deletion and/or addition compared to the native or genomic sequence; removal of one or more intron; deletion of one or more upstream or downstream regulatory regions; and deletion of the 5' and/or 3' untranslated region associated with the genomic nucleic acid sequence. In some embodiments the
25 nucleic acid molecule encoding a PIP-72 polypeptide is a non-genomic sequence.

A variety of polynucleotides that encode a PIP-72 polypeptides or related proteins are contemplated. Such polynucleotides are useful for production of PIP-72 polypeptides in host cells when operably linked to suitable promoter, transcription termination and/or polyadenylation sequences. Such polynucleotides are also useful as probes for isolating
30 homologous or substantially homologous polynucleotides that encode PIP-72 polypeptides or related proteins.

Sources of polynucleotides that encode PIP-72 polypeptides or related proteins include but not limited to *Halomonas anticariensis*, *Photorhabdus luminescens*, *Xenorhabdus bovienii*, *Burkholderia pseudomallei*, *Burkholderia multivorans*, *Burkholderia thailandensis*, *Paludibacterium yongneupense*, *Pseudomonas rhodesiae*; *Pseudomonas entomophila*, *Pseudomonas chlororaphis*; *Pseudomonas mandelii*; *Pseudomonas*
35

congelans; *Pseudomonas mandelii*; *Pseudomonas plecoglossicida*, *Pseudomonas protegens*, *Pseudomonas ficuserectae*; *Pseudomonas mosselii* or *Pseudomonas brassicacearum* strain. Sources of polynucleotides that encode PIP-72 polypeptides or related proteins include but not limited to: a *Pseudomonas chlororaphis* strain which

5 contains the PIP-72Aa polynucleotide of SEQ ID NO: 1 encoding the PIP-72Aa polypeptide of SEQ ID NO: 2; a *Pseudomonas rhodesiae* strain which contains the PIP-72Ba polynucleotide of SEQ ID NO: 3 encoding the PIP-72Ba polypeptide of SEQ ID NO: 4; a *Pseudomonas chlororaphis* strain which contains the PIP-72Ca polynucleotide of SEQ ID NO: 5 encoding the PIP-72Ca polypeptide of SEQ ID NO: 6; a *Pseudomonas*

10 *mandelii* strain which contains the PIP-72Cb polynucleotide of SEQ ID NO: 7 encoding the PIP-72Cb polypeptide of SEQ ID NO: 8; a *Pseudomonas congelans* strain which contains the PIP-72Da polynucleotide of SEQ ID NO: 9 encoding the PIP-72Da polypeptide of SEQ ID NO: 10; a *Pseudomonas mandelii* strain which contains the PIP-72Db polynucleotide of SEQ ID NO: 11 encoding the PIP-72Db polypeptide of SEQ ID

15 NO: 12; a *Pseudomonas ficuserectae* strain which contains the PIP-72Dc polynucleotide of SEQ ID NO: 13 encoding the PIP-72Dc polypeptide of SEQ ID NO: 14; a *Pseudomonas mosselii* strain which contains the PIP-72Fa polynucleotide of SEQ ID NO: 17 encoding the PIP-72Fa polypeptide of SEQ ID NO: 18; a *Pseudomonas chlororaphis* strain which contains the PIP-72Ff polynucleotide of SEQ ID NO: 27 encoding the PIP-

20 72Ff polypeptide of SEQ ID NO: 28; a *Pseudomonas chlororaphis* strain which contains the PIP-72Gb polynucleotide of SEQ ID NO: 31 encoding the PIP-72Gb polypeptide of SEQ ID NO: 32; a *Pseudomonas chlororaphis* strain which contains the PIP-72Ab polynucleotide of SEQ ID NO: 949 encoding the PIP-72Ab polypeptide of SEQ ID NO: 927; a *Pseudomonas brassicacearum* strain which contains the PIP-72Bb polynucleotide

25 of SEQ ID NO: 950 encoding the PIP-72Ab polypeptide of SEQ ID NO: 928; a *Pseudomonas entomophila* strain which contains the PIP-72Fh polynucleotide of SEQ ID NO: 954 encoding the PIP-72AFh polypeptide of SEQ ID NO: 932; a *Pseudomonas entomophila* strain which contains the PIP-72Fh polynucleotide of SEQ ID NO: 955 encoding the PIP-72AFh polypeptide of SEQ ID NO: 933; a *Pseudomonas chlororaphis*

30 strain which contains the PIP-72Fj polynucleotide of SEQ ID NO: 956 encoding the PIP-72Fj polypeptide of SEQ ID NO: 934; a *Pseudomonas chlororaphis* strain which contains the PIP-72Fk polynucleotide of SEQ ID NO: 957 encoding the PIP-72Fk polypeptide of SEQ ID NO: 935; a *Burkholderia multivorans* strain which contains the PIP-72Fl polynucleotide of SEQ ID NO: 958 encoding the PIP-72Fl polypeptide of SEQ ID NO: 936;

35 a *Pseudomonas chlororaphis* strain which contains the PIP-72Gg polynucleotide of SEQ ID NO: 961 encoding the PIP-72Gg polypeptide of SEQ ID NO: 939; a *Pseudomonas*

chlororaphis strain which contains the PIP-72Gh polynucleotide of SEQ ID NO: 962 encoding the PIP-72Gh polypeptide of SEQ ID NO: 940; a *Pseudomonas mosselii* strain which contains the PIP-72Gi polynucleotide of SEQ ID NO: 963 encoding the PIP-72Gi polypeptide of SEQ ID NO: 941; a *Pseudomonas protegens* strain which contains the PIP-72Gk polynucleotide of SEQ ID NO: 965 encoding the PIP-72Gk polypeptide of SEQ ID NO: 943; a *Pseudomonas plecoglossicida* strain which contains the PIP-72Gl polynucleotide of SEQ ID NO: 966 encoding the PIP-72Gl polypeptide of SEQ ID NO: 944; and a *Pseudomonas chlororaphis* strain which contains the PIP-72Gn polynucleotide of SEQ ID NO: 968 encoding the PIP-72Gn polypeptide of SEQ ID NO: 946. These polynucleotide sequences were isolated from a *Halomonas*, *Photorhabdus*, *Xenorhabdus*, *Burkholderia*, *Paludibacterium* or *Pseudomonas* host and are thus suitable for expression of the encoded PIP-72 polypeptide in other bacterial hosts. For example, SEQ ID NO: 1, SEQ ID NO: 3, SEQ ID NO: 5, SEQ ID NO: 7, SEQ ID NO: 9, SEQ ID NO: 11, SEQ ID NO: 13, SEQ ID NO: 17, SEQ ID NO: 27 and SEQ ID NO: 31, SEQ ID NO: 949, SEQ ID NO: 950, SEQ ID NO: 955, SEQ ID NO: 956, SEQ ID NO: 957, SEQ ID NO: 958, SEQ ID NO: 961, SEQ ID NO: 962, SEQ ID NO: 963, SEQ ID NO: 965, SEQ ID NO: 966, SEQ ID NO: 967, SEQ ID NO: 968 can be used to express PIP-72 polypeptides in bacterial hosts that include but are not limited to *Agrobacterium*, *Bacillus*, *Escherichia*, *Salmonella*, *Pseudomonas* and *Rhizobium* bacterial host cells. The polynucleotides are also useful as probes for isolating homologous or substantially homologous polynucleotides that encode PIP-72 polypeptides or related proteins. Such probes can be used to identify homologous or substantially homologous polynucleotides derived from *Halomonas*, *Photorhabdus*, *Xenorhabdus*, *Burkholderia*, *Paludibacterium*, *Pseudomonas* or other related bacteria.

Polynucleotides that encode a PIP-72 polypeptide can also be synthesized de novo from a PIP-72 polypeptide sequence. The sequence of the polynucleotide gene can be deduced from a PIP-72 polypeptide sequence through use of the genetic code. Computer programs such as "BackTranslate" (GCG™ Package, Acclerys, Inc. San Diego, Calif.) can be used to convert a peptide sequence to the corresponding nucleotide sequence encoding the peptide. Furthermore, synthetic PIP-72 polynucleotide sequences of the disclosure can be designed so that they will be expressed in plants. US Patent Number 5,500,365 describes a method for synthesizing plant genes to improve the expression level of the protein encoded by the synthesized gene. This method relates to the modification of the structural gene sequences of the exogenous transgene, to cause them to be more efficiently transcribed, processed, translated and expressed by the plant. Features of genes that are expressed well in plants include elimination of sequences that can cause undesired intron splicing or polyadenylation in the coding region of a gene

transcript while retaining substantially the amino acid sequence of the toxic portion of the insecticidal protein. A similar method for obtaining enhanced expression of transgenes in monocotyledonous plants is disclosed in US Patent Number 5,689,052.

In some embodiments the nucleic acid molecule encoding a PIP-72 polypeptide is
 5 a polynucleotide having the sequence set forth in SEQ ID NO: 1; SEQ ID NO: 3, SEQ ID NO: 5, SEQ ID NO: 7, SEQ ID NO: 9, SEQ ID NO: 11, SEQ ID NO: 13, SEQ ID NO: 17, SEQ ID NO: 27, SEQ ID NO: 31, SEQ ID NO: 949, SEQ ID NO: 950, SEQ ID NO: 955, SEQ ID NO: 956, SEQ ID NO: 957, SEQ ID NO: 958, SEQ ID NO: 961, SEQ ID NO: 962, SEQ ID NO: 963, SEQ ID NO: 965, SEQ ID NO: 966, SEQ ID NO: 967, SEQ ID NO: 968,
 10 and variants, fragments and complements thereof. "Complement" is used herein to refer to a nucleic acid sequence that is sufficiently complementary to a given nucleic acid sequence such that it can hybridize to the given nucleic acid sequence to thereby form a stable duplex. "Polynucleotide sequence variants" is used herein to refer to a nucleic acid sequence that except for the degeneracy of the genetic code encodes the same
 15 polypeptide.

In some embodiments the nucleic acid molecule encodes a PIP-72 polypeptide comprising an amino acid sequence having at least about 50%, 55%, 60%, 65%, 70%, 75%, 80%, 81%, 82%, 83%, 84%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99% or greater sequence identity compared to SEQ ID NO:
 20 2, SEQ ID NO: 4, SEQ ID NO: 6, SEQ ID NO: 8, SEQ ID NO: 10, SEQ ID NO: 12, SEQ ID NO: 14, SEQ ID NO: 18, SEQ ID NO: 28 or SEQ ID NO: 32, SEQ ID NO: 927, SEQ ID NO: 928, SEQ ID NO: 932, SEQ ID NO: 933, SEQ ID NO: 934, SEQ ID NO: 935, SEQ ID NO: 936, SEQ ID NO: 939, SEQ ID NO: 940, SEQ ID NO: 941, SEQ ID NO: 943, SEQ ID NO: 944, SEQ ID NO: 945 or SEQ ID NO: 946.

25 In some embodiments the nucleic acid molecule encodes a PIP-72 polypeptide comprising an amino acid sequence having at least 50% identity to SEQ ID NO: 2 and a hydrophobic interface surface.

In some embodiments the nucleic acid molecule encodes a PIP-72 polypeptide comprising an amino acid sequence having at least 50% identity to SEQ ID NO: 2 and a
 30 hydrophobic interface surface comprising residues selected from positions 16, 18, 19, 20, 21, 22, 26, 27, 45, 46, 48, 50, 57, 59, 61, 85, and 86, corresponding to SEQ ID NO: 2.

In some embodiments the nucleic acid molecule encodes a PIP-72 polypeptide comprising an amino acid sequence having at least 50% identity to SEQ ID NO: 2, a hydrophobic interface surface comprising residues selected from positions 16, 18, 19, 20,
 35 21, 22, 26, 27, 45, 46, 48, 50, 57, 59, 61, 85, and 86, corresponding to SEQ ID NO: 2, and the amino acid at position 20 is tryptophan.

In some embodiments the nucleic acid molecule encodes a PIP-72 polypeptide comprising an amino acid sequence having at least 50% identity to SEQ ID NO: 2, a hydrophobic interface surface comprising residues selected from positions 16, 18, 19, 20, 21, 22, 26, 27, 45, 46, 48, 50, 57, 59, 61, 85, and 86, corresponding to SEQ ID NO: 2, and further comprises 1 to 45 amino acid substitutions at position(s) 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 17, 18, 19, 20, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 42, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 56, 58, 60, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85 or 86 compared to the corresponding amino acid of SEQ ID NO: 2.

In some embodiments the nucleic acid molecule encodes a PIP-72 polypeptide comprising an amino acid sequence having at least 50% identity to SEQ ID NO: 2, a hydrophobic interface surface comprising residues selected from positions 16, 18, 19, 20, 21, 22, 26, 27, 45, 46, 48, 50, 57, 59, 61, 85, and 86, corresponding to SEQ ID NO: 2, the amino acid at position 21 is tryptophan, and further comprises 1 to 45 amino acid substitutions at position(s) 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 17, 18, 19, 20, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 42, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 56, 58, 60, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85 or 86 compared to the corresponding amino acid of SEQ ID NO: 2.

In some embodiments the nucleic acid molecule encodes a PIP-72 polypeptide comprising an amino acid sequence having at least 50% identity to SEQ ID NO: 2, a hydrophobic interface surface corresponding to residues selected from positions 16, 18, 19, 20, 21, 22, 26, 27, 45, 46, 48, 50, 57, 59, 61, 85, and 86, corresponding to SEQ ID NO: 2, and the amino acid at position 2 is Gly, Ala, Cys, Asp, Glu, Ile, Lys, Leu, Asn, Arg, Ser, Thr, Val, Trp or Tyr; the amino acid at position 3 is Ile or Trp; the amino acid at position 4 is Thr, Ala, Asp, Glu, His, Ile, Lys, Leu, Arg, Ser, Val, Trp or Tyr; the amino acid at position 5 is Val, Ala, Cys, Gly, His, Ile or Tyr; the amino acid at position 6 is Thr, Ala, Cys, Phe, Gly, His, Ile, Lys, Met, Pro, Gln, Arg, Ser, Trp or Tyr; the amino acid at position 7 is Asn, Ala or Val; the amino acid at position 8 is Asn, Ala, Cys, Asp, Glu, Gly, His, Ile, Lys, Leu, Met, Gln, Arg, Ser, Thr or Val; the amino acid at position 9 is Ser, Ala, Cys, Gly or Thr; the amino acid at position 10 is Ser, Ala, Glu, Phe, Gly, His, Ile, Lys, Leu, Asn, Pro, Gln, Arg, Thr or Trp; the amino acid at position 11 is Asn, Ala, Cys, Asp, Glu, Gly, His, Ile, Lys, Leu, Met, Gln, Ser, Thr, Val or Tyr; the amino acid at position 12 is Pro, Ala, Cys, Asp, Glu, Gly, His, Lys, Leu, Asn, Gln, Arg, Ser, Thr, Val, Trp or Tyr; the amino acid at position 13 is Ile, Asn, Gln or Val; the amino acid at position 14 is Glu, Ala, Cys, Phe, His, Lys or Gln; the amino acid at position 15 is Val, Ala, Cys, Ile, Met or Arg; the amino

acid at position 17 is Ile, Glu or Val; the amino acid at position 18 is Asn or Ser; the amino acid at position 19 is His, Ala, Glu, Lys, Leu, Pro, Arg, Ser or Tyr; the amino acid at position 20 is Trp; the amino acid at position 22 is Ser, Ala, Asp, Phe, Gly, His, Ile, Lys, Leu, Met, Asn, Pro, Gln, Arg, Thr, Val or Tyr; the amino acid at position 23 is Asp, Ala, Gly, His, Lys, Met, Asn, Gln, Ser, Thr or Val; the amino acid at position 24 is Gly, Asp or Phe; the amino acid at position 25 is Asp, Ala, Glu, Phe, Asn or Gln; the amino acid at position 26 is Thr, Glu or Pro; the amino acid at position 27 is Ser, Ala, Cys, Asp, Glu, Phe, Gly, His, Asn, Gln, Arg or Thr; the amino acid at position 28 is Phe, Pro, Trp or Tyr; the amino acid at position 29 is Phe, Ala, Cys, Ile, Leu, Gln, Arg, Trp or Tyr; the amino acid at position 30 is Ser, Ala, Cys, Asp, Glu, Phe, Gly, His, Lys, Leu, Met, Asn, Pro, Gln, Arg, Thr, Val, Trp or Tyr; the amino acid at position 31 is Val, Ile or Leu; the amino acid at position 32 is Gly, Ala, Asp, Glu, Phe, His, Lys, Leu, Met, Asn, Pro, Gln, Arg, Ser, Thr, Val, Trp or Tyr; the amino acid at position 33 is Asn, Ala, Cys, Asp, Glu, Phe, Gly, His, Ile, Lys, Leu, Pro, Gln, Arg, Ser, Thr, Val or Tyr; the amino acid at position 34 is Gly, Glu, Phe, His, Lys, Leu, Met, Asn, Gln, Arg, Ser, Thr or Tyr; the amino acid at position 35 is Lys, Ala, Cys, Asp, Gly, His, Ile, Leu, Met, Asn, Gln, Arg, Ser, Thr or Val; the amino acid at position 36 is Gln, Ala, Cys, Glu, Gly, His, Ile, Lys, Leu, Asn, Pro, Arg, Ser, Thr or Val; the amino acid at position 37 is Glu, Ala, Cys, Asp, Phe, Gly, Ile, Lys, Leu, Met, Asn, Ser, Thr or Val; the amino acid at position 38 is Thr, Ala, Cys, Asp, Glu, Phe, Gly, His, Ile, Leu, Met, Asn, Gln, Arg, Ser, Val, Trp or Tyr; the amino acid at position 39 is Trp or Phe; the amino acid at position 40 is Asp, Ala, Cys, Glu, Phe, Gly, His, Ile, Lys, Leu, Met, Asn, Gln, Arg, Ser, Thr, Val, Trp or Tyr; the amino acid at position 42 is Ser, Ala, Cys, Asp, Glu, Phe, Gly, Ile, Lys, Leu, Met, Asn, Gln, Arg, Thr, Val, Trp or Tyr; the amino acid at position 44 is Ser, Ala, Asp, Glu, Gly, Leu, Met, Asn, Pro, Gln, Thr, Val or Tyr; the amino acid at position 45 is Arg, Lys or Ser; the amino acid at position 46 is Gly, Ala or Gln; the amino acid at position 47 is Phe, Cys, Val or Tyr; the amino acid at position 48 is Val, Ile or Leu; the amino acid at position 49 is Leu, Cys, Phe, Met, Arg or Tyr; the amino acid at position 50 is Ser, Ala, Cys, Asp, Ile, Met, Pro, Gln, Thr or Val; the amino acid at position 51 is Leu, Ala, Cys, Met or Val; the amino acid at position 52 is Lys, Cys, Phe, His, Ile, Leu, Met, Asn, Arg, Ser, Thr, Trp or Tyr; the amino acid at position 53 is Lys, Ala, Cys, Asp, Glu, Phe, His, Ile, Leu, Met, Asn, Gln, Arg, Ser, Thr, Val or Tyr; the amino acid at position 54 is Asn, Cys, Asp, Glu, Phe, Gly, Lys, Met, Gln, Arg, Ser or Trp; the amino acid at position 56 is Ala, Gly, Leu, Asn, Pro, Gln, Arg, Ser or Thr; the amino acid at position 57 is Gln, Glu, Leu, Met, Ser or Thr; the amino acid at position 58 is His, Ala, Asp, Phe, Leu, Met, Asn, Arg, Trp or Tyr; the amino acid at position 60 is Tyr, Glu or Phe; the amino acid at position 63 is Gln, Cys, Gly, Ile, Leu, Met, Asn, Thr, Val or Tyr; the amino acid at

position 64 is Ala, Phe, Gly, His, Arg, Ser or Tyr; the amino acid at position 65 is Ser, Ala, Cys, Asp, Glu, Phe, Gly, His, Ile, Leu, Asn, Thr or Val; the amino acid at position 66 is Ser, Ala or Gly; the amino acid at position 67 is Lys, Ala, Cys, Asp, Phe, His, Ile, Leu, Met, Asn, Gln, Arg, Ser, Thr, Val, Trp or Tyr; the amino acid at position 68 is Ile Asp, Leu or Val; the amino acid at position 69 is Glu, Ala, Cys, Asp, Phe, His, Ile, Leu, Met, Gln, Arg, Ser, Thr, Val or Tyr; the amino acid at position 70 is Val, Cys or Ile; the amino acid at position 71 is Asp, Ala, Cys, Gly, His, Ile, Leu, Met, Asn, Ser, Thr, Val or Tyr; the amino acid at position 72 is Asn, Ala, Cys, Asp, Glu, Gly, Lys, Met, Pro, Gln, Arg, Ser, Thr, Val or Trp; the amino acid at position 73 is Asn, Ala, Cys, Asp, Phe, Gly, His, Ile, Leu, Ser, Thr, Val or Tyr; the amino acid at position 74 is Ala, Cys, Asp, Phe, Gly, His, Ile, Leu, Asn, Gln, Arg, Ser, Thr, Val or Tyr; the amino acid at position 75 is Val, Cys, Ile or Leu; the amino acid at position 76 is Lys, Ala, Cys, Phe, His, Ile, Leu, Gln, Arg, Ser, Thr, Val, Trp or Tyr; the amino acid at position 77 is Asp Tyr; the amino acid at position 78 is Gln, Ala, Cys, Asp, Phe, Gly, His, Ile, Leu, Met, Asn, Arg, Ser, Thr, Val or Tyr; the amino acid at position 79 is Gly, Arg, Ala, Cys, Asp, Glu, Phe, His, Lys, Leu, Asn, Gln, Arg, Ser, Thr, Trp or Tyr; the amino acid at position 80 is Arg, Ala, Cys, Asp, Phe, Gly, His, Ile, Leu, Asn, Ser, Thr, Val or Tyr; the amino acid at position 81 is Leu, Ala, Cys, Asp, Phe, Gly, His, Ile, Asn, Pro, Arg, Ser, Thr or Val; the amino acid at position 82 is Ile, Ala, Leu, Met, Arg or Val; the amino acid at position 83 is Glu, Ala, Cys, Asp, Phe, Gly, His, Ile, Lys, Leu, Asn, Pro, Arg, Ser, Thr, Val or Tyr; the amino acid at position 84 is Pro, Ala, Cys, Glu, Ile, Ser, Val, Trp or Tyr; the amino acid at position 85 is Leu, Cys, Gly or Val; and the amino acid at position 86 is Ser, Ala, Ile, Thr or Val, and wherein 1 to 14 amino acids are optionally deleted from the N-terminus and/or C-terminus of the PIP-72 polypeptide.

In some embodiments the nucleic acid molecule encodes a PIP-72 polypeptide comprising an amino acid sequence having at least 50% identity to SEQ ID NO: 2, a hydrophobic interface surface corresponding to residues selected from positions 16, 18, 19, 20, 21, 22, 26, 27, 45, 46, 48, 50, 57, 59, 61, 85, and 86, corresponding to SEQ ID NO: 2, and the amino acid at position 2 is Gly, Lys or Ala; the amino acid at position 3 is Ile or Leu; the amino acid at position 4 is Thr or Ser; the amino acid at position 5 is Val or Ile; the amino acid at position 6 is Thr or Lys; the amino acid at position 8 is Asn, Lys, Gly or Ser; the amino acid at position 9 is Ser or Ala; the amino acid at position 11 is Asn, Lys, His or Thr; the amino acid at position 12 is Pro, Thr, Lys or Ser; the amino acid at position 13 is Ile or Val; the amino acid at position 14 is Glu or Asp; the amino acid at position 15 is Val, Ala or Ile; the amino acid at position 16 is Ala or Ser; the amino acid at position 17 is Ile or Val; the amino acid at position 18 is Asn or Ser; the amino acid at position 19 is His, Lys, Arg, Gln or Ala; the amino acid at position 21 is Gly or Arg; the amino acid at

position 22 is Ser, Lys, Asn, Asp or Thr; the amino acid at position 25 is Asp or Asn; the amino acid at position 26 is Thr or Asp; the amino acid at position 27 is Ser, Thr, Asn or Lys; the amino acid at position 28 is Phe, Tyr or Pro; the amino acid at position 29 is Phe or Tyr; the amino acid at position 30 is Ser, Gly or Lys; the amino acid at position 31 is Val, Ile or Met; the amino acid at position 32 is Gly, Ala or Asp; the amino acid at position 33 is Asn, Ser, Gln or Pro; the amino acid at position 35 is Lys, Glu or Ser; the amino acid at position 36 is Gln, Asn or Ser; the amino acid at position 37 is Glu or Asp; the amino acid at position 38 is Thr or Ser; the amino acid at position 42 is Ser or Asn; the amino acid at position 44 is Ser, Asp, Ala or Leu; the amino acid at position 47 is Phe or Tyr; the amino acid at position 48 is Leu or Met; the amino acid at position 49 is Leu or Met; the amino acid at position 50 is Ser, Ala or Tyr; the amino acid at position 51 is Leu or Val; the amino acid at position 52 is Lys or Gln; the amino acid at position 53 is Lys, Arg, Met or Leu; the amino acid at position 54 is Asn, Lys or Gly; the amino acid at position 55 is Gly or Ser; the amino acid at position 56 is Ala, Thr, Gln or Ser; the amino acid at position 57 is Gln, Val or Ala; the amino acid at position 58 is His, Ala, Lys, Tyr or Thr; the amino acid at position 59 is Pro or Thr; the amino acid at position 62 is Val or Ile; the amino acid at position 63 is Gln, Ser or Leu; the amino acid at position 64 is Ala, Gln or Ser; the amino acid at position 65 is Ser or Thr; the amino acid at position 67 is Lys, Gln, Arg or Asn; the amino acid at position 69 is Glu, Lys or Val; the amino acid at position 70 is Val or Ile; the amino acid at position 71 is Asp, Glu or Tyr; the amino acid at position 72 is Asn, His, Ser or Asp; the amino acid at position 73 is Asn, Ser or Asp; the amino acid at position 74 is Ala, Thr, Met, Ile or Lys; the amino acid at position 76 is Lys or Thr; the amino acid at position 78 is Gln, His or Ser; the amino acid at position 80 is Arg, Glu or Gln; the amino acid at position 81 is Leu, Pro, Ala or Thr; the amino acid at position 82 is Ile or Leu; the amino acid at position 83 is Glu, His, Asn, Gln or Leu; the amino acid at position 85 is Leu, Val or Ala; and the amino acid at position 86 is Ser, Ala, Tyr or Asn, and wherein, 1 to 14 amino acids are optionally deleted from the N-terminus and/or C-terminus of the PIP-72 polypeptide and/or an amino acid is inserted between residue 24 and 25 relative to SEQ ID NO: 2.

In some embodiments the nucleic acid molecule encodes a PIP-72 polypeptide comprising an amino acid sequence having at least 50% identity to SEQ ID NO: 2, a hydrophobic interface surface corresponding to residues selected from positions 16, 18, 19, 20, 21, 22, 26, 27, 45, 46, 48, 50, 57, 59, 61, 85, and 86, corresponding to SEQ ID NO: 2, and the amino acid at position 2 is Gly, Lys, Ala or Arg; the amino acid at position 3 is Ile, Leu or Val; the amino acid at position 4 is Thr or Ser; the amino acid at position 5 is Val, Ile or Leu; the amino acid at position 6 is Thr, Lys, Ser or Arg; the amino acid at

position 8 is Asn, Lys, Gly, Ser, Gln, Arg, Thr or Ala; the amino acid at position 9 is Ser, Ala or Thr; the amino acid at position 11 is Asn, Lys, Thr, Gln, Arg, His or Ser; the amino acid at position 12 is Pro, Thr, Lys, Ser or Arg; the amino acid at position 13 is Ile, Val or Leu; the amino acid at position 14 is Glu or Asp; the amino acid at position 15 is Val, Ala, Ile or Leu; the amino acid at position 16 is Ala or Ser; the amino acid at position 17 is Ile, Val or Leu; the amino acid at position 18 is Asn, Ser, Gln or Thr; the amino acid at position 19 is His, Lys, Ala, Gln, Asn or Arg; the amino acid at position 20 is Trp; the amino acid at position 21 is Gly, Arg or Lys; the amino acid at position 22 is Ser, Lys, Asn, Thr, Arg, Asp, Glu or Gln; the amino acid at position 25 is Asp, Asn, Glu or Gln; the amino acid at position 26 is Thr, Asp, Ser or Glu; the amino acid at position 27 is Ser, Thr, Lys, Asn, Gln or Arg; the amino acid at position 28 is Phe, Tyr, Pro or Trp; the amino acid at position 29 is Phe, Tyr or Trp; the amino acid at position 30 is Ser, Gly, Lys, Thr or Arg; the amino acid at position 31 is Val, Ile, Met or Leu; the amino acid at position 32 is Gly, Ala, Asp or Glu; the amino acid at position 33 is Asn, Ser, Gln, Pro or Thr; the amino acid at position 35 is Lys, Glu, Ser, Arg or Thr; the amino acid at position 36 is Gln, Ser, Asn or Thr; the amino acid at position 37 is Glu or Asp; the amino acid at position 38 is Thr or Ser; the amino acid at position 42 is Ser, Asn, Thr or Gln; the amino acid at position 44 is Ser, Asp, Ala, Leu, Thr, Glu, Ile or Val; the amino acid at position 47 is Phe, Tyr or Trp; the amino acid at position 48 is Leu, Met, Ile or Val; the amino acid at position 49 is Leu, Met, Ile or Val; the amino acid at position 50 is Ser, Ala, Tyr or Thr; the amino acid at position 51 is Leu, Val or Ile; the amino acid at position 52 is Lys, Gln, Arg or Asn; the amino acid at position 53 is Lys, Arg, Met, Leu, Ile or Val; the amino acid at position 54 is Asn, Lys, Gly, Gln or Arg; the amino acid at position 55 is Gly, Ser or Thr; the amino acid at position 56 is Ala, Thr, Gln, Ser or Asn; the amino acid at position 57 is Gln, Val, Ala, Asn, Leu or Ile; the amino acid at position 58 is His, Ala, Lys, Tyr or Thr; the amino acid at position 59 is Pro, Thr or Ser; the amino acid at position 62 is Val, Ile or Leu; the amino acid at position 63 is Gln, Ser, Leu, Asn, Thr, Ile or Val; the amino acid at position 64 is Ala, Gln, Ser, Asn or Thr; the amino acid at position 65 is Ser or Thr; the amino acid at position 67 is Lys, Gln, Asn or Arg; the amino acid at position 69 is Glu, Val, Asp, Lys, Arg, Ile or Leu; the amino acid at position 70 is Val, Ile or Leu; the amino acid at position 71 is Asp, Glu, Tyr or Trp; the amino acid at position 72 is Asn, His, Ser, Asp, Gln, Thr or Glu; the amino acid at position 73 is Asn, Ser, Asp, Gln, Thr or Glu; the amino acid at position 74 is Ala, Thr, Met, Ile, Lys, Ser, Leu, Val or Arg; the amino acid at position 76 is Lys, Thr, Arg or Ser; the amino acid at position 78 is Gln, His, Ser, Asn or Thr; the amino acid at position 80 is Arg, Glu, Gln, Lys, Asp or Asn; the amino acid at position 81 is Leu, Pro, Thr, Ile, Val, Ala or Ser; the amino acid at position 82 is Ile, Leu or Val; the amino

acid at position 83 is Glu, His, Asn, Leu, Gln, Ile or Val; the amino acid at position 85 is Leu, Val or Ala; and the amino acid at position 86 is Ser, Ala, Tyr, Asn or Thr, and wherein, 1 to 14 amino acids are optionally deleted from the N-terminus and/or C-terminus of the PIP-72 polypeptide and/or an amino acid is inserted between residue 24 and 25 relative to SEQ ID NO: 2.

In some embodiments the nucleic acid molecule encodes a PIP-72 polypeptide comprising an amino acid sequence having at least 50% identity to SEQ ID NO: 2, a hydrophobic interface surface corresponding to residues selected from positions 16, 18, 19, 20, 21, 22, 26, 27, 45, 46, 48, 50, 57, 59, 61, 85, and 86, corresponding to SEQ ID NO: 2, and the amino acid at position 2 is Gly, Ala, Cys, Asp, Glu, Ile, Lys, Leu, Asn, Arg, Ser, Thr, Val, Trp or Tyr; the amino acid at position 3 is Ile, Leu, Val or Trp; the amino acid at position 4 is Thr, Ala, Asp, Glu, His, Ile, Lys, Leu, Arg, Ser, Val, Trp or Tyr; the amino acid at position 5 is Val, Ala, Cys, Gly, His, Ile, Leu or Tyr; the amino acid at position 6 is Thr, Ala, Cys, Phe, Gly, His, Ile, Lys, Met, Pro, Gln, Arg, Ser, Trp or Tyr; the amino acid at position 7 is Asn, Ala or Val; the amino acid at position 8 is Asn, Lys, Gly, Ser, Gln, Arg, Thr, Ala, Cys, Asp, Glu, His, Ile, Leu, Met or Val; the amino acid at position 9 is Ser, Ala, Cys, Gly or Thr; the amino acid at position 11 is Asn, Lys, Thr, Gln, Arg, Ser, Ala, Cys, Asp, Glu, Gly, His, Ile, Leu, Met, Val or Tyr; the amino acid at position 12 is Pro, Thr, Lys, Ser, Arg, Ala, Cys, Asp, Glu, Gly, His, Leu, Asn, Gln, Arg, Val, Trp or Tyr; the amino acid at position 13 is Ile, Asn, Gln, Leu or Val; the amino acid at position 14 is Glu, Ala, Cys, Phe, His, Lys, Asp or Gln; the amino acid at position 15 is Val, Ala, Ile, Leu, Cys, Met or Arg; the amino acid at position 16 is Ala or Ser; the amino acid at position 17 is Ile, Glu, Leu or Val; the amino acid at position 18 is Asn, Gln, Thr or Ser; the amino acid at position 19 is His, Lys, Ala, Arg, Glu, Leu, Pro, Ser or Tyr; the amino acid at position 20 is Trp; the amino acid at position 21 is Gly, Arg or Lys; the amino acid at position 22 is Ser, Ala, Asp, Phe, Gly, His, Ile, Lys, Leu, Met, Asn, Pro, Gln, Arg, Thr, Val or Tyr; the amino acid at position 23 is Asp, Ala, Gly, His, Lys, Met, Asn, Gln, Ser, Thr or Val; the amino acid at position 24 is Gly, Asp or Phe; the amino acid at position 25 is Asp, Ala, Glu, Phe, Asn or Gln; the amino acid at position 26 is Thr, Glu, Asp, Ser or Pro; the amino acid at position 27 is Ser, Thr, Lys, Arg, Ala, Cys, Asp, Glu, Phe, Gly, His, Asn or Gln; the amino acid at position 28 is Phe, Tyr, Pro or Trp; the amino acid at position 29 is Phe, Ala, Cys, Ile, Leu, Gln, Arg, Trp or Tyr; the amino acid at position 30 is Ser, Gly, Lys, Thr, Arg, Ala, Cys, Asp, Glu, Phe, His, Leu, Met, Asn, Pro, Gln, Val, Trp or Tyr; the amino acid at position 31 is Val, Ile, Met or Leu; the amino acid at position 32 is Gly, Ala, Asp, Glu, Phe, His, Lys, Leu, Met, Asn, Pro, Gln, Arg, Ser, Thr, Val, Trp or Tyr; the amino acid at position 33 is Asn, Ser, Gln, Pro, Thr, Ala, Cys, Asp, Glu, Phe, Gly, His, Ile, Lys, Leu, Arg, Val or

Tyr; the amino acid at position 34 is Gly, Glu, Phe, His, Lys, Leu, Met, Asn, Gln, Arg, Ser, Thr or Tyr; the amino acid at position 35 is Lys, Glu, Ala, Cys, Asp, Gly, His, Ile, Leu, Met, Asn, Gln, Arg, Ser, Thr or Val; the amino acid at position 36 is Gln, Ala, Cys, Glu, Gly, His, Ile, Lys, Leu, Asn, Pro, Arg, Ser, Thr or Val; the amino acid at position 37 is Glu, Asp, Ala, Cys, Phe, Gly, Ile, Lys, Leu, Met, Asn, Ser, Thr or Val; the amino acid at position 38 is Thr, Ser, Ala, Cys, Asp, Glu, Phe, Gly, His, Ile, Leu, Met, Asn, Gln, Arg, Val, Trp or Tyr; the amino acid at position 39 is Trp or Phe; the amino acid at position 40 is Asp, Ala, Cys, Glu, Phe, Gly, His, Ile, Lys, Leu, Met, Asn, Gln, Arg, Ser, Thr, Val, Trp or Tyr; the amino acid at position 42 is Ser, Asn, Thr, Ala, Cys, Asp, Glu, Phe, Gly, Ile, Lys, Leu, Met, Arg, Val, Trp, Tyr or Gln; the amino acid at position 44 is Ser, Asp, Ala, Leu, Thr, Glu, Ile, Ala, Gly, Leu, Met, Asn, Pro, Gln, Val, Tyr or Val; the amino acid at position 45 is Arg, Lys or Ser; the amino acid at position 46 is Gly, Ala or Gln; the amino acid at position 47 is Phe, Tyr Cys, Val or Trp; the amino acid at position 48 is Leu, Met, Ile, Cys, Phe, Met, Arg, Tyr or Val; the amino acid at position 49 is Leu, Met, Ile or Val; the amino acid at position 50 is Ser, Ala, Tyr, Cys, Asp, Ile, Met, Pro, Gln, Val or Thr; the amino acid at position 51 is Leu, Val, Ala, Cys, Met or Ile; the amino acid at position 52 is Lys, Cys, Phe, His, Ile, Leu, Met, Asn, Arg, Ser, Thr, Gln, Trp or Tyr; the amino acid at position 53 is Lys, Arg, Met, Leu, Ile, Ala, Cys, Asp, Glu, Phe, His, Asn, Gln, Ser, Thr, Tyr or Val; the amino acid at position 54 is Asn, Cys, Asp, Glu, Phe, Gly, Lys, Met, Gln, Arg, Ser or Trp; the amino acid at position 55 is Gly, Ser or Thr; the amino acid at position 56 is Ala, Thr, Gln, Ser, Gly, Leu, Pro, Arg or Asn; the amino acid at position 57 is Gln, Glu, Leu, Met, Ser, Val, Ala, Asn, Ile or Thr; the amino acid at position 58 is His, Ala, Lys, Asp, Phe, Leu, Met, Asn, Arg, Trp, Tyr or Thr; the amino acid at position 59 is Pro, Thr or Ser; the amino acid at position 60 is Tyr, Glu or Phe; the amino acid at position 62 is Val, Ile or Leu; the amino acid at position 63 is Gln, Ser, Cys, Gly, Ile, Leu, Met, Asn, Thr, Val or Tyr; the amino acid at position 64 is Ala, Gln, Asn, Phe, Gly, His, Arg, Ser or Tyr; the amino acid at position 65 is Ser, Ala, Cys, Asp, Glu, Phe, Gly, His, Ile, Leu, Asn, Val or Thr; the amino acid at position 66 is Ser, Ala or Gly; the amino acid at position 67 is Lys, Gln, Asn or Arg; the amino acid at position 67 is Lys, Ala, Cys, Asp, Phe, His, Ile, Leu, Met, Asn, Gln, Arg, Ser, Thr, Val, Trp or Tyr; the amino acid at position 68 is Ile Asp, Leu or Val; the amino acid at position 69 is Glu, Ala, Cys, Asp, Phe, His, Ile, Leu, Met, Gln, Arg, Ser, Thr, Val or Tyr; the amino acid at position 70 is Val, Ile, Cys or Leu; the amino acid at position 71 is Asp, Glu, Tyr, Ala, Cys, Gly, His, Ile, Leu, Met, Asn, Ser, Thr, Val or Trp; the amino acid at position 72 is Asn, Ala, Cys, Asp, Glu, Gly, Lys, Met, Pro, Gln, Arg, Ser, Thr, Val, His or Trp; the amino acid at position 73 is Asn, Ser, Asp, Gln, Thr, Ala, Cys, Phe, Gly, His, Ile, Leu, Val, Tyr or Glu; the amino acid at position 74 is Ala, Thr, Met, Ile, Lys, Ser, Leu, Val, Cys, Asp,

Phe, Gly, His, Asn, Gln, Tyr or Arg; the amino acid at position 75 is Val, Cys, Ile or Leu; the amino acid at position 76 is Lys, Ala, Cys, Phe, His, Ile, Leu, Gln, Arg, Ser, Thr, Val, Trp or Tyr; the amino acid at position 77 is Asp Tyr; the amino acid at position 78 is Gln, His, Ser, Asn, Ala, Cys, Asp, Phe, Gly, Ile, Leu, Met, Asn, Arg, Val, Tyr or Thr; the amino acid at position 79 is Gly, Arg, Ala, Cys, Asp, Glu, Phe, His, Lys, Leu, Asn, Gln, Arg, Ser, Thr, Trp or Tyr; the amino acid at position 80 is Arg, Glu, Gln, Lys, Asp, Ala, Cys, Phe, Gly, His, Ile, Leu, Ser, Thr, Val, Tyr or Asn; the amino acid at position 81 is Leu, Pro, Thr, Ile, Val, Ala, Cys, Asp, Phe, Gly, His or Ser; the amino acid at position 82 is Ile, Ala, Leu, Met, Arg and Val; the amino acid at position 83 is Glu, His, Asn, Leu, Gln, Ile, Ala, Cys, Asp, Phe, Gly, Lys, Pro, Arg, Ser, Thr, Tyr or Val; the amino acid at position 84 is Pro, Ala, Cys, Glu, Ile, Ser, Val, Trp or Tyr; the amino acid at position 85 is Leu, Val, Cys, Gly or Ala; and the amino acid at position 86 is Ser, Ala, Tyr, Asn, Ile, Val or Thr, and wherein, 1 to 14 amino acids are optionally deleted from the N-terminus and/or C-terminus of the PIP-72 polypeptide and/or an amino acid is inserted between residue 24 and 25 relative to SEQ ID NO: 2.

In some embodiments the nucleic acid molecules encode a PIP-72 polypeptide comprising an amino acid motif as represented by positions 37-51 of SEQ ID NO: 846, SEQ ID NO: 847, SEQ ID NO: 848 or SEQ ID NO: 849.

In some embodiments exemplary nucleic acid molecules encode a PIP-72 polypeptide of SEQ ID NO: 2, SEQ ID NO: 4, SEQ ID NO: 6, SEQ ID NO: 8, SEQ ID NO: 10, SEQ ID NO: 12, SEQ ID NO: 14, SEQ ID NO: 18, SEQ ID NO: 28, SEQ ID NO: 32, any one of SEQ ID NO: 528 - SEQ ID NO: 768, any one of SEQ ID NO: 825 – SEQ ID NO: 844, SEQ ID NO: 771, SEQ ID NO: 772, SEQ ID NO: 852, any one of SEQ ID NO: 903 – 914, SEQ ID NO: 927, SEQ ID NO: 928, SEQ ID NO: 932, SEQ ID NO: 933, SEQ ID NO: 934, SEQ ID NO: 935, SEQ ID NO: 936, SEQ ID NO: 939, SEQ ID NO: 940, SEQ ID NO: 941, SEQ ID NO: 943, SEQ ID NO: 944, SEQ ID NO: 945 or SEQ ID NO: 946, as well as amino acid substitutions deletions, insertions and fragments thereof and combinations thereof.

In some embodiments the nucleic acid molecules encode a PIP-72 polypeptide of Table 14, Table 17, Table 20, Table 23, Table 24, Table 26, Table 28, and/or Table 29, combinations of the amino acid substitutions thereof, and deletions and/or insertions thereof.

In some embodiments a nucleic acid molecule encoding the PIP-72 polypeptide is a non-genomic nucleic acid sequence. As used herein a “non-genomic nucleic acid sequence” or “non-genomic nucleic acid molecule” refers to a nucleic acid molecule that has one or more change in the nucleic acid sequence compared to a native or genomic

nucleic acid sequence. In some embodiments the change to a native or genomic nucleic acid molecule includes but is not limited to: changes in the nucleic acid sequence due to the degeneracy of the genetic code; codon optimization of the nucleic acid sequence for expression in plants; changes in the nucleic acid sequence to introduce at least one amino acid substitution, insertion, deletion and/or addition compared to the native or genomic sequence; removal of one or more intron associated with the genomic nucleic acid sequence; insertion of one or more heterologous introns; deletion of one or more upstream or downstream regulatory regions associated with the genomic nucleic acid sequence; insertion of one or more heterologous upstream or downstream regulatory regions; deletion of the 5' and/or 3' untranslated region associated with the genomic nucleic acid sequence; insertion of a heterologous 5' and/or 3' untranslated region; and modification of a polyadenylation site. In some embodiments the non-genomic nucleic acid molecule is a cDNA. In some embodiments the non-genomic nucleic acid molecule is a synthetic nucleic acid sequence.

In some embodiments the non-genomic nucleic acid molecule encodes a PIP-72 polypeptide comprising an amino acid sequence having at least 50% identity to the amino acid sequence of SEQ ID NO: 2, SEQ ID NO: 4, SEQ ID NO: 6, SEQ ID NO: 8, SEQ ID NO: 10, SEQ ID NO: 12, SEQ ID NO: 14, SEQ ID NO: 18, SEQ ID NO: 28, SEQ ID NO: 32, SEQ ID NO: 927, SEQ ID NO: 928, SEQ ID NO: 932, SEQ ID NO: 933, SEQ ID NO: 934, SEQ ID NO: 935, SEQ ID NO: 936, SEQ ID NO: 939, SEQ ID NO: 940, SEQ ID NO: 941, SEQ ID NO: 943, SEQ ID NO: 944, SEQ ID NO: 945 or SEQ ID NO: 946, wherein the PIP-72 polypeptide comprises a hydrophobic interface surface and has at least one amino acid change compared to native sequence.

Also provided are nucleic acid molecules that encode transcription and/or translation products that are subsequently spliced to ultimately produce functional PIP-72 polypeptides. Splicing can be accomplished in vitro or in vivo, and can involve cis- or trans-splicing. The substrate for splicing can be polynucleotides (e.g., RNA transcripts) or polypeptides. An example of cis-splicing of a polynucleotide is where an intron inserted into a coding sequence is removed and the two flanking exon regions are spliced to generate a PIP-72 polypeptide encoding sequence. An example of trans splicing would be where a polynucleotide is encrypted by separating the coding sequence into two or more fragments that can be separately transcribed and then spliced to form the full-length pesticidal encoding sequence. The use of a splicing enhancer sequence, which can be introduced into a construct, can facilitate splicing either in cis or trans-splicing of polypeptides (US Patent Numbers 6,365,377 and 6,531,316). Thus, in some embodiments the polynucleotides do not directly encode a full-length PIP-72 polypeptide,

but rather encode a fragment or fragments of a PIP-72 polypeptide. These polynucleotides can be used to express a functional PIP-72 polypeptide through a mechanism involving splicing, where splicing can occur at the level of polynucleotide (e.g., intron/exon) and/or polypeptide (e.g., intein/extein). This can be useful, for example, in controlling expression of pesticidal activity, since a functional pesticidal polypeptide will only be expressed if all required fragments are expressed in an environment that permits splicing processes to generate functional product. In another example, introduction of one or more insertion sequences into a polynucleotide can facilitate recombination with a low homology polynucleotide; use of an intron or intein for the insertion sequence facilitates the removal of the intervening sequence, thereby restoring function of the encoded variant.

Nucleic acid molecules that are fragments of these nucleic acid sequences encoding PIP-72 polypeptides are also encompassed by the embodiments. "Fragment" as used herein refers to a portion of the nucleic acid sequence encoding a PIP-72 polypeptide. A fragment of a nucleic acid sequence may encode a biologically active portion of a PIP-72 polypeptide or it may be a fragment that can be used as a hybridization probe or PCR primer using methods disclosed below. Nucleic acid molecules that are fragments of a nucleic acid sequence encoding a PIP-72 polypeptide comprise at least about 130, 140, 150, 160, 170, 180, 190, 200, 210, 220, 230, 240, 250 or 260, contiguous nucleotides or up to the number of nucleotides present in a full-length nucleic acid sequence encoding a PIP-72 polypeptide disclosed herein, depending upon the intended use. "Contiguous nucleotides" is used herein to refer to nucleotide residues that are immediately adjacent to one another. Fragments of the nucleic acid sequences of the embodiments will encode protein fragments that retain the biological activity of the PIP-72 polypeptide and, hence, retain insecticidal activity. "Retains PIP-72 activity" is used herein to refer to a polypeptide having at least about 10%, at least about 30%, at least about 50%, at least about 70%, 80%, 90%, 95% or higher of the insecticidal activity of the full-length PIP-72Aa polypeptide of SEQ ID NO: 2. In one embodiment, the insecticidal activity is Lepidoptera activity. In one embodiment, the insecticidal activity is against a Coleopteran species. In one embodiment, the insecticidal activity is against a *Diabrotica* species. In one embodiment, the insecticidal activity is against one or more insect pests of the corn rootworm complex: Western corn rootworm, *Diabrotica virgifera virgifera*; northern corn rootworm, *D. barberi*; Southern corn rootworm or spotted cucumber beetle; *Diabrotica undecimpunctata howardi*, and the Mexican corn rootworm, *D. virgifera zea*. In one embodiment, the insecticidal activity is against Western corn rootworm, *Diabrotica virgifera virgifera*.

In some embodiments a fragment of a nucleic acid sequence encoding a biologically active portion of a PIP-72 polypeptide will encode at least about 15, 20, 30, 40, 50, 60, 70, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84 or 85, contiguous amino acids or up to the total number of amino acids present in a full-length PIP-72 polypeptide of the

5 embodiments. In some embodiments, the fragment is an N-terminal and/or a C-terminal truncation of at least about 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14 or more amino acids from the N-terminus and/ or C-terminus relative to SEQ ID NO: 2, SEQ ID NO: 4, SEQ ID NO: 6, SEQ ID NO: 8, SEQ ID NO: 10, SEQ ID NO: 12, SEQ ID NO: 14, SEQ ID NO: 18, SEQ ID NO: 28, SEQ ID NO: 32, any one of SEQ ID NO: 528 - SEQ ID NO: 768, any one

10 of SEQ ID NO: 825 – SEQ ID NO: 844, SEQ ID NO: 771, SEQ ID NO: 772, SEQ ID NO: 852, any one of SEQ ID NO: 903 – 914, SEQ ID NO: 927, SEQ ID NO: 928, SEQ ID NO: 932, SEQ ID NO: 933, SEQ ID NO: 934, SEQ ID NO: 935, SEQ ID NO: 936, SEQ ID NO: 939, SEQ ID NO: 940, SEQ ID NO: 941, SEQ ID NO: 943, SEQ ID NO: 944, SEQ ID NO: 945 or SEQ ID NO: 946 or variants thereof, e.g., by proteolysis, insertion of a start codon,

15 deletion of the codons encoding the deleted amino acids with the concomitant insertion of a stop codon or by insertion of a stop codon in the coding sequence. In some embodiments, the fragments encompassed herein result from the removal of the N-terminal 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13 or 14 or more amino acids from the N-terminus relative to SEQ ID NO: 2, SEQ ID NO: 4, SEQ ID NO: 6, SEQ ID NO: 8, SEQ ID

20 NO: 10, SEQ ID NO: 12, SEQ ID NO: 14, SEQ ID NO: 18, SEQ ID NO: 28, SEQ ID NO: 32, any one of SEQ ID NO: 528 - SEQ ID NO: 768, any one of SEQ ID NO: 825 – SEQ ID NO: 844, SEQ ID NO: 771, SEQ ID NO: 772, SEQ ID NO: 852, any one of SEQ ID NO: 903 – 914, SEQ ID NO: 927, SEQ ID NO: 928, SEQ ID NO: 932, SEQ ID NO: 933, SEQ ID NO: 934, SEQ ID NO: 935, SEQ ID NO: 936, SEQ ID NO: 939, SEQ ID NO: 940, SEQ

25 ID NO: 941, SEQ ID NO: 943, SEQ ID NO: 944, SEQ ID NO: 945 or SEQ ID NO: 946 or variants thereof, e.g., by proteolysis or by insertion of a start codon in the coding sequence. In some embodiments, the fragments encompassed herein result from the removal of the N-terminal 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14 amino acids relative to SEQ ID NO: 2, SEQ ID NO: 4, SEQ ID NO: 6, SEQ ID NO: 8, SEQ ID NO: 10, SEQ ID

30 NO: 12, SEQ ID NO: 14, SEQ ID NO: 18, SEQ ID NO: 28 or SEQ ID NO: 32, any one of SEQ ID NO: 528 - SEQ ID NO: 768, any one of SEQ ID NO: 825 – SEQ ID NO: 844, SEQ ID NO: 771, SEQ ID NO: 772, SEQ ID NO: 852, any one of SEQ ID NO: 903 – 914, SEQ ID NO: 927, SEQ ID NO: 928, SEQ ID NO: 932, SEQ ID NO: 933, SEQ ID NO: 934, SEQ ID NO: 935, SEQ ID NO: 936, SEQ ID NO: 939, SEQ ID NO: 940, SEQ ID NO: 941, SEQ

35 ID NO: 943, SEQ ID NO: 944, SEQ ID NO: 945 or SEQ ID NO: 946 or variants thereof, e.g., by proteolysis or by insertion of a start codon in the coding sequence.

In some embodiments a PIP-72 polypeptide is encoded by a nucleic acid sequence sufficiently homologous to the nucleic acid sequence of SEQ ID NO: 1, SEQ ID NO: 3, SEQ ID NO: 5, SEQ ID NO: 7, SEQ ID NO: 9, SEQ ID NO: 11, SEQ ID NO: 13, SEQ ID NO: 17, SEQ ID NO: 27, SEQ ID NO: 31, SEQ ID NO: 949, SEQ ID NO: 950, SEQ ID NO: 954, SEQ ID NO: 955, SEQ ID NO: 956, SEQ ID NO: 957, SEQ ID NO: 958, SEQ ID NO: 961, SEQ ID NO: 962, SEQ ID NO: 963, SEQ ID NO: 965, SEQ ID NO: 966, SEQ ID NO: 967 or SEQ ID NO: 968. "Sufficiently homologous" is used herein to refer to an amino acid or nucleic acid sequence that has at least about 50%, 55%, 60%, 65%, 70%, 75%, 80%, 81%, 82%, 83%, 84%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99% or greater sequence homology compared to a reference sequence using one of the alignment programs described herein using standard parameters. One of skill in the art will recognize that these values can be appropriately adjusted to determine corresponding homology of proteins encoded by two nucleic acid sequences by taking into account codon degeneracy, amino acid similarity, reading frame positioning, and the like. In some embodiments the sequence homology is against the full length sequence of the polynucleotide encoding a PIP-72 polypeptide or against the full length sequence of a PIP-72 polypeptide. In some embodiments the PIP-72 polypeptide has at least about 50%, 55%, 60%, 65%, 70%, 75%, 80%, 81%, 82%, 83%, 84%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99% or greater sequence identity compared to SEQ ID NO: 2, SEQ ID NO: 4, SEQ ID NO: 6, SEQ ID NO: 8, SEQ ID NO: 10, SEQ ID NO: 12, SEQ ID NO: 14, SEQ ID NO: 18, SEQ ID NO: 28 or SEQ ID NO: 32, SEQ ID NO: 927, SEQ ID NO: 928, SEQ ID NO: 932, SEQ ID NO: 933, SEQ ID NO: 934, SEQ ID NO: 935, SEQ ID NO: 936, SEQ ID NO: 939, SEQ ID NO: 940, SEQ ID NO: 941, SEQ ID NO: 943, SEQ ID NO: 944, SEQ ID NO: 945 or SEQ ID NO: 946. In some embodiments the sequence identity is against the full length sequence of the polynucleotide encoding a PIP-72 polypeptide or against the full length sequence of a PIP-72 polypeptide. In some embodiments the sequence identity is calculated using ClustalW algorithm in the ALIGNX® module of the Vector NTI® Program Suite (Invitrogen Corporation, Carlsbad, Calif.) with all default parameters. In some embodiments the sequence identity is across the entire length of polypeptide calculated using ClustalW algorithm in the ALIGNX module of the Vector NTI Program Suite (Invitrogen Corporation, Carlsbad, Calif.) with all default parameters.

To determine the percent identity of two amino acid sequences or of two nucleic acid sequences, the sequences are aligned for optimal comparison purposes. The percent identity between the two sequences is a function of the number of identical positions shared by the sequences (i.e., percent identity=number of identical

positions/total number of positions (e.g., overlapping positions)×100). In one embodiment, the two sequences are the same length. In another embodiment, the comparison is across the entirety of the reference sequence (e.g., across the entirety of one of SEQ ID NO: 1, SEQ ID NO: 2). The percent identity between two sequences can
5 be determined using techniques similar to those described below, with or without allowing gaps. In calculating percent identity, typically exact matches are counted.

The determination of percent identity between two sequences can be accomplished using a mathematical algorithm. A non-limiting example of a mathematical algorithm utilized for the comparison of two sequences is the algorithm of Karlin and
10 Altschul, (1990) *Proc. Natl. Acad. Sci. USA* 87:2264, modified as in Karlin and Altschul, (1993) *Proc. Natl. Acad. Sci. USA* 90:5873-5877. Such an algorithm is incorporated into the BLASTN and BLASTX programs of Altschul, *et al.*, (1990) *J. Mol. Biol.* 215:403. BLAST nucleotide searches can be performed with the BLASTN program, score=100, wordlength=12, to obtain nucleic acid sequences homologous to pesticidal nucleic acid
15 molecules of the embodiments. BLAST protein searches can be performed with the BLASTX program, score=50, wordlength=3, to obtain amino acid sequences homologous to pesticidal protein molecules of the embodiments. To obtain gapped alignments for comparison purposes, Gapped BLAST (in BLAST 2.0) can be utilized as described in Altschul, *et al.*, (1997) *Nucleic Acids Res.* 25:3389. Alternatively, PSI-Blast can be used
20 to perform an iterated search that detects distant relationships between molecules. See, Altschul, *et al.*, (1997) *supra*. When utilizing BLAST, Gapped BLAST, and PSI-Blast programs, the default parameters of the respective programs (e.g., BLASTX and BLASTN) can be used. Alignment may also be performed manually by inspection.

Another non-limiting example of a mathematical algorithm utilized for the
25 comparison of sequences is the ClustalW algorithm (Higgins, *et al.*, (1994) *Nucleic Acids Res.* 22:4673-4680). ClustalW compares sequences and aligns the entirety of the amino acid or DNA sequence, and thus can provide data about the sequence conservation of the entire amino acid sequence. The ClustalW algorithm is used in several commercially available DNA/amino acid analysis software packages, such as the ALIGNX® module of
30 the Vector NTI® Program Suite (Invitrogen Corporation, Carlsbad, Calif.). After alignment of amino acid sequences with ClustalW, the percent amino acid identity can be assessed. A non-limiting example of a software program useful for analysis of ClustalW alignments is GENEDOC™. GENEDOC™ (Karl Nicholas) allows assessment of amino acid (or DNA) similarity and identity between multiple proteins. Another non-limiting example of a
35 mathematical algorithm utilized for the comparison of sequences is the algorithm of Myers and Miller, (1988) *CAB/OS* 4:11-17. Such an algorithm is incorporated into the ALIGN

program (version 2.0), which is part of the GCG Wisconsin Genetics Software Package, Version 10 (available from Accelrys, Inc., 9685 Scranton Rd., San Diego, Calif., USA). When utilizing the ALIGN program for comparing amino acid sequences, a PAM120 weight residue table, a gap length penalty of 12, and a gap penalty of 4 can be used.

5 Another non-limiting example of a mathematical algorithm utilized for the comparison of sequences is the algorithm of Needleman and Wunsch, (1970) *J. Mol. Biol.* 48(3):443-453, used GAP Version 10 software to determine sequence identity or similarity using the following default parameters: % identity and % similarity for a nucleic acid sequence using GAP Weight of 50 and Length Weight of 3, and the nwsgapdna.cmpii
10 scoring matrix; % identity or % similarity for an amino acid sequence using GAP weight of 8 and length weight of 2, and the BLOSUM62 scoring program. Equivalent programs may also be used. "Equivalent program" is used herein to refer to any sequence comparison program that, for any two sequences in question, generates an alignment having identical nucleotide residue matches and an identical percent sequence identity when compared to
15 the corresponding alignment generated by GAP Version 10.

The embodiments also encompass nucleic acid molecules encoding PIP-72 polypeptide variants. "Variants" of the PIP-72 polypeptide encoding nucleic acid sequences include those sequences that encode the PIP-72 polypeptides disclosed herein but that differ conservatively because of the degeneracy of the genetic code as
20 well as those that are sufficiently identical as discussed above. Naturally occurring allelic variants can be identified with the use of well-known molecular biology techniques, such as polymerase chain reaction (PCR) and hybridization techniques as outlined below. Variant nucleic acid sequences also include synthetically derived nucleic acid sequences that have been generated, for example, by using site-directed mutagenesis but which still
25 encode the PIP-72 polypeptides disclosed as discussed below.

The present disclosure provides isolated or recombinant polynucleotides that encode any of the PIP-72 polypeptides disclosed herein. Those having ordinary skill in the art will readily appreciate that due to the degeneracy of the genetic code, a multitude of nucleotide sequences encoding PIP-72 polypeptides of the present disclosure exist. Table
30 1 is a codon table that provides the synonymous codons for each amino acid. For example, the codons AGA, AGG, CGA, CGC, CGG, and CGU all encode the amino acid arginine. Thus, at every position in the nucleic acids of the disclosure where an arginine is specified by a codon, the codon can be altered to any of the corresponding codons described above without altering the encoded polypeptide. It is understood that U in an
35 RNA sequence corresponds to T in a DNA sequence.

Table 1

Alanine	Ala	GCA	GCC	GCG	GCU		
Cysteine	Cys	UGC	UGU				
Aspartic acid	Asp	GAC	GAU				
Glutamic acid	Glu	GAA	GAG				
Phenylalanine	Phe	UUC	UUU				
Glycine	Gly	GGA	GGC	GGG	GGU		
Histidine	His	CAC	CAU				
Isoleucine	Ile	AUA	AUC	AUU			
Lysine	Lys	AAA	AAG				
Leucine	Leu	UUA	UUG	CUA	CUC	CUG	CUU
Methionine	Met	AUG					
Asparagine	Asn	AAC	AAU				
Proline	Pro	CCA	CCC	CCG	CCU		
Glutamine	Gln	CAA	CAG				
Arginine	Arg	AGA	AGG	CGA	CGC	CGG	CGU
Serine	Ser	AGC	AGU	UCA	UCC	UCG	UCU
Threonine	Thr	ACA	ACC	ACG	ACU		
Valine	Val	GUA	GUC	GUG	UU		
Tryptophan	Trp	UGG					
Tyrosine	Tyr	UAC	UAU				

The skilled artisan will further appreciate that changes can be introduced by mutation of the nucleic acid sequences thereby leading to changes in the amino acid sequence of the encoded PIP-72 polypeptides, without altering the biological activity of the proteins. Thus, variant nucleic acid molecules can be created by introducing one or more nucleotide substitutions, additions and/or deletions into the corresponding nucleic acid sequence disclosed herein, such that one or more amino acid substitutions, additions or deletions are introduced into the encoded protein. Mutations can be introduced by standard techniques, such as site-directed mutagenesis and PCR-mediated mutagenesis. Such variant nucleic acid sequences are also encompassed by the present disclosure.

Alternatively, variant nucleic acid sequences can be made by introducing mutations randomly along all or part of the coding sequence, such as by saturation

mutagenesis, and the resultant mutants can be screened for ability to confer pesticidal activity to identify mutants that retain activity. Following mutagenesis, the encoded protein can be expressed recombinant, and the activity of the protein can be determined using standard assay techniques.

5 The polynucleotides of the disclosure and fragments thereof are optionally used as substrates for a variety of recombination and recursive recombination reactions, in addition to standard cloning methods as set forth in, e.g., Amusable, Berger and Sambrook, i.e., to produce additional pesticidal polypeptide homologues and fragments thereof with desired properties. A variety of such reactions are known, including those
10 developed by the inventors and their co-workers. Methods for producing a variant of any nucleic acid listed herein comprising recursively recombining such polynucleotide with a second (or more) polynucleotide, thus forming a library of variant polynucleotides are also embodiments of the disclosure, as are the libraries produced, the cells comprising the libraries and any recombinant polynucleotide produces by such methods. Additionally,
15 such methods optionally comprise selecting a variant polynucleotide from such libraries based on pesticidal activity, as is wherein such recursive recombination is done in vitro or in vivo.

 A variety of diversity generating protocols, including nucleic acid recursive recombination protocols are available and fully described in the art. The procedures can
20 be used separately, and/or in combination to produce one or more variants of a nucleic acid or set of nucleic acids, as well as variants of encoded proteins. Individually and collectively, these procedures provide robust, widely applicable ways of generating diversified nucleic acids and sets of nucleic acids (including, e.g., nucleic acid libraries) useful, e.g., for the engineering or rapid evolution of nucleic acids, proteins, pathways,
25 cells and/or organisms with new and/or improved characteristics.

 While distinctions and classifications are made in the course of the ensuing discussion for clarity, it will be appreciated that the techniques are often not mutually exclusive. Indeed, the various methods can be used singly or in combination, in parallel or in series, to access diverse sequence variants.

30 The result of any of the diversity generating procedures described herein can be the generation of one or more nucleic acids, which can be selected or screened for nucleic acids with or which confer desirable properties or that encode proteins with or which confer desirable properties. Following diversification by one or more of the methods herein or otherwise available to one of skill, any nucleic acids that are produced
35 can be selected for a desired activity or property, e.g. pesticidal activity or, such activity at a desired pH, etc. This can include identifying any activity that can be detected, for

example, in an automated or automatable format, by any of the assays in the art, see, e.g., discussion of screening of insecticidal activity, *infra*. A variety of related (or even unrelated) properties can be evaluated, in serial or in parallel, at the discretion of the practitioner.

5 Descriptions of a variety of diversity generating procedures for generating modified nucleic acid sequences, e.g., those coding for polypeptides having pesticidal activity or fragments thereof, are found in the following publications and the references cited therein: Soong, *et al.*, (2000) *Nat Genet* 25(4):436-439; Stemmer, *et al.*, (1999) *Tumor Targeting* 4:1-4; Ness, *et al.*, (1999) *Nat Biotechnol* 17:893-896; Chang, *et al.*, (1999) *Nat*
10 *Biotechnol* 17:793-797; Minshull and Stemmer, (1999) *Curr Opin Chem Biol* 3:284-290; Christians, *et al.*, (1999) *Nat Biotechnol* 17:259-264; Crameri, *et al.*, (1998) *Nature* 391:288-291; Crameri, *et al.*, (1997) *Nat Biotechnol* 15:436-438; Zhang, *et al.*, (1997) *PNAS USA* 94:4504-4509; Patten, *et al.*, (1997) *Curr Opin Biotechnol* 8:724-733; Crameri, *et al.*, (1996) *Nat Med* 2:100-103; Crameri, *et al.*, (1996) *Nat Biotechnol* 14:315-
15 319; Gates, *et al.*, (1996) *J Mol Biol* 255:373-386; Stemmer, (1996) "Sexual PCR and Assembly PCR" In: *The Encyclopedia of Molecular Biology*. VCH Publishers, New York. pp. 447-457; Crameri and Stemmer, (1995) *BioTechniques* 18:194-195; Stemmer, *et al.*, (1995) *Gene*, 164:49-53; Stemmer, (1995) *Science* 270: 1510; Stemmer, (1995) *Bio/Technology* 13:549-553; Stemmer, (1994) *Nature* 370:389-391 and Stemmer, (1994)
20 *PNAS USA* 91:10747-10751.

 Mutational methods of generating diversity include, for example, site-directed mutagenesis (Ling, *et al.*, (1997) *Anal Biochem* 254(2):157-178; Dale, *et al.*, (1996) *Methods Mol Biol* 57:369-374; Smith, (1985) *Ann Rev Genet* 19:423-462; Botstein and Shortle, (1985) *Science* 229:1193-1201; Carter, (1986) *Biochem J* 237:1-7 and Kunkel,
25 (1987) "The efficiency of oligonucleotide directed mutagenesis" in *Nucleic Acids & Molecular Biology* (Eckstein and Lilley, eds., Springer Verlag, Berlin)); mutagenesis using uracil containing templates (Kunkel, (1985) *PNAS USA* 82:488-492; Kunkel, *et al.*, (1987) *Methods Enzymol* 154:367-382 and Bass, *et al.*, (1988) *Science* 242:240-245); oligonucleotide-directed mutagenesis (Zoller and Smith, (1983) *Methods Enzymol*
30 100:468-500; Zoller and Smith, (1987) *Methods Enzymol* 154:329-350 (1987); Zoller and Smith, (1982) *Nucleic Acids Res* 10:6487-6500), phosphorothioate-modified DNA mutagenesis (Taylor, *et al.*, (1985) *Nucl Acids Res* 13:8749-8764; Taylor, *et al.*, (1985) *Nucl Acids Res* 13:8765-8787 (1985); Nakamaye and Eckstein, (1986) *Nucl Acids Res* 14:9679-9698; Sayers, *et al.*, (1988) *Nucl Acids Res* 16:791-802 and Sayers, *et al.*,
35 (1988) *Nucl Acids Res* 16:803-814); mutagenesis using gapped duplex DNA (Kramer, *et al.*, (1984) *Nucl Acids Res* 12:9441-9456; Kramer and Fritz, (1987) *Methods Enzymol*

154:350-367; Kramer, *et al.*, (1988) *Nucl Acids Res* 16:7207 and Fritz, *et al.*, (1988) *Nucl Acids Res* 16:6987-6999).

Additional suitable methods include point mismatch repair (Kramer, *et al.*, (1984) *Cell* 38:879-887), mutagenesis using repair-deficient host strains (Carter, *et al.*, (1985) *Nucl Acids Res* 13:4431-4443 and Carter, (1987) *Methods in Enzymol* 154:382-403), deletion mutagenesis (Eghtedarzadeh and Henikoff, (1986) *Nucl Acids Res* 14:5115), restriction-selection and restriction-purification (Wells, *et al.*, (1986) *Phil Trans R Soc Lond A* 317:415-423), mutagenesis by total gene synthesis (Nambiar, *et al.*, (1984) *Science* 223:1299-1301; Sakamar and Khorana, (1988) *Nucl Acids Res* 14:6361-6372; Wells, *et al.*, (1985) *Gene* 34:315-323 and Grundström, *et al.*, (1985) *Nucl Acids Res* 13:3305-3316), double-strand break repair (Mandecki, (1986) *PNAS USA*, 83:7177-7181 and Arnold, (1993) *Curr Opin Biotech* 4:450-455). Additional details on many of the above methods can be found in *Methods Enzymol* Volume 154, which also describes useful controls for trouble-shooting problems with various mutagenesis methods.

Additional details regarding various diversity generating methods can be found in the following US Patents, PCT Publications and Applications and EPO publications: US Patent Number 5,723,323, US Patent Number 5,763,192, US Patent Number 5,814,476, US Patent Number 5,817,483, US Patent Number 5,824,514, US Patent Number 5,976,862, US Patent Number 5,605,793, US Patent Number 5,811,238, US Patent Number 5,830,721, US Patent Number 5,834,252, US Patent Number 5,837,458, WO 1995/22625, WO 1996/33207, WO 1997/20078, WO 1997/35966, WO 1999/41402, WO 1999/41383, WO 1999/41369, WO 1999/41368, EP 752008, EP 0932670, WO 1999/23107, WO 1999/21979, WO 1998/31837, WO 1998/27230, WO 1998/27230, WO 2000/00632, WO 2000/09679, WO 1998/42832, WO 1999/29902, WO 1998/41653, WO 1998/41622, WO 1998/42727, WO 2000/18906, WO 2000/04190, WO 2000/42561, WO 2000/42559, WO 2000/42560, WO 2001/23401 and PCT/US01/06775.

The nucleotide sequences of the embodiments can also be used to isolate corresponding sequences from other organisms, particularly other bacteria, particularly a *Pseudomonas* species and more particularly a *Pseudomonas putida*, a *Pseudomonas fulva* or a *Pseudomonas chlororaphis* strain. In this manner, methods such as PCR, hybridization, and the like can be used to identify such sequences based on their sequence homology to the sequences set forth herein. Sequences that are selected based on their sequence identity to the entire sequences set forth herein or to fragments thereof are encompassed by the embodiments. Such sequences include sequences that are orthologs of the disclosed sequences. The term "orthologs" refers to genes derived from a common ancestral gene and which are found in different species as a result of

speciation. Genes found in different species are considered orthologs when their nucleotide sequences and/or their encoded protein sequences share substantial identity as defined elsewhere herein. Functions of orthologs are often highly conserved among species.

5 In a PCR approach, oligonucleotide primers can be designed for use in PCR reactions to amplify corresponding DNA sequences from cDNA or genomic DNA extracted from any organism of interest. Methods for designing PCR primers and PCR cloning are generally known in the art and are disclosed in Sambrook, *et al.*, (1989) *Molecular Cloning: A Laboratory Manual* (2d ed., Cold Spring Harbor Laboratory Press,
10 Plainview, New York), hereinafter "Sambrook". See also, Innis, *et al.*, eds. (1990) *PCR Protocols: A Guide to Methods and Applications* (Academic Press, New York); Innis and Gelfand, eds. (1995) *PCR Strategies* (Academic Press, New York); and Innis and Gelfand, eds. (1999) *PCR Methods Manual* (Academic Press, New York). Known methods of PCR include, but are not limited to, methods using paired primers, nested
15 primers, single specific primers, degenerate primers, gene-specific primers, vector-specific primers, partially-mismatched primers, and the like.

To identify potential PIP-72 polypeptides from bacterial collections, the bacterial cell lysates can be screened with antibodies generated against a PIP-72 polypeptide using Western blotting and/or ELISA methods. This type of assays can be performed in a
20 high throughput fashion. Positive samples can be further analyzed by various techniques such as antibody based protein purification and identification. Methods of generating antibodies are well known in the art as discussed infra.

Alternatively, mass spectrometry based protein identification method can be used to identify homologs of PIP-72 polypeptides using protocols in the literatures (Scott
25 Patterson, (1998), 10.22, 1-24, Current Protocol in Molecular Biology published by John Wiley & Son Inc.). Specifically, LC-MS/MS based protein identification method is used to associate the MS data of given cell lysate or desired molecular weight enriched samples (excised from SDS-PAGE gel of relevant molecular weight bands to PIP-72) with sequence information of PIP-72 (e.g., SEQ ID NO: 2)) and its homologs. Any match in
30 peptide sequences indicates the potential of having the homologs in the samples. Additional techniques (protein purification and molecular biology) can be used to isolate the protein and identify the sequences of the homologs.

In hybridization methods, all or part of the pesticidal nucleic acid sequence can be used to screen cDNA or genomic libraries. Methods for construction of such cDNA and
35 genomic libraries are generally known in the art and are disclosed in Sambrook and Russell, (2001), *supra*. The so-called hybridization probes may be genomic DNA

fragments, cDNA fragments, RNA fragments or other oligonucleotides and may be labeled with a detectable group such as ^{32}P or any other detectable marker, such as other radioisotopes, a fluorescent compound, an enzyme or an enzyme co-factor. Probes for hybridization can be made by labeling synthetic oligonucleotides based on the known
5 PIP-72 polypeptide-encoding nucleic acid sequence disclosed herein. Degenerate primers designed on the basis of conserved nucleotides or amino acid residues in the nucleic acid sequence or encoded amino acid sequence can additionally be used. The probe typically comprises a region of nucleic acid sequence that hybridizes under stringent conditions to at least about 12, at least about 25, at least about 50, 75, 100, 125,
10 150, 175 or 200 consecutive nucleotides of nucleic acid sequence encoding a PIP-72 polypeptide of the disclosure or a fragment or variant thereof. Methods for the preparation of probes for hybridization are generally known in the art and are disclosed in Sambrook and Russell, (2001), *supra*, herein incorporated by reference.

For example, an entire nucleic acid sequence, encoding a PIP-72 polypeptide,
15 disclosed herein or one or more portions thereof may be used as a probe capable of specifically hybridizing to corresponding nucleic acid sequences encoding PIP-72 polypeptide-like sequences and messenger RNAs. To achieve specific hybridization under a variety of conditions, such probes include sequences that are unique and are preferably at least about 10 nucleotides in length or at least about 20 nucleotides in
20 length. Such probes may be used to amplify corresponding pesticidal sequences from a chosen organism by PCR. This technique may be used to isolate additional coding sequences from a desired organism or as a diagnostic assay to determine the presence of coding sequences in an organism. Hybridization techniques include hybridization screening of plated DNA libraries (either plaques or colonies; see, for example,
25 Sambrook, *et al.*, (1989) Molecular Cloning: A Laboratory Manual (2d ed., Cold Spring Harbor Laboratory Press, Cold Spring Harbor, N.Y.).

Hybridization of such sequences may be carried out under stringent conditions. "Stringent conditions" or "stringent hybridization conditions" is used herein to refer to conditions under which a probe will hybridize to its target sequence to a detectably
30 greater degree than to other sequences (e.g., at least 2-fold over background). Stringent conditions are sequence-dependent and will be different in different circumstances. By controlling the stringency of the hybridization and/or washing conditions, target sequences that are 100% complementary to the probe can be identified (homologous probing). Alternatively, stringency conditions can be adjusted to allow some mismatching in
35 sequences so that lower degrees of similarity are detected (heterologous probing).

Generally, a probe is less than about 1000 nucleotides in length, preferably less than 500 nucleotides in length.

Typically, stringent conditions will be those in which the salt concentration is less than about 1.5 M Na ion, typically about 0.01 to 1.0 M Na ion concentration (or other salts) at pH 7.0 to 8.3 and the temperature is at least about 30°C for short probes (e.g., 10 to 50 nucleotides) and at least about 60°C for long probes (e.g., greater than 50 nucleotides). Stringent conditions may also be achieved with the addition of destabilizing agents such as formamide. Exemplary low stringency conditions include hybridization with a buffer solution of 30 to 35% formamide, 1 M NaCl, 1% SDS (sodium dodecyl sulphate) at 37°C., and a wash in 1× to 2×SSC (20×SSC=3.0 M NaCl/0.3 M trisodium citrate) at 50 to 55°C. Exemplary moderate stringency conditions include hybridization in 40 to 45% formamide, 1.0 M NaCl, 1% SDS at 37°C., and a wash in 0.5× to 1×SSC at 55 to 60°C. Exemplary high stringency conditions include hybridization in 50% formamide, 1 M NaCl, 1% SDS at 37°C., and a wash in 0.1×SSC at 60 to 65°C. Optionally, wash buffers may comprise about 0.1% to about 1% SDS. Duration of hybridization is generally less than about 24 hours, usually about 4 to about 12 hours.

Specificity is typically the function of post-hybridization washes, the critical factors being the ionic strength and temperature of the final wash solution. For DNA-DNA hybrids, the T_m can be approximated from the equation of Meinkoth and Wahl, (1984) *Anal. Biochem.* 138:267-284: $T_m = 81.5^\circ\text{C} + 16.6 (\log M) + 0.41 (\% \text{ GC}) - 0.61 (\% \text{ form}) - 500/L$; where M is the molarity of monovalent cations, % GC is the percentage of guanosine and cytosine nucleotides in the DNA, % form is the percentage of formamide in the hybridization solution, and L is the length of the hybrid in base pairs. The T_m is the temperature (under defined ionic strength and pH) at which 50% of a complementary target sequence hybridizes to a perfectly matched probe. T_m is reduced by about 1°C for each 1% of mismatching; thus, T_m , hybridization, and/or wash conditions can be adjusted to hybridize to sequences of the desired identity. For example, if sequences with $\geq 90\%$ identity are sought, the T_m can be decreased 10°C. Generally, stringent conditions are selected to be about 5°C lower than the thermal melting point (T_m) for the specific sequence and its complement at a defined ionic strength and pH. However, severely stringent conditions can utilize a hybridization and/or wash at 1, 2, 3 or 4°C lower than the thermal melting point (T_m); moderately stringent conditions can utilize a hybridization and/or wash at 6, 7, 8, 9 or 10°C lower than the thermal melting point (T_m); low stringency conditions can utilize a hybridization and/or wash at 11, 12, 13, 14, 15 or 20°C lower than the thermal melting point (T_m). Using the equation, hybridization and wash compositions, and desired T_m , those of ordinary skill will understand that variations in the stringency of

hybridization and/or wash solutions are inherently described. If the desired degree of mismatching results in a T_m of less than 45°C (aqueous solution) or 32°C (formamide solution), it is preferred to increase the SSC concentration so that a higher temperature can be used. An extensive guide to the hybridization of nucleic acids is found in Tijssen, (1993) Laboratory Techniques in Biochemistry and Molecular Biology-Hybridization with Nucleic Acid Probes, Part I, Chapter 2 (Elsevier, N.Y.); and Ausubel, *et al.*, eds. (1995) Current Protocols in Molecular Biology, Chapter 2 (Greene Publishing and Wiley-Interscience, New York). See, Sambrook, *et al.*, (1989) Molecular Cloning: A Laboratory Manual (2d ed., Cold Spring Harbor Laboratory Press, Cold Spring Harbor, N.Y.).

In some embodiments nucleic acid molecules are provided that encode a polypeptide comprising an amino acid sequence having at least 75%, at least 80%, at least 85%, at least 90%, at least 95% or greater sequence identity to the amino acid sequence set forth in SEQ ID NO: 20, SEQ ID NO: 22, SEQ ID NO: 24, SEQ ID NO: 26, SEQ ID NO: 30, SEQ ID NO: 34, SEQ ID NO: 36, SEQ ID NO: 929, SEQ ID NO: 930, SEQ ID NO: 931, SEQ ID NO: 937, SEQ ID NO: 938, SEQ ID NO: 942, SEQ ID NO: 947, or SEQ ID NO: 948 wherein the polypeptide has insecticidal activity.

Proteins and Variants and Fragments Thereof

PIP-72 polypeptides are also encompassed by the disclosure. “*Pseudomonas* Insecticidal Protein-72”, “PIP-72 polypeptide” or “PIP-72 protein” as used herein interchangeably refers to a polypeptide having pesticidal activity including but not limited to insecticidal activity against one or more insect pests of the Coleoptera order, and is sufficiently homologous to the protein of SEQ ID NO: 2. A variety of PIP-72 polypeptides are contemplated. Sources of polynucleotides that encode PIP-72 polypeptides or related proteins include but are not limited to: a *Pseudomonas chlororaphis* strain which contains the PIP-72Aa polynucleotide of SEQ ID NO: 1 encoding the PIP-72Aa polypeptide of SEQ ID NO: 2; a *Pseudomonas rhodesiae* strain which contains the PIP-72Ba polynucleotide of SEQ ID NO: 3 encoding the PIP-72Ba polypeptide of SEQ ID NO: 4; a *Pseudomonas chlororaphis* strain which contains the PIP-72Ca polynucleotide of SEQ ID NO: 5 encoding the PIP-72Ca polypeptide of SEQ ID NO: 6; a *Pseudomonas mandelii* strain which contains the PIP-72Cb polynucleotide of SEQ ID NO: 7 encoding the PIP-72Cb polypeptide of SEQ ID NO: 8; a *Pseudomonas congelans* strain which contains the PIP-72Da polynucleotide of SEQ ID NO: 9 encoding the PIP-72Da polypeptide of SEQ ID NO: 10; a *Pseudomonas mandelii* strain which contains the PIP-72Db polynucleotide of SEQ ID NO: 11 encoding the PIP-72Db polypeptide of SEQ ID NO: 12; a *Pseudomonas ficuserectae* strain which contains the PIP-72Dc polynucleotide of SEQ ID NO: 13

encoding the PIP-72Dc polypeptide of SEQ ID NO: 14; a *Pseudomonas mosselii* strain which contains the PIP-72Fa polynucleotide of SEQ ID NO: 17 encoding the PIP-72Fa polypeptide of SEQ ID NO: 18; a *Pseudomonas chlororaphis* strain which contains the PIP-72Ff polynucleotide of SEQ ID NO: 27 encoding the PIP-72Ff polypeptide of SEQ ID NO: 28 and a *Pseudomonas chlororaphis* strain which contains the PIP-72Gb polynucleotide of SEQ ID NO: 31 encoding the PIP-72Gb polypeptide of SEQ ID NO: 32; a *Pseudomonas chlororaphis* strain which contains the PIP-72Ab polynucleotide of SEQ ID NO: 949 encoding the PIP-72Ab polypeptide of SEQ ID NO: 927; a *Pseudomonas brassicacearum* strain which contains the PIP-72Bb polynucleotide of SEQ ID NO: 950 encoding the PIP-72Ab polypeptide of SEQ ID NO: 928; a *Pseudomonas entomophila* strain which contains the PIP-72Fh polynucleotide of SEQ ID NO: 954 encoding the PIP-72AFh polypeptide of SEQ ID NO: 932; a *Pseudomonas entomophila* strain which contains the PIP-72Fh polynucleotide of SEQ ID NO: 955 encoding the PIP-72AFh polypeptide of SEQ ID NO: 933; a *Pseudomonas chlororaphis* strain which contains the PIP-72Fj polynucleotide of SEQ ID NO: 956 encoding the PIP-72Fj polypeptide of SEQ ID NO: 934; a *Pseudomonas chlororaphis* strain which contains the PIP-72Fk polynucleotide of SEQ ID NO: 957 encoding the PIP-72Fk polypeptide of SEQ ID NO: 935; a *Burkholderia multivorans* strain which contains the PIP-72Fl polynucleotide of SEQ ID NO: 958 encoding the PIP-72Fl polypeptide of SEQ ID NO: 936; a *Pseudomonas chlororaphis* strain which contains the PIP-72Gg polynucleotide of SEQ ID NO: 961 encoding the PIP-72Gg polypeptide of SEQ ID NO: 939; a *Pseudomonas chlororaphis* strain which contains the PIP-72Gh polynucleotide of SEQ ID NO: 962 encoding the PIP-72Gh polypeptide of SEQ ID NO: 940; a *Pseudomonas mosselii* strain which contains the PIP-72Gi polynucleotide of SEQ ID NO: 963 encoding the PIP-72Gi polypeptide of SEQ ID NO: 941; a *Pseudomonas protegens* strain which contains the PIP-72Gk polynucleotide of SEQ ID NO: 965 encoding the PIP-72Gk polypeptide of SEQ ID NO: 943; a *Pseudomonas plecoglossicida* strain which contains the PIP-72Gl polynucleotide of SEQ ID NO: 966 encoding the PIP-72Gl polypeptide of SEQ ID NO: 944; and a *Pseudomonas chlororaphis* strain which contains the PIP-72Gn polynucleotide of SEQ ID NO: 968 encoding the PIP-72Gn polypeptide of SEQ ID NO: 946. In some embodiments, the insecticidal activity is against western corn rootworm, *Diabrotica virgifera virgifera*.

In some embodiments a PIP-72 polypeptide is sufficiently homologous to the amino acid sequence of SEQ ID NO: 2, SEQ ID NO: 4, SEQ ID NO: 6, SEQ ID NO: 8, SEQ ID NO: 10, SEQ ID NO: 12, SEQ ID NO: 14, SEQ ID NO: 18, SEQ ID NO: 28, SEQ ID NO: 32, SEQ ID NO: 927, SEQ ID NO: 928, SEQ ID NO: 932, SEQ ID NO: 933, SEQ ID NO: 934, SEQ ID NO: 935, SEQ ID NO: 936, SEQ ID NO: 939, SEQ ID NO: 940, SEQ

ID NO: 941, SEQ ID NO: 943, SEQ ID NO: 944, SEQ ID NO: 945 or SEQ ID NO: 946.

"Sufficiently homologous" is used herein to refer to an amino acid sequence that has at least about 50%, 51%, 52%, 53%, 54%, 55%, 56%, 57%, 58%, 59%, 60%, 61%, 62%, 63%, 64%, 65%, 66%, 67%, 68%, 69%, 70%, 71%, 72%, 73%, 74%, 75%, 76%, 77%, 78%, 78%, 80%, 81%, 82%, 83%, 84%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98% or 99% or greater sequence homology compared to a reference sequence using one of the alignment programs described herein using standard parameters. One of skill in the art will recognize that these values can be appropriately adjusted to determine corresponding homology of proteins taking into account amino acid similarity and the like. In some embodiments the sequence homology is against the full length sequence a PIP-72 polypeptide. In some embodiments the PIP-72 polypeptide has at least about 50%, 51%, 52%, 53%, 54%, 55%, 56%, 57%, 58%, 59%, 60%, 61%, 62%, 63%, 64%, 65%, 66%, 67%, 68%, 69%, 70%, 71%, 72%, 73%, 74%, 75%, 76%, 77%, 78%, 78%, 80%, 81%, 82%, 83%, 84%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98% or 99% or greater sequence identity compared to SEQ ID NO: 2, SEQ ID NO: 4, SEQ ID NO: 6, SEQ ID NO: 8, SEQ ID NO: 10, SEQ ID NO: 12, SEQ ID NO: 14, SEQ ID NO: 18, SEQ ID NO: 28, SEQ ID NO: 32, SEQ ID NO: 927, SEQ ID NO: 928, SEQ ID NO: 932, SEQ ID NO: 933, SEQ ID NO: 934, SEQ ID NO: 935, SEQ ID NO: 936, SEQ ID NO: 939, SEQ ID NO: 940, SEQ ID NO: 941, SEQ ID NO: 943, SEQ ID NO: 944, SEQ ID NO: 945 or SEQ ID NO: 946. In some embodiments the sequence identity is against the full length sequence of a PIP-72 polypeptide. In some embodiments the sequence identity is calculated using ClustalW algorithm in the ALIGNX® module of the Vector NTI® Program Suite (Invitrogen Corporation, Carlsbad, Calif.) with all default parameters. In some embodiments the sequence identity is across the entire length of polypeptide calculated using ClustalW algorithm in the ALIGNX® module of the Vector NTI® Program Suite (Invitrogen Corporation, Carlsbad, Calif.) with all default parameters.

Terms used to describe the protein structural motifs and secondary structures herein have their standard meaning in the art. See for example: Creighton, Thomas A., *Proteins: Structures and Molecular Properties*, W.H. Freeman; Second ed. (1992); Kabsch, et. al., Dictionary of Protein Secondary Structure, *Biopolymers*, Vol. 22, 2577-2637 (1983).

In some embodiments recombinant PIP-72 polypeptides are provided having at least 50%, 51%, 52%, 53%, 54%, 55%, 56%, 57%, 58%, 59%, 60%, 61%, 62%, 63%, 64%, 65%, 66%, 67%, 68%, 69%, 70%, 71%, 72%, 73%, 74%, 75%, 76%, 77%, 78%, 78%, 80%, 81%, 82%, 83%, 84%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%,

94%, 95%, 96%, 97%, 98%, 99% or greater sequence identity to the amino acid sequence of SEQ ID NO: 2; and a structure comprising a hydrophobic interface surface.

In some embodiments recombinant PIP-72 polypeptides are provided having at least 50%, 51%, 52%, 53%, 54%, 55%, 56%, 57%, 58%, 59%, 60%, 61%, 62%, 63%, 64%, 65%, 66%, 67%, 68%, 69%, 70%, 71%, 72%, 73%, 74%, 75%, 76%, 77%, 78%, 78%, 80%, 81%, 82%, 83%, 84%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99% or greater sequence identity to the amino acid sequence of SEQ ID NO: 2, and a structure comprising: 1) a hydrophobic interface surface; and 2) a flat β -sandwich formed by the packing of a) a β -sheet 1 and b) a β -sheet

2. In some embodiments the flat β -sandwich is approximately 35Å x 28Å x 21Å.

In some embodiments recombinant PIP-72 polypeptides are provided having at least 50%, 51%, 52%, 53%, 54%, 55%, 56%, 57%, 58%, 59%, 60%, 61%, 62%, 63%, 64%, 65%, 66%, 67%, 68%, 69%, 70%, 71%, 72%, 73%, 74%, 75%, 76%, 77%, 78%, 78%, 80%, 81%, 82%, 83%, 84%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99% or greater sequence identity to the amino acid sequence of SEQ ID NO: 2; and a structure comprising: 1) a hydrophobic interface surface; and 2) a flat β -sandwich formed by the packing of a) a β -sheet 2, and b) a β -sheet 1 comprising: an N-termini portion; a C-termini portion; a β -strand 1 (β 1); a β -strand 4 (β 4), a β -strand 7 (β 7); and a β -strand 8 (β 8), where β 1 and β 4 as well as β 7 and β 8 are antiparallel, whereas β 1 and β 4 are parallel to one another.

In some embodiments recombinant PIP-72 polypeptides are provided having at least 50%, 51%, 52%, 53%, 54%, 55%, 56%, 57%, 58%, 59%, 60%, 61%, 62%, 63%, 64%, 65%, 66%, 67%, 68%, 69%, 70%, 71%, 72%, 73%, 74%, 75%, 76%, 77%, 78%, 78%, 80%, 81%, 82%, 83%, 84%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99% or greater sequence identity to the amino acid sequence of SEQ ID NO: 2; and a structure comprising: 1) a hydrophobic interface surface; and 2) a flat β -sandwich formed by the packing of a) a β -sheet 1; and b) a β -sheet 2 comprising: a β -strand 2 (β 2); a β -strand 3 (β 3); a β -strand 5 (β 5); and a β -strand 6 (β 6), where β 2, β 3, β 5 and β 6 are all antiparallel to each other.

In some embodiments recombinant PIP-72 polypeptides are provided having at least 50%, 51%, 52%, 53%, 54%, 55%, 56%, 57%, 58%, 59%, 60%, 61%, 62%, 63%, 64%, 65%, 66%, 67%, 68%, 69%, 70%, 71%, 72%, 73%, 74%, 75%, 76%, 77%, 78%, 78%, 80%, 81%, 82%, 83%, 84%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99% or greater sequence identity to the amino acid sequence of SEQ ID NO: 2; and a structure comprising: 1) a hydrophobic interface surface; and 2) a flat β -sandwich formed by the packing of a) a β -sheet 1 comprising: an

N-termini portion; a C-termini portion; a β -strand 1 (β 1); a β -strand 4 (β 4); a β -strand 7 (β 7); and a β -strand 8 (β 8), where β 1 and β 4 as well as β 7 and β 8 are antiparallel, whereas β 1 and β 4 are parallel to one another, and b) a β -sheet 2 comprising a β -strand 2 (β 2); a β -strand 3 (β 3); a β -strand 5 (β 5); and a β -strand 6 (β 6), where β 2, β 3, β 5 and β 6 are all antiparallel to each other.

In some embodiments recombinant PIP-72 polypeptides are provided having at least 50%, 51%, 52%, 53%, 54%, 55%, 56%, 57%, 58%, 59%, 60%, 61%, 62%, 63%, 64%, 65%, 66%, 67%, 68%, 69%, 70%, 71%, 72%, 73%, 74%, 75%, 76%, 77%, 78%, 78%, 80%, 81%, 82%, 83%, 84%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99% or greater sequence identity to the amino acid sequence of SEQ ID NO: 2, and a structure comprising: 1) a hydrophobic interface surface; and 2) a flat β -sandwich formed by the packing of a) a β -sheet 1 comprising: an N-terminal region; a C-termini region; a β -strand 1 (β 1); a β -strand 4 (β 4); a β -strand 7 (β 7); a β -strand 8 (β 8), where β 1 and β 4 as well as β 7 and β 8 are antiparallel, whereas β 1 and β 4 are parallel to one another; and b) a β -sheet 2 comprising a β -strand 2 (β 2), a β -strand 3 (β 3), a β -strand 5 (β 5), a β -strand 6 (β 6), where β 2, β 3, β 5 and β 6 are all antiparallel to each other; 3) a loop 1 between β 1 and β 2; 4) a loop 2 between β 2 and β 3; 5) a loop 3 between β 3 and β 4; 6) a loop 4 between β 4 and β 5; 7) a loop 5 between β 5 and β 6; 8) a loop 6 between β 6 and β 7; and 9) a loop 7 between β 7 and β 8.

In some embodiments recombinant PIP-72 polypeptides are provided having at least 50%, 51%, 52%, 53%, 54%, 55%, 56%, 57%, 58%, 59%, 60%, 61%, 62%, 63%, 64%, 65%, 66%, 67%, 68%, 69%, 70%, 71%, 72%, 73%, 74%, 75%, 76%, 77%, 78%, 78%, 80%, 81%, 82%, 83%, 84%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99% or greater sequence identity to the amino acid sequence of SEQ ID NO: 2; and a structure comprising 1) a hydrophobic interface surface comprising residues in β 2, loop 2, loop 4, β 5, loop 5, β 6, and the C-terminal region; 2) a flat β -sandwich formed by the packing of a) a β -sheet 1 comprising the N-termini portion, C-termini portion, a β -strand 1 (β 1), a β -strand 4 (β 4), a β -strand 7 (β 7), and a β -strand 8 (β 8), where β 1 and β 4 as well as β 7 and β 8 are antiparallel, whereas β 1 and β 4 are parallel to one another; and b) a β -sheet 2 comprising a β -strand 2 (β 2), a β -strand 3 (β 3), a β -strand 5 (β 5), a β -strand 6 (β 6), where β 2, β 3, β 5 and β 6 are all antiparallel to each other; 3) a loop 1 between β 1 and β 2; 4) a loop 2 between β 2 and β 3; 5) a loop 3 between β 3 and β 4; 6) a loop 4 between β 4 and β 5; 7) a loop 5 between β 5 and β 6; 8) a loop 6 between β 6 and β 7; and 9) a loop 7 between β 7 and β 8.

In some embodiments recombinant PIP-72 polypeptides are provided having at least 50%, 51%, 52%, 53%, 54%, 55%, 56%, 57%, 58%, 59%, 60%, 61%, 62%, 63%,

64%, 65%, 66%, 67%, 68%, 69%, 70%, 71%, 72%, 73%, 74%, 75%, 76%, 77%, 78%, 78%, 80%, 81%, 82%, 83%, 84%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99% or greater sequence identity to the amino acid sequence of SEQ ID NO: 2; and a structure comprising 1) a hydrophobic interface surface; and 2) a flat β -sandwich formed by the packing of a) a β -sheet 1 comprising an N-termini portion, a C-termini portion, a β -strand 1 (β 1) comprising residues about 4 to about 9, a β -strand 4 (β 4) comprising residues about 36 to about 40, a β -strand 7 (β 7) comprising residues about 68 to about 72, a β -strand 8 (β 8) comprising residues about 75 to about 78 corresponding to SEQ ID NO: 2, where β 1 and β 4 as well as β 7 and β 8 are antiparallel, whereas β 1 and β 4 are parallel to one another; and b) a β -sheet 2 comprising a β -strand 2 (β 2) comprising residues about 15 to about 18, a β -strand 3 (β 3) comprising residues about 28 to about 33, a β -strand 5 (β 5) comprising residues about 48 to about 53, and a β -strand 6 (β 6) comprising residues about 58 to about 62 corresponding to SEQ ID NO: 2, where β 2, β 3, β 5 and β 6 are all antiparallel to each other.

In some embodiments recombinant PIP-72 polypeptides are provided having at least 50%, 51%, 52%, 53%, 54%, 55%, 56%, 57%, 58%, 59%, 60%, 61%, 62%, 63%, 64%, 65%, 66%, 67%, 68%, 69%, 70%, 71%, 72%, 73%, 74%, 75%, 76%, 77%, 78%, 78%, 80%, 81%, 82%, 83%, 84%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99% or greater sequence identity to the amino acid sequence of SEQ ID NO: 2; and a structure comprising 1) a hydrophobic interface surface; and 2) a flat β -sandwich formed by the packing of a) a β -sheet 1 comprising an N-termini portion, a C-termini portion, a β -strand 1 (β 1) comprising residues about 4 to about 9, a β -strand 4 (β 4) comprising residues about 36 to about 40, a β -strand 7 (β 7) comprising residues about 68 to about 72, and a β -strand 8 (β 8) comprising residues about 75 to about 78 corresponding to SEQ ID NO: 2, where β 1 and β 4 as well as β 7 and β 8 are antiparallel, whereas β 1 and β 4 are parallel to one another; b) a β -sheet 2 comprising: a β -strand 2 (β 2) comprising residues about 15 to about 18, a β -strand 3 (β 3) comprising residues about 28 to about 33, a β -strand 5 (β 5) comprising residues about 48 to about 53, and a β -strand 6 (β 6) comprising residues about 58 to about 62 corresponding to SEQ ID NO: 2, where β 2, β 3, β 5 and β 6 are all antiparallel to each other; 3) a loop 1 between β 1 and β 2; 4) a loop 2 between β 2 and β 3; 5) a loop 3 between β 3 and β 4; 6) a loop 4 between β 4 and β 5; 7) a loop 5 between β 5 and β 6; 8) a loop 6 between β 6 and β 7; and 9) a loop 7 between β 7 and β 8.

In some embodiments recombinant PIP-72 polypeptides are provided having at least 50%, 51%, 52%, 53%, 54%, 55%, 56%, 57%, 58%, 59%, 60%, 61%, 62%, 63%, 64%, 65%, 66%, 67%, 68%, 69%, 70%, 71%, 72%, 73%, 74%, 75%, 76%, 77%, 78%,

78%, 80%, 81%, 82%, 83%, 84%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99% or greater sequence identity to the amino acid sequence of SEQ ID NO: 2; and a structure comprising 1) a hydrophobic interface surface comprising residues in β 2, loop 2, loop 4, β 5, loop 5, β 6, and the C-terminal region; b) a flat β -sandwich formed by the packing of a) a β -sheet 1 comprising the N-termini, C-termini, a β -strand 1 (β 1) comprising residues about 4 to about 9, a β -strand 4 (β 4) comprising residues about 36 to about 40, a β -strand 7 (β 7) comprising residues about 68 to about 72, and a β -strand 8 (β 8) comprising residues about 75 to about 78 corresponding to SEQ ID NO: 2, where β 1 and β 4 as well as β 7 and β 8 are antiparallel, whereas β 1 and β 4 are parallel to one another; a β -sheet 2 comprising a β -strand 2 (β 2) comprising residues about 15 to about 18, a β -strand 3 (β 3) comprising residues about 28 to about 33, a β -strand 5 (β 5) comprising residues about 48 to about 53, and a β -strand 6 (β 6) comprising residues about 58 to about 62 corresponding to SEQ ID NO: 2, where β 2, β 3, β 5 and β 6 are all antiparallel to each other; a loop 1 between β 1 and β 2, a loop 2 between β 2 and β 3, 3) a loop 1 between β 1 and β 2; 4) a loop 2 between β 2 and β 3; 5) a loop 3 between β 3 and β 4; 6) a loop 4 between β 4 and β 5; 7) a loop 5 between β 5 and β 6; 8) a loop 6 between β 6 and β 7; and 9) a loop 7 between β 7 and β 8.

In some embodiments recombinant PIP-72 polypeptides are provided having at least 50%, 51%, 52%, 53%, 54%, 55%, 56%, 57%, 58%, 59%, 60%, 61%, 62%, 63%, 64%, 65%, 66%, 67%, 68%, 69%, 70%, 71%, 72%, 73%, 74%, 75%, 76%, 77%, 78%, 78%, 80%, 81%, 82%, 83%, 84%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99% or greater sequence identity to the amino acid sequence of SEQ ID NO: 2; and a structure comprising 1) a hydrophobic interface surface comprising residues selected from positions 16, 18, 19, 20, 21, 22, 26, 27, 45, 46, 48, 50, 57, 59, 61, 85, and 86, corresponding to SEQ ID NO: 2; and 2) a flat β -sandwich formed by the packing of a) a β -sheet 1 comprising the N-termini, C-termini, a β -strand 1 (β 1) comprising residues about 4 to about 9, a β -strand 4 (β 4) comprising residues about 36 to about 40, a β -strand 7 (β 7) comprising residues about 68 to about 72, and a β -strand 8 (β 8) comprising residues about 75 to about 78 corresponding to SEQ ID NO: 2, where β 1 and β 4 as well as β 7 and β 8 are antiparallel, whereas β 1 and β 4 are parallel to one another; and 2) a β -sheet 2 comprising a β -strand 2 (β 2) comprising residues about 15 to about 18, a β -strand 3 (β 3) comprising residues about 28 to about 33, a β -strand 5 (β 5) comprising residues about 48 to about 53, and a β -strand 6 (β 6) comprising residues about 58 to about 62 corresponding to SEQ ID NO: 2, where β 2, β 3, β 5 and β 6 are all antiparallel to each other; 3) a loop 1 between β 1 and β 2; 4) a loop 2 between β 2 and β 3;

5) a loop 3 between $\beta 3$ and $\beta 4$; 6) a loop 4 between $\beta 4$ and $\beta 5$; 7) a loop 5 between $\beta 5$ and $\beta 6$; 8) a loop 6 between $\beta 6$ and $\beta 7$; and 9) a loop 7 between $\beta 7$ and $\beta 8$.

In some embodiments recombinant PIP-72 polypeptides are provided having at least 50%, 51%, 52%, 53%, 54%, 55%, 56%, 57%, 58%, 59%, 60%, 61%, 62%, 63%,
 5 64%, 65%, 66%, 67%, 68%, 69%, 70%, 71%, 72%, 73%, 74%, 75%, 76%, 77%, 78%, 78%, 80%, 81%, 82%, 83%, 84%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99% or greater sequence identity to the amino acid sequence of SEQ ID NO: 2; and a structure comprising 1) a hydrophobic interface surface comprising residues selected from positions 16, 18, 19, 20, 21, 22, 26, 27, 45, 46, 48, 50,
 10 57, 59, 61, 85, and 86 corresponding to SEQ ID NO: 2, and where the amino acid at residue 20 is tryptophan; and 2) a flat β -sandwich formed by the packing of a) a β -sheet 1 comprising the N-termini, C-termini, a β -strand 1 ($\beta 1$) comprising residues about 4 to about 9, a β -strand 4 ($\beta 4$) comprising residues about 36 to about 40, a β -strand 7 ($\beta 7$) comprising residues about 68 to about 72, and a β -strand 8 ($\beta 8$) comprising residues
 15 about 75 to about 78 corresponding to SEQ ID NO: 2, where $\beta 1$ and $\beta 4$ as well as $\beta 7$ and $\beta 8$ are antiparallel, whereas $\beta 1$ and $\beta 4$ are parallel to one another; and 2) a β -sheet 2 comprising a β -strand 2 ($\beta 2$) comprising residues about 15 to about 18, a β -strand 3 ($\beta 3$) comprising residues about 28 to about 33, a β -strand 5 ($\beta 5$) comprising residues about 48 to about 53, and a β -strand 6 ($\beta 6$) comprising residues about 58 to about 62
 20 corresponding to SEQ ID NO: 2, where $\beta 2$, $\beta 3$, $\beta 5$ and $\beta 6$ are all antiparallel to each other; 3) a loop 1 between $\beta 1$ and $\beta 2$; 4) a loop 2 between $\beta 2$ and $\beta 3$; 5) a loop 3 between $\beta 3$ and $\beta 4$; 6) a loop 4 between $\beta 4$ and $\beta 5$; 7) a loop 5 between $\beta 5$ and $\beta 6$; 8) a loop 6 between $\beta 6$ and $\beta 7$; and 9) a loop 7 between $\beta 7$ and $\beta 8$.

In some embodiments the PIP-72 polypeptide comprises an amino acid sequence
 25 having at least 50% identity to SEQ ID NO: 2 and a hydrophobic interface surface comprising residues selected from positions 16, 18, 19, 20, 21, 22, 26, 27, 45, 46, 48, 50, 57, 59, 61, 85, and 86, corresponding to SEQ ID NO: 2.

In some embodiments the PIP-72 polypeptide comprises an amino acid sequence having at least 50% identity to SEQ ID NO: 2, a hydrophobic interface surface comprising
 30 residues selected from positions 16, 18, 19, 20, 21, 22, 26, 27, 45, 46, 48, 50, 57, 59, 61, 85, and 86, corresponding to SEQ ID NO: 2, and the amino acid at position 20 is tryptophan.

In some embodiments the PIP-72 polypeptide comprises an amino acid sequence having at least 50% identity to SEQ ID NO: 2, a hydrophobic interface surface comprising
 35 residues selected from positions 16, 18, 19, 20, 21, 22, 26, 27, 45, 46, 48, 50, 57, 59, 61, 85, and 86, corresponding to SEQ ID NO: 2, and further comprises 1 to 45 amino acid

substitutions at position(s) 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 17, 18, 19, 20, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 42, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 56, 58, 60, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85 or 86 compared to the corresponding amino acid of SEQ ID NO: 2.

In some embodiments the PIP-72 polypeptide comprises an amino acid sequence having at least 50% identity to SEQ ID NO: 2, a hydrophobic interface surface comprising residues selected from positions 16, 18, 19, 20, 21, 22, 26, 27, 45, 46, 48, 50, 57, 59, 61, 85, and 86, corresponding to SEQ ID NO: 2, the amino acid at position 21 is tryptophan, and further comprises 1 to 45 amino acid substitutions at position(s) 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 17, 18, 19, 20, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 42, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 56, 58, 60, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85 or 86 compared to the corresponding amino acid of SEQ ID NO: 2.

In some embodiments the PIP-72 polypeptide comprises an amino acid sequence having at least 50% identity to SEQ ID NO: 2, a hydrophobic interface surface corresponding to residues selected from positions 16, 18, 19, 20, 21, 22, 26, 27, 45, 46, 48, 50, 57, 59, 61, 85, and 86, corresponding to SEQ ID NO: 2, and the amino acid at position 2 is Gly, Ala, Cys, Asp, Glu, Ile, Lys, Leu, Asn, Arg, Ser, Thr, Val, Trp or Tyr; the amino acid at position 3 is Ile or Trp; the amino acid at position 4 is Thr, Ala, Asp, Glu, His, Ile, Lys, Leu, Arg, Ser, Val, Trp or Tyr; the amino acid at position 5 is Val, Ala, Cys, Gly, His, Ile or Tyr; the amino acid at position 6 is Thr, Ala, Cys, Phe, Gly, His, Ile, Lys, Met, Pro, Gln, Arg, Ser, Trp or Tyr; the amino acid at position 7 is Asn, Ala or Val; the amino acid at position 8 is Asn, Ala, Cys, Asp, Glu, Gly, His, Ile, Lys, Leu, Met, Gln, Arg, Ser, Thr or Val; the amino acid at position 9 is Ser, Ala, Cys, Gly or Thr; the amino acid at position 10 is Ser, Ala, Glu, Phe, Gly, His, Ile, Lys, Leu, Asn, Pro, Gln, Arg, Thr or Trp; the amino acid at position 11 is Asn, Ala, Cys, Asp, Glu, Gly, His, Ile, Lys, Leu, Met, Gln, Ser, Thr, Val or Tyr; the amino acid at position 12 is Pro, Ala, Cys, Asp, Glu, Gly, His, Lys, Leu, Asn, Gln, Arg, Ser, Thr, Val, Trp or Tyr; the amino acid at position 13 is Ile, Asn, Gln or Val; the amino acid at position 14 is Glu, Ala, Cys, Phe, His, Lys or Gln; the amino acid at position 15 is Val, Ala, Cys, Ile, Met or Arg; the amino acid at position 17 is Ile, Glu or Val; the amino acid at position 18 is Asn or Ser; the amino acid at position 19 is His, Ala, Glu, Lys, Leu, Pro, Arg, Ser or Tyr; the amino acid at position 20 is Trp; the amino acid at position 22 is Ser, Ala, Asp, Phe, Gly, His, Ile, Lys, Leu, Met, Asn, Pro, Gln, Arg, Thr, Val or Tyr; the amino acid at position 23 is Asp, Ala, Gly, His, Lys, Met, Asn, Gln, Ser, Thr or Val; the amino acid at position 24 is Gly, Asp or Phe; the amino acid at position 25 is Asp,

Ala, Glu, Phe, Asn or Gln; the amino acid at position 26 is Thr, Glu or Pro; the amino acid at position 27 is Ser, Ala, Cys, Asp, Glu, Phe, Gly, His, Asn, Gln, Arg or Thr; the amino acid at position 28 is Phe, Pro, Trp or Tyr; the amino acid at position 29 is Phe, Ala, Cys, Ile, Leu, Gln, Arg, Trp or Tyr; the amino acid at position 30 is Ser, Ala, Cys, Asp, Glu, Phe, Gly, His, Lys, Leu, Met, Asn, Pro, Gln, Arg, Thr, Val, Trp or Tyr; the amino acid at position 31 is Val, Ile or Leu; the amino acid at position 32 is Gly, Ala, Asp, Glu, Phe, His, Lys, Leu, Met, Asn, Pro, Gln, Arg, Ser, Thr, Val, Trp or Tyr; the amino acid at position 33 is Asn, Ala, Cys, Asp, Glu, Phe, Gly, His, Ile, Lys, Leu, Pro, Gln, Arg, Ser, Thr, Val or Tyr; the amino acid at position 34 is Gly, Glu, Phe, His, Lys, Leu, Met, Asn, Gln, Arg, Ser, Thr or Tyr; the amino acid at position 35 is Lys, Ala, Cys, Asp, Gly, His, Ile, Leu, Met, Asn, Gln, Arg, Ser, Thr or Val; the amino acid at position 36 is Gln, Ala, Cys, Glu, Gly, His, Ile, Lys, Leu, Asn, Pro, Arg, Ser, Thr or Val; the amino acid at position 37 is Glu, Ala, Cys, Asp, Phe, Gly, Ile, Lys, Leu, Met, Asn, Ser, Thr or Val; the amino acid at position 38 is Thr, Ala, Cys, Asp, Glu, Phe, Gly, His, Ile, Leu, Met, Asn, Gln, Arg, Ser, Val, Trp or Tyr; the amino acid at position 39 is Trp or Phe; the amino acid at position 40 is Asp, Ala, Cys, Glu, Phe, Gly, His, Ile, Lys, Leu, Met, Asn, Gln, Arg, Ser, Thr, Val, Trp or Tyr; the amino acid at position 42 is Ser, Ala, Cys, Asp, Glu, Phe, Gly, Ile, Lys, Leu, Met, Asn, Gln, Arg, Thr, Val, Trp or Tyr; the amino acid at position 44 is Ser, Ala, Asp, Glu, Gly, Leu, Met, Asn, Pro, Gln, Thr, Val or Tyr; the amino acid at position 45 is Arg, Lys or Ser; the amino acid at position 46 is Gly, Ala or Gln; the amino acid at position 47 is Phe, Cys, Val or Tyr; the amino acid at position 48 is Val, Ile or Leu; the amino acid at position 49 is Leu, Cys, Phe, Met, Arg or Tyr; the amino acid at position 50 is Ser, Ala, Cys, Asp, Ile, Met, Pro, Gln, Thr or Val; the amino acid at position 51 is Leu, Ala, Cys, Met or Val; the amino acid at position 52 is Lys, Cys, Phe, His, Ile, Leu, Met, Asn, Arg, Ser, Thr, Trp or Tyr; the amino acid at position 53 is Lys, Ala, Cys, Asp, Glu, Phe, His, Ile, Leu, Met, Asn, Gln, Arg, Ser, Thr, Val or Tyr; the amino acid at position 54 is Asn, Cys, Asp, Glu, Phe, Gly, Lys, Met, Gln, Arg, Ser or Trp; the amino acid at position 56 is Ala, Gly, Leu, Asn, Pro, Gln, Arg, Ser or Thr; the amino acid at position 57 is Gln, Glu, Leu, Met, Ser or Thr; the amino acid at position 58 is His, Ala, Asp, Phe, Leu, Met, Asn, Arg, Trp or Tyr; the amino acid at position 60 is Tyr, Glu or Phe; the amino acid at position 63 is Gln, Cys, Gly, Ile, Leu, Met, Asn, Thr, Val or Tyr; the amino acid at position 64 is Ala, Phe, Gly, His, Arg, Ser or Tyr; the amino acid at position 65 is Ser, Ala, Cys, Asp, Glu, Phe, Gly, His, Ile, Leu, Asn, Thr or Val; the amino acid at position 66 is Ser, Ala or Gly; the amino acid at position 67 is Lys, Ala, Cys, Asp, Phe, His, Ile, Leu, Met, Asn, Gln, Arg, Ser, Thr, Val, Trp or Tyr; the amino acid at position 68 is Ile Asp, Leu or Val; the amino acid at position 69 is Glu, Ala, Cys, Asp, Phe, His, Ile, Leu, Met, Gln, Arg, Ser, Thr, Val or Tyr; the amino acid at position

70 is Val, Cys or Ile; the amino acid at position 71 is Asp, Ala, Cys, Gly, His, Ile, Leu, Met, Asn, Ser, Thr, Val or Tyr; the amino acid at position 72 is Asn, Ala, Cys, Asp, Glu, Gly, Lys, Met, Pro, Gln, Arg, Ser, Thr, Val or Trp; the amino acid at position 73 is Asn, Ala, Cys, Asp, Phe, Gly, His, Ile, Leu, Ser, Thr, Val or Tyr; the amino acid at position 74 is Ala, Cys, Asp, Phe, Gly, His, Ile, Leu, Asn, Gln, Arg, Ser, Thr, Val or Tyr; the amino acid at position 75 is Val, Cys, Ile or Leu; the amino acid at position 76 is Lys, Ala, Cys, Phe, His, Ile, Leu, Gln, Arg, Ser, Thr, Val, Trp or Tyr; the amino acid at position 77 is Asp Tyr; the amino acid at position 78 is Gln, Ala, Cys, Asp, Phe, Gly, His, Ile, Leu, Met, Asn, Arg, Ser, Thr, Val or Tyr; the amino acid at position 79 is Gly, Arg, Ala, Cys, Asp, Glu, Phe, His, Lys, Leu, Asn, Gln, Arg, Ser, Thr, Trp or Tyr; the amino acid at position 80 is Arg, Ala, Cys, Asp, Phe, Gly, His, Ile, Leu, Asn, Ser, Thr, Val or Tyr; the amino acid at position 81 is Leu, Ala, Cys, Asp, Phe, Gly, His, Ile, Asn, Pro, Arg, Ser, Thr or Val; the amino acid at position 82 is Ile, Ala, Leu, Met, Arg or Val; the amino acid at position 83 is Glu, Ala, Cys, Asp, Phe, Gly, His, Ile, Lys, Leu, Asn, Pro, Arg, Ser, Thr, Val or Tyr; the amino acid at position 84 is Pro, Ala, Cys, Glu, Ile, Ser, Val, Trp or Tyr; the amino acid at position 85 is Leu, Cys, Gly or Val; and the amino acid at position 86 is Ser, Ala, Ile, Thr or Val, and wherein 1 to 14 amino acids are optionally deleted from the N-terminus and/or C-terminus of the PIP-72 polypeptide.

In some embodiments the PIP-72 polypeptide comprises an amino acid sequence having at least 50% identity to SEQ ID NO: 2, a hydrophobic interface surface corresponding to residues selected from positions 16, 18, 19, 20, 21, 22, 26, 27, 45, 46, 48, 50, 57, 59, 61, 85, and 86, corresponding to SEQ ID NO: 2, and the amino acid at position 2 is Gly, Lys or Ala; the amino acid at position 3 is Ile or Leu; the amino acid at position 4 is Thr or Ser; the amino acid at position 5 is Val or Ile; the amino acid at position 6 is Thr or Lys; the amino acid at position 8 is Asn, Lys, Gly or Ser; the amino acid at position 9 is Ser or Ala; the amino acid at position 11 is Asn, Lys, His or Thr; the amino acid at position 12 is Pro, Thr, Lys or Ser; the amino acid at position 13 is Ile or Val; the amino acid at position 14 is Glu or Asp; the amino acid at position 15 is Val, Ala or Ile; the amino acid at position 16 is Ala or Ser; the amino acid at position 17 is Ile or Val; the amino acid at position 18 is Asn or Ser; the amino acid at position 19 is His, Lys, Arg, Gln or Ala; the amino acid at position 21 is Gly or Arg; the amino acid at position 22 is Ser, Lys, Asn, Asp or Thr; the amino acid at position 25 is Asp or Asn; the amino acid at position 26 is Thr or Asp; the amino acid at position 27 is Ser, Thr, Asn or Lys; the amino acid at position 28 is Phe, Tyr or Pro; the amino acid at position 29 is Phe or Tyr; the amino acid at position 30 is Ser, Gly or Lys; the amino acid at position 31 is Val, Ile or Met; the amino acid at position 32 is Gly, Ala or Asp; the amino acid at position 33 is Asn,

Ser, Gln or Pro; the amino acid at position 35 is Lys, Glu or Ser; the amino acid at position 36 is Gln, Asn or Ser; the amino acid at position 37 is Glu or Asp; the amino acid at position 38 is Thr or Ser; the amino acid at position 42 is Ser or Asn; the amino acid at position 44 is Ser, Asp, Ala or Leu; the amino acid at position 47 is Phe or Tyr; the amino acid at position 48 is Leu or Met; the amino acid at position 49 is Leu or Met; the amino acid at position 50 is Ser, Ala or Tyr; the amino acid at position 51 is Leu or Val; the amino acid at position 52 is Lys or Gln; the amino acid at position 53 is Lys, Arg, Met or Leu; the amino acid at position 54 is Asn, Lys or Gly; the amino acid at position 55 is Gly or Ser; the amino acid at position 56 is Ala, Thr, Gln or Ser; the amino acid at position 57 is Gln, Val or Ala; the amino acid at position 58 is His, Ala, Lys, Tyr or Thr; the amino acid at position 59 is Pro or Thr; the amino acid at position 62 is Val or Ile; the amino acid at position 63 is Gln, Ser or Leu; the amino acid at position 64 is Ala, Gln or Ser; the amino acid at position 65 is Ser or Thr; the amino acid at position 67 is Lys, Gln, Arg or Asn; the amino acid at position 69 is Glu, Lys or Val; the amino acid at position 70 is Val or Ile; the amino acid at position 71 is Asp, Glu or Tyr; the amino acid at position 72 is Asn, His, Ser or Asp; the amino acid at position 73 is Asn, Ser or Asp; the amino acid at position 74 is Ala, Thr, Met, Ile or Lys; the amino acid at position 76 is Lys or Thr; the amino acid at position 78 is Gln, His or Ser; the amino acid at position 80 is Arg, Glu or Gln; the amino acid at position 81 is Leu, Pro, Ala or Thr; the amino acid at position 82 is Ile or Leu; the amino acid at position 83 is Glu, His, Asn, Gln or Leu; the amino acid at position 85 is Leu, Val or Ala; and the amino acid at position 86 is Ser, Ala, Tyr or Asn, and wherein, 1 to 14 amino acids are optionally deleted from the N-terminus and/or C-terminus of the PIP-72 polypeptide and/or an amino acid is inserted between residue 24 and 25 relative to SEQ ID NO: 2.

In some embodiments the PIP-72 polypeptide comprises an amino acid sequence having at least 50% identity to SEQ ID NO: 2, a hydrophobic interface surface corresponding to residues selected from positions 16, 18, 19, 20, 21, 22, 26, 27, 45, 46, 48, 50, 57, 59, 61, 85, and 86, corresponding to SEQ ID NO: 2, and the amino acid at position 2 is Gly, Lys, Ala or Arg; the amino acid at position 3 is Ile, Leu or Val; the amino acid at position 4 is Thr or Ser; the amino acid at position 5 is Val, Ile or Leu; the amino acid at position 6 is Thr, Lys, Ser or Arg; the amino acid at position 8 is Asn, Lys, Gly, Ser, Gln, Arg, Thr or Ala; the amino acid at position 9 is Ser, Ala or Thr; the amino acid at position 11 is Asn, Lys, Thr, Gln, Arg, His or Ser; the amino acid at position 12 is Pro, Thr, Lys, Ser or Arg; the amino acid at position 13 is Ile, Val or Leu; the amino acid at position 14 is Glu or Asp; the amino acid at position 15 is Val, Ala, Ile or Leu; the amino acid at position 16 is Ala or Ser; the amino acid at position 17 is Ile, Val or Leu; the amino acid at

position 18 is Asn, Ser, Gln or Thr; the amino acid at position 19 is His, Lys, Ala, Gln, Asn or Arg; the amino acid at position 20 is Trp; the amino acid at position 21 is Gly, Arg or Lys; the amino acid at position 22 is Ser, Lys, Asn, Thr, Arg, Asp, Glu or Gln; the amino acid at position 25 is Asp, Asn, Glu or Gln; the amino acid at position 26 is Thr, Asp, Ser or Glu; the amino acid at position 27 is Ser, Thr, Lys, Asn, Gln or Arg; the amino acid at position 28 is Phe, Tyr, Pro or Trp; the amino acid at position 29 is Phe, Tyr or Trp; the amino acid at position 30 is Ser, Gly, Lys, Thr or Arg; the amino acid at position 31 is Val, Ile, Met or Leu; the amino acid at position 32 is Gly, Ala, Asp or Glu; the amino acid at position 33 is Asn, Ser, Gln, Pro or Thr; the amino acid at position 35 is Lys, Glu, Ser, Arg or Thr; the amino acid at position 36 is Gln, Ser, Asn or Thr; the amino acid at position 37 is Glu or Asp; the amino acid at position 38 is Thr or Ser; the amino acid at position 42 is Ser, Asn, Thr or Gln; the amino acid at position 44 is Ser, Asp, Ala, Leu, Thr, Glu, Ile or Val; the amino acid at position 47 is Phe, Tyr or Trp; the amino acid at position 48 is Leu, Met, Ile or Val; the amino acid at position 49 is Leu, Met, Ile or Val; the amino acid at position 50 is Ser, Ala, Tyr or Thr; the amino acid at position 51 is Leu, Val or Ile; the amino acid at position 52 is Lys, Gln, Arg or Asn; the amino acid at position 53 is Lys, Arg, Met, Leu, Ile or Val; the amino acid at position 54 is Asn, Lys, Gly, Gln or Arg; the amino acid at position 55 is Gly, Ser or Thr; the amino acid at position 56 is Ala, Thr, Gln, Ser or Asn; the amino acid at position 57 is Gln, Val, Ala, Asn, Leu or Ile; the amino acid at position 58 is His, Ala, Lys, Tyr or Thr; the amino acid at position 59 is Pro, Thr or Ser; the amino acid at position 62 is Val, Ile or Leu; the amino acid at position 63 is Gln, Ser, Leu, Asn, Thr, Ile or Val; the amino acid at position 64 is Ala, Gln, Ser, Asn or Thr; the amino acid at position 65 is Ser or Thr; the amino acid at position 67 is Lys, Gln, Asn or Arg; the amino acid at position 69 is Glu, Val, Asp, Lys, Arg, Ile or Leu; the amino acid at position 70 is Val, Ile or Leu; the amino acid at position 71 is Asp, Glu, Tyr or Trp; the amino acid at position 72 is Asn, His, Ser, Asp, Gln, Thr or Glu; the amino acid at position 73 is Asn, Ser, Asp, Gln, Thr or Glu; the amino acid at position 74 is Ala, Thr, Met, Ile, Lys, Ser, Leu, Val or Arg; the amino acid at position 76 is Lys, Thr, Arg or Ser; the amino acid at position 78 is Gln, His, Ser, Asn or Thr; the amino acid at position 80 is Arg, Glu, Gln, Lys, Asp or Asn; the amino acid at position 81 is Leu, Pro, Thr, Ile, Val, Ala or Ser; the amino acid at position 82 is Ile, Leu or Val; the amino acid at position 83 is Glu, His, Asn, Leu, Gln, Ile or Val; the amino acid at position 85 is Leu, Val or Ala; and the amino acid at position 86 is Ser, Ala, Tyr, Asn or Thr, and wherein, 1 to 14 amino acids are optionally deleted from the N-terminus and/or C-terminus of the PIP-72 polypeptide and/or an amino acid is inserted between residue 24 and 25 relative to SEQ ID NO: 2.

In some embodiments the PIP-72 polypeptide comprises an amino acid sequence having at least 50% identity to SEQ ID NO: 2, a hydrophobic interface surface corresponding to residues selected from positions 16, 18, 19, 20, 21, 22, 26, 27, 45, 46, 48, 50, 57, 59, 61, 85, and 86, corresponding to SEQ ID NO: 2, and the amino acid at position 2 is Gly, Ala, Cys, Asp, Glu, Ile, Lys, Leu, Asn, Arg, Ser, Thr, Val, Trp or Tyr; the amino acid at position 3 is Ile, Leu, Val or Trp; the amino acid at position 4 is Thr, Ala, Asp, Glu, His, Ile, Lys, Leu, Arg, Ser, Val, Trp or Tyr; the amino acid at position 5 is Val, Ala, Cys, Gly, His, Ile, Leu or Tyr; the amino acid at position 6 is Thr, Ala, Cys, Phe, Gly, His, Ile, Lys, Met, Pro, Gln, Arg, Ser, Trp or Tyr; the amino acid at position 7 is Asn, Ala or Val; the amino acid at position 8 is Asn, Lys, Gly, Ser, Gln, Arg, Thr, Ala, Cys, Asp, Glu, His, Ile, Leu, Met or Val; the amino acid at position 9 is Ser, Ala, Cys, Gly or Thr; the amino acid at position 11 is Asn, Lys, Thr, Gln, Arg, Ser, Ala, Cys, Asp, Glu, Gly, His, Ile, Leu, Met, Val or Tyr; the amino acid at position 12 is Pro, Thr, Lys, Ser, Arg, Ala, Cys, Asp, Glu, Gly, His, Leu, Asn, Gln, Arg, Val, Trp or Tyr; the amino acid at position 13 is Ile, Asn, Gln, Leu or Val; the amino acid at position 14 is Glu, Ala, Cys, Phe, His, Lys, Asp or Gln; the amino acid at position 15 is Val, Ala, Ile, Leu, Cys, Met or Arg; the amino acid at position 16 is Ala or Ser; the amino acid at position 17 is Ile, Glu, Leu or Val; the amino acid at position 18 is Asn, Gln, Thr or Ser; the amino acid at position 19 is His, Lys, Ala, Arg, Glu, Leu, Pro, Ser or Tyr; the amino acid at position 20 is Trp; the amino acid at position 21 is Gly, Arg or Lys; the amino acid at position 22 is Ser, Ala, Asp, Phe, Gly, His, Ile, Lys, Leu, Met, Asn, Pro, Gln, Arg, Thr, Val or Tyr; the amino acid at position 23 is Asp, Ala, Gly, His, Lys, Met, Asn, Gln, Ser, Thr or Val; the amino acid at position 24 is Gly, Asp or Phe; the amino acid at position 25 is Asp, Ala, Glu, Phe, Asn or Gln; the amino acid at position 26 is Thr, Glu, Asp, Ser or Pro; the amino acid at position 27 is Ser, Thr, Lys, Arg, Ala, Cys, Asp, Glu, Phe, Gly, His, Asn or Gln; the amino acid at position 28 is Phe, Tyr, Pro or Trp; the amino acid at position 29 is Phe, Ala, Cys, Ile, Leu, Gln, Arg, Trp or Tyr; the amino acid at position 30 is Ser, Gly, Lys, Thr, Arg, Ala, Cys, Asp, Glu, Phe, His, Leu, Met, Asn, Pro, Gln, Val, Trp or Tyr; the amino acid at position 31 is Val, Ile, Met or Leu; the amino acid at position 32 is Gly, Ala, Asp, Glu, Phe, His, Lys, Leu, Met, Asn, Pro, Gln, Arg, Ser, Thr, Val, Trp or Tyr; the amino acid at position 33 is Asn, Ser, Gln, Pro, Thr, Ala, Cys, Asp, Glu, Phe, Gly, His, Ile, Lys, Leu, Arg, Val or Tyr; the amino acid at position 34 is Gly, Glu, Phe, His, Lys, Leu, Met, Asn, Gln, Arg, Ser, Thr or Tyr; the amino acid at position 35 is Lys, Glu, Ala, Cys, Asp, Gly, His, Ile, Leu, Met, Asn, Gln, Arg, Ser, Thr or Val; the amino acid at position 36 is Gln, Ala, Cys, Glu, Gly, His, Ile, Lys, Leu, Asn, Pro, Arg, Ser, Thr or Val; the amino acid at position 37 is Glu, Asp, Ala, Cys, Phe, Gly, Ile, Lys, Leu, Met, Asn, Ser, Thr or Val; the amino acid at position 38 is Thr, Ser, Ala, Cys, Asp,

Glu, Phe, Gly, His, Ile, Leu, Met, Asn, Gln, Arg, Val, Trp or Tyr; the amino acid at position 39 is Trp or Phe; the amino acid at position 40 is Asp, Ala, Cys, Glu, Phe, Gly, His, Ile, Lys, Leu, Met, Asn, Gln, Arg, Ser, Thr, Val, Trp or Tyr; the amino acid at position 42 is Ser, Asn, Thr, Ala, Cys, Asp, Glu, Phe, Gly, Ile, Lys, Leu, Met, Arg, Val, Trp, Tyr or Gln;

5 the amino acid at position 44 is Ser, Asp, Ala, Leu, Thr, Glu, Ile, Ala, Gly, Leu, Met, Asn, Pro, Gln, Val, Tyr or Val; the amino acid at position 45 is Arg, Lys or Ser; the amino acid at position 46 is Gly, Ala or Gln; the amino acid at position 47 is Phe, Tyr Cys, Val or Trp; the amino acid at position 48 is Leu, Met, Ile, Cys, Phe, Met, Arg, Tyr or Val; the amino acid at position 49 is Leu, Met, Ile or Val; the amino acid at position 50 is Ser, Ala, Tyr,

10 Cys, Asp, Ile, Met, Pro, Gln, Val or Thr; the amino acid at position 51 is Leu, Val, Ala, Cys, Met or Ile; the amino acid at position 52 is Lys, Cys, Phe, His, Ile, Leu, Met, Asn, Arg, Ser, Thr, Gln, Trp or Tyr; the amino acid at position 53 is Lys, Arg, Met, Leu, Ile, Ala, Cys, Asp, Glu, Phe, His, Asn, Gln, Ser, Thr, Tyr or Val; the amino acid at position 54 is Asn, Cys, Asp, Glu, Phe, Gly, Lys, Met, Gln, Arg, Ser or Trp; the amino acid at position 55 is Gly,

15 Ser or Thr; the amino acid at position 56 is Ala, Thr, Gln, Ser, Gly, Leu, Pro, Arg or Asn; the amino acid at position 57 is Gln, Glu, Leu, Met, Ser, Val, Ala, Asn, Ile or Thr; the amino acid at position 58 is His, Ala, Lys, Asp, Phe, Leu, Met, Asn, Arg, Trp, Tyr or Thr; the amino acid at position 59 is Pro, Thr or Ser; the amino acid at position 60 is Tyr, Glu or Phe; the amino acid at position 62 is Val, Ile or Leu; the amino acid at position 63 is

20 Gln, Ser, Cys, Gly, Ile, Leu, Met, Asn, Thr, Val or Tyr; the amino acid at position 64 is Ala, Gln, Asn, Phe, Gly, His, Arg, Ser or Tyr; the amino acid at position 65 is Ser, Ala, Cys, Asp, Glu, Phe, Gly, His, Ile, Leu, Asn, Val or Thr; the amino acid at position 66 is Ser, Ala or Gly; the amino acid at position 67 is Lys, Gln, Asn or Arg; the amino acid at position 67 is Lys, Ala, Cys, Asp, Phe, His, Ile, Leu, Met, Asn, Gln, Arg, Ser, Thr, Val, Trp or Tyr; the

25 amino acid at position 68 is Ile Asp, Leu or Val; the amino acid at position 69 is Glu, Ala, Cys, Asp, Phe, His, Ile, Leu, Met, Gln, Arg, Ser, Thr, Val or Tyr; the amino acid at position 70 is Val, Ile, Cys or Leu; the amino acid at position 71 is Asp, Glu, Tyr, Ala, Cys, Gly, His, Ile, Leu, Met, Asn, Ser, Thr, Val or Trp; the amino acid at position 72 is Asn, Ala, Cys, Asp, Glu, Gly, Lys, Met, Pro, Gln, Arg, Ser, Thr, Val, His or Trp; the amino acid at position

30 73 is Asn, Ser, Asp, Gln, Thr, Ala, Cys, Phe, Gly, His, Ile, Leu, Val, Tyr or Glu; the amino acid at position 74 is Ala, Thr, Met, Ile, Lys, Ser, Leu, Val, Cys, Asp, Phe, Gly, His, Asn, Gln, Tyr or Arg; the amino acid at position 75 is Val, Cys, Ile or Leu; the amino acid at position 76 is Lys, Ala, Cys, Phe, His, Ile, Leu, Gln, Arg, Ser, Thr, Val, Trp or Tyr; the amino acid at position 77 is Asp Tyr; the amino acid at position 78 is Gln, His, Ser, Asn,

35 Ala, Cys, Asp, Phe, Gly, Ile, Leu, Met, Asn, Arg, Val, Tyr or Thr; the amino acid at position 79 is Gly, Arg, Ala, Cys, Asp, Glu, Phe, His, Lys, Leu, Asn, Gln, Arg, Ser, Thr, Trp or Tyr;

the amino acid at position 80 is Arg, Glu, Gln, Lys, Asp, Ala, Cys, Phe, Gly, His, Ile, Leu, Ser, Thr, Val, Tyr or Asn; the amino acid at position 81 is Leu, Pro, Thr, Ile, Val, Ala, Cys, Asp, Phe, Gly, His or Ser; the amino acid at position 82 is Ile, Ala, Leu, Met, Arg and Val; the amino acid at position 83 is Glu, His, Asn, Leu, Gln, Ile, Ala, Cys, Asp, Phe, Gly, Lys, Pro, Arg, Ser, Thr, Tyr or Val; the amino acid at position 84 is Pro, Ala, Cys, Glu, Ile, Ser, Val, Trp or Tyr; the amino acid at position 85 is Leu, Val, Cys, Gly or Ala; and the amino acid at position 86 is Ser, Ala, Tyr, Asn, Ile, Val or Thr, and wherein, 1 to 14 amino acids are optionally deleted from the N-terminus and/or C-terminus of the PIP-72 polypeptide and/or an amino acid is inserted between residue 24 and 25 relative to SEQ ID NO: 2.

In some embodiments the nucleic acid molecules encode a PIP-72 polypeptide comprising an amino acid motif as represented by positions 37-51 of SEQ ID NO: 846, SEQ ID NO: 847, SEQ ID NO: 848 or SEQ ID NO: 849.

In some embodiments the PIP-72 polypeptide is labeled with a detectable label. The label can be a radioisotope, fluorescent compound, chemiluminescent compound, quantum dot, enzyme, or enzyme co-factor, or any other labels known in the art.

As used herein, the terms “protein,” “peptide molecule,” or “polypeptide” includes any molecule that comprises five or more amino acids. It is well known in the art that protein, peptide or polypeptide molecules may undergo modification, including post-translational modifications, such as, but not limited to, disulfide bond formation, glycosylation, phosphorylation or oligomerization. Thus, as used herein, the terms “protein,” “peptide molecule” or “polypeptide” includes any protein that is modified by any biological or non-biological process. The terms “amino acid” and “amino acids” refer to all naturally occurring L-amino acids.

A “recombinant protein” is used herein to refer to a protein that is no longer in its natural environment, for example in vitro or in a recombinant bacterial or plant host cell. A PIP-72 polypeptide that is substantially free of cellular material includes preparations of protein having less than about 30%, 20%, 10% or 5% (by dry weight) of non-pesticidal protein (also referred to herein as a “contaminating protein”).

“Fragments” or “biologically active portions” include polypeptide fragments comprising amino acid sequences sufficiently identical to a PIP-72 polypeptide and that exhibit insecticidal activity. “Fragments” or “biologically active portions” of PIP-72 polypeptides includes fragments comprising amino acid sequences sufficiently identical to the amino acid sequence set forth in SEQ ID NO: 6, SEQ ID NO: 8, SEQ ID NO: 10, SEQ ID NO: 12, SEQ ID NO: 14, SEQ ID NO: 18, SEQ ID NO: 28, SEQ ID NO: 32, any one of SEQ ID NO: 528 - SEQ ID NO: 768, any one of SEQ ID NO: 825 – SEQ ID NO: 844, SEQ ID NO: 771, SEQ ID NO: 772, SEQ ID NO: 852, any one of SEQ ID NO: 903 – SEQ ID

NO: 914, SEQ ID NO: 927, SEQ ID NO: 928, SEQ ID NO: 932, SEQ ID NO: 933, SEQ ID NO: 934, SEQ ID NO: 935, SEQ ID NO: 936, SEQ ID NO: 939, SEQ ID NO: 940, SEQ ID NO: 941, SEQ ID NO: 943, SEQ ID NO: 944, SEQ ID NO: 945 or SEQ ID NO: 946, respectively. A biologically active portion of a PIP-72 polypeptide can be a polypeptide that is, for example, 10, 25, 50, 55, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84 or 85 amino acids in length. Such biologically active portions can be prepared by recombinant techniques and evaluated for insecticidal activity. As used here, a fragment comprises at least 8 contiguous amino acids of a PIP-72 polypeptide. In some embodiments a PIP-72 polypeptide fragment comprises at least 8 contiguous amino acids of SEQ ID NO: 2, SEQ ID NO: 4, SEQ ID NO: 6, SEQ ID NO: 8, SEQ ID NO: 10, SEQ ID NO: 12, SEQ ID NO: 14, SEQ ID NO: 18, SEQ ID NO: 28, SEQ ID NO: 32, any one of SEQ ID NO: 528 - SEQ ID NO: 768, any one of SEQ ID NO: 825 – SEQ ID NO: 844, SEQ ID NO: 771, SEQ ID NO: 772, SEQ ID NO: 852, any one of SEQ ID NO: 903 – SEQ ID NO: 914, SEQ ID NO: 927, SEQ ID NO: 928, SEQ ID NO: 932, SEQ ID NO: 933, SEQ ID NO: 934, SEQ ID NO: 935, SEQ ID NO: 936, SEQ ID NO: 939, SEQ ID NO: 940, SEQ ID NO: 941, SEQ ID NO: 943, SEQ ID NO: 944, SEQ ID NO: 945 or SEQ ID NO: 946. In some embodiments, the PIP-72 polypeptide fragment is an N-terminal and/or a C-terminal truncation of at least about 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14 or more amino acids from the N-terminus and/or C-terminus relative to SEQ ID NO: 2, SEQ ID NO: 4, SEQ ID NO: 6, SEQ ID NO: 8, SEQ ID NO: 10, SEQ ID NO: 12, SEQ ID NO: 14, SEQ ID NO: 18, SEQ ID NO: 28, SEQ ID NO: 32, any one of SEQ ID NO: 528 - SEQ ID NO: 768, any one of SEQ ID NO: 825 – SEQ ID NO: 844, SEQ ID NO: 771, SEQ ID NO: 772, SEQ ID NO: 852, any one of SEQ ID NO: 903 – SEQ ID NO: 914, SEQ ID NO: 927, SEQ ID NO: 928, SEQ ID NO: 932, SEQ ID NO: 933, SEQ ID NO: 934, SEQ ID NO: 935, SEQ ID NO: 936, SEQ ID NO: 939, SEQ ID NO: 940, SEQ ID NO: 941, SEQ ID NO: 943, SEQ ID NO: 944, SEQ ID NO: 945 or SEQ ID NO: 946, e.g., by proteolysis, by insertion of a start codon, by deletion of the codons encoding the deleted amino acids and concomitant insertion of a start codon, and/or insertion of a stop codon.

In some embodiments, the PIP-72 polypeptide fragments encompassed herein result from the removal of the N-terminal 1, 2, 3, 4, 5, 6, 7, 8, 9 or 10 or more amino acids relative to SEQ ID NO: 2, SEQ ID NO: 4, SEQ ID NO: 6, SEQ ID NO: 8, SEQ ID NO: 10, SEQ ID NO: 12, SEQ ID NO: 14, SEQ ID NO: 18, SEQ ID NO: 28, SEQ ID NO: 32, any one of SEQ ID NO: 528 - SEQ ID NO: 768, any one of SEQ ID NO: 825 – SEQ ID NO: 844, SEQ ID NO: 771, SEQ ID NO: 772, SEQ ID NO: 852, any one of SEQ ID NO: 903 – SEQ ID NO: 914, SEQ ID NO: 927, SEQ ID NO: 928, SEQ ID NO: 932, SEQ ID NO: 933, SEQ ID NO: 934, SEQ ID NO: 935, SEQ ID NO: 936, SEQ ID NO: 939, SEQ ID NO: 940,

SEQ ID NO: 941, SEQ ID NO: 943, SEQ ID NO: 944, SEQ ID NO: 945 or SEQ ID NO: 946, e.g., by proteolysis or by insertion of a start codon, by deletion of the codons encoding the deleted amino acids and concomitant insertion of a start codon.

In some embodiments, the PIP-72 polypeptide fragments encompassed herein
 5 result from the removal of the N-terminal 1, 2, 3, 4, 5, 6, 7, 8, 9 or 10 amino acids relative
 to SEQ ID NO: 2, SEQ ID NO: 4, SEQ ID NO: 6, SEQ ID NO: 8 or variants thereof
 including, but not limited to any one of SEQ ID NO: 528 - SEQ ID NO: 768, any one of
 SEQ ID NO: 825 – SEQ ID NO: 844, SEQ ID NO: 771, SEQ ID NO: 772, SEQ ID NO:
 852, any one of SEQ ID NO: 903 – SEQ ID NO: 914, SEQ ID NO: 927, SEQ ID NO: 928,
 10 SEQ ID NO: 932, SEQ ID NO: 933, SEQ ID NO: 934, SEQ ID NO: 935, SEQ ID NO: 936,
 SEQ ID NO: 939, SEQ ID NO: 940, SEQ ID NO: 941, SEQ ID NO: 943, SEQ ID NO: 944,
 SEQ ID NO: 945 or SEQ ID NO: 946. In some embodiments the truncation is of the first 4
 amino acids of SEQ ID NO: 2, SEQ ID NO: 4, SEQ ID NO: 6, SEQ ID NO: 8, SEQ ID NO:
 10, SEQ ID NO: 12, SEQ ID NO: 14, SEQ ID NO: 18, SEQ ID NO: 28, SEQ ID NO: 32 or
 15 variants thereof including, but not limited to any one of SEQ ID NO: 528 - SEQ ID NO:
 768, any one of SEQ ID NO: 825 – SEQ ID NO: 844, SEQ ID NO: 771, SEQ ID NO: 772,
 SEQ ID NO: 852, any one of SEQ ID NO: 903 – SEQ ID NO: 914, SEQ ID NO: 927, SEQ
 ID NO: 928, SEQ ID NO: 932, SEQ ID NO: 933, SEQ ID NO: 934, SEQ ID NO: 935, SEQ
 ID NO: 936, SEQ ID NO: 939, SEQ ID NO: 940, SEQ ID NO: 941, SEQ ID NO: 943, SEQ
 20 ID NO: 944, SEQ ID NO: 945 or SEQ ID NO: 946.

“Variants” as used herein refers to proteins or polypeptides having an amino acid
 sequence that is at least about 50%, 51%, 52%, 53%, 54%, 55%, 56%, 57%, 58%, 59%,
 60%, 61%, 62%, 63%, 64%, 65%, 66%, 67%, 68%, 69%, 70%, 71%, 72%, 73%, 74%,
 75%, 76%, 77%, 78%, 78%, 80%, 81%, 82%, 83%, 84%, 85%, 86%, 87%, 88%, 89%,
 25 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98% or 99% identical to the parental amino
 acid sequence. The term “about” as used herein with respect to % sequence identity
 means up to and including $\pm 0.5\%$ in 0.1% increments. For example “about 90%”
 sequence identity includes 89.5%, 89.6%, 89.7%, 89.8%, 89.9%, 90%, 90.1%, 90.2%,
 90.3%, 90.4% and 90.5%.

30 In some embodiments a PIP-72 polypeptide has at least about 50%, 51%, 52%,
 53%, 54%, 55%, 56%, 57%, 58%, 59%, 60%, 61%, 62%, 63%, 64%, 65%, 66%, 67%,
 68%, 69%, 70%, 71%, 72%, 73%, 74%, 75%, 76%, 77%, 78%, 78%, 80%, 81%, 82%,
 83%, 84%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%,
 98% or 99% identity across the entire length of the amino acid sequence of SEQ ID NO:
 35 2, SEQ ID NO: 4, SEQ ID NO: 6, SEQ ID NO: 8, SEQ ID NO: 10, SEQ ID NO: 12, SEQ ID
 NO: 14, SEQ ID NO: 18, SEQ ID NO: 28, SEQ ID NO: 32, SEQ ID NO: 927, SEQ ID NO:

928, SEQ ID NO: 932, SEQ ID NO: 933, SEQ ID NO: 934, SEQ ID NO: 935, SEQ ID NO: 936, SEQ ID NO: 939, SEQ ID NO: 940, SEQ ID NO: 941, SEQ ID NO: 943, SEQ ID NO: 944, SEQ ID NO: 945 or SEQ ID NO: 946.

In some embodiments a PIP-72 polypeptide has at least about 50%, 51%, 52%, 53%, 54%, 55%, 56%, 57%, 58%, 59%, 60%, 61%, 62%, 63%, 64%, 65%, 66%, 67%, 68%, 69%, 70%, 71%, 72%, 73%, 74%, 75%, 76%, 77%, 78%, 78%, 80%, 81%, 82%, 83%, 84%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99% or greater identity across the entire length of the amino acid sequence of SEQ ID NO: 2.

In some embodiments the sequence identity is across the entire length of polypeptide calculated using ClustalW algorithm in the ALIGNX® module of the Vector NTI® Program Suite (Invitrogen Corporation, Carlsbad, Calif.) with all default parameters.

In some embodiments the PIP-72 polypeptide comprises an amino acid motif as represented by amino acid residues 37-51 of SEQ ID NO: 846, SEQ ID NO: 847, SEQ ID NO: 848 or SEQ ID NO: 849.

In some embodiments, the PIP-72 polypeptide comprises an amino acid sequence of SEQ ID NO: 2 having an amino acid substitution at one or more residues selected from residues 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 42, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 56, 57, 58, 59, 60, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85 or 86, of SEQ ID NO: 2 in any combination, and optionally the PIP-72 polypeptide further comprises a deletion of 1 to 5 amino acids, an insertion of 1 to 5 amino acids, addition of one or more amino acids at the N-terminus and/or addition of one or more amino acids at the C-terminus relative to SEQ ID NO: 2, in any combination.

In some embodiments, the PIP-72 polypeptide comprises an amino acid sequence of SEQ ID NO: 2 having an amino acid substitution at one or more residues selected from residues 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 17, 18, 19, 20, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 42, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 56, 58, 60, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85 or 86 of SEQ ID NO: 2, in any combination, and optionally the PIP-72 polypeptide further comprises a deletion of 1 to 5 amino acids, an insertion of 1 to 5 amino acids, addition of one or more amino acids at the N-terminus or addition of one or more amino acids at the C-terminus relative to SEQ ID NO: 2, in any combination.

In some embodiments, the PIP-72 polypeptide comprises an amino acid sequence of SEQ ID NO: 2 having an amino acid substitution at 1 to 45 residues selected from

residues 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 42, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 56, 57, 58, 59, 60, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85 and 86, of SEQ ID NO: 2 in any combination, and optionally
 5 the PIP-72 polypeptide further comprises a deletion of 1 to 5 amino acids, an insertion of 1 to 5 amino acids, addition of one or more amino acids at the N-terminus and/or addition of one or more amino acids at the C-terminus relative to SEQ ID NO: 2, in any combination.

In some embodiments, the PIP-72 polypeptide comprises an amino acid sequence
 10 of SEQ ID NO: 2 having an amino acid substitution compared to the native amino acid of SEQ ID NO: 2 at 1 to 45 residues selected from residues 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 17, 18, 19, 20, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 42, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 56, 58, 60, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85 and 86 of SEQ ID NO: 2, in
 15 any combination, and optionally the PIP-72 polypeptide further comprises a deletion of 1 to 5 amino acids, an insertion of 1 to 5 amino acids, addition of one or more amino acids at the N-terminus and/or addition of one or more amino acids at the C-terminus relative to SEQ ID NO: 2, in any combination.

In specific embodiments, the substitution is an alanine for the native amino acid at
 20 the recited position(s). Also encompassed are the nucleic acid sequence(s) encoding the variant protein or polypeptide.

In some embodiments the PIP-72 polypeptide comprising an amino acid sequence of SEQ ID NO: 846, wherein Xaa at position 2 is Gly, Ala, Cys, Asp, Glu, Ile, Lys, Leu, Asn, Arg, Ser, Thr, Val, Trp or Tyr; Xaa at position 3 is Ile or Trp; Xaa at position 4 is Thr,
 25 Ala, Asp, Glu, His, Ile, Lys, Leu, Arg, Ser, Val, Trp or Tyr; Xaa at position 5 is Val, Ala, Cys, Gly, His, Ile or Tyr; Xaa at position 6 is Thr, Ala, Cys, Phe, Gly, His, Ile, Lys, Met, Pro, Gln, Arg, Ser, Trp or Tyr; Xaa at position 7 is Asn, Ala or Val; Xaa at position 8 is Asn, Ala, Cys, Asp, Glu, Gly, His, Ile, Lys, Leu, Met, Gln, Arg, Ser, Thr or Val; Xaa at position 9 is Ser, Ala, Cys, Gly or Thr; Xaa at position 10 is Ser, Ala, Glu, Phe, Gly, His,
 30 Ile, Lys, Leu, Asn, Pro, Gln, Arg, Thr or Trp; Xaa at position 11 is Asn, Ala, Cys, Asp, Glu, Gly, His, Ile, Lys, Leu, Met, Gln, Ser, Thr, Val or Tyr; Xaa at position 12 is Pro, Ala, Cys, Asp, Glu, Gly, His, Lys, Leu, Asn, Gln, Arg, Ser, Thr, Val, Trp or Tyr; Xaa at position 13 is Ile, Asn, Gln or Val; Xaa at position 14 is Glu, Ala, Cys, Phe, His, Lys or Gln; Xaa at position 15 is Val, Ala, Cys, Ile, Met or Arg; Xaa at position 17 is Ile, Glu or Val; Xaa at position 18 is Asn or Ser; Xaa at position 19 is His, Ala, Glu, Lys, Leu, Pro, Arg, Ser or Tyr; Xaa at position 20 is Trp, Ala or Thr; Xaa at position 22 is Ser, Ala, Asp, Phe, Gly,

His, Ile, Lys, Leu, Met, Asn, Pro, Gln, Arg, Thr, Val or Tyr; Xaa at position 23 is Asp, Ala, Gly, His, Lys, Met, Asn, Gln, Ser, Thr or Val; Xaa at position 24 is Gly, Asp or Phe; Xaa at position 25 is Asp, Ala, Glu, Phe, Asn or Gln; Xaa at position 26 is Thr, Glu or Pro; Xaa at position 27 is Ser, Ala, Cys, Asp, Glu, Phe, Gly, His, Asn, Gln, Arg or Thr; Xaa at position 28 is Phe, Pro, Trp or Tyr; Xaa at position 29 is Phe, Ala, Cys, Ile, Leu, Gln, Arg, Trp or Tyr; Xaa at position 30 is Ser, Ala, Cys, Asp, Glu, Phe, Gly, His, Lys, Leu, Met, Asn, Pro, Gln, Arg, Thr, Val, Trp or Tyr; Xaa at position 31 is Val, Ile or Leu; Xaa at position 32 is Gly, Ala, Asp, Glu, Phe, His, Lys, Leu, Met, Asn, Pro, Gln, Arg, Ser, Thr, Val, Trp or Tyr; Xaa at position 33 is Asn, Ala, Cys, Asp, Glu, Phe, Gly, His, Ile, Lys, Leu, Pro, Gln, Arg, Ser, Thr, Val or Tyr; Xaa at position 34 is Gly, Glu, Phe, His, Lys, Leu, Met, Asn, Gln, Arg, Ser, Thr or Tyr; Xaa at position 35 is Lys, Ala, Cys, Asp, Gly, His, Ile, Leu, Met, Asn, Gln, Arg, Ser, Thr or Val; Xaa at position 36 is Gln, Ala, Cys, Glu, Gly, His, Ile, Lys, Leu, Asn, Pro, Arg, Ser, Thr or Val; Xaa at position 37 is Glu, Ala, Cys, Asp, Phe, Gly, Ile, Lys, Leu, Met, Asn, Ser, Thr or Val; Xaa at position 38 is Thr, Ala, Cys, Asp, Glu, Phe, Gly, His, Ile, Leu, Met, Asn, Gln, Arg, Ser, Val, Trp or Tyr; Xaa at position 39 is Trp or Phe; Xaa at position 40 is Asp, Ala, Cys, Glu, Phe, Gly, His, Ile, Lys, Leu, Met, Asn, Gln, Arg, Ser, Thr, Val, Trp or Tyr; Xaa at position 42 is Ser, Ala, Cys, Asp, Glu, Phe, Gly, Ile, Lys, Leu, Met, Asn, Gln, Arg, Thr, Val, Trp or Tyr; Xaa at position 44 is Ser, Ala, Asp, Glu, Gly, Leu, Met, Asn, Pro, Gln, Thr, Val or Tyr; Xaa at position 45 is Arg, Lys or Ser; Xaa at position 46 is Gly, Ala or Gln; Xaa at position 47 is Phe, Cys, Val or Tyr; Xaa at position 48 is Val, Ile or Leu; Xaa at position 49 is Leu, Cys, Phe, Met, Arg or Tyr; Xaa at position 50 is Ser, Ala, Cys, Asp, Ile, Met, Pro, Gln, Thr or Val; Xaa at position 51 is Leu, Ala, Cys, Met or Val; Xaa at position 52 is Lys, Cys, Phe, His, Ile, Leu, Met, Asn, Arg, Ser, Thr, Trp or Tyr; Xaa at position 53 is Lys, Ala, Cys, Asp, Glu, Phe, His, Ile, Leu, Met, Asn, Gln, Arg, Ser, Thr, Val or Tyr; Xaa at position 54 is Asn, Cys, Asp, Glu, Phe, Gly, Lys, Met, Gln, Arg, Ser or Trp; Xaa at position 56 is Ala, Gly, Leu, Asn, Pro, Gln, Arg, Ser or Thr; Xaa at position 57 is Gln, Glu, Leu, Met, Ser or Thr; Xaa at position 58 is His, Ala, Asp, Phe, Leu, Met, Asn, Arg, Trp or Tyr; Xaa at position 60 is Tyr, Glu or Phe; Xaa at position 63 is Gln, Cys, Gly, Ile, Leu, Met, Asn, Thr, Val or Tyr; Xaa at position 64 is Ala, Phe, Gly, His, Arg, Ser or Tyr; Xaa at position 65 is Ser, Ala, Cys, Asp, Glu, Phe, Gly, His, Ile, Leu, Asn, Thr or Val; Xaa at position 66 is Ser, Ala or Gly; Xaa at position 67 is Lys, Ala, Cys, Asp, Phe, His, Ile, Leu, Met, Asn, Gln, Arg, Ser, Thr, Val, Trp or Tyr; Xaa at position 68 is Ile Asp, Leu or Val; Xaa at position 69 is Glu, Ala, Cys, Asp, Phe, His, Ile, Leu, Met, Gln, Arg, Ser, Thr, Val or Tyr; Xaa at position 70 is Val, Cys or Ile; Xaa at position 71 is Asp, Ala, Cys, Gly, His, Ile, Leu, Met, Asn, Ser, Thr, Val or Tyr; Xaa at position 72 is Asn, Ala, Cys, Asp, Glu, Gly, Lys, Met, Pro, Gln, Arg, Ser, Thr, Val or Trp; Xaa at position 73 is Asn, Ala, Cys, Asp,

Phe, Gly, His, Ile, Leu, Ser, Thr, Val or Tyr; Xaa at position 74 is Ala, Cys, Asp, Phe, Gly, His, Ile, Leu, Asn, Gln, Arg, Ser, Thr, Val or Tyr; Xaa at position 75 is Val, Cys, Ile or Leu; Xaa at position 76 is Lys, Ala, Cys, Phe, His, Ile, Leu, Gln, Arg, Ser, Thr, Val, Trp or Tyr; Xaa at position 77 is Asp Tyr; Xaa at position 78 is Gln, Ala, Cys, Asp, Phe, Gly, His, Ile, Leu, Met, Asn, Arg, Ser, Thr, Val or Tyr; Xaa at position 79 is Gly, Arg, Ala, Cys, Asp, Glu, Phe, His, Lys, Leu, Asn, Gln, Arg, Ser, Thr, Trp or Tyr; Xaa at position 80 is Arg, Ala, Cys, Asp, Phe, Gly, His, Ile, Leu, Asn, Ser, Thr, Val or Tyr; Xaa at position 81 is Leu, Ala, Cys, Asp, Phe, Gly, His, Ile, Asn, Pro, Arg, Ser, Thr or Val; Xaa at position 82 is Ile, Ala, Leu, Met, Arg or Val; Xaa at position 83 is Glu, Ala, Cys, Asp, Phe, Gly, His, Ile, Lys, Leu, Asn, Pro, Arg, Ser, Thr, Val or Tyr; Xaa at position 84 is Pro, Ala, Cys, Glu, Ile, Ser, Val, Trp or Tyr; Xaa at position 85 is Leu, Cys, Gly or Val; and Xaa at position 86 is Ser, Ala, Ile, Thr or Val, and wherein 1 to 14 amino acids are optionally deleted from the N-terminus and/or C-terminus of the PIP-72 polypeptide.

In some embodiments a PIP-72 polypeptide comprises an amino acid sequence of SEQ ID NO: 846 having 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44 or 45, amino acid substitutions, in any combination, at residues designated by Xaa in SEQ ID NO: 846 compared to the native amino acid at the corresponding position of SEQ ID NO: 2.

In some embodiments a PIP-72 polypeptide comprises an amino acid sequence of SEQ ID NO: 846 having 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28 or 29 amino acid substitutions, in any combination, at residues designated by Xaa in SEQ ID NO: 846 compared to the native amino acid at the corresponding position of SEQ ID NO: 2.

In some embodiments a PIP-72 polypeptide comprises an amino acid sequence of SEQ ID NO: 847, wherein Xaa at position 2 is Gly, Lys or Ala; Xaa at position 3 is Ile or Leu; Xaa at position 4 is Thr or Ser; Xaa at position 5 is Val or Ile; Xaa at position 6 is Thr or Lys; Xaa at position 8 is Asn, Lys, Gly or Ser; Xaa at position 9 is Ser or Ala; Xaa at position 11 is Asn, Lys, His or Thr; Xaa at position 12 is Pro, Thr, Lys or Ser; Xaa at position 13 is Ile or Val; Xaa at position 14 is Glu or Asp; Xaa at position 15 is Val, Ala or Ile; Xaa at position 16 is Ala or Ser; Xaa at position 17 is Ile or Val; Xaa at position 18 is Asn or Ser; Xaa at position 19 is His, Lys, Arg, Gln or Ala; Xaa at position 21 is Gly or Arg; Xaa at position 22 is Ser, Lys, Asn, Asp or Thr; Xaa at position 25 is Asp or Asn; Xaa at position 26 is Thr or Asp; Xaa at position 27 is Ser, Thr, Asn or Lys; Xaa at position 28 is Phe, Tyr or Pro; Xaa at position 29 is Phe or Tyr; Xaa at position 30 is Ser, Gly or Lys; Xaa at position 31 is Val, Ile or Met; Xaa at position 32 is Gly, Ala or Asp; Xaa at position

33 is Asn, Ser, Gln or Pro; Xaa at position 35 is Lys, Glu or Ser; Xaa at position 36 is Gln, Asn or Ser; Xaa at position 37 is Glu or Asp; Xaa at position 38 is Thr or Ser; Xaa at position 42 is Ser or Asn; Xaa at position 44 is Ser, Asp, Ala or Leu; Xaa at position 47 is Phe or Tyr; Xaa at position 48 is Leu or Met; Xaa at position 49 is Leu or Met; Xaa at position 50 is Ser, Ala or Tyr; Xaa at position 51 is Leu or Val; Xaa at position 52 is Lys or Gln; Xaa at position 53 is Lys, Arg, Met or Leu; Xaa at position 54 is Asn, Lys or Gly; Xaa at position 55 is Gly or Ser; Xaa at position 56 is Ala, Thr, Gln or Ser; Xaa at position 57 is Gln, Val or Ala; Xaa at position 58 is His, Ala, Lys, Tyr or Thr; Xaa at position 59 is Pro or Thr; Xaa at position 62 is Val or Ile; Xaa at position 63 is Gln, Ser or Leu; Xaa at position 64 is Ala, Gln or Ser; Xaa at position 65 is Ser or Thr; Xaa at position 67 is Lys, Gln, Arg or Asn; Xaa at position 69 is Glu, Lys or Val; Xaa at position 70 is Val or Ile; Xaa at position 71 is Asp, Glu or Tyr; Xaa at position 72 is Asn, His, Ser or Asp; Xaa at position 73 is Asn, Ser or Asp; Xaa at position 74 is Ala, Thr, Met, Ile or Lys; Xaa at position 76 is Lys or Thr; Xaa at position 78 is Gln, His or Ser; Xaa at position 80 is Arg, Glu or Gln; Xaa at position 81 is Leu, Pro, Ala or Thr; Xaa at position 82 is Ile or Leu; Xaa at position 83 is Glu, His, Asn, Gln or Leu; Xaa at position 85 is Leu, Val or Ala; and Xaa at position 86 is Ser, Ala, Tyr or Asn, and wherein 1 to 14 amino acids are optionally deleted from the N-terminus and/or C-terminus of the PIP-72 polypeptide and/or an amino acid is inserted between residue 24 and 25 relative to SEQ ID NO: 847.

In some embodiments a PIP-72 polypeptide comprises an amino acid sequence of SEQ ID NO: 847 having 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44 or 45 amino acid substitutions, in any combination, at residues designated by Xaa in SEQ ID NO: 847 compared to the native amino acid at the corresponding position of SEQ ID NO: 2.

In some embodiments a PIP-72 polypeptide comprises an amino acid sequence of SEQ ID NO: 847 having 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28 or 29 amino acid substitutions, in any combination, at residues designated by Xaa in SEQ ID NO: 847 compared to the native amino acid at the corresponding position of SEQ ID NO: 2.

In some embodiments a PIP-72 polypeptide comprises an amino acid sequence of SEQ ID NO: 848, wherein Xaa at position 2 is Gly, Lys, Ala or Arg; Xaa at position 3 is Ile, Leu or Val; Xaa at position 4 is Thr or Ser; Xaa at position 5 is Val, Ile or Leu; Xaa at position 6 is Thr, Lys, Ser or Arg; Xaa at position 8 is Asn, Lys, Gly, Ser, Gln, Arg, Thr or Ala; Xaa at position 9 is Ser, Ala or Thr; Xaa at position 11 is Asn, Lys, Thr, Gln, Arg, His or Ser; Xaa at position 12 is Pro, Thr, Lys, Ser or Arg; Xaa at position 13 is Ile, Val or Leu;

Xaa at position 14 is Glu or Asp; Xaa at position 15 is Val, Ala, Ile or Leu; Xaa at position 16 is Ala or Ser; Xaa at position 17 is Ile, Val or Leu; Xaa at position 18 is Asn, Ser, Gln or Thr; Xaa at position 19 is His, Lys, Ala, Gln, Asn or Arg; Xaa at position 21 is Gly, Arg or Lys; Xaa at position 22 is Ser, Lys, Asn, Thr, Arg, Asp, Glu or Gln; Xaa at position 25 is Asp, Asn, Glu or Gln; Xaa at position 26 is Thr, Asp, Ser or Glu; Xaa at position 27 is Ser, Thr, Lys, Asn, Gln or Arg; Xaa at position 28 is Phe, Tyr, Pro or Trp; Xaa at position 29 is Phe, Tyr or Trp; Xaa at position 30 is Ser, Gly, Lys, Thr or Arg; Xaa at position 31 is Val, Ile, Met or Leu; Xaa at position 32 is Gly, Ala, Asp or Glu; Xaa at position 33 is Asn, Ser, Gln, Pro or Thr; Xaa at position 35 is Lys, Glu, Ser, Arg or Thr; Xaa at position 36 is Gln, Ser, Asn or Thr; Xaa at position 37 is Glu or Asp; Xaa at position 38 is Thr or Ser; Xaa at position 42 is Ser, Asn, Thr or Gln; Xaa at position 44 is Ser, Asp, Ala, Leu, Thr, Glu, Ile or Val; Xaa at position 47 is Phe, Tyr or Trp; Xaa at position 48 is Leu, Met, Ile or Val; Xaa at position 49 is Leu, Met, Ile or Val; Xaa at position 50 is Ser, Ala, Tyr or Thr; Xaa at position 51 is Leu, Val or Ile; Xaa at position 52 is Lys, Gln, Arg or Asn; Xaa at position 53 is Lys, Arg, Met, Leu, Ile or Val; Xaa at position 54 is Asn, Lys, Gly, Gln or Arg; Xaa at position 55 is Gly, Ser or Thr; Xaa at position 56 is Ala, Thr, Gln, Ser or Asn; Xaa at position 57 is Gln, Val, Ala, Asn, Leu or Ile; Xaa at position 58 is His, Ala, Lys, Tyr or Thr; Xaa at position 59 is Pro, Thr or Ser; Xaa at position 62 is Val, Ile or Leu; Xaa at position 63 is Gln, Ser, Leu, Asn, Thr, Ile or Val; Xaa at position 64 is Ala, Gln, Ser, Asn or Thr; Xaa at position 65 is Ser or Thr; Xaa at position 67 is Lys, Gln, Asn or Arg; Xaa at position 69 is Glu, Val, Asp, Lys, Arg, Ile or Leu; Xaa at position 70 is Val, Ile or Leu; Xaa at position 71 is Asp, Glu, Tyr or Trp; Xaa at position 72 is Asn, His, Ser, Asp, Gln, Thr or Glu; Xaa at position 73 is Asn, Ser, Asp, Gln, Thr or Glu; Xaa at position 74 is Ala, Thr, Met, Ile, Lys, Ser, Leu, Val or Arg; Xaa at position 76 is Lys, Thr, Arg or Ser; Xaa at position 78 is Gln, His, Ser, Asn or Thr; Xaa at position 80 is Arg, Glu, Gln, Lys, Asp or Asn; Xaa at position 81 is Leu, Pro, Thr, Ile, Val, Ala or Ser; Xaa at position 82 is Ile, Leu or Val; Xaa at position 83 is Glu, His, Asn, Leu, Gln, Ile or Val; Xaa at position 85 is Leu, Val or Ala; and Xaa at position 86 is Ser, Ala, Tyr, Asn or Thr, and wherein 1 to 14 amino acids are optionally deleted from the N-terminus and/or C-terminus of the PIP-72 polypeptide and/or an amino acid is inserted between residue 24 and 25 relative to SEQ ID NO: 848.

In some embodiments a PIP-72 polypeptide comprises an amino acid sequence of SEQ ID NO: 848 having 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44 or 45 amino acid substitutions, in any combination, at residues designated by Xaa in SEQ

ID NO: 848 compared to the native amino acid at the corresponding position of SEQ ID NO: 2.

In some embodiments a PIP-72 polypeptide comprises an amino acid sequence of SEQ ID NO: 848 having 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28 or 29 amino acid substitutions, in any combination, at residues designated by Xaa in SEQ ID NO: 848 compared to the native amino acid at the corresponding position of SEQ ID NO: 2.

In some embodiments a PIP-72 polypeptide comprises an amino acid sequence of SEQ ID NO: 849 wherein Xaa at position 2 is Gly, Ala, Cys, Asp, Glu, Ile, Lys, Leu, Asn, Arg, Ser, Thr, Val, Trp or Tyr; Xaa at position 3 is Ile, Leu, Val or Trp; Xaa at position 4 is Thr, Ala, Asp, Glu, His, Ile, Lys, Leu, Arg, Ser, Val, Trp or Tyr; Xaa at position 5 is Val, Ala, Cys, Gly, His, Ile, Leu or Tyr; Xaa at position 6 is Thr, Ala, Cys, Phe, Gly, His, Ile, Lys, Met, Pro, Gln, Arg, Ser, Trp or Tyr; Xaa at position 7 is Asn, Ala or Val; Xaa at position 8 is Asn, Lys, Gly, Ser, Gln, Arg, Thr, Ala, Cys, Asp, Glu, His, Ile, Leu, Met or Val; Xaa at position 9 is Ser, Ala, Cys, Gly or Thr; Xaa at position 11 is Asn, Lys, Thr, Gln, Arg, Ser, Ala, Cys, Asp, Glu, Gly, His, Ile, Leu, Met, Val or Tyr; Xaa at position 12 is Pro, Thr, Lys, Ser, Arg, Ala, Cys, Asp, Glu, Gly, His, Leu, Asn, Gln, Arg, Val, Trp or Tyr; Xaa at position 13 is Ile, Asn, Gln, Leu or Val; Xaa at position 14 is Glu, Ala, Cys, Phe, His, Lys, Asp or Gln; Xaa at position 15 is Val, Ala, Ile, Leu, Cys, Met or Arg; Xaa at position 16 is Ala or Ser; Xaa at position 17 is Ile, Glu, Leu or Val; Xaa at position 18 is Asn, Gln, Thr or Ser; Xaa at position 19 is His, Lys, Ala, Arg, Glu, Leu, Pro, Ser or Tyr; Xaa at position 20 is Trp, Ala or Thr; Xaa at position 21 is Gly, Arg or Lys; Xaa at position 22 is Ser, Ala, Asp, Phe, Gly, His, Ile, Lys, Leu, Met, Asn, Pro, Gln, Arg, Thr, Val or Tyr; Xaa at position 23 is Asp, Ala, Gly, His, Lys, Met, Asn, Gln, Ser, Thr or Val; Xaa at position 24 is Gly, Asp or Phe; Xaa at position 25 is Asp, Ala, Glu, Phe, Asn or Gln; Xaa at position 26 is Thr, Glu, Asp, Ser or Pro; Xaa at position 27 is Ser, Thr, Lys, Arg, Ala, Cys, Asp, Glu, Phe, Gly, His, Asn or Gln; Xaa at position 28 is Phe, Tyr, Pro or Trp; Xaa at position 29 is Phe, Ala, Cys, Ile, Leu, Gln, Arg, Trp or Tyr; Xaa at position 30 is Ser, Gly, Lys, Thr, Arg, Ala, Cys, Asp, Glu, Phe, His, Leu, Met, Asn, Pro, Gln, Val, Trp or Tyr; Xaa at position 31 is Val, Ile, Met or Leu; Xaa at position 32 is Gly, Ala, Asp, Glu, Phe, His, Lys, Leu, Met, Asn, Pro, Gln, Arg, Ser, Thr, Val, Trp or Tyr; Xaa at position 33 is Asn, Ser, Gln, Pro, Thr, Ala, Cys, Asp, Glu, Phe, Gly, His, Ile, Lys, Leu, Arg, Val or Tyr; Xaa at position 34 is Gly, Glu, Phe, His, Lys, Leu, Met, Asn, Gln, Arg, Ser, Thr or Tyr; Xaa at position 35 is Lys, Glu, Ala, Cys, Asp, Gly, His, Ile, Leu, Met, Asn, Gln, Arg, Ser, Thr or Val; Xaa at position 36 is Gln, Ala, Cys, Glu, Gly, His, Ile, Lys, Leu, Asn, Pro, Arg, Ser, Thr or Val; Xaa at position 37 is Glu, Asp, Ala, Cys, Phe, Gly, Ile, Lys, Leu, Met, Asn, Ser, Thr or Val; Xaa at position 38 is Thr,

Ser, Ala, Cys, Asp, Glu, Phe, Gly, His, Ile, Leu, Met, Asn, Gln, Arg, Val, Trp or Tyr; Xaa at position 39 is Trp or Phe; Xaa at position 40 is Asp, Ala, Cys, Glu, Phe, Gly, His, Ile, Lys, Leu, Met, Asn, Gln, Arg, Ser, Thr, Val, Trp or Tyr; Xaa at position 42 is Ser, Asn, Thr, Ala, Cys, Asp, Glu, Phe, Gly, Ile, Lys, Leu, Met, Arg, Val, Trp, Tyr or Gln; Xaa at position 44 is Ser, Asp, Ala, Leu, Thr, Glu, Ile, Ala, Gly, Leu, Met, Asn, Pro, Gln, Val, Tyr or Val; Xaa at position 45 is Arg, Lys or Ser; Xaa at position 46 is Gly, Ala or Gln; Xaa at position 47 is Phe, Tyr Cys, Val or Trp; Xaa at position 48 is Leu, Met, Ile, Cys, Phe, Met, Arg, Tyr or Val; Xaa at position 49 is Leu, Met, Ile or Val; Xaa at position 50 is Ser, Ala, Tyr, Cys, Asp, Ile, Met, Pro, Gln, Val or Thr; Xaa at position 51 is Leu, Val, Ala, Cys, Met or Ile; Xaa at position 52 is Lys, Cys, Phe, His, Ile, Leu, Met, Asn, Arg, Ser, Thr, Gln, Trp or Tyr; Xaa at position 53 is Lys, Arg, Met, Leu, Ile, Ala, Cys, Asp, Glu, Phe, His, Asn, Gln, Ser, Thr, Tyr or Val; Xaa at position 54 is Asn, Cys, Asp, Glu, Phe, Gly, Lys, Met, Gln, Arg, Ser or Trp; Xaa at position 55 is Gly, Ser or Thr; Xaa at position 56 is Ala, Thr, Gln, Ser, Gly, Leu, Pro, Arg or Asn; Xaa at position 57 is Gln, Glu, Leu, Met, Ser, Val, Ala, Asn, Ile or Thr; Xaa at position 58 is His, Ala, Lys, Asp, Phe, Leu, Met, Asn, Arg, Trp, Tyr or Thr; Xaa at position 59 is Pro, Thr or Ser; Xaa at position 60 is Tyr, Glu or Phe; Xaa at position 62 is Val, Ile or Leu; Xaa at position 63 is Gln, Ser, Cys, Gly, Ile, Leu, Met, Asn, Thr, Val or Tyr; Xaa at position 64 is Ala, Gln, Asn, Phe, Gly, His, Arg, Ser or Tyr; Xaa at position 65 is Ser, Ala, Cys, Asp, Glu, Phe, Gly, His, Ile, Leu, Asn, Val or Thr; Xaa at position 66 is Ser, Ala or Gly; Xaa at position 67 is Lys, Gln, Asn or Arg; Xaa at position 67 is Lys, Ala, Cys, Asp, Phe, His, Ile, Leu, Met, Asn, Gln, Arg, Ser, Thr, Val, Trp or Tyr; Xaa at position 68 is Ile Asp, Leu or Val; Xaa at position 69 is Glu, Ala, Cys, Asp, Phe, His, Ile, Leu, Met, Gln, Arg, Ser, Thr, Val or Tyr; Xaa at position 70 is Val, Ile, Cys or Leu; Xaa at position 71 is Asp, Glu, Tyr, Ala, Cys, Gly, His, Ile, Leu, Met, Asn, Ser, Thr, Val or Trp; Xaa at position 72 is Asn, Ala, Cys, Asp, Glu, Gly, Lys, Met, Pro, Gln, Arg, Ser, Thr, Val, His or Trp; Xaa at position 73 is Asn, Ser, Asp, Gln, Thr, Ala, Cys, Phe, Gly, His, Ile, Leu, Val, Tyr or Glu; Xaa at position 74 is Ala, Thr, Met, Ile, Lys, Ser, Leu, Val, Cys, Asp, Phe, Gly, His, Asn, Gln, Tyr or Arg; Xaa at position 75 is Val, Cys, Ile or Leu; Xaa at position 76 is Lys, Ala, Cys, Phe, His, Ile, Leu, Gln, Arg, Ser, Thr, Val, Trp or Tyr; Xaa at position 77 is Asp Tyr; Xaa at position 78 is Gln, His, Ser, Asn, Ala, Cys, Asp, Phe, Gly, Ile, Leu, Met, Asn, Arg, Val, Tyr or Thr; Xaa at position 79 is Gly, Arg, Ala, Cys, Asp, Glu, Phe, His, Lys, Leu, Asn, Gln, Arg, Ser, Thr, Trp or Tyr; Xaa at position 80 is Arg, Glu, Gln, Lys, Asp, Ala, Cys, Phe, Gly, His, Ile, Leu, Ser, Thr, Val, Tyr or Asn; Xaa at position 81 is Leu, Pro, Thr, Ile, Val, Ala, Cys, Asp, Phe, Gly, His or Ser; Xaa at position 82 is Ile, Ala, Leu, Met, Arg and Val; Xaa at position 83 is Glu, His, Asn, Leu, Gln, Ile, Ala, Cys, Asp, Phe, Gly, Lys, Pro, Arg, Ser, Thr, Tyr or Val; Xaa at position 84 is Pro, Ala, Cys, Glu, Ile, Ser, Val, Trp or Tyr; Xaa

at position 85 is Leu, Val, Cys, Gly or Ala; and Xaa at position 86 is Ser, Ala, Tyr, Asn, Ile, Val or Thr, and wherein, 1 to 14 amino acids are optionally deleted from the N-terminus and/or C-terminus of the PIP-72 polypeptide and/or an amino acid is inserted between residue 24 and 25 relative to SEQ ID NO: 849.

5 In some embodiments a PIP-72 polypeptide comprises an amino acid sequence of SEQ ID NO: 849 having 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44 or 45 amino acid substitutions, in any combination, at residues designated by Xaa in SEQ ID NO: 849 compared to the native amino acid at the corresponding position of SEQ ID NO: 2.

10 In some embodiments a PIP-72 polypeptide comprises an amino acid sequence of SEQ ID NO: 849 having 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28 or 29 amino acid substitutions, in any combination, at residues designated by Xaa in SEQ ID NO: 849 compared to the native amino acid at the corresponding position of SEQ ID NO: 2.

15 In some embodiments exemplary PIP-72 polypeptides are encoded by the polynucleotide sequence set forth in SEQ ID NO: 1, SEQ ID NO: 3, SEQ ID NO: 5, SEQ ID NO: 7, SEQ ID NO: 9, SEQ ID NO: 11, SEQ ID NO: 13, SEQ ID NO: 17, SEQ ID NO: 27, SEQ ID NO: 31, any one of SEQ ID NO: 287 - SEQ ID NO: 527, any one of SEQ ID NO: 796 - SEQ ID NO: 815, SEQ ID NO: 769, SEQ ID NO: 770, SEQ ID NO: 850, SEQ ID NO: 852, any one of SEQ ID NO: 853 – SEQ ID NO: 864, any one of SEQ ID NO: 915 – SEQ ID NO: 926, SEQ ID NO: 949, SEQ ID NO: 950, SEQ ID NO: 954, SEQ ID NO: 955, SEQ ID NO: 956, SEQ ID NO: 957, SEQ ID NO: 958, SEQ ID NO: 961, SEQ ID NO: 962, SEQ ID NO: 963, SEQ ID NO: 965, SEQ ID NO: 966, SEQ ID NO: 967 or SEQ ID NO: 968.

25 In some embodiments the PIP-72 polypeptide is encoded by the polynucleotide of SEQ ID NO: 1, SEQ ID NO: 3, SEQ ID NO: 5, SEQ ID NO: 7, SEQ ID NO: 9, SEQ ID NO: 11, SEQ ID NO: 13, SEQ ID NO: 17, SEQ ID NO: 27, SEQ ID NO: 31, SEQ ID NO: 769, SEQ ID NO: 770, SEQ ID NO: 850, SEQ ID NO: 852, SEQ ID NO: 949, SEQ ID NO: 950, SEQ ID NO: 954, SEQ ID NO: 955, SEQ ID NO: 956, SEQ ID NO: 957, SEQ ID NO: 958, SEQ ID NO: 961, SEQ ID NO: 962, SEQ ID NO: 963, SEQ ID NO: 965, SEQ ID NO: 966, SEQ ID NO: 967 or SEQ ID NO: 968.

30 In some embodiments exemplary PIP-72 polypeptides are set forth in SEQ ID NO: 2, SEQ ID NO: 4, SEQ ID NO: 6, SEQ ID NO: 8, SEQ ID NO: 10, SEQ ID NO: 12, SEQ ID NO: 14; SEQ ID NO: 18, SEQ ID NO: 28, SEQ ID NO: 32, SEQ ID NO: 528, SEQ ID NO: 529, SEQ ID NO: 530, SEQ ID NO: 531, SEQ ID NO: 532, SEQ ID NO: 533, SEQ ID NO:

534, SEQ ID NO: 535, SEQ ID NO: 536, SEQ ID NO: 537, SEQ ID NO: 538, SEQ ID NO:
539, SEQ ID NO: 540, SEQ ID NO: 541, SEQ ID NO: 542, SEQ ID NO: 543, SEQ ID NO:
544, SEQ ID NO: 545, SEQ ID NO: 546, SEQ ID NO: 547, SEQ ID NO: 548, SEQ ID NO:
549, SEQ ID NO: 550, SEQ ID NO: 551, SEQ ID NO: 552, SEQ ID NO: 553, SEQ ID NO:
5 554, SEQ ID NO: 555, SEQ ID NO: 556, SEQ ID NO: 557, SEQ ID NO: 558, SEQ ID NO:
559, SEQ ID NO: 560, SEQ ID NO: 561, SEQ ID NO: 562, SEQ ID NO: 563, SEQ ID NO:
564, SEQ ID NO: 565, SEQ ID NO: 566, SEQ ID NO: 567, SEQ ID NO: 568, SEQ ID NO:
569, SEQ ID NO: 570, SEQ ID NO: 571, SEQ ID NO: 572, SEQ ID NO: 573, SEQ ID NO:
574, SEQ ID NO: 575, SEQ ID NO: 576, SEQ ID NO: 577, SEQ ID NO: 578, SEQ ID NO:
10 579, SEQ ID NO: 580, SEQ ID NO: 581, SEQ ID NO: 582, SEQ ID NO: 583, SEQ ID NO:
584, SEQ ID NO: 585, SEQ ID NO: 586, SEQ ID NO: 587, SEQ ID NO: 588, SEQ ID NO:
589, SEQ ID NO: 590, SEQ ID NO: 591, SEQ ID NO: 592, SEQ ID NO: 593, SEQ ID NO:
594, SEQ ID NO: 595, SEQ ID NO: 596, SEQ ID NO: 597, SEQ ID NO: 598, SEQ ID NO:
599, SEQ ID NO: 600, SEQ ID NO: 601, SEQ ID NO: 602, SEQ ID NO: 603, SEQ ID NO:
15 604, SEQ ID NO: 605, SEQ ID NO: 606, SEQ ID NO: 607, SEQ ID NO: 608, SEQ ID NO:
609, SEQ ID NO: 610, SEQ ID NO: 611, SEQ ID NO: 612, SEQ ID NO: 613, SEQ ID NO:
614, SEQ ID NO: 615, SEQ ID NO: 616, SEQ ID NO: 617, SEQ ID NO: 618, SEQ ID NO:
619, SEQ ID NO: 620, SEQ ID NO: 621, SEQ ID NO: 622, SEQ ID NO: 623, SEQ ID NO:
624, SEQ ID NO: 625, SEQ ID NO: 626, SEQ ID NO: 627, SEQ ID NO: 628, SEQ ID NO:
20 629, SEQ ID NO: 630, SEQ ID NO: 631, SEQ ID NO: 632, SEQ ID NO: 633, SEQ ID NO:
634, SEQ ID NO: 635, SEQ ID NO: 636, SEQ ID NO: 637, SEQ ID NO: 638, SEQ ID NO:
639, SEQ ID NO: 640, SEQ ID NO: 641, SEQ ID NO: 642, SEQ ID NO: 643, SEQ ID NO:
644, SEQ ID NO: 645, SEQ ID NO: 646, SEQ ID NO: 647, SEQ ID NO: 648, SEQ ID NO:
649, SEQ ID NO: 650, SEQ ID NO: 651, SEQ ID NO: 652, SEQ ID NO: 653, SEQ ID NO:
25 654, SEQ ID NO: 655, SEQ ID NO: 656, SEQ ID NO: 657, SEQ ID NO: 658, SEQ ID NO:
659, SEQ ID NO: 660, SEQ ID NO: 661, SEQ ID NO: 662, SEQ ID NO: 663, SEQ ID NO:
664, SEQ ID NO: 665, SEQ ID NO: 666, SEQ ID NO: 667, SEQ ID NO: 668, SEQ ID NO:
669, SEQ ID NO: 670, SEQ ID NO: 671, SEQ ID NO: 672, SEQ ID NO: 673, SEQ ID NO:
674, SEQ ID NO: 675, SEQ ID NO: 676, SEQ ID NO: 677, SEQ ID NO: 678, SEQ ID NO:
30 679, SEQ ID NO: 680, SEQ ID NO: 681, SEQ ID NO: 682, SEQ ID NO: 683, SEQ ID NO:
684, SEQ ID NO: 685, SEQ ID NO: 686, SEQ ID NO: 687, SEQ ID NO: 688, SEQ ID NO:
689, SEQ ID NO: 690, SEQ ID NO: 691, SEQ ID NO: 692, SEQ ID NO: 693, SEQ ID NO:
694, SEQ ID NO: 695, SEQ ID NO: 696, SEQ ID NO: 697, SEQ ID NO: 698, SEQ ID NO:
699, SEQ ID NO: 700, SEQ ID NO: 701, SEQ ID NO: 702, SEQ ID NO: 703, SEQ ID NO:
35 704, SEQ ID NO: 705, SEQ ID NO: 706, SEQ ID NO: 707, SEQ ID NO: 708, SEQ ID NO:
709, SEQ ID NO: 710, SEQ ID NO: 711, SEQ ID NO: 712, SEQ ID NO: 713, SEQ ID NO:

714, SEQ ID NO: 715, SEQ ID NO: 716, SEQ ID NO: 717, SEQ ID NO: 718, SEQ ID NO:
 719, SEQ ID NO: 720, SEQ ID NO: 721, SEQ ID NO: 722, SEQ ID NO: 723, SEQ ID NO:
 724, SEQ ID NO: 725, SEQ ID NO: 726, SEQ ID NO: 727, SEQ ID NO: 728, SEQ ID NO:
 729, SEQ ID NO: 730, SEQ ID NO: 731, SEQ ID NO: 732, SEQ ID NO: 733, SEQ ID NO:
 5 734, SEQ ID NO: 735, SEQ ID NO: 736, SEQ ID NO: 737, SEQ ID NO: 738, SEQ ID NO:
 739, SEQ ID NO: 740, SEQ ID NO: 741, SEQ ID NO: 742, SEQ ID NO: 743, SEQ ID NO:
 744, SEQ ID NO: 745, SEQ ID NO: 746, SEQ ID NO: 747, SEQ ID NO: 748, SEQ ID NO:
 749, SEQ ID NO: 750, SEQ ID NO: 751, SEQ ID NO: 752, SEQ ID NO: 753, SEQ ID NO:
 754, SEQ ID NO: 755, SEQ ID NO: 756, SEQ ID NO: 757, SEQ ID NO: 758, SEQ ID NO:
 10 759, SEQ ID NO: 760, SEQ ID NO: 761, SEQ ID NO: 762, SEQ ID NO: 763, SEQ ID NO:
 764, SEQ ID NO: 765, SEQ ID NO: 766, SEQ ID NO: 767, SEQ ID NO: 768, SEQ ID NO:
 771, SEQ ID NO: 772, SEQ ID NO: 825, SEQ ID NO: 826, SEQ ID NO: 827, SEQ ID NO:
 828, SEQ ID NO: 829, SEQ ID NO: 830, SEQ ID NO: 831, SEQ ID NO: 832, SEQ ID NO:
 833, SEQ ID NO: 834, SEQ ID NO: 835, SEQ ID NO: 836, SEQ ID NO: 837, SEQ ID NO:
 15 838, SEQ ID NO: 839, SEQ ID NO: 840, SEQ ID NO: 841, SEQ ID NO: 842, SEQ ID NO:
 843, SEQ ID NO: 844, SEQ ID NO: 852, SEQ ID NO: 853, SEQ ID NO: 854, SEQ ID NO:
 855, SEQ ID NO: 856, SEQ ID NO: 857, SEQ ID NO: 858, SEQ ID NO: 859, SEQ ID NO:
 860, SEQ ID NO: 861, SEQ ID NO: 862, SEQ ID NO: 863, SEQ ID NO: 864, SEQ ID NO:
 903, SEQ ID NO: 904, SEQ ID NO: 905, SEQ ID NO: 906, SEQ ID NO: 907, SEQ ID NO:
 20 908, SEQ ID NO: 909, SEQ ID NO: 910, SEQ ID NO: 911, SEQ ID NO: 912, SEQ ID NO:
 913, SEQ ID NO: 914, SEQ ID NO: 927, SEQ ID NO: 928, SEQ ID NO: 932, SEQ ID NO:
 933, SEQ ID NO: 934, SEQ ID NO: 935, SEQ ID NO: 936, SEQ ID NO: 939, SEQ ID NO:
 940, SEQ ID NO: 941, SEQ ID NO: 943, SEQ ID NO: 944, SEQ ID NO: 945 and SEQ ID
 NO: 946.

25 In some embodiments the PIP-72 polypeptide comprises an amino acid sequence
 of SEQ ID NO: 2, SEQ ID NO: 4, SEQ ID NO: 6, SEQ ID NO: 8, SEQ ID NO: 10, SEQ ID
 NO: 12, SEQ ID NO: 14; SEQ ID NO: 18, SEQ ID NO: 28, SEQ ID NO: 32, SEQ ID NO:
 927, SEQ ID NO: 928, SEQ ID NO: 932, SEQ ID NO: 933, SEQ ID NO: 934, SEQ ID NO:
 935, SEQ ID NO: 936, SEQ ID NO: 939, SEQ ID NO: 940, SEQ ID NO: 941, SEQ ID NO:
 30 943, SEQ ID NO: 944, SEQ ID NO: 945 or SEQ ID NO: 946 .

In some embodiments exemplary PIP-72 polypeptides are the polypeptides shown
 in Table 14, Table 17, Table 20, Table 23, Table 24, Table 26, Table 28, and/or Table 29
 and any combinations of the amino acid substitutions thereof as well as deletions and or
 insertions and fragments thereof.

35 In some embodiments a PIP-72 polypeptide has a calculated molecular weight of
 between about 6 kDa and about 13 kDa between about 7 kDa and about 12 kDa,

between about 8 kDa and about 11 kDa, between about 9 kDa and about 10 kDa, about 8.75 kDa, about 9 kDa, about 9.25 kDa, about 9.5 kDa, about 9.75 kDa, about 10 kDa, about 10.25 kDa, and about 10.5 kDa. As used herein, the term “about” used in the context of molecular weight of a PIP-72 polypeptide means ± 0.25 kilodaltons.

5 In some embodiments the PIP-72 polypeptide has a modified physical property. As used herein, the term “physical property” refers to any parameter suitable for describing the physical-chemical characteristics of a protein. As used herein, “physical property of interest” and “property of interest” are used interchangeably to refer to physical properties of proteins that are being investigated and/or modified. Examples of physical properties
10 include, but are not limited to net surface charge and charge distribution on the protein surface, net hydrophobicity and hydrophobic residue distribution on the protein surface, surface charge density, surface hydrophobicity density, total count of surface ionizable groups, surface tension, protein size and its distribution in solution, melting temperature, heat capacity, and second virial coefficient. Examples of physical properties also include,
15 but are not limited to solubility, folding, stability, and digestibility. In some embodiments the PIP-72 polypeptide has increased digestibility of proteolytic fragments in an insect gut. Models for digestion by simulated gastric fluids are known to one skilled in the art (Fuchs, R.L. and J.D. Astwood. *Food Technology* 50: 83-88, 1996; Astwood, J.D., et al *Nature Biotechnology* 14: 1269-1273, 1996; Fu TJ et al *J. Agric Food Chem.* 50: 7154-7160,
20 2002).

In some embodiments variants include polypeptides that differ in amino acid sequence due to mutagenesis. Variant proteins encompassed by the disclosure are biologically active, that is they continue to possess the desired biological activity (i.e. pesticidal activity) of the native protein. In some embodiment the variant will have at least
25 about 10%, at least about 30%, at least about 50%, at least about 70%, at least about 80% or more of the insecticidal activity of the native protein. In some embodiments, the variants may have improved activity over the native protein.

Bacterial genes quite often possess multiple methionine initiation codons in proximity to the start of the open reading frame. Often, translation initiation at one or
30 more of these start codons will lead to generation of a functional protein. These start codons can include ATG codons. However, bacteria such as *Bacillus* sp. also recognize the codon GTG as a start codon, and proteins that initiate translation at GTG codons contain a methionine at the first amino acid. On rare occasions, translation in bacterial systems can initiate at a TTG codon, though in this event the TTG encodes a methionine.
35 Furthermore, it is not often determined a priori which of these codons are used naturally in the bacterium. Thus, it is understood that use of one of the alternate methionine codons

may also lead to generation of pesticidal proteins. These pesticidal proteins are encompassed in the present disclosure and may be used in the methods of the present disclosure. It will be understood that, when expressed in plants, it will be necessary to alter the alternate start codon to ATG for proper translation.

5 In another aspect the PIP-72 polypeptide may be expressed as a precursor protein with an intervening sequence that catalyzes multi-step, post translational protein splicing. Protein splicing involves the excision of an intervening sequence from a polypeptide with the concomitant joining of the flanking sequences to yield a new polypeptide (Chong, *et al.*, (1996) *J. Biol. Chem.*, 271:22159-22168). This intervening sequence or protein
 10 splicing element, referred to as inteins, which catalyze their own excision through three coordinated reactions at the N-terminal and C-terminal splice junctions: an acyl rearrangement of the N-terminal cysteine or serine; a transesterification reaction between the two termini to form a branched ester or thioester intermediate and peptide bond cleavage coupled to cyclization of the intein C-terminal asparagine to free the intein
 15 (Evans, *et al.*, (2000) *J. Biol. Chem.*, 275:9091-9094. The elucidation of the mechanism of protein splicing has led to a number of intein-based applications (Comb, *et al.*, US Patent Number 5,496,714; Comb, *et al.*, US Patent Number 5,834,247; Camarero and Muir, (1999) *J. Amer. Chem. Soc.* 121:5597-5598; Chong, *et al.*, (1997) *Gene* 192:271-281, Chong, *et al.*, (1998) *Nucleic Acids Res.* 26:5109-5115; Chong, *et al.*, (1998) *J. Biol. Chem.* 273:10567-10577; Cotton, *et al.*, (1999) *J. Am. Chem. Soc.* 121:1100-1101; Evans, *et al.*, (1999) *J. Biol. Chem.* 274:18359-18363; Evans, *et al.*, (1999) *J. Biol. Chem.* 274:3923-3926; Evans, *et al.*, (1998) *Protein Sci.* 7:2256-2264; Evans, *et al.*, (2000) *J. Biol. Chem.* 275:9091-9094; Iwai and Pluckthun, (1999) *FEBS Lett.* 459:166-172; Mathys, *et al.*, (1999) *Gene* 231:1-13; Mills, *et al.*, (1998) *Proc. Natl. Acad. Sci. USA* 95:3543-3548; Muir, *et al.*, (1998) *Proc. Natl. Acad. Sci. USA* 95:6705-6710; Otomo, *et al.*, (1999) *Biochemistry* 38:16040-16044; Otomo, *et al.*, (1999) *J. Biomol. NMR* 14:105-114; Scott, *et al.*, (1999) *Proc. Natl. Acad. Sci. USA* 96:13638-13643; Severinov and Muir, (1998) *J. Biol. Chem.* 273:16205-16209; Shingledecker, *et al.*, (1998) *Gene* 207:187-195; Southworth, *et al.*, (1998) *EMBO J.* 17:918-926; Southworth, *et al.*, (1999) *Biotechniques* 27:110-120; Wood, *et al.*, (1999) *Nat. Biotechnol.* 17:889-892; Wu, *et al.*, (1998a) *Proc. Natl. Acad. Sci. USA* 95:9226-9231; Wu, *et al.*, (1998b) *Biochim Biophys Acta* 1387:422-432; Xu, *et al.*, (1999) *Proc. Natl. Acad. Sci. USA* 96:388-393; Yamazaki, *et al.*, (1998) *J. Am. Chem. Soc.*, 120:5591-5592). For the application of inteins in plant transgenes, see, Yang, *et al.*, (*Transgene Res* 15:583-593 (2006)) and Evans, *et al.*, (*Annu. Rev. Plant Biol.* 56:375-392 (2005)).
 35

In another aspect the PIP-72 polypeptide may be encoded by two separate genes where the intein of the precursor protein comes from the two genes, referred to as a split-intein, and the two portions of the precursor are joined by a peptide bond formation. This peptide bond formation is accomplished by intein-mediated trans-splicing. For this purpose, a first and a second expression cassette comprising the two separate genes further code for inteins capable of mediating protein trans-splicing. By trans-splicing, the proteins and polypeptides encoded by the first and second fragments may be linked by peptide bond formation. Trans-splicing inteins may be selected from the nucleolar and organellar genomes of different organisms including eukaryotes, archaeobacteria and eubacteria. Inteins that may be used for are listed at neb.com/neb/inteins.html, which can be accessed on the world-wide web using the "www" prefix). The nucleotide sequence coding for an intein may be split into a 5' and a 3' part that code for the 5' and the 3' part of the intein, respectively. Sequence portions not necessary for intein splicing (e.g. homing endonuclease domain) may be deleted. The intein coding sequence is split such that the 5' and the 3' parts are capable of trans-splicing. For selecting a suitable splitting site of the intein coding sequence, the considerations published by Southworth, *et al.*, (1998) *EMBO J.* 17:918-926 may be followed. In constructing the first and the second expression cassette, the 5' intein coding sequence is linked to the 3' end of the first fragment coding for the N-terminal part of the PIP-72 polypeptide and the 3' intein coding sequence is linked to the 5' end of the second fragment coding for the C-terminal part of the PIP-72 polypeptide.

In general, the trans-splicing partners can be designed using any split intein, including any naturally-occurring or artificially-split split intein. Several naturally-occurring split inteins are known, for example: the split intein of the DnaE gene of *Synechocystis sp.* PCC6803 (see, Wu, *et al.*, (1998) *Proc Natl Acad Sci USA.* 95(16):9226-31 and Evans, *et al.*, (2000) *J Biol Chem.* 275(13):9091-4 and of the DnaE gene from *Nostoc punctiforme* (see, Iwai, *et al.*, (2006) *FEBS Lett.* 580(7):1853-8). Non-split inteins have been artificially split in the laboratory to create new split inteins, for example: the artificially split Ssp DnaB intein (see, Wu, *et al.*, (1998) *Biochim Biophys Acta.* 1387:422-32) and split Sce VMA intein (see, Brenzel, *et al.*, (2006) *Biochemistry.* 45(6):1571-8) and an artificially split fungal mini-intein (see, Elleuche, *et al.*, (2007) *Biochem Biophys Res Commun.* 355(3):830-4). There are also intein databases available that catalogue known inteins (see for example the online-database available at: bioinformatics.weizmann.ac.il/~pietro/inteins/Inteinstable.html, which can be accessed on the world-wide web using the "www" prefix).

Naturally-occurring non-split inteins may have endonuclease or other enzymatic activities that can typically be removed when designing an artificially-split split intein. Such mini-inteins or minimized split inteins are well known in the art and are typically less than 200 amino acid residues long (see, Wu, *et al.*, (1998) *Biochim Biophys Acta*. 1387:422-32). Suitable split inteins may have other purification enabling polypeptide elements added to their structure, provided that such elements do not inhibit the splicing of the split intein or are added in a manner that allows them to be removed prior to splicing. Protein splicing has been reported using proteins that comprise bacterial intein-like (BIL) domains (see, Amitai, *et al.*, (2003) *Mol Microbiol.* 47:61-73) and hedgehog (Hog) auto-processing domains (the latter is combined with inteins when referred to as the Hog/intein superfamily or HINT family (see, Dassa, *et al.*, (2004) *J Biol Chem.* 279:32001-7) and domains such as these may also be used to prepare artificially-split inteins. In particular, non-splicing members of such families may be modified by molecular biology methodologies to introduce or restore splicing activity in such related species. Recent studies demonstrate that splicing can be observed when a N-terminal split intein component is allowed to react with a C-terminal split intein component not found in nature to be its “partner”; for example, splicing has been observed utilizing partners that have as little as 30 to 50% homology with the “natural” splicing partner (see, Dassa, *et al.*, (2007) *Biochemistry.* 46(1):322-30). Other such mixtures of disparate split intein partners have been shown to be unreactive one with another (see, Brenzel, *et al.*, (2006) *Biochemistry.* 45(6):1571-8). However, it is within the ability of a person skilled in the relevant art to determine whether a particular pair of polypeptides is able to associate with each other to provide a functional intein, using routine methods and without the exercise of inventive skill.

In another aspect the PIP-72 polypeptide is a circular permuted variant. In certain embodiments the PIP-72 polypeptide is a circular permuted variant of the polypeptide of SEQ ID NO: 2, SEQ ID NO: 4, SEQ ID NO: 6, SEQ ID NO: 8, SEQ ID NO: 10, SEQ ID NO: 12, SEQ ID NO: 14, SEQ ID NO: 18, SEQ ID NO: 28, SEQ ID NO: 32, any one of SEQ ID NO: 528 - SEQ ID NO: 768, any one of SEQ ID NO: 825 – SEQ ID NO: 844, SEQ ID NO: 771, SEQ ID NO: 772, SEQ ID NO: 852, any one of SEQ ID NO: 903 – SEQ ID NO: 914, SEQ ID NO: 927, SEQ ID NO: 928, SEQ ID NO: 932, SEQ ID NO: 933, SEQ ID NO: 934, SEQ ID NO: 935, SEQ ID NO: 936, SEQ ID NO: 939, SEQ ID NO: 940, SEQ ID NO: 941, SEQ ID NO: 943, SEQ ID NO: 944, SEQ ID NO: 945, or SEQ ID NO: 946.

The development of recombinant DNA methods has made it possible to study the effects of sequence transposition on protein folding, structure and function. The approach used in creating new sequences resembles that of naturally occurring pairs of proteins

that are related by linear reorganization of their amino acid sequences (Cunningham, *et al.*, (1979) *Proc. Natl. Acad. Sci. U.S.A.* 76:3218-3222; Teather and Erfle, (1990) *J. Bacteriol.* 172:3837-3841; Schimming, *et al.*, (1992) *Eur. J. Biochem.* 204:13-19; Yamiuchi and Minamikawa, (1991) *FEBS Lett.* 260:127-130; MacGregor, *et al.*, (1996) *FEBS Lett.* 378:263-266). The first in vitro application of this type of rearrangement to proteins was described by Goldenberg and Creighton (*J. Mol. Biol.* 165:407-413, 1983). In creating a circular permuted variant a new N-terminus is selected at an internal site (breakpoint) of the original sequence, the new sequence having the same order of amino acids as the original from the breakpoint until it reaches an amino acid that is at or near the original C-terminus. At this point the new sequence is joined, either directly or through an additional portion of sequence (linker), to an amino acid that is at or near the original N-terminus and the new sequence continues with the same sequence as the original until it reaches a point that is at or near the amino acid that was N-terminal to the breakpoint site of the original sequence, this residue forming the new C-terminus of the chain. The length of the amino acid sequence of the linker can be selected empirically or with guidance from structural information or by using a combination of the two approaches. When no structural information is available, a small series of linkers can be prepared for testing using a design whose length is varied in order to span a range from 0 to 50 Å and whose sequence is chosen in order to be consistent with surface exposure (hydrophilicity, Hopp and Woods, (1983) *Mol. Immunol.* 20:483-489; Kyte and Doolittle, (1982) *J. Mol. Biol.* 157:105-132; solvent exposed surface area, Lee and Richards, (1971) *J. Mol. Biol.* 55:379-400) and the ability to adopt the necessary conformation without deranging the configuration of the pesticidal polypeptide (conformationally flexible; Karplus and Schulz, (1985) *Naturwissenschaften* 72:212-213). Assuming an average of translation of 2.0 to 3.8 Å per residue, this would mean the length to test would be between 0 to 30 residues, with 0 to 15 residues being the preferred range. Exemplary of such an empirical series would be to construct linkers using a cassette sequence such as Gly-Gly-Gly-Ser repeated n times, where n is 1, 2, 3 or 4. Those skilled in the art will recognize that there are many such sequences that vary in length or composition that can serve as linkers with the primary consideration being that they be neither excessively long nor short (cf., Sandhu, (1992) *Critical Rev. Biotech.* 12:437-462); if they are too long, entropy effects will likely destabilize the three-dimensional fold, and may also make folding kinetically impractical, and if they are too short, they will likely destabilize the molecule because of torsional or steric strain. Those skilled in the analysis of protein structural information will recognize that using the distance between the chain ends, defined as the distance between the c-alpha carbons, can be used to define the length of the sequence to be

used or at least to limit the number of possibilities that must be tested in an empirical selection of linkers. They will also recognize that it is sometimes the case that the positions of the ends of the polypeptide chain are ill-defined in structural models derived from x-ray diffraction or nuclear magnetic resonance spectroscopy data, and that when
5 true, this situation will therefore need to be taken into account in order to properly estimate the length of the linker required. From those residues whose positions are well defined are selected two residues that are close in sequence to the chain ends, and the distance between their α -carbons is used to calculate an approximate length for a linker between them. Using the calculated length as a guide, linkers with a range of
10 number of residues (calculated using 2 to 3.8 Å per residue) are then selected. These linkers may be composed of the original sequence, shortened or lengthened as necessary, and when lengthened the additional residues may be chosen to be flexible and hydrophilic as described above; or optionally the original sequence may be substituted for using a series of linkers, one example being the Gly-Gly-Gly-Ser cassette
15 approach mentioned above; or optionally a combination of the original sequence and new sequence having the appropriate total length may be used. Sequences of pesticidal polypeptides capable of folding to biologically active states can be prepared by appropriate selection of the beginning (amino terminus) and ending (carboxyl terminus) positions from within the original polypeptide chain while using the linker sequence as
20 described above. Amino and carboxyl termini are selected from within a common stretch of sequence, referred to as a breakpoint region, using the guidelines described below. A novel amino acid sequence is thus generated by selecting amino and carboxyl termini from within the same breakpoint region. In many cases the selection of the new termini will be such that the original position of the carboxyl terminus immediately preceded that
25 of the amino terminus. However, those skilled in the art will recognize that selections of termini anywhere within the region may function, and that these will effectively lead to either deletions or additions to the amino or carboxyl portions of the new sequence. It is a central tenet of molecular biology that the primary amino acid sequence of a protein dictates folding to the three-dimensional structure necessary for expression of its
30 biological function. Methods are known to those skilled in the art to obtain and interpret three-dimensional structural information using x-ray diffraction of single protein Crystals or nuclear magnetic resonance spectroscopy of protein solutions. Examples of structural information that are relevant to the identification of breakpoint regions include the location and type of protein secondary structure (α and 3-10 helices, parallel and anti-parallel
35 beta sheets, chain reversals and turns, and loops; Kabsch and Sander, (1983) *Biopolymers* 22:2577-2637; the degree of solvent exposure of amino acid residues, the

extent and type of interactions of residues with one another (Chothia, (1984) *Ann. Rev. Biochem.* 53:537-572) and the static and dynamic distribution of conformations along the polypeptide chain (Alber and Mathews, (1987) *Methods Enzymol.* 154:511-533). In some cases additional information is known about solvent exposure of residues; one example is

5 a site of post-translational attachment of carbohydrate which is necessarily on the surface of the protein. When experimental structural information is not available or is not feasible to obtain, methods are also available to analyze the primary amino acid sequence in order to make predictions of protein tertiary and secondary structure, solvent accessibility and the occurrence of turns and loops. Biochemical methods are also sometimes applicable

10 for empirically determining surface exposure when direct structural methods are not feasible; for example, using the identification of sites of chain scission following limited proteolysis in order to infer surface exposure (Gentile and Salvatore, (1993) *Eur. J. Biochem.* 218:603-621). Thus using either the experimentally derived structural information or predictive methods (e.g., Srinivisan and Rose, (1995) *Proteins: Struct.,*

15 *Funct. & Genetics* 22:81-99) the parental amino acid sequence is inspected to classify regions according to whether or not they are integral to the maintenance of secondary and tertiary structure. The occurrence of sequences within regions that are known to be involved in periodic secondary structure (alpha and 3-10 helices, parallel and anti-parallel beta sheets) are regions that should be avoided. Similarly, regions of amino acid

20 sequence that are observed or predicted to have a low degree of solvent exposure are more likely to be part of the so-called hydrophobic core of the protein and should also be avoided for selection of amino and carboxyl termini. In contrast, those regions that are known or predicted to be in surface turns or loops, and especially those regions that are known not to be required for biological activity, are the preferred sites for location of the

25 extremes of the polypeptide chain. Continuous stretches of amino acid sequence that are preferred based on the above criteria are referred to as a breakpoint region. Polynucleotides encoding circular permuted PIP-72 polypeptides with new N-terminus/C-terminus which contain a linker region separating the original C-terminus and N-terminus can be made essentially following the method described in Mullins, *et al.*, (1994) *J. Am.*

30 *Chem. Soc.* 116:5529-5533. Multiple steps of polymerase chain reaction (PCR) amplifications are used to rearrange the DNA sequence encoding the primary amino acid sequence of the protein. Polynucleotides encoding circular permuted PIP-72 polypeptides with new N-terminus/C-terminus which contain a linker region separating the original C-terminus and N-terminus can be made based on the tandem-duplication

35 method described in Horlick, *et al.*, (1992) *Protein Eng.* 5:427-431. Polymerase chain

reaction (PCR) amplification of the new N-terminus/C-terminus genes is performed using a tandemly duplicated template DNA.

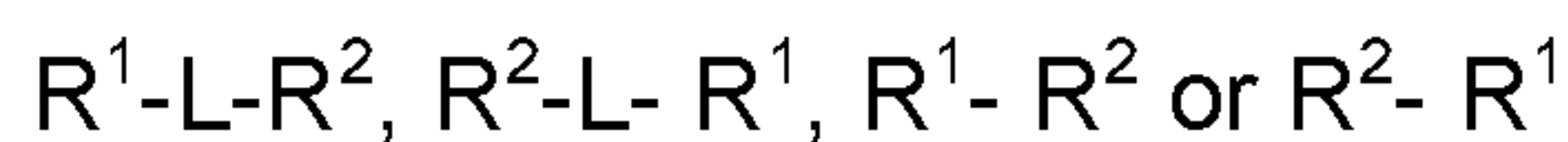
In another aspect fusion proteins are provided that include within its amino acid sequence an amino acid sequence comprising a PIP-72 polypeptide including but not limited to the polypeptide of SEQ ID NO: 2, SEQ ID NO: 4, SEQ ID NO: 6, SEQ ID NO: 8, SEQ ID NO: 10, SEQ ID NO: 12, SEQ ID NO: 14, SEQ ID NO: 18, SEQ ID NO: 28, SEQ ID NO: 32, any one of SEQ ID NO: 528 - SEQ ID NO: 768, any one of SEQ ID NO: 825 – SEQ ID NO: 844, SEQ ID NO: 771, SEQ ID NO: 772, SEQ ID NO: 846, SEQ ID NO: 847, SEQ ID NO: 848, SEQ ID NO: 849, SEQ ID NO: 852, any one of SEQ ID NO: 903 – SEQ ID NO: 914, any one of SEQ ID NO: 927 – SEQ ID NO: 948, and active fragments thereof.

Methods for design and construction of fusion proteins (and polynucleotides encoding same) are known to those of skill in the art. Polynucleotides encoding a PIP-72 polypeptide may be fused to signal sequences which will direct the localization of the PIP-72 polypeptide to particular compartments of a prokaryotic or eukaryotic cell and/or direct the secretion of the PIP-72 polypeptide of the embodiments from a prokaryotic or eukaryotic cell. For example, in *E. coli*, one may wish to direct the expression of the protein to the periplasmic space. Examples of signal sequences or proteins (or fragments thereof) to which the PIP-72 polypeptide may be fused in order to direct the expression of the polypeptide to the periplasmic space of bacteria include, but are not limited to, the *pefB* signal sequence, the maltose binding protein (MBP) signal sequence, MBP, the *ompA* signal sequence, the signal sequence of the periplasmic *E. coli* heat-labile enterotoxin B-subunit and the signal sequence of alkaline phosphatase. Several vectors are commercially available for the construction of fusion proteins which will direct the localization of a protein, such as the pMAL series of vectors (particularly the pMAL-p series) available from New England Biolabs® (240 County Road, Ipswich, MA 01938-2723). In a specific embodiment, the PIP-72 polypeptide may be fused to the *pefB* pectate lyase signal sequence to increase the efficiency of expression and purification of such polypeptides in Gram-negative bacteria (see, US Patent Numbers 5,576,195 and 5,846,818). Plant plastid transit peptide / polypeptide fusions are well known in the art (see, US Patent Number 7,193,133). Apoplast transit peptides such as rice or barley alpha-amylase secretion signal are also well known in the art. The plastid transit peptide is generally fused N-terminal to the polypeptide to be targeted (e.g., the fusion partner). In one embodiment, the fusion protein consists essentially of the plastid transit peptide and the PIP-72 polypeptide to be targeted. In another embodiment, the fusion protein comprises the plastid transit peptide and the polypeptide to be targeted. In such

embodiments, the plastid transit peptide is preferably at the N-terminus of the fusion protein. However, additional amino acid residues may be N-terminal to the plastid transit peptide providing that the fusion protein is at least partially targeted to a plastid. In a specific embodiment, the plastid transit peptide is in the N-terminal half, N-terminal third or N-terminal quarter of the fusion protein. Most or all of the plastid transit peptide is generally cleaved from the fusion protein upon insertion into the plastid. The position of cleavage may vary slightly between plant species, at different plant developmental stages, as a result of specific intercellular conditions or the particular combination of transit peptide/fusion partner used. In one embodiment, the plastid transit peptide cleavage is homogenous such that the cleavage site is identical in a population of fusion proteins. In another embodiment, the plastid transit peptide is not homogenous, such that the cleavage site varies by 1-10 amino acids in a population of fusion proteins. The plastid transit peptide can be recombinantly fused to a second protein in one of several ways. For example, a restriction endonuclease recognition site can be introduced into the nucleotide sequence of the transit peptide at a position corresponding to its C-terminal end and the same or a compatible site can be engineered into the nucleotide sequence of the protein to be targeted at its N-terminal end. Care must be taken in designing these sites to ensure that the coding sequences of the transit peptide and the second protein are kept "in frame" to allow the synthesis of the desired fusion protein. In some cases, it may be preferable to remove the initiator methionine codon of the second protein when the new restriction site is introduced. The introduction of restriction endonuclease recognition sites on both parent molecules and their subsequent joining through recombinant DNA techniques may result in the addition of one or more extra amino acids between the transit peptide and the second protein. This generally does not affect targeting activity as long as the transit peptide cleavage site remains accessible and the function of the second protein is not altered by the addition of these extra amino acids at its N-terminus. Alternatively, one skilled in the art can create a precise cleavage site between the transit peptide and the second protein (with or without its initiator methionine) using gene synthesis (Stemmer, *et al.*, (1995) *Gene* 164:49-53) or similar methods. In addition, the transit peptide fusion can intentionally include amino acids downstream of the cleavage site. The amino acids at the N-terminus of the mature protein can affect the ability of the transit peptide to target proteins to plastids and/or the efficiency of cleavage following protein import. This may be dependent on the protein to be targeted. See, e.g., Comai, *et al.*, (1988) *J. Biol. Chem.* 263(29):15104-9.

In some embodiments fusion proteins are provided comprising a PIP-72 polypeptide, and an insecticidal polypeptide joined by an amino acid linker.

In some embodiments fusion proteins are provided represented by a formula selected from the group consisting of:



wherein R^1 is a PIP-72 polypeptide or the polypeptide of SEQ ID NO: 2, SEQ ID NO: 4, SEQ ID NO: 6, SEQ ID NO: 8, SEQ ID NO: 10, SEQ ID NO: 12, SEQ ID NO: 14, SEQ ID NO: 18, SEQ ID NO: 28, SEQ ID NO: 32, any one of SEQ ID NO: 528 - SEQ ID NO: 768, any one of SEQ ID NO: 825 – SEQ ID NO: 844, SEQ ID NO: 771, SEQ ID NO: 772, SEQ ID NO: 852, any one of SEQ ID NO: 903 – SEQ ID NO: 914, SEQ ID NO: 927, SEQ ID NO: 928, SEQ ID NO: 932, SEQ ID NO: 933, SEQ ID NO: 934, SEQ ID NO: 935, SEQ ID NO: 936, SEQ ID NO: 939, SEQ ID NO: 940, SEQ ID NO: 941, SEQ ID NO: 943, SEQ ID NO: 944, SEQ ID NO: 945, or SEQ ID NO: 946, R^2 is an insecticidal polypeptide. The R^1 polypeptide is fused either directly or through a linker (L) segment to the R^2 polypeptide. The term "directly" defines fusions in which the polypeptides are joined without a peptide linker. Thus "L" represents a chemical bound or polypeptide segment to which both R^1 and R^2 are fused in frame, most commonly L is a linear peptide to which R^1 and R^2 are bound by amide bonds linking the carboxy terminus of R^1 to the amino terminus of L and carboxy terminus of L to the amino terminus of R^2 . By "fused in frame" is meant that there is no translation termination or disruption between the reading frames of R^1 and R^2 . The linking group (L) is generally a polypeptide of between 1 and 500 amino acids in length. The linkers joining the two molecules are preferably designed to (1) allow the two molecules to fold and act independently of each other, (2) not have a propensity for developing an ordered secondary structure which could interfere with the functional domains of the two proteins, (3) have minimal hydrophobic or charged characteristic which could interact with the functional protein domains and (4) provide steric separation of R^1 and R^2 such that R^1 and R^2 could interact simultaneously with their corresponding receptors on a single cell. Typically surface amino acids in flexible protein regions include Gly, Asn and Ser. Virtually any permutation of amino acid sequences containing Gly, Asn and Ser would be expected to satisfy the above criteria for a linker sequence. Other neutral amino acids, such as Thr and Ala, may also be used in the linker sequence. Additional amino acids may also be included in the linkers due to the addition of unique restriction sites in the linker sequence to facilitate construction of the fusions.

In some embodiments the linkers comprise sequences selected from the group of formulas: $(\text{Gly}_3\text{Ser})_n$, $(\text{Gly}_4\text{Ser})_n$, $(\text{Gly}_5\text{Ser})_n$, $(\text{Gly}_n\text{Ser})_n$ or $(\text{AlaGlySer})_n$ where n is an integer. One example of a highly-flexible linker is the (GlySer)-rich spacer region present within the pIII protein of the filamentous bacteriophages, e.g. bacteriophages M13 or fd

(Schaller, *et al.*, 1975). This region provides a long, flexible spacer region between two domains of the pIII surface protein. Also included are linkers in which an endopeptidase recognition sequence is included. Such a cleavage site may be valuable to separate the individual components of the fusion to determine if they are properly folded and active in vitro. Examples of various endopeptidases include, but are not limited to, Plasmin, Enterokinase, Kallikrein, Urokinase, Tissue Plasminogen activator, clostripain, Chymosin, Collagenase, Russell's Viper Venom Protease, Postproline cleavage enzyme, V8 protease, Thrombin and factor Xa. In some embodiments the linker comprises the amino acids EEKKN (SEQ ID NO: 488) from the multi-gene expression vehicle (MGEV), which is cleaved by vacuolar proteases as disclosed in US Patent Application Publication Number US 2007/0277263. In other embodiments, peptide linker segments from the hinge region of heavy chain immunoglobulins IgG, IgA, IgM, IgD or IgE provide an angular relationship between the attached polypeptides. Especially useful are those hinge regions where the cysteines are replaced with serines. Linkers of the present disclosure include sequences derived from murine IgG gamma 2b hinge region in which the cysteines have been changed to serines. The fusion proteins are not limited by the form, size or number of linker sequences employed and the only requirement of the linker is that functionally it does not interfere adversely with the folding and function of the individual molecules of the fusion.

In another embodiment PIP-72 polypeptide dimers are provided. In some embodiments the dimer is PIP-72 polypeptide homo-dimer. In some embodiments the dimer is PIP-72 polypeptide hetero-dimer comprising a first PIP-72 polypeptide and a second PIP-72 polypeptide where the first and second polypeptide are independently selected from the PIP-72 polypeptides of the disclosure. In some embodiments the PIP-72 polypeptides are covalently linked with or without a peptide linker.

In some embodiments the PIP-72 polypeptide of the dimer is labeled with a detectable label. The label can be a radioisotope, fluorescent compound, chemiluminescent compound, quantum dot, enzyme, or enzyme co-factor, or any other labels known in the art.

In some embodiments the PIP-72 polypeptide is labeled with a detectable label. The label can be a radioisotope, fluorescent compound, chemiluminescent compound, quantum dot, enzyme, or enzyme co-factor, or any other labels known in the art.

In another embodiment chimeric PIP-72 polypeptides are provided that are created through joining two or more portions of PIP-72 genes, which originally encoded separate PIP-72 proteins to create a chimeric gene. The translation of the chimeric gene results in a single chimeric PIP-72 polypeptide with regions, motifs or domains derived

from each of the original polypeptides. In certain embodiments the chimeric protein comprises portions, motifs or domains of PIP-72Aa (SEQ ID NO: 2), PIP-72Ba (SEQ ID NO: 4), PIP-72Ca (SEQ ID NO: 6) and PIP-72Cb (SEQ ID NO: 8), PIP-72Da (SEQ ID NO: 10), PIP-72Db (SEQ ID NO: 12), PIP-72Dc (SEQ ID NO: 14), PIP-72Fa (SEQ ID NO: 18),
 5 PIP-72Ff (SEQ ID NO: 28) and PIP-72Gb (SEQ ID NO: 32), PIP-72Ab (SEQ ID NO: 927), PIP-72Bb (SEQ ID NO: 928), PIP-72Fh (SEQ ID NO: 932), PIP-72Fi (SEQ ID NO: 933), PIP-72Fj (SEQ ID NO: 934), PIP-72Fk (SEQ ID NO: 935), PIP-72Fi (SEQ ID NO: 936), PIP-72Gg (SEQ ID NO: 939), PIP-72Gh (SEQ ID NO: 940), PIP-72Gi (SEQ ID NO: 941), PIP-72Gk (SEQ ID NO: 943), PIP-72Gi (SEQ ID NO: 944), PIP-72Gm (SEQ ID NO: 945)
 10 or PIP-72Gn (SEQ ID NO: 946) in any combination.

It is recognized that DNA sequences may be altered by various methods, and that these alterations may result in DNA sequences encoding proteins with amino acid sequences different than that encoded by the wild-type (or native) pesticidal protein. In some embodiments a PIP-72 polypeptide may be altered in various ways including amino
 15 acid substitutions, deletions, truncations and insertions of one or more amino acids, including up to 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45 or more amino acid substitutions, deletions and/or insertions or combinations thereof compared to SEQ ID NO: 2, SEQ ID NO: 4, SEQ ID NO: 6, SEQ ID NO: 8, SEQ ID NO:
 20 10, SEQ ID NO: 12, SEQ ID NO: 14, SEQ ID NO: 18, SEQ ID NO: 28, SEQ ID NO: 32, any one of SEQ ID NO: 528 - SEQ ID NO: 768, any one of SEQ ID NO: 825 – SEQ ID NO: 844, SEQ ID NO: 771, SEQ ID NO: 772, SEQ ID NO: 852, SEQ ID NO: 846, SEQ ID NO: 847, SEQ ID NO: 848, SEQ ID NO: 849, any one of SEQ ID NO: 903 – SEQ ID NO: 914, SEQ ID NO: 927, SEQ ID NO: 928, SEQ ID NO: 932, SEQ ID NO: 933, SEQ ID NO:
 25 934, SEQ ID NO: 935, SEQ ID NO: 936, SEQ ID NO: 939, SEQ ID NO: 940, SEQ ID NO: 941, SEQ ID NO: 943, SEQ ID NO: 944, SEQ ID NO: 945, or SEQ ID NO: 946.

Methods for such manipulations are generally known in the art. For example, amino acid sequence variants of a PIP-72 polypeptide can be prepared by mutations in the DNA. This may also be accomplished by one of several forms of mutagenesis and/or
 30 in directed evolution. In some aspects, the changes encoded in the amino acid sequence will not substantially affect the function of the protein. Such variants will possess the desired pesticidal activity. However, it is understood that the ability of a PIP-72 polypeptide to confer pesticidal activity may be improved by the use of such techniques upon the compositions of this disclosure.

35 For example, conservative amino acid substitutions may be made at one or more, predicted, nonessential amino acid residues. A “nonessential” amino acid residue is a

residue that can be altered from the wild-type sequence of a PIP-72 polypeptide without altering the biological activity. A “conservative amino acid substitution” is one in which the amino acid residue is replaced with an amino acid residue having a similar side chain. Families of amino acid residues having similar side chains have been defined in the art.

5 These families include: amino acids with basic side chains (e.g., lysine, arginine, histidine); acidic side chains (e.g., aspartic acid, glutamic acid); polar, negatively charged residues and their amides (e.g., aspartic acid, asparagine, glutamic, acid, glutamine; uncharged polar side chains (e.g., glycine, asparagine, glutamine, serine, threonine, tyrosine, cysteine); small aliphatic, nonpolar or slightly polar residues (e.g., Alanine, 10 serine, threonine, proline, glycine); nonpolar side chains (e.g., alanine, valine, leucine, isoleucine, proline, phenylalanine, methionine, tryptophan); large aliphatic, nonpolar residues (e.g., methionine, leucine, isoleucine, valine, cysteine); beta-branched side chains (e.g., threonine, valine, isoleucine); aromatic side chains (e.g., tyrosine, phenylalanine, tryptophan, histidine); large aromatic side chains (e.g., tyrosine, 15 phenylalanine, tryptophan).

Amino acid substitutions may be made in nonconserved regions that retain function. In general, such substitutions would not be made for conserved amino acid residues or for amino acid residues residing within a conserved motif, where such residues are essential for protein activity. Examples of residues that are conserved and 20 that may be essential for protein activity include, for example, residues that are identical between all proteins contained in an alignment of similar or related toxins to the sequences of the embodiments (e.g., residues that are identical in an alignment of homologs). Examples of residues that are conserved but that may allow conservative amino acid substitutions and still retain activity include, for example, residues that have 25 only conservative substitutions between all proteins contained in an alignment of similar or related toxins to the sequences of the embodiments (e.g., residues that have only conservative substitutions between all proteins contained in the alignment of the homologs). However, one of skill in the art would understand that functional variants may have minor conserved or nonconserved alterations in the conserved residues. Guidance 30 as to appropriate amino acid substitutions that do not affect biological activity of the protein of interest may be found in the model of Dayhoff, *et al.*, (1978) *Atlas of Protein Sequence and Structure* (Natl. Biomed. Res. Found., Washington, D.C.), herein incorporated by reference.

In making such changes, the hydropathic index of amino acids may be considered. 35 The importance of the hydropathic amino acid index in conferring interactive biologic function on a protein is generally understood in the art (Kyte and Doolittle, (1982) *J Mol*

Biol. 157(1):105-32). It is accepted that the relative hydropathic character of the amino acid contributes to the secondary structure of the resultant protein, which in turn defines the interaction of the protein with other molecules, for example, enzymes, substrates, receptors, DNA, antibodies, antigens, and the like.

5 It is known in the art that certain amino acids may be substituted by other amino acids having a similar hydropathic index or score and still result in a protein with similar biological activity, i.e., still obtain a biological functionally equivalent protein. Each amino acid has been assigned a hydropathic index on the basis of its hydrophobicity and charge characteristics (Kyte and Doolittle, *ibid*). These are: isoleucine (+4.5); valine (+4.2);
 10 leucine (+3.8); phenylalanine (+2.8); cysteine/cysteine (+2.5); methionine (+1.9); alanine (+1.8); glycine (−0.4); threonine (−0.7); serine (−0.8); tryptophan (−0.9); tyrosine (−1.3); proline (−1.6); histidine (−3.2); glutamate (−3.5); glutamine (−3.5); aspartate (−3.5); asparagine (−3.5); lysine (−3.9) and arginine (−4.5). In making such changes, the substitution of amino acids whose hydropathic indices are within +2 is preferred, those
 15 which are within +1 are particularly preferred, and those within +0.5 are even more particularly preferred.

It is also understood in the art that the substitution of like amino acids can be made effectively on the basis of hydrophilicity. US Patent Number 4,554,101, states that the greatest local average hydrophilicity of a protein, as governed by the hydrophilicity of
 20 its adjacent amino acids, correlates with a biological property of the protein.

As detailed in US Patent Number 4,554,101, the following hydrophilicity values have been assigned to amino acid residues: arginine (+3.0); lysine (+3.0); aspartate (+3.0+0.1); glutamate (+3.0+0.1); serine (+0.3); asparagine (+0.2); glutamine (+0.2); glycine (0); threonine (−0.4); proline (−0.5+0.1); alanine (−0.5); histidine (−0.5); cysteine
 25 (−1.0); methionine (−1.3); valine (−1.5); leucine (−1.8); isoleucine (−1.8); tyrosine (−2.3); phenylalanine (−2.5); tryptophan (−3.4).

Alternatively, alterations may be made to the protein sequence of many proteins at the amino or carboxy terminus without substantially affecting activity. This can include insertions, deletions or alterations introduced by modern molecular methods, such as
 30 PCR, including PCR amplifications that alter or extend the protein coding sequence by virtue of inclusion of amino acid encoding sequences in the oligonucleotides utilized in the PCR amplification. Alternatively, the protein sequences added can include entire protein-coding sequences, such as those used commonly in the art to generate protein fusions. Such fusion proteins are often used to (1) increase expression of a protein of interest (2)
 35 introduce a binding domain, enzymatic activity or epitope to facilitate either protein purification, protein detection or other experimental uses known in the art (3) target

secretion or translation of a protein to a subcellular organelle, such as the periplasmic space of Gram-negative bacteria, mitochondria or chloroplasts of plants or the endoplasmic reticulum of eukaryotic cells, the latter of which often results in glycosylation of the protein.

5 Variant nucleotide and amino acid sequences of the disclosure also encompass sequences derived from mutagenic and recombinogenic procedures such as DNA shuffling. With such a procedure, one or more different PIP-72 polypeptide coding regions can be used to create a new PIP-72 polypeptide possessing the desired properties. In this manner, libraries of recombinant polynucleotides are generated from a
10 population of related sequence polynucleotides comprising sequence regions that have substantial sequence identity and can be homologously recombined in vitro or in vivo. For example, using this approach, sequence motifs encoding a domain of interest may be shuffled between a pesticidal gene and other known pesticidal genes to obtain a new gene coding for a protein with an improved property of interest, such as an increased
15 insecticidal activity. Strategies for such DNA shuffling are known in the art. See, for example, Stemmer, (1994) *Proc. Natl. Acad. Sci. USA* 91:10747-10751; Stemmer, (1994) *Nature* 370:389-391; Cramer, *et al.*, (1997) *Nature Biotech.* 15:436-438; Moore, *et al.*, (1997) *J. Mol. Biol.* 272:336-347; Zhang, *et al.*, (1997) *Proc. Natl. Acad. Sci. USA* 94:4504-4509; Cramer, *et al.*, (1998) *Nature* 391:288-291; and US Patent Numbers
20 5,605,793 and 5,837,458.

Domain swapping or shuffling is another mechanism for generating altered PIP-72 polypeptides. Domains may be swapped between PIP-72 polypeptides, resulting in hybrid or chimeric toxins with improved insecticidal activity or target spectrum. Methods for generating recombinant proteins and testing them for pesticidal activity are well known
25 in the art (see, for example, Naimov, *et al.*, (2001) *Appl. Environ. Microbiol.* 67:5328-5330; de Maagd, *et al.*, (1996) *Appl. Environ. Microbiol.* 62:1537-1543; Ge, *et al.*, (1991) *J. Biol. Chem.* 266:17954-17958; Schnepf, *et al.*, (1990) *J. Biol. Chem.* 265:20923-20930; Rang, *et al.*, (1999) *Appl. Environ. Microbiol.* 65:2918-2925).

Both DNA shuffling and site-directed mutagenesis were used to define polypeptide
30 sequences that possess pesticidal activity. In Examples 8 & 9 DNA shuffling was used to generate a library of active variants by recombination of the diversity present in GBP_A3175 (SEQ ID NO: 20) and PIP-72Da (SEQ ID NO: 10). The person skilled in the art will be able to use comparisons to other proteins or functional assays to further define motifs. High throughput screening can be used to test variations of those motifs to
35 determine the role of specific residues. Given that knowledge for several motifs, one can

then define the requirements for a functional protein. Knowledge of the motifs allows the skilled artisan to design sequence variations that would not impact function.

Alignment of homologs of PIP-72 homologs (Figures 1, 2, 3, 4 & 5) allowed identification of residues that are conserved among homologs in this family (Figure 1). In Example 10 and 11, saturation mutagenesis was used to make and test substitutions at selected amino acid positions. These mutants were tested for activity and a number of active substitutions not present among the homologues were identified providing an understanding of the functional constraints at these residues.

In some embodiments polypeptides are provided comprising an amino acid sequence having at least 75%, at least 80%, at least 85%, at least 90%, at least 95% or greater sequence identity to the amino acid sequence set forth in SEQ ID NO: 20, SEQ ID NO: 24, SEQ ID NO: 30, SEQ ID NO: 34, SEQ ID NO: 36, SEQ ID NO: 929, SEQ ID NO: 930, SEQ ID NO: 931, SEQ ID NO: 937, SEQ ID NO: 938, SEQ ID NO: 942, SEQ ID NO: 947, or SEQ ID NO: 948, wherein the polypeptide has insecticidal activity.

Methods for engineering PIP-72 polypeptides

Methods for engineering PIP-72 polypeptides are also encompassed by the disclosure. In some embodiments the method for engineering PIP-72 polypeptides uses rational protein design based on a secondary, tertiary or quaternary structure model of the PIP-72 polypeptide. In some embodiments the method uses structural coordinates determined by X-ray crystallography or solution NMR. *In silico* modeling tools are well known to one skilled in the art and can be used in the methods of the disclosure. In some embodiments the rational protein design uses an *in silico* modeling tool selected from but not limited to PyMOL (PyMOL Molecular Graphics System, Version 1.7.4 Schrödinger, LLC.), Maestro©, BioLuminate (Zhu, K.; et al., *Proteins*, 2014, **82**(8), 1646–1655; Salam, N.K et al., *Protein Eng. Des. Sel.*, 2014, **27**(10), 365-74; Beard, H. et al. *PLoS ONE*, 2013, 8(12), e82849), MOE© (Molecular Operating Environment (MOE), 2013.08; Chemical Computing Group Inc., 1010 Sherbooke St. West, Suite #910, Montreal, QC, Canada, H3A 2R7, 2015), Jmol, and Discovery Studio© (Accelrys Software Inc. Discovery Studio Modeling Environment, Release 3.5.0, San Diego: Accelrys Software Inc. 2013). In some embodiments the modeling uses Discovery Studio© software.

In some embodiments the PIP-72 polypeptide is engineered by the method of the disclosure to have a modified physical property compared to the native PIP-72 polypeptide. In some embodiments the modified physical properties include, but are not limited to net surface charge and charge distribution on the protein surface, net

hydrophobicity and hydrophobic residue distribution on the protein surface, surface charge density, surface hydrophobicity density, total count of surface ionizable groups, surface tension, protein size and its distribution in solution, melting temperature, heat capacity, and second virial coefficient. In some embodiments the modified physical in-
5 properties include, but are not limited to solubility, folding, stability, protease stability, digestibility, planta expression, insecticidal potency, spectrum of insecticidal activity, dimer subunit affinity, ion channel activity, and receptor binding. In some embodiments the modified physical property is improved protease stability, improved in-planta expression, improved solubility, improved potency, improved dimer affinity, improved ion-channel
10 activity, and/or improved receptor binding.

Using the methods of the disclosure, proteolytically-sensitive sites can be identified and may be modified or utilized to produce more stable or more biologically active PIP-72 polypeptides.

Using methods of the disclosure, sites involved in receptor binding can be
15 identified and may be modified to create PIP-72 polypeptides having enhanced insecticidal activity; enhanced ability to form channels; and reduced size.

Using methods of the disclosure, occupation of a site by a water molecule can be identified and can be modified to create PIP-72 molecules having modified flexibility in a region or increasing the number of hydrophobic residues along that surface, which may
20 be involved in receptor binding, pore formation or dimerization.

Using methods of the disclosure, hydrogen bonding in a region can be identified and the amino acids may be substituted to modify the number of hydrogen bonds, including salt bridges, to create PIP-72 polypeptides having a modified hydrophobic interaction surface and/or modified insecticidal activity.

Using methods of the disclosure, loop regions can be identified and may be
25 modified to create PIP-72 polypeptides having modified channel formation, folding, and/or receptor binding.

Using methods of the disclosure, complex electrostatic surfaces and hydrophobic or hydrophilic interactions can be identified and modified to create PIP-72 polypeptides
30 having modified dimerization and/or receptor interaction

Using methods of the disclosure, metal binding sites can be identified and modified to create PIP-72 polypeptides having modified ion channel activity.

Using methods of the disclosure, amino acids that may be buried or otherwise removed from the surface of the protein that hold in place the three-dimensional structure
35 can be identified and modified to create PIP-72 polypeptides having modified stability or flexibility.

Using methods of the disclosure, non-specific binding sites to other biomolecules can be identified and modified to create PIP-72 polypeptides having modified receptor binding to the specific receptor and enhanced toxicity.

Applying various computational tools known to one skilled in the art, coupled with the understanding of saturated mutagenesis, and the structural/functional relationship for PIP-72 polypeptides as disclosed herein, one skilled in the art can identify and modify various physical properties of PIP-72 polypeptides for the better overall performance as an insecticidal protein against the desired targets. Combinatory mutagenesis at various loop regions as defined in Table 31 in different combination can enhance specificity to the current active targets and potentially can also change activity spectrum against different targets. Such targeted combinatorial mutagenesis can be achieved with incorporation of mutagenic oligo nucleotides or generated by gene synthesis or the combination of both approaches. Mutagenesis on defined loop regions can also enhance physical properties of PIP-72 polypeptides such as increasing protein stability by reducing protease degradation ability and increasing thermostability etc. In additional combinatorial mutagenesis can be applied to the amino acid residues involved in hydrophobic interface surface. Such changes can be incorporated as homo dimer (each monomer contains same mutation(s)) or as hetero dimer (each monomer contains different mutation(s)) physically linked with or without a peptide linker. Enhancement of hydrophobic interface surface can potentially increase insecticidal activity, thermostability and other physical properties. Finally, improved variants from both loop and dimer interface mutagenesis can be combined to further improve the insecticidal activity, target specificity and physical properties. Additional improvements can also be achieved through mutagenesis of other part of the molecule such as various beta-sheets to increase stability and activity.

Compositions

Compositions comprising a PIP-72 polypeptide of the disclosure are also embraced. In some embodiments the composition comprises a PIP-72 polypeptide. In some embodiments the composition comprises a PIP-72 fusion protein. In some embodiments the composition comprises a PIP-72 polypeptide dimer.

Antibodies

Antibodies to a PIP-72 polypeptide of the embodiments or to variants or fragments thereof are also encompassed. The antibodies of the disclosure include polyclonal and monoclonal antibodies as well as fragments thereof which retain their ability to bind to PIP-72 proteins found in the insect gut. An antibody, monoclonal antibody or fragment

thereof is said to be capable of binding a molecule if it is capable of specifically reacting with the molecule to thereby bind the molecule to the antibody, monoclonal antibody or fragment thereof. The term "antibody" (Ab) or "monoclonal antibody" (Mab) is meant to include intact molecules as well as fragments or binding regions or domains thereof (such as, for example, Fab and F(ab).sub.2 fragments) which are capable of binding hapten. Such fragments are typically produced by proteolytic cleavage, such as papain or pepsin. Alternatively, hapten-binding fragments can be produced through the application of recombinant DNA technology or through synthetic chemistry. Methods for the preparation of the antibodies of the present disclosure are generally known in the art. For example, see, *Antibodies, A Laboratory Manual*, Ed Harlow and David Lane (eds.) Cold Spring Harbor Laboratory, N.Y. (1988), as well as the references cited therein. Standard reference works setting forth the general principles of immunology include: Klein, J. *Immunology: The Science of Cell-Noncell Discrimination*, John Wiley & Sons, N.Y. (1982); Dennett, *et al.*, *Monoclonal Antibodies, Hybridoma: A New Dimension in Biological Analyses*, Plenum Press, N.Y. (1980) and Campbell, "Monoclonal Antibody Technology," In *Laboratory Techniques in Biochemistry and Molecular Biology*, Vol. 13, Burdon, *et al.*, (eds.), Elsevier, Amsterdam (1984). See also, US Patent Numbers 4,196,265; 4,609,893; 4,713,325; 4,714,681; 4,716,111; 4,716,117 and 4,720,459. PIP-72 polypeptide antibodies or antigen-binding portions thereof can be produced by a variety of techniques, including conventional monoclonal antibody methodology, for example the standard somatic cell hybridization technique of Kohler and Milstein, (1975) *Nature* 256:495. Other techniques for producing monoclonal antibody can also be employed such as viral or oncogenic transformation of B lymphocytes. An animal system for preparing hybridomas is a murine system. Immunization protocols and techniques for isolation of immunized splenocytes for fusion are known in the art. Fusion partners (e.g., murine myeloma cells) and fusion procedures are also known. The antibody and monoclonal antibodies of the disclosure can be prepared by utilizing a PIP-72 polypeptide as antigens.

A kit for detecting the presence of a PIP-72 polypeptide or detecting the presence of a nucleotide sequence encoding a PIP-72 polypeptide, in a sample is provided. In one embodiment, the kit provides antibody-based reagents for detecting the presence of a PIP-72 polypeptide in a tissue sample. In another embodiment, the kit provides labeled nucleic acid probes useful for detecting the presence of one or more polynucleotides encoding PIP-72 polypeptide(s). The kit is provided along with appropriate reagents and controls for carrying out a detection method, as well as instructions for use of the kit.

Nucleotide Constructs, Expression Cassettes and Vectors

The use of the term "nucleotide constructs" herein is not intended to limit the embodiments to nucleotide constructs comprising DNA. Those of ordinary skill in the art will recognize that nucleotide constructs particularly polynucleotides and oligonucleotides
5 composed of ribonucleotides and combinations of ribonucleotides and deoxyribonucleotides may also be employed in the methods disclosed herein. The nucleotide constructs, nucleic acids, and nucleotide sequences of the embodiments additionally encompass all complementary forms of such constructs, molecules, and sequences. Further, the nucleotide constructs, nucleotide molecules, and nucleotide
10 sequences of the embodiments encompass all nucleotide constructs, molecules, and sequences which can be employed in the methods of the embodiments for transforming plants including, but not limited to, those comprised of deoxyribonucleotides, ribonucleotides, and combinations thereof. Such deoxyribonucleotides and ribonucleotides include both naturally occurring molecules and synthetic analogues. The
15 nucleotide constructs, nucleic acids, and nucleotide sequences of the embodiments also encompass all forms of nucleotide constructs including, but not limited to, single-stranded forms, double-stranded forms, hairpins, stem-and-loop structures and the like.

A further embodiment relates to a transformed organism such as an organism selected from plant and insect cells, bacteria, yeast, baculovirus, protozoa, nematodes
20 and algae. The transformed organism comprises a DNA molecule of the embodiments, an expression cassette comprising the DNA molecule or a vector comprising the expression cassette, which may be stably incorporated into the genome of the transformed organism.

The sequences of the embodiments are provided in DNA constructs for expression
25 in the organism of interest. The construct will include 5' and 3' regulatory sequences operably linked to a sequence of the embodiments. The term "operably linked" as used herein refers to a functional linkage between a promoter and a second sequence, wherein the promoter sequence initiates and mediates transcription of the DNA sequence corresponding to the second sequence. Generally, operably linked means that the
30 nucleic acid sequences being linked are contiguous and where necessary to join two protein coding regions in the same reading frame. The construct may additionally contain at least one additional gene to be cotransformed into the organism. Alternatively, the additional gene(s) can be provided on multiple DNA constructs.

In some embodiments the DNA construct comprises a polynucleotide encoding a
35 PIP-72 polypeptide of the embodiments operably linked to a heterologous regulatory sequence.

Such a DNA construct is provided with a plurality of restriction sites for insertion of the PIP-72 polypeptide gene sequence to be under the transcriptional regulation of the regulatory regions. The DNA construct may additionally contain selectable marker genes.

The DNA construct will generally include in the 5' to 3' direction of transcription: a transcriptional and translational initiation region (i.e., a promoter), a DNA sequence of the
 5 embodiments, and a transcriptional and translational termination region (i.e., termination region) functional in the organism serving as a host. The transcriptional initiation region (i.e., the promoter) may be native, analogous, foreign or heterologous to the host organism and/or to the sequence of the embodiments. Additionally, the promoter may be
 10 the natural sequence or alternatively a synthetic sequence. The term "foreign" as used herein indicates that the promoter is not found in the native organism into which the promoter is introduced. Where the promoter is "foreign" or "heterologous" to the sequence of the embodiments, it is intended that the promoter is not the native or naturally occurring promoter for the operably linked sequence of the embodiments. As
 15 used herein, a chimeric gene comprises a coding sequence operably linked to a transcription initiation region that is heterologous to the coding sequence. Where the promoter is a native or natural sequence, the expression of the operably linked sequence is altered from the wild-type expression, which results in an alteration in phenotype.

In some embodiments the DNA construct may also include a transcriptional
 20 enhancer sequence. As used herein, the term an "enhancer" refers to a DNA sequence which can stimulate promoter activity, and may be an innate element of the promoter or a heterologous element inserted to enhance the level or tissue-specificity of a promoter. Various enhancers are known in the art including for example, introns with gene expression enhancing properties in plants (US Patent Application Publication Number
 25 2009/0144863, the ubiquitin intron (i.e., the maize ubiquitin intron 1 (see, for example, NCBI sequence S94464; Christensen and Quail (1996) *Transgenic Res.* 5:213-218; Christensen et al. (1992) *Plant Molecular Biology* 18:675-689)), the omega enhancer or the omega prime enhancer (Gallie, *et al.*, (1989) *Molecular Biology of RNA* ed. Cech (Liss, New York) 237-256 and Gallie, *et al.*, (1987) *Gene* 60:217-25), the CaMV 35S
 30 enhancer (see, e.g., Benfey, *et al.*, (1990) *EMBO J.* 9:1685-96), the maize Adhl intron (Kyojuka et al. (1991) *Mol. Gen. Genet.* 228:40-48; Kyojuka et al. (1990) *Maydica* 35:353-357), the enhancers of US Patent Number 7,803,992, and the sugarcane bacilliform viral (SCBV) enhancer of WO2013130813 may also be used, each of which is incorporated by reference. The above list of transcriptional enhancers is not meant to be
 35 limiting. Any appropriate transcriptional enhancer can be used in the embodiments.

The termination region may be native with the transcriptional initiation region, may be native with the operably linked DNA sequence of interest, may be native with the plant host or may be derived from another source (i.e., foreign or heterologous to the promoter, the sequence of interest, the plant host or any combination thereof).

5 Convenient termination regions are available from the Ti-plasmid of *A. tumefaciens*, such as the octopine synthase and nopaline synthase termination regions. See also, Guerineau, *et al.*, (1991) *Mol. Gen. Genet.* 262:141-144; Proudfoot, (1991) *Cell* 64:671-674; Sanfacon, *et al.*, (1991) *Genes Dev.* 5:141-149; Mogen, *et al.*, (1990) *Plant Cell* 2:1261-1272; Munroe, *et al.*, (1990) *Gene* 91:151-158; Ballas, *et al.*, (1989) *Nucleic*
10 *Acids Res.* 17:7891-7903 and Joshi, *et al.*, (1987) *Nucleic Acid Res.* 15:9627-9639.

Where appropriate, a nucleic acid may be optimized for increased expression in the host organism. Thus, where the host organism is a plant, the synthetic nucleic acids can be synthesized using plant-preferred codons for improved expression. See, for example, Campbell and Gowri, (1990) *Plant Physiol.* 92:1-11 for a discussion of host-
15 preferred codon usage. For example, although nucleic acid sequences of the embodiments may be expressed in both monocotyledonous and dicotyledonous plant species, sequences can be modified to account for the specific codon preferences and GC content preferences of monocotyledons or dicotyledons as these preferences have been shown to differ (Murray *et al.* (1989) *Nucleic Acids Res.* 17:477-498). Thus, the
20 maize-preferred codon for a particular amino acid may be derived from known gene sequences from maize. Maize codon usage for 28 genes from maize plants is listed in Table 4 of Murray, *et al.*, *supra*. Methods are available in the art for synthesizing plant-preferred genes. See, for example, US Patent Numbers 5,380,831, and 5,436,391 and Murray, *et al.*, (1989) *Nucleic Acids Res.* 17:477-498, and Liu H et al. *Mol Bio Rep*
25 37:677-684, 2010, herein incorporated by reference. A *Zea mays* codon usage table can be also found at kazusa.or.jp/codon/cgi-bin/showcodon.cgi?species=4577, which can be accessed using the www prefix. Table 2 shows a maize optimal codon analysis (adapted from Liu H et al. *Mol Bio Rep* 37:677-684, 2010).

30

Table 2

Amino Acid	Codon	High Count	RSCU	Low Count	RSCU	Amino Acid	Codon	High Count	RSCU	Low Count	RSCU
Phe	UUU	115	0.04	2,301	1.22	Ala	GCU	629	0.17	3,063	1.59
	UUC*	5,269	1.96	1,485	0.78		GCC*	8,057	2.16	1,136	0.59
Ser	UCU	176	0.13	2,498	1.48		GCA	369	0.1	2,872	1.49
	UCC*	3,489	2.48	1,074	0.63		GCG*	5,835	1.57	630	0.33
	UCA	104	0.07	2,610	1.54	Tyr	UAU	71	0.04	1,632	1.22
	UCG*	1,975	1.4	670	0.4		UAC*	3,841	1.96	1,041	0.78
	AGU	77	0.05	1,788	1.06	His	CAU	131	0.09	1,902	1.36

	AGC*	2,617	1.86	1,514	0.89		CAC*	2,800	1.91	897	0.64
Leu	UUA	10	0.01	1,326	0.79	Cys	UGU	52	0.04	1,233	1.12
	UUG	174	0.09	2,306	1.37		UGC*	2,291	1.96	963	0.88
	CUU	223	0.11	2,396	1.43	Gln	CAA	99	0.05	2,312	1.04
	CUC*	5,979	3.08	1,109	0.66		CAG*	3,557	1.95	2,130	0.96
	CUA	106	0.05	1,280	0.76	Arg	CGU	153	0.12	751	0.74
	CUG*	5,161	2.66	1,646	0.98		CGC*	4,278	3.25	466	0.46
Pro	CCU	427	0.22	1,900	1.47		CGA	92	0.07	659	0.65
	CCC*	3,035	1.59	601	0.47		CGG*	1,793	1.36	631	0.62
	CCA	311	0.16	2,140	1.66		AGA	83	0.06	1,948	1.91
	CCG*	3,846	2.02	513	0.4		AGG*	1,493	1.14	1,652	1.62
Ile	AUU	138	0.09	2,388	1.3	Asn	AAU	131	0.07	3,074	1.26
	AUC*	4,380	2.85	1,353	0.74		AAC*	3,814	1.93	1,807	0.74
	AUA	88	0.06	1,756	0.96	Lys	AAA	130	0.05	3,215	0.98
Thr	ACU	136	0.09	1,990	1.43		AAG*	5,047	1.95	3,340	1.02
	ACC*	3,398	2.25	991	0.71	Asp	GAU	312	0.09	4,217	1.38
	ACA	133	0.09	2,075	1.5		GAC*	6,729	1.91	1,891	0.62
	ACG*	2,378	1.57	495	0.36	Gly	GGU	363	0.13	2,301	1.35
Val	GUU	182	0.07	2,595	1.51		GGC*	7,842	2.91	1,282	0.75
	GUC*	4,584	1.82	1,096	0.64		GGA	397	0.15	2,044	1.19
	GUA	74	0.03	1,325	0.77		GGG*	2,186	0.81	1,215	0.71
	GUG*	5,257	2.08	1,842	1.07	Glu	GAA	193	0.06	4,080	1.1
							GAG*	6,010	1.94	3,307	0.9

Codon usage was compared using Chi squared contingency test to identify optimal codons. Codons that occur significantly more often ($P \leq 0.01$) are indicated with an asterisk.

- 5 A *Glycine max* codon usage table is shown in Table 3 and can also be found at kazusa.or.jp/codon/cgi-bin/showcodon.cgi?species=3847&aa=1&style=N, which can be accessed using the www prefix.

Table 3

TTT	F	21.2	(10493)	TCT	S	18.4	(9107)
TTC	F	21.2	(10487)	TCC	S	12.9	(6409)
TTA	L	9.2	(4545)	TCA	S	15.6	(7712)
TTG	L	22.9	(11340)	TCG	S	4.8	(2397)
CTT	L	23.9	(11829)	CCT	P	18.9	(9358)
CTC	L	17.1	(8479)	CCC	P	10.1	(5010)
CTA	L	8.5	(4216)	CCA	P	19.1	(9461)
CTG	L	12.7	(6304)	CCG	P	4.7	(2312)
ATT	I	25.1	(12411)	ACT	T	17.1	(8490)
ATC	I	16.3	(8071)	ACC	T	14.3	(7100)
ATA	I	12.9	(6386)	ACA	T	14.9	(7391)
ATG	M	22.7	(11218)	ACG	T	4.3	(2147)
GTT	V	26.1	(12911)	GCT	A	26.7	(13201)
GTC	V	11.9	(5894)	GCC	A	16.2	(8026)
GTA	V	7.7	(3803)	GCA	A	21.4	(10577)
GTG	V	21.4	(10610)	GCG	A	6.3	(3123)
TAT	Y	15.7	(7779)	TGT	C	8.1	(3995)

TAC	Y	14.9	(7367)	TGC	C	8.0	(3980)
TAA	*	0.9	(463)	TGA	*	1.0	(480)
TAG	*	0.5	(263)	TGG	W	13.0	(6412)
CAT	H	14.0	(6930)	CGT	R	6.6	(3291)
CAC	H	11.6	(5759)	CGC	R	6.2	(3093)
CAA	Q	20.5	(10162)	CGA	R	4.1	(2018)
CAG	Q	16.2	(8038)	CGG	R	3.1	(1510)
AAT	N	22.4	(11088)	AGT	S	12.6	(6237)
AAC	N	22.8	(11284)	AGC	S	11.3	(5594)
AAA	K	26.9	(13334)	AGA	R	14.8	(7337)
AAG	K	35.9	(17797)	AGG	R	13.3	(6574)
GAT	D	32.4	(16040)	GGT	G	20.9	(10353)
GAC	D	20.4	(10097)	GGC	G	13.4	(6650)
GAA	E	33.2	(16438)	GGA	G	22.3	(11022)
GAG	E	33.2	(16426)	GGG	G	13.0	(6431)

In some embodiments the recombinant nucleic acid molecule encoding a PIP-72 polypeptide has maize optimized codons.

Additional sequence modifications are known to enhance gene expression in a cellular host. These include elimination of sequences encoding spurious polyadenylation signals, exon-intron splice site signals, transposon-like repeats, and other well-characterized sequences that may be deleterious to gene expression. The GC content of the sequence may be adjusted to levels average for a given cellular host, as calculated by reference to known genes expressed in the host cell. The term "host cell" as used herein refers to a cell which contains a vector and supports the replication and/or expression of the expression vector is intended. Host cells may be prokaryotic cells such as *E. coli* or eukaryotic cells such as yeast, insect, amphibian or mammalian cells or monocotyledonous or dicotyledonous plant cells. An example of a monocotyledonous host cell is a maize host cell. When possible, the sequence is modified to avoid predicted hairpin secondary mRNA structures.

The expression cassettes may additionally contain 5' leader sequences. Such leader sequences can act to enhance translation. Translation leaders are known in the art and include: picornavirus leaders, for example, EMCV leader (Encephalomyocarditis 5' noncoding region) (Elroy-Stein, *et al.*, (1989) *Proc. Natl. Acad. Sci. USA* 86:6126-6130); potyvirus leaders, for example, TEV leader (Tobacco Etch Virus) (Gallie, *et al.*, (1995) *Gene* 165(2):233-238), MDMV leader (Maize Dwarf Mosaic Virus), human immunoglobulin heavy-chain binding protein (BiP) (Macejak, *et al.*, (1991) *Nature* 353:90-94); untranslated leader from the coat protein mRNA of alfalfa mosaic virus (AMV RNA 4) (Jobling, *et al.*, (1987) *Nature* 325:622-625); tobacco mosaic virus leader (TMV) (Gallie, *et al.*, (1989) in *Molecular Biology of RNA*, ed. Cech (Liss, New York), pp. 237-256) and

maize chlorotic mottle virus leader (MCMV) (Lommel, *et al.*, (1991) *Virology* 81:382-385). See also, Della-Cioppa, *et al.*, (1987) *Plant Physiol.* 84:965-968. Such constructs may also contain a "signal sequence" or "leader sequence" to facilitate co-translational or post-translational transport of the peptide to certain intracellular structures such as the chloroplast (or other plastid), endoplasmic reticulum or Golgi apparatus.

"Signal sequence" as used herein refers to a sequence that is known or suspected to result in cotranslational or post-translational peptide transport across the cell membrane. In eukaryotes, this typically involves secretion into the Golgi apparatus, with some resulting glycosylation. Insecticidal toxins of bacteria are often synthesized as protoxins, which are proteolytically activated in the gut of the target pest (Chang, (1987) *Methods Enzymol.* 153:507-516). In some embodiments, the signal sequence is located in the native sequence or may be derived from a sequence of the embodiments. "Leader sequence" as used herein refers to any sequence that when translated, results in an amino acid sequence sufficient to trigger co-translational transport of the peptide chain to a subcellular organelle. Thus, this includes leader sequences targeting transport and/or glycosylation by passage into the endoplasmic reticulum, passage to vacuoles, plastids including chloroplasts, mitochondria, and the like. Nuclear-encoded proteins targeted to the chloroplast thylakoid lumen compartment have a characteristic bipartite transit peptide, composed of a stromal targeting signal peptide and a lumen targeting signal peptide. The stromal targeting information is in the amino-proximal portion of the transit peptide. The lumen targeting signal peptide is in the carboxyl-proximal portion of the transit peptide, and contains all the information for targeting to the lumen. Recent research in proteomics of the higher plant chloroplast has achieved in the identification of numerous nuclear-encoded lumen proteins (Kieselbach *et al.* *FEBS LETT* 480:271-276, 2000; Peltier *et al.* *Plant Cell* 12:319-341, 2000; Bricker *et al.* *Biochim. Biophys Acta* 1503:350-356, 2001), the lumen targeting signal peptide of which can potentially be used in accordance with the present disclosure. About 80 proteins from *Arabidopsis*, as well as homologous proteins from spinach and garden pea, are reported by Kieselbach *et al.*, *Photosynthesis Research*, 78:249-264, 2003. In particular, Table 2 of this publication, which is incorporated into the description herewith by reference, discloses 85 proteins from the chloroplast lumen, identified by their accession number (see also US Patent Application Publication 2009/09044298). In addition, the recently published draft version of the rice genome (Goff *et al.*, *Science* 296:92-100, 2002) is a suitable source for lumen targeting signal peptide which may be used in accordance with the present disclosure.

Suitable chloroplast transit peptides (CTP) are well known to one skilled in the art also include chimeric CTPs comprising but not limited to, an N-terminal domain, a central

domain or a C-terminal domain from a CTP from *Oryza sativa* 1-deoxy-D xyulose-5-Phosphate Synthase *Oryza sativa*-Superoxide dismutase *Oryza sativa*-soluble starch synthase *Oryza sativa*-NADP-dependent Malic acid enzyme *Oryza sativa*-Phospho-2-dehydro-3-deoxyheptonate Aldolase 2 *Oryza sativa*-L-Ascorbate peroxidase 5 *Oryza*
 5 *sativa*-Phosphoglucan water dikinase, *Zea Mays* ssRUBISCO, *Zea Mays*-beta-glucosidase, *Zea Mays*-Malate dehydrogenase, *Zea Mays* Thioredoxin M-type (US Patent Application Publication 2012/0304336). Chloroplast transit peptides of US Patent Publications US20130205440A1, US20130205441A1 and US20130210114A1.

The PIP-72 polypeptide gene to be targeted to the chloroplast may be optimized
 10 for expression in the chloroplast to account for differences in codon usage between the plant nucleus and this organelle. In this manner, the nucleic acids of interest may be synthesized using chloroplast-preferred codons. See, for example, US Patent Number 5,380,831, herein incorporated by reference.

In preparing the expression cassette, the various DNA fragments may be
 15 manipulated so as to provide for the DNA sequences in the proper orientation and, as appropriate, in the proper reading frame. Toward this end, adapters or linkers may be employed to join the DNA fragments or other manipulations may be involved to provide for convenient restriction sites, removal of superfluous DNA, removal of restriction sites or the like. For this purpose, *in vitro* mutagenesis, primer repair, restriction, annealing,
 20 resubstitutions, e.g., transitions and transversions, may be involved.

A number of promoters can be used in the practice of the embodiments. The promoters can be selected based on the desired outcome. The nucleic acids can be combined with constitutive, tissue-preferred, inducible or other promoters for expression in the host organism. Promoters of the present invention include homologues of cis
 25 elements known to effect gene regulation that show homology with the promoter sequences of the present invention. These cis elements include, but are not limited to, oxygen responsive cis elements (Cowen et al., J Biol. Chem. 268(36):26904-26910 (1993)), light regulatory elements (Bruce and Quail, Plant Cell 2 (11):1081-1089 (1990); Bruce et al., EMBO J. 10:3015-3024 (1991); Rocholl et al., Plant Sci. 97:189-198 (1994); Block et al., Proc. Natl. Acad. Sci. USA 87:5387-5391 (1990); Giuliano et al., Proc. Natl.
 30 Acad. Sci. USA 85:7089-7093 (1988); Staiger et al., Proc. Natl. Acad. Sci. USA 86:6930-6934 (1989); Izawa et al., Plant Cell 6:1277-1287 (1994); Menkens et al., Trends in Biochemistry 20:506-510 (1995); Foster et al., FASEB J. 8:192-200 (1994); Plesse et al., Mol Gen Gene 254:258-266 (1997); Green et al., EMBO J. 6:2543-2549 (1987); Kuhlemeier et al., Ann. Rev Plant Physiol. 38:221-257 (1987); Villain et al., J. Biol. Chem.
 35 271:32593-32598 (1996); Lam et al., Plant Cell 2:857-866 (1990); Gilmartin et al., Plant

Cell 2:369-378 (1990); Datta et al., Plant Cell 1:1069-1077 (1989); Gilmartin et al., Plant Cell 2:369-378 (1990); Castresana et al., EMBO J. 7:1929-1936 (1988); Ueda et al., Plant Cell 1:217-227 (1989); Terzaghi et al., Annu. Rev. Plant Physiol. Plant Mol. Biol. 46:445-474 (1995); Green et al., EMBO J. 6:2543-2549 (1987); Villain et al., J. Biol. Chem. 271:32593-32598 (1996); Tjaden et al., Plant Cell 6:107-118 (1994); Tjaden et al., Plant Physiol. 108:1109-1117 (1995); Ngai et al., Plant J. 12:1021-1234 (1997); Bruce et al., EMBO J. 10:3015-3024 (1991); Ngai et al., Plant J. 12:1021-1034 (1997)), elements responsive to gibberellin, (Muller et al., J. Plant Physiol. 145:606-613 (1995); Croissant et al., Plant Science 116:27-35 (1996); Lohmer et al., EMBO J. 10:617-624 (1991); Rogers et al., Plant Cell 4:1443-1451 (1992); Lanahan et al., Plant Cell 4:203-211 (1992); Skriver et al., Proc. Natl. Acad. Sci. USA 88:7266-7270 (1991); Gilmartin et al., Plant Cell 2:369-378 (1990); Huang et al., Plant Mol. Biol. 14:655-668 (1990), Gubler et al., Plant Cell 7:1879-1891 (1995)), elements responsive to abscisic acid, (Busk et al., Plant Cell 9:2261-2270 (1997); Guiltinan et al., Science 250:267-270 (1990); Shen et al., Plant Cell 7:295-307 (1995); Shen et al., Plant Cell 8:1107-1119 (1996); Seo et al., Plant Mol. Biol. 27:1119-1131 (1995); Marcotte et al., Plant Cell 1:969-976 (1989); Shen et al., Plant Cell 7:295-307 (1995); Iwasaki et al., Mol Gen Genet 247:391-398 (1995); Hattori et al., Genes Dev. 6:609-618 (1992); Thomas et al., Plant Cell 5:1401-1410 (1993)), elements similar to abscisic acid responsive elements, (Ellerstrom et al., Plant Mol. Biol. 32:1019-1027 (1996)), auxin responsive elements (Liu et al., Plant Cell 6:645-657 (1994); Liu et al., Plant Physiol. 115:397-407 (1997); Kosugi et al., Plant J. 7:877-886 (1995); Kosugi et al., Plant Cell 9:1607-1619 (1997); Ballas et al., J. Mol. Biol. 233:580-596 (1993)), a cis element responsive to methyl jasmonate treatment (Beaudoin and Rothstein, Plant Mol. Biol. 33:835-846 (1997)), a cis element responsive to abscisic acid and stress response (Straub et al., Plant Mol. Biol. 26:617-630 (1994)), ethylene responsive cis elements (Itzhaki et al., Proc. Natl. Acad. Sci. USA 91:8925-8929 (1994); Montgomery et al., Proc. Natl. Acad. Sci. USA 90:5939-5943 (1993); Sessa et al., Plant Mol. Biol. 28:145-153 (1995); Shinshi et al., Plant Mol. Biol. 27:923-932 (1995)), salicylic acid cis responsive elements, (Strange et al., Plant J. 11:1315-1324 (1997); Qin et al., Plant Cell 6:863-874 (1994)), a cis element that responds to water stress and abscisic acid (Lam et al., J. Biol. Chem. 266:17131-17135 (1991); Thomas et al., Plant Cell 5:1401-1410 (1993); Pla et al., Plant Mol Biol 21:259-266 (1993)), a cis element essential for M phase-specific expression (Ito et al., Plant Cell 10:331-341 (1998)), sucrose responsive elements (Huang et al., Plant Mol. Biol. 14:655-668 (1990); Hwang et al., Plant Mol Biol 36:331-341 (1998); Grierson et al., Plant J. 5:815-826 (1994)), heat shock response elements (Pelham et al., Trends Genet. 1:31-35 (1985)), elements responsive to auxin and/or salicylic acid and

also reported for light regulation (Lam et al., Proc. Natl. Acad. Sci. USA 86:7890-7897 (1989); Benfey et al., Science 250:959-966 (1990)), elements responsive to ethylene and salicylic acid (Ohme-Takagi et al., Plant Mol. Biol. 15:941-946 (1990)), elements responsive to wounding and abiotic stress (Loake et al., Proc. Natl. Acad. Sci. USA 89:9230-9234 (1992); Mhiri et al., Plant Mol. Biol. 33:257-266 (1997)), antioxidant response elements (Rushmore et al., J. Biol. Chem. 266:11632-11639; Dalton et al., Nucleic Acids Res. 22:5016-5023 (1994)), Sph elements (Suzuki et al., Plant Cell 9:799-807 1997)), elicitor responsive elements, (Fukuda et al., Plant Mol. Biol. 34:81-87 (1997); Rushton et al., EMBO J. 15:5690-5700 (1996)), metal responsive elements (Stuart et al., Nature 317:828-831 (1985); Westin et al., EMBO J. 7:3763-3770 (1988); Thiele et al., Nucleic Acids Res. 20:1183-1191 (1992); Faisst et al., Nucleic Acids Res. 20:3-26 (1992)), low temperature responsive elements, (Baker et al., Plant Mol. Biol. 24:701-713 (1994); Jiang et al., Plant Mol. Biol. 30:679-684 (1996); Nordin et al., Plant Mol. Biol. 21:641-653 (1993); Zhou et al., J. Biol. Chem. 267:23515-23519 (1992)), drought responsive elements, (Yamaguchi et al., Plant Cell 6:251-264 (1994); Wang et al., Plant Mol. Biol. 28:605-617 (1995); Bray EA, Trends in Plant Science 2:48-54 (1997)) enhancer elements for glutenin, (Colot et al., EMBO J. 6:3559-3564 (1987); Thomas et al., Plant Cell 2:1171-1180 (1990); Kreis et al., Philos. Trans. R. Soc. Lond., B314:355-365 (1986)), light-independent regulatory elements, (Lagrange et al., Plant Cell 9:1469-1479 (1997); Villain et al., J. Biol. Chem. 271:32593-32598 (1996)), OCS enhancer elements, (Bouchez et al., EMBO J. 8:4197-4204 (1989); Foley et al., Plant J. 3:669-679 (1993)), ACGT elements, (Foster et al., FASEB J. 8:192-200 (1994); Izawa et al., Plant Cell 6:1277-1287 (1994); Izawa et al., J. Mol. Biol. 230:1131-1144 (1993)), negative cis elements in plastid related genes, (Zhou et al., J. Biol. Chem. 267:23515-23519 (1992); Lagrange et al., Mol. Cell Biol. 13:2614-2622 (1993); Lagrange et al., Plant Cell 9:1469-1479 (1997); Zhou et al., J. Biol. Chem. 267:23515-23519 (1992)), prolamin box elements, (Forde et al., Nucleic Acids Res. 13:7327-7339 (1985); Colot et al., EMBO J. 6:3559-3564 (1987); Thomas et al., Plant Cell 2:1171-1180 (1990); Thompson et al., Plant Mol. Biol. 15:755-764 (1990); Vicente et al., Proc. Natl. Acad. Sci. USA 94:7685-7690 (1997)), elements in enhancers from the IgM heavy chain gene (Gillies et al., Cell 33:717-728 (1983); Whittier et al., Nucleic Acids Res. 15:2515-2535 (1987)). Examples of promoters include: those described in U.S. Pat. No. 6,437,217 (maize RS81 promoter), U.S. Pat. No. 5,641,876 (rice actin promoter), U.S. Pat. No. 6,426,446 (maize RS324 promoter), U.S. Pat. No. 6,429,362 (maize PR-1 promoter), U.S. Pat. No. 6,232,526 (maize A3 promoter), U.S. Pat. No. 6,177,611 (constitutive maize promoters), U.S. Pat. Nos. 5,322,938, 5,352,605, 5,359,142 and 5,530,196 (35S promoter), U.S. Pat. No. 6,433,252 (maize L3 oleosin

promoter, P-Zm.L3), U.S. Pat. No. 6,429,357 (rice actin 2 promoter as well as a rice actin 2 intron), U.S. Pat. No. 5,837,848 (root specific promoter), U.S. Pat. No. 6,294,714 (light inducible promoters), U.S. Pat. No. 6,140,078 (salt inducible promoters), U.S. Pat. No. 6,252,138 (pathogen inducible promoters), U.S. Pat. No. 6,175,060 (phosphorus deficiency inducible promoters), U.S. Pat. No. 6,635,806 (gama-coixin promoter, P-Cl.Gcx), U.S. patent application Ser. No. 09/757,089 (maize chloroplast aldolase promoter), and US Patent Number 8,772,466 (maize transcription factor Nuclear Factor B (NFB2)).

Suitable constitutive promoters for use in a plant host cell include, for example, the core promoter of the Rsyn7 promoter and other constitutive promoters disclosed in WO 1999/43838 and US Patent Number 6,072,050; the core CaMV 35S promoter (Odell, *et al.*, (1985) *Nature* 313:810-812); rice actin (McElroy, *et al.*, (1990) *Plant Cell* 2:163-171); ubiquitin (Christensen, *et al.*, (1989) *Plant Mol. Biol.* 12:619-632 and Christensen, *et al.*, (1992) *Plant Mol. Biol.* 18:675-689); pEMU (Last, *et al.*, (1991) *Theor. Appl. Genet.* 81:581-588); MAS (Velten, *et al.*, (1984) *EMBO J.* 3:2723-2730); ALS promoter (US Patent Number 5,659,026) and the like. Other constitutive promoters include, for example, those discussed in US Patent Numbers 5,608,149; 5,608,144; 5,604,121; 5,569,597; 5,466,785; 5,399,680; 5,268,463; 5,608,142 and 6,177,611. Suitable constitutive promoters also include promoters that have strong expression in nearly all tissues but have low expression in pollen, including but not limited to: Banana Streak Virus (Acuminata Yunnan) promoters (BSV(AY)) disclosed in US patent US8,338,662; Banana Streak Virus (Acuminata Vietnam) promoters (BSV(AV)) disclosed in US patent US8,350,121; and Banana Streak Virus (Mysore) promoters (BSV(MYS)) disclosed in US patent US8,395,022.

Depending on the desired outcome, it may be beneficial to express the gene from an inducible promoter. Of particular interest for regulating the expression of the nucleotide sequences of the embodiments in plants are wound-inducible promoters. Such wound-inducible promoters, may respond to damage caused by insect feeding, and include potato proteinase inhibitor (pin II) gene (Ryan, (1990) *Ann. Rev. Phytopath.* 28:425-449; Duan, *et al.*, (1996) *Nature Biotechnology* 14:494-498); wun1 and wun2, US Patent Number 5,428,148; win1 and win2 (Stanford, *et al.*, (1989) *Mol. Gen. Genet.* 215:200-208); systemin (McGurl, *et al.*, (1992) *Science* 225:1570-1573); WIP1 (Rohmeier, *et al.*, (1993) *Plant Mol. Biol.* 22:783-792; Eckelkamp, *et al.*, (1993) *FEBS Letters* 323:73-76); MPI gene (Corderok, *et al.*, (1994) *Plant J.* 6(2):141-150) and the like, herein incorporated by reference.

Additionally, pathogen-inducible promoters may be employed in the methods and nucleotide constructs of the embodiments. Such pathogen-inducible promoters include those from pathogenesis-related proteins (PR proteins), which are induced following infection by a pathogen; e.g., PR proteins, SAR proteins, beta-1,3-glucanase, chitinase, etc. See, for example, Redolfi, *et al.*, (1983) *Neth. J. Plant Pathol.* 89:245-254; Uknes, *et al.*, (1992) *Plant Cell* 4: 645-656 and Van Loon, (1985) *Plant Mol. Virol.* 4:111-116. See also, WO 1999/43819, herein incorporated by reference.

Of interest are promoters that are expressed locally at or near the site of pathogen infection. See, for example, Marineau, *et al.*, (1987) *Plant Mol. Biol.* 9:335-342; Matton, *et al.*, (1989) *Molecular Plant-Microbe Interactions* 2:325-331; Somsisch, *et al.*, (1986) *Proc. Natl. Acad. Sci. USA* 83:2427-2430; Somsisch, *et al.*, (1988) *Mol. Gen. Genet.* 2:93-98 and Yang, (1996) *Proc. Natl. Acad. Sci. USA* 93:14972-14977. See also, Chen, *et al.*, (1996) *Plant J.* 10:955-966; Zhang, *et al.*, (1994) *Proc. Natl. Acad. Sci. USA* 91:2507-2511; Warner, *et al.*, (1993) *Plant J.* 3:191-201; Siebertz, *et al.*, (1989) *Plant Cell* 1:961-968; US Patent Number 5,750,386 (nematode-inducible) and the references cited therein. Of particular interest is the inducible promoter for the maize PRms gene, whose expression is induced by the pathogen *Fusarium moniliforme* (see, for example, Cordero, *et al.*, (1992) *Physiol. Mol. Plant Path.* 41:189-200).

Chemical-regulated promoters can be used to modulate the expression of a gene in a plant through the application of an exogenous chemical regulator. Depending upon the objective, the promoter may be a chemical-inducible promoter, where application of the chemical induces gene expression or a chemical-repressible promoter, where application of the chemical represses gene expression. Chemical-inducible promoters are known in the art and include, but are not limited to, the maize In2-2 promoter, which is activated by benzenesulfonamide herbicide safeners, the maize GST promoter, which is activated by hydrophobic electrophilic compounds that are used as pre-emergent herbicides, and the tobacco PR-1a promoter, which is activated by salicylic acid. Other chemical-regulated promoters of interest include steroid-responsive promoters (see, for example, the glucocorticoid-inducible promoter in Schena, *et al.*, (1991) *Proc. Natl. Acad. Sci. USA* 88:10421-10425 and McNellis, *et al.*, (1998) *Plant J.* 14(2):247-257) and tetracycline-inducible and tetracycline-repressible promoters (see, for example, Gatz, *et al.*, (1991) *Mol. Gen. Genet.* 227:229-237 and US Patent Numbers 5,814,618 and 5,789,156), herein incorporated by reference.

Tissue-preferred promoters can be utilized to target enhanced PIP-72 polypeptide expression within a particular plant tissue. Tissue-preferred promoters include those discussed in Yamamoto, *et al.*, (1997) *Plant J.* 12(2)255-265; Kawamata, *et al.*, (1997)

Plant Cell Physiol. 38(7):792-803; Hansen, *et al.*, (1997) *Mol. Gen Genet.* 254(3):337-343; Russell, *et al.*, (1997) *Transgenic Res.* 6(2):157-168; Rinehart, *et al.*, (1996) *Plant Physiol.* 112(3):1331-1341; Van Camp, *et al.*, (1996) *Plant Physiol.* 112(2):525-535; Canevascini, *et al.*, (1996) *Plant Physiol.* 112(2):513-524; Yamamoto, *et al.*, (1994) *Plant Cell Physiol.* 35(5):773-778; Lam, (1994) *Results Probl. Cell Differ.* 20:181-196; Orozco, *et al.*, (1993) *Plant Mol Biol.* 23(6):1129-1138; Matsuoka, *et al.*, (1993) *Proc Natl. Acad. Sci. USA* 90(20):9586-9590 and Guevara-Garcia, *et al.*, (1993) *Plant J.* 4(3):495-505. Such promoters can be modified, if necessary, for weak expression.

Leaf-preferred promoters are known in the art. See, for example, Yamamoto, *et al.*, (1997) *Plant J.* 12(2):255-265; Kwon, *et al.*, (1994) *Plant Physiol.* 105:357-67; Yamamoto, *et al.*, (1994) *Plant Cell Physiol.* 35(5):773-778; Gotor, *et al.*, (1993) *Plant J.* 3:509-18; Orozco, *et al.*, (1993) *Plant Mol. Biol.* 23(6):1129-1138 and Matsuoka, *et al.*, (1993) *Proc. Natl. Acad. Sci. USA* 90(20):9586-9590.

Root-preferred or root-specific promoters are known and can be selected from the many available from the literature or isolated *de novo* from various compatible species. See, for example, Hire, *et al.*, (1992) *Plant Mol. Biol.* 20(2):207-218 (soybean root-specific glutamine synthetase gene); Keller and Baumgartner, (1991) *Plant Cell* 3(10):1051-1061 (root-specific control element in the GRP 1.8 gene of French bean); Sanger, *et al.*, (1990) *Plant Mol. Biol.* 14(3):433-443 (root-specific promoter of the mannopine synthase (MAS) gene of *Agrobacterium tumefaciens*) and Miao, *et al.*, (1991) *Plant Cell* 3(1):11-22 (full-length cDNA clone encoding cytosolic glutamine synthetase (GS), which is expressed in roots and root nodules of soybean). See also, Bogusz, *et al.*, (1990) *Plant Cell* 2(7):633-641, where two root-specific promoters isolated from hemoglobin genes from the nitrogen-fixing nonlegume *Parasponia andersonii* and the related non-nitrogen-fixing nonlegume *Trema tomentosa* are described. The promoters of these genes were linked to a β -glucuronidase reporter gene and introduced into both the nonlegume *Nicotiana tabacum* and the legume *Lotus corniculatus*, and in both instances root-specific promoter activity was preserved. Leach and Aoyagi, (1991) describe their analysis of the promoters of the highly expressed rolC and rolD root-inducing genes of *Agrobacterium rhizogenes* (see, *Plant Science* (Limerick) 79(1):69-76). They concluded that enhancer and tissue-preferred DNA determinants are dissociated in those promoters. Teeri, *et al.*, (1989) used gene fusion to lacZ to show that the *Agrobacterium* T-DNA gene encoding octopine synthase is especially active in the epidermis of the root tip and that the TR2' gene is root specific in the intact plant and stimulated by wounding in leaf tissue, an especially desirable combination of characteristics for use with an insecticidal or larvicidal gene (see, *EMBO J.* 8(2):343-350). The TR1' gene fused to *nptII* (neomycin phosphotransferase II)

showed similar characteristics. Additional root-preferred promoters include the VfENOD-GRP3 gene promoter (Kuster, *et al.*, (1995) *Plant Mol. Biol.* 29(4):759-772) and rolB promoter (Capana, *et al.*, (1994) *Plant Mol. Biol.* 25(4):681-691. See also, US Patent Numbers 5,837,876; 5,750,386; 5,633,363; 5,459,252; 5,401,836; 5,110,732 and 5,023,179. *Arabidopsis thaliana* root-preferred regulatory sequences are disclosed in US Patent Application US20130117883. Root-preferred sorghum (*Sorghum bicolor*) RCc3 promoters are disclosed in US Patent Application US20120210463. The root-preferred maize promoters of US Patent Application Publication 20030131377, US Patent Number 7,645,919, and 8,735,655. The root cap-specific 1 (ZmRCP1) maize promoters of US Patent Application Publication 20130025000. The root-preferred maize promoters of US Patent Application Publication 20130312136.

"Seed-preferred" promoters include both "seed-specific" promoters (those promoters active during seed development such as promoters of seed storage proteins) as well as "seed-germinating" promoters (those promoters active during seed germination). See, Thompson, *et al.*, (1989) *BioEssays* 10:108, herein incorporated by reference. Such seed-preferred promoters include, but are not limited to, Cim1 (cytokinin-induced message); cZ19B1 (maize 19 kDa zein); and milps (myo-inositol-1-phosphate synthase) (see, US Patent Number 6,225,529, herein incorporated by reference). Gamma-zein and Glb-1 are endosperm-specific promoters. For dicots, seed-specific promoters include, but are not limited to, Kunitz trypsin inhibitor 3 (KTI3) (Jofuku and Goldberg, (1989) *Plant Cell* 1:1079-1093), bean β -phaseolin, napin, β -conglycinin, glycinin 1, soybean lectin, cruciferin, and the like. For monocots, seed-specific promoters include, but are not limited to, maize 15 kDa zein, 22 kDa zein, 27 kDa zein, g-zein, waxy, shrunken 1, shrunken 2, globulin 1, etc. See also, WO 2000/12733, where seed-preferred promoters from *end1* and *end2* genes are disclosed; herein incorporated by reference. In dicots, seed specific promoters include but are not limited to seed coat promoter from *Arabidopsis*, pBAN; and the early seed promoters from *Arabidopsis*, p26, p63, and p63tr (US Patent Numbers 7,294,760 and 7,847,153). A promoter that has "preferred" expression in a particular tissue is expressed in that tissue to a greater degree than in at least one other plant tissue. Some tissue-preferred promoters show expression almost exclusively in the particular tissue.

Where low level expression is desired, weak promoters will be used. Generally, the term "weak promoter" as used herein refers to a promoter that drives expression of a coding sequence at a low level. By low level expression at levels of about 1/1000 transcripts to about 1/100,000 transcripts to about 1/500,000 transcripts is intended. Alternatively, it is recognized that the term "weak promoters" also encompasses

promoters that drive expression in only a few cells and not in others to give a total low level of expression. Where a promoter drives expression at unacceptably high levels, portions of the promoter sequence can be deleted or modified to decrease expression levels.

5 Such weak constitutive promoters include, for example the core promoter of the Rsyn7 promoter (WO 1999/43838 and US Patent Number 6,072,050), the core 35S CaMV promoter, and the like. Other constitutive promoters include, for example, those disclosed in US Patent Numbers 5,608,149; 5,608,144; 5,604,121; 5,569,597; 5,466,785; 5,399,680; 5,268,463; 5,608,142 and 6,177,611, herein incorporated by reference.

10 The above list of promoters is not meant to be limiting. Any appropriate promoter can be used in the embodiments.

 Generally, the expression cassette will comprise a selectable marker gene for the selection of transformed cells. Selectable marker genes are utilized for the selection of transformed cells or tissues. Marker genes include genes encoding antibiotic resistance, such as those encoding neomycin phosphotransferase II (NEO) and hygromycin phosphotransferase (HPT), as well as genes conferring resistance to herbicidal compounds, such as glufosinate ammonium, bromoxynil, imidazolinones and 2,4-dichlorophenoxyacetate (2,4-D). Additional examples of suitable selectable marker genes include, but are not limited to, genes encoding resistance to chloramphenicol (Herrera Estrella, *et al.*, (1983) *EMBO J.* 2:987-992); methotrexate (Herrera Estrella, *et al.*, (1983) *Nature* 303:209-213 and Meijer, *et al.*, (1991) *Plant Mol. Biol.* 16:807-820); streptomycin (Jones, *et al.*, (1987) *Mol. Gen. Genet.* 210:86-91); spectinomycin (Bretagne-Sagnard, *et al.*, (1996) *Transgenic Res.* 5:131-137); bleomycin (Hille, *et al.*, (1990) *Plant Mol. Biol.* 7:171-176); sulfonamide (Guerineau, *et al.*, (1990) *Plant Mol. Biol.* 15:127-136); bromoxynil (Stalker, *et al.*, (1988) *Science* 242:419-423); glyphosate (Shaw, *et al.*, (1986) *Science* 233:478-481 and US Patent Application Serial Numbers 10/004,357 and 10/427,692); phosphinothricin (DeBlock, *et al.*, (1987) *EMBO J.* 6:2513-2518). See generally, Yarranton, (1992) *Curr. Opin. Biotech.* 3:506-511; Christopherson, *et al.*, (1992) *Proc. Natl. Acad. Sci. USA* 89:6314-6318; Yao, *et al.*, (1992) *Cell* 71:63-72; Reznikoff, (1992) *Mol. Microbiol.* 6:2419-2422; Barkley, *et al.*, (1980) in *The Operon*, pp. 177-220; Hu, *et al.*, (1987) *Cell* 48:555-566; Brown, *et al.*, (1987) *Cell* 49:603-612; Figge, *et al.*, (1988) *Cell* 52:713-722; Deuschle, *et al.*, (1989) *Proc. Natl. Acad. Sci. USA* 86:5400-5404; Fuerst, *et al.*, (1989) *Proc. Natl. Acad. Sci. USA* 86:2549-2553; Deuschle, *et al.*, (1990) *Science* 248:480-483; Gossen, (1993) Ph.D. Thesis, University of Heidelberg; Reines, *et al.*, (1993) *Proc. Natl. Acad. Sci. USA* 90:1917-1921; Labow, *et al.*, (1990) *Mol. Cell. Biol.* 10:3343-3356; Zambretti, *et al.*, (1992) *Proc. Natl. Acad. Sci. USA* 89:3952-3956; Baim, *et al.*, (1991) *Proc. Natl. Acad. Sci. USA* 88:5072-5076;

Wyborski, *et al.*, (1991) *Nucleic Acids Res.* 19:4647-4653; Hillenand-Wissman, (1989) *Topics Mol. Struc. Biol.* 10:143-162; Degenkolb, *et al.*, (1991) *Antimicrob. Agents Chemother.* 35:1591-1595; Kleinschmidt, *et al.*, (1988) *Biochemistry* 27:1094-1104; Bonin, (1993) Ph.D. Thesis, University of Heidelberg; Gossen, *et al.*, (1992) *Proc. Natl. Acad. Sci. USA* 89:5547-5551; Oliva, *et al.*, (1992) *Antimicrob. Agents Chemother.* 36:913-919; Hlavka, *et al.*, (1985) *Handbook of Experimental Pharmacology*, Vol. 78 (Springer-Verlag, Berlin) and Gill, *et al.*, (1988) *Nature* 334:721-724. Such disclosures are herein incorporated by reference.

The above list of selectable marker genes is not meant to be limiting. Any selectable marker gene can be used in the embodiments.

Plant Transformation

The methods of the embodiments involve introducing a polypeptide or polynucleotide into a plant. "Introducing" is as used herein means presenting to the plant the polynucleotide or polypeptide in such a manner that the sequence gains access to the interior of a cell of the plant. The methods of the embodiments do not depend on a particular method for introducing a polynucleotide or polypeptide into a plant, only that the polynucleotide or polypeptides gains access to the interior of at least one cell of the plant. Methods for introducing polynucleotide or polypeptides into plants are known in the art including, but not limited to, stable transformation methods, transient transformation methods, and virus-mediated methods.

"Stable transformation" is as used herein means that the nucleotide construct introduced into a plant integrates into the genome of the plant and is capable of being inherited by the progeny thereof. "Transient transformation" as used herein means that a polynucleotide is introduced into the plant and does not integrate into the genome of the plant or a polypeptide is introduced into a plant. "Plant" as used herein refers to whole plants, plant organs (e.g., leaves, stems, roots, etc.), seeds, plant cells, propagules, embryos and progeny of the same. Plant cells can be differentiated or undifferentiated (e.g. callus, suspension culture cells, protoplasts, leaf cells, root cells, phloem cells and pollen).

Transformation protocols as well as protocols for introducing nucleotide sequences into plants may vary depending on the type of plant or plant cell, i.e., monocot or dicot, targeted for transformation. Suitable methods of introducing nucleotide sequences into plant cells and subsequent insertion into the plant genome include microinjection (Crossway, *et al.*, (1986) *Biotechniques* 4:320-334), electroporation (Riggs, *et al.*, (1986) *Proc. Natl. Acad. Sci. USA* 83:5602-5606), *Agrobacterium*-mediated

transformation (US Patent Numbers 5,563,055 and 5,981,840), direct gene transfer (Paszkowski, *et al.*, (1984) *EMBO J.* 3:2717-2722) and ballistic particle acceleration (see, for example, US Patent Numbers 4,945,050; 5,879,918; 5,886,244 and 5,932,782; Tomes, *et al.*, (1995) in *Plant Cell, Tissue, and Organ Culture: Fundamental Methods*, ed. Gamborg and Phillips, (Springer-Verlag, Berlin) and McCabe, *et al.*, (1988) *Biotechnology* 6:923-926) and Lecl transformation (WO 00/28058). For potato transformation see, Tu, *et al.*, (1998) *Plant Molecular Biology* 37:829-838 and Chong, *et al.*, (2000) *Transgenic Research* 9:71-78. Additional transformation procedures can be found in Weissinger, *et al.*, (1988) *Ann. Rev. Genet.* 22:421-477; Sanford, *et al.*, (1987) *Particulate Science and Technology* 5:27-37 (onion); Christou, *et al.*, (1988) *Plant Physiol.* 87:671-674 (soybean); McCabe, *et al.*, (1988) *Bio/Technology* 6:923-926 (soybean); Finer and McMullen, (1991) *In Vitro Cell Dev. Biol.* 27P:175-182 (soybean); Singh, *et al.*, (1998) *Theor. Appl. Genet.* 96:319-324 (soybean); Datta, *et al.*, (1990) *Biotechnology* 8:736-740 (rice); Klein, *et al.*, (1988) *Proc. Natl. Acad. Sci. USA* 85:4305-4309 (maize); Klein, *et al.*, (1988) *Biotechnology* 6:559-563 (maize); US Patent Numbers 5,240,855; 5,322,783 and 5,324,646; Klein, *et al.*, (1988) *Plant Physiol.* 91:440-444 (maize); Fromm, *et al.*, (1990) *Biotechnology* 8:833-839 (maize); Hooykaas-Van Slogteren, *et al.*, (1984) *Nature (London)* 311:763-764; US Patent Number 5,736,369 (cereals); Bytebier, *et al.*, (1987) *Proc. Natl. Acad. Sci. USA* 84:5345-5349 (Liliaceae); De Wet, *et al.*, (1985) in *The Experimental Manipulation of Ovule Tissues*, ed. Chapman, *et al.*, (Longman, New York), pp. 197-209 (pollen); Kaeppler, *et al.*, (1990) *Plant Cell Reports* 9:415-418 and Kaeppler, *et al.*, (1992) *Theor. Appl. Genet.* 84:560-566 (whisker-mediated transformation); D'Halluin, *et al.*, (1992) *Plant Cell* 4:1495-1505 (electroporation); Li, *et al.*, (1993) *Plant Cell Reports* 12:250-255 and Christou and Ford, (1995) *Annals of Botany* 75:407-413 (rice); Osjoda, *et al.*, (1996) *Nature Biotechnology* 14:745-750 (maize via *Agrobacterium tumefaciens*); all of which are herein incorporated by reference.

In specific embodiments, the sequences of the embodiments can be provided to a plant using a variety of transient transformation methods. Such transient transformation methods include, but are not limited to, the introduction of the PIP-72 polypeptide or variants and fragments thereof directly into the plant or the introduction of the PIP-72 polypeptide transcript into the plant. Such methods include, for example, microinjection or particle bombardment. See, for example, Crossway, *et al.*, (1986) *Mol Gen. Genet.* 202:179-185; Nomura, *et al.*, (1986) *Plant Sci.* 44:53-58; Hepler, *et al.*, (1994) *Proc. Natl. Acad. Sci.* 91:2176-2180 and Hush, *et al.*, (1994) *The Journal of Cell Science* 107:775-784, all of which are herein incorporated by reference. Alternatively, the PIP-72 polypeptide polynucleotide can be transiently transformed into the plant using techniques

known in the art. Such techniques include viral vector system and the precipitation of the polynucleotide in a manner that precludes subsequent release of the DNA. Thus, transcription from the particle-bound DNA can occur, but the frequency with which it is released to become integrated into the genome is greatly reduced. Such methods include
5 the use of particles coated with polyethylimine (PEI; Sigma #P3143).

Methods are known in the art for the targeted insertion of a polynucleotide at a specific location in the plant genome. In one embodiment, the insertion of the polynucleotide at a desired genomic location is achieved using a site-specific recombination system. See, for example, WO 1999/25821, WO 1999/25854, WO
10 1999/25840, WO 1999/25855 and WO 1999/25853, all of which are herein incorporated by reference. Briefly, the polynucleotide of the embodiments can be contained in transfer cassette flanked by two non-identical recombination sites. The transfer cassette is introduced into a plant have stably incorporated into its genome a target site which is flanked by two non-identical recombination sites that correspond to the sites of the
15 transfer cassette. An appropriate recombinase is provided and the transfer cassette is integrated at the target site. The polynucleotide of interest is thereby integrated at a specific chromosomal position in the plant genome.

Plant transformation vectors may be comprised of one or more DNA vectors needed for achieving plant transformation. For example, it is a common practice in the art
20 to utilize plant transformation vectors that are comprised of more than one contiguous DNA segment. These vectors are often referred to in the art as “binary vectors”. Binary vectors as well as vectors with helper plasmids are most often used for Agrobacterium-mediated transformation, where the size and complexity of DNA segments needed to achieve efficient transformation is quite large, and it is advantageous to separate
25 functions onto separate DNA molecules. Binary vectors typically contain a plasmid vector that contains the cis-acting sequences required for T-DNA transfer (such as left border and right border), a selectable marker that is engineered to be capable of expression in a plant cell, and a “gene of interest” (a gene engineered to be capable of expression in a plant cell for which generation of transgenic plants is desired). Also present on this
30 plasmid vector are sequences required for bacterial replication. The cis-acting sequences are arranged in a fashion to allow efficient transfer into plant cells and expression therein. For example, the selectable marker gene and the pesticidal gene are located between the left and right borders. Often a second plasmid vector contains the trans-acting factors that mediate T-DNA transfer from Agrobacterium to plant cells. This plasmid often
35 contains the virulence functions (Vir genes) that allow infection of plant cells by Agrobacterium, and transfer of DNA by cleavage at border sequences and vir-mediated

DNA transfer, as is understood in the art (Hellens and Mullineaux, (2000) *Trends in Plant Science* 5:446-451). Several types of *Agrobacterium* strains (e.g. LBA4404, GV3101, EHA101, EHA105, etc.) can be used for plant transformation. The second plasmid vector is not necessary for transforming the plants by other methods such as microprojection, microinjection, electroporation, polyethylene glycol, etc.

In general, plant transformation methods involve transferring heterologous DNA into target plant cells (e.g., immature or mature embryos, suspension cultures, undifferentiated callus, protoplasts, etc.), followed by applying a maximum threshold level of appropriate selection (depending on the selectable marker gene) to recover the transformed plant cells from a group of untransformed cell mass. Following integration of heterologous foreign DNA into plant cells, one then applies a maximum threshold level of appropriate selection in the medium to kill the untransformed cells and separate and proliferate the putatively transformed cells that survive from this selection treatment by transferring regularly to a fresh medium. By continuous passage and challenge with appropriate selection, one identifies and proliferates the cells that are transformed with the plasmid vector. Molecular and biochemical methods can then be used to confirm the presence of the integrated heterologous gene of interest into the genome of the transgenic plant.

Explants are typically transferred to a fresh supply of the same medium and cultured routinely. Subsequently, the transformed cells are differentiated into shoots after placing on regeneration medium supplemented with a maximum threshold level of selecting agent. The shoots are then transferred to a selective rooting medium for recovering rooted shoot or plantlet. The transgenic plantlet then grows into a mature plant and produces fertile seeds (e.g., Hiei, *et al.*, (1994) *The Plant Journal* 6:271-282; Ishida, *et al.*, (1996) *Nature Biotechnology* 14:745-750). Explants are typically transferred to a fresh supply of the same medium and cultured routinely. A general description of the techniques and methods for generating transgenic plants are found in Ayres and Park, (1994) *Critical Reviews in Plant Science* 13:219-239 and Bommineni and Jauhar, (1997) *Maydica* 42:107-120. Since the transformed material contains many cells; both transformed and non-transformed cells are present in any piece of subjected target callus or tissue or group of cells. The ability to kill non-transformed cells and allow transformed cells to proliferate results in transformed plant cultures. Often, the ability to remove non-transformed cells is a limitation to rapid recovery of transformed plant cells and successful generation of transgenic plants.

The cells that have been transformed may be grown into plants in accordance with conventional ways. See, for example, McCormick, *et al.*, (1986) *Plant Cell Reports* 5:81-

84. These plants may then be grown, and either pollinated with the same transformed strain or different strains, and the resulting hybrid having constitutive or inducible expression of the desired phenotypic characteristic identified. Two or more generations may be grown to ensure that expression of the desired phenotypic characteristic is stably maintained and inherited and then seeds harvested to ensure that expression of the desired phenotypic characteristic has been achieved.

The nucleotide sequences of the embodiments may be provided to the plant by contacting the plant with a virus or viral nucleic acids. Generally, such methods involve incorporating the nucleotide construct of interest within a viral DNA or RNA molecule. It is recognized that the recombinant proteins of the embodiments may be initially synthesized as part of a viral polyprotein, which later may be processed by proteolysis *in vivo* or *in vitro* to produce the desired PIP-72 polypeptide. It is also recognized that such a viral polyprotein, comprising at least a portion of the amino acid sequence of a PIP-72 polypeptide of the embodiments, may have the desired pesticidal activity. Such viral polyproteins and the nucleotide sequences that encode for them are encompassed by the embodiments. Methods for providing plants with nucleotide constructs and producing the encoded proteins in the plants, which involve viral DNA or RNA molecules are known in the art. See, for example, US Patent Numbers 5,889,191; 5,889,190; 5,866,785; 5,589,367 and 5,316,931; herein incorporated by reference.

Methods for transformation of chloroplasts are known in the art. See, for example, Svab, *et al.*, (1990) *Proc. Natl. Acad. Sci. USA* 87:8526-8530; Svab and Maliga, (1993) *Proc. Natl. Acad. Sci. USA* 90:913-917; Svab and Maliga, (1993) *EMBO J.* 12:601-606. The method relies on particle gun delivery of DNA containing a selectable marker and targeting of the DNA to the plastid genome through homologous recombination. Additionally, plastid transformation can be accomplished by transactivation of a silent plastid-borne transgene by tissue-preferred expression of a nuclear-encoded and plastid-directed RNA polymerase. Such a system has been reported in McBride, *et al.*, (1994) *Proc. Natl. Acad. Sci. USA* 91:7301-7305.

The embodiments further relate to plant-propagating material of a transformed plant of the embodiments including, but not limited to, seeds, tubers, corms, bulbs, leaves and cuttings of roots and shoots.

The embodiments may be used for transformation of any plant species, including, but not limited to, monocots and dicots. Examples of plants of interest include, but are not limited to, corn (*Zea mays*), *Brassica* sp. (e.g., *B. napus*, *B. rapa*, *B. juncea*), particularly those *Brassica* species useful as sources of seed oil, alfalfa (*Medicago sativa*), rice (*Oryza sativa*), rye (*Secale cereale*), sorghum (*Sorghum bicolor*, *Sorghum vulgare*), millet (e.g.,

pearl millet (*Pennisetum glaucum*), proso millet (*Panicum miliaceum*), foxtail millet (*Setaria italica*), finger millet (*Eleusine coracana*), sunflower (*Helianthus annuus*), safflower (*Carthamus tinctorius*), wheat (*Triticum aestivum*), soybean (*Glycine max*), tobacco (*Nicotiana tabacum*), potato (*Solanum tuberosum*), peanuts (*Arachis hypogaea*), cotton
 5 (*Gossypium barbadense*, *Gossypium hirsutum*), sweet potato (*Ipomoea batatas*), cassava (*Manihot esculenta*), coffee (*Coffea* spp.), coconut (*Cocos nucifera*), pineapple (*Ananas comosus*), citrus trees (*Citrus* spp.), cocoa (*Theobroma cacao*), tea (*Camellia sinensis*), banana (*Musa* spp.), avocado (*Persea americana*), fig (*Ficus casica*), guava (*Psidium guajava*), mango (*Mangifera indica*), olive (*Olea europaea*), papaya (*Carica papaya*),
 10 cashew (*Anacardium occidentale*), macadamia (*Macadamia integrifolia*), almond (*Prunus amygdalus*), sugar beets (*Beta vulgaris*), sugarcane (*Saccharum* spp.), oats, barley, vegetables ornamentals, and conifers.

Vegetables include tomatoes (*Lycopersicon esculentum*), lettuce (e.g., *Lactuca sativa*), green beans (*Phaseolus vulgaris*), lima beans (*Phaseolus limensis*), peas (*Lathyrus*
 15 spp.), and members of the genus *Cucumis* such as cucumber (*C. sativus*), cantaloupe (*C. cantalupensis*), and musk melon (*C. melo*). Ornamentals include azalea (*Rhododendron* spp.), hydrangea (*Macrophylla hydrangea*), hibiscus (*Hibiscus rosasanensis*), roses (*Rosa* spp.), tulips (*Tulipa* spp.), daffodils (*Narcissus* spp.), petunias (*Petunia hybrida*), carnation (*Dianthus caryophyllus*), poinsettia (*Euphorbia pulcherrima*), and chrysanthemum. Conifers
 20 that may be employed in practicing the embodiments include, for example, pines such as loblolly pine (*Pinus taeda*), slash pine (*Pinus elliotii*), ponderosa pine (*Pinus ponderosa*), lodgepole pine (*Pinus contorta*), and Monterey pine (*Pinus radiata*); Douglas-fir (*Pseudotsuga menziesii*); Western hemlock (*Tsuga canadensis*); Sitka spruce (*Picea glauca*); redwood (*Sequoia sempervirens*); true firs such as silver fir (*Abies amabilis*) and
 25 balsam fir (*Abies balsamea*); and cedars such as Western red cedar (*Thuja plicata*) and Alaska yellow-cedar (*Chamaecyparis nootkatensis*). Plants of the embodiments include crop plants (for example, corn, alfalfa, sunflower, *Brassica*, soybean, cotton, safflower, peanut, sorghum, wheat, millet, tobacco, etc.), such as corn and soybean plants.

Turf grasses include, but are not limited to: annual bluegrass (*Poa annua*); annual
 30 ryegrass (*Lolium multiflorum*); Canada bluegrass (*Poa compressa*); Chewing's fescue (*Festuca rubra*); colonial bentgrass (*Agrostis tenuis*); creeping bentgrass (*Agrostis palustris*); crested wheatgrass (*Agropyron desertorum*); fairway wheatgrass (*Agropyron cristatum*); hard fescue (*Festuca longifolia*); Kentucky bluegrass (*Poa pratensis*); orchardgrass (*Dactylis glomerata*); perennial ryegrass (*Lolium perenne*); red fescue (*Festuca rubra*); redtop
 35 (*Agrostis alba*); rough bluegrass (*Poa trivialis*); sheep fescue (*Festuca ovina*); smooth brome grass (*Bromus inermis*); tall fescue (*Festuca arundinacea*); timothy (*Phleum pratense*);

velvet bentgrass (*Agrostis canina*); weeping alkaligrass (*Puccinellia distans*); western wheatgrass (*Agropyron smithii*); Bermuda grass (*Cynodon* spp.); St. Augustine grass (*Stenotaphrum secundatum*); zoysia grass (*Zoysia* spp.); Bahia grass (*Paspalum notatum*); carpet grass (*Axonopus affinis*); centipede grass (*Eremochloa ophiuroides*); kikuyu grass
 5 (*Pennisetum clandestinum*); seashore paspalum (*Paspalum vaginatum*); blue gramma (*Bouteloua gracilis*); buffalo grass (*Buchloe dactyloids*); sideoats gramma (*Bouteloua curtipendula*).

Plants of interest include grain plants that provide seeds of interest, oil-seed plants, and leguminous plants. Seeds of interest include grain seeds, such as corn,
 10 wheat, barley, rice, sorghum, rye, millet, etc. Oil-seed plants include cotton, soybean, safflower, sunflower, *Brassica*, maize, alfalfa, palm, coconut, flax, castor, olive, etc. Leguminous plants include beans and peas. Beans include guar, locust bean, fenugreek, soybean, garden beans, cowpea, mung bean, lima bean, fava bean, lentils, chickpea, etc.

15 Evaluation of Plant Transformation

Following introduction of heterologous foreign DNA into plant cells, the transformation or integration of heterologous gene in the plant genome is confirmed by various methods such as analysis of nucleic acids, proteins and metabolites associated with the integrated gene.

20 PCR analysis is a rapid method to screen transformed cells, tissue or shoots for the presence of incorporated gene at the earlier stage before transplanting into the soil (Sambrook and Russell, (2001) *Molecular Cloning: A Laboratory Manual*. Cold Spring Harbor Laboratory Press, Cold Spring Harbor, NY). PCR is carried out using oligonucleotide primers specific to the gene of interest or *Agrobacterium* vector
 25 background, etc.

Plant transformation may be confirmed by Southern blot analysis of genomic DNA (Sambrook and Russell, (2001) *supra*). In general, total DNA is extracted from the transformant, digested with appropriate restriction enzymes, fractionated in an agarose gel and transferred to a nitrocellulose or nylon membrane. The membrane or "blot" is
 30 then probed with, for example, radiolabeled ³²P target DNA fragment to confirm the integration of introduced gene into the plant genome according to standard techniques (Sambrook and Russell, (2001) *supra*).

In Northern blot analysis, RNA is isolated from specific tissues of transformant, fractionated in a formaldehyde agarose gel, and blotted onto a nylon filter according to
 35 standard procedures that are routinely used in the art (Sambrook and Russell, (2001) *supra*). Expression of RNA encoded by the pesticidal gene is then tested by hybridizing

the filter to a radioactive probe derived from a pesticidal gene, by methods known in the art (Sambrook and Russell, (2001) *supra*).

Western blot, biochemical assays and the like may be carried out on the transgenic plants to confirm the presence of protein encoded by the pesticidal gene by
5 standard procedures (Sambrook and Russell, 2001, *supra*) using antibodies that bind to one or more epitopes present on the PIP-72 polypeptide.

Stacking of traits in transgenic plant

Transgenic plants may comprise a stack of one or more insecticidal
10 polynucleotides disclosed herein with one or more additional polynucleotides resulting in the production or suppression of multiple polypeptide sequences. Transgenic plants comprising stacks of polynucleotide sequences can be obtained by either or both of traditional breeding methods or through genetic engineering methods. These methods include, but are not limited to, breeding individual lines each comprising a polynucleotide
15 of interest, transforming a transgenic plant comprising a gene disclosed herein with a subsequent gene and co- transformation of genes into a single plant cell. As used herein, the term “stacked” includes having the multiple traits present in the same plant (i.e., both traits are incorporated into the nuclear genome, one trait is incorporated into the nuclear genome and one trait is incorporated into the genome of a plastid or both traits are
20 incorporated into the genome of a plastid). In one non-limiting example, “stacked traits” comprise a molecular stack where the sequences are physically adjacent to each other. A trait, as used herein, refers to the phenotype derived from a particular sequence or groups of sequences. Co-transformation of genes can be carried out using single transformation vectors comprising multiple genes or genes carried separately on multiple
25 vectors. If the sequences are stacked by genetically transforming the plants, the polynucleotide sequences of interest can be combined at any time and in any order. The traits can be introduced simultaneously in a co-transformation protocol with the polynucleotides of interest provided by any combination of transformation cassettes. For example, if two sequences will be introduced, the two sequences can be contained in
30 separate transformation cassettes (trans) or contained on the same transformation cassette (cis). Expression of the sequences can be driven by the same promoter or by different promoters. In certain cases, it may be desirable to introduce a transformation cassette that will suppress the expression of the polynucleotide of interest. This may be combined with any combination of other suppression cassettes or overexpression
35 cassettes to generate the desired combination of traits in the plant. It is further recognized that polynucleotide sequences can be stacked at a desired genomic location

using a site-specific recombination system. See, for example, WO 1999/25821, WO 1999/25854, WO 1999/25840, WO 1999/25855 and WO 1999/25853, all of which are herein incorporated by reference.

In some embodiments the polynucleotides encoding the PIP-72 polypeptides disclosed herein, alone or stacked with one or more additional insect resistance traits can be stacked with one or more additional input traits (e.g., herbicide resistance, fungal resistance, virus resistance, stress tolerance, disease resistance, male sterility, stalk strength, and the like) or output traits (e.g., increased yield, modified starches, improved oil profile, balanced amino acids, high lysine or methionine, increased digestibility, improved fiber quality, drought resistance, and the like). Thus, the polynucleotide embodiments can be used to provide a complete agronomic package of improved crop quality with the ability to flexibly and cost effectively control any number of agronomic pests.

Transgenes useful for stacking include but are not limited to:

1. Transgenes that Confer Resistance to Insects or Disease and that Encode:

(A) Plant disease resistance genes. Plant defenses are often activated by specific interaction between the product of a disease resistance gene (R) in the plant and the product of a corresponding avirulence (Avr) gene in the pathogen. A plant variety can be transformed with cloned resistance gene to engineer plants that are resistant to specific pathogen strains. See, for example, Jones, *et al.*, (1994) *Science* 266:789 (cloning of the tomato Cf-9 gene for resistance to *Cladosporium fulvum*); Martin, *et al.*, (1993) *Science* 262:1432 (tomato Pto gene for resistance to *Pseudomonas syringae* pv. tomato encodes a protein kinase); Mindrinos, *et al.*, (1994) *Cell* 78:1089 (*Arabidopsis* RSP2 gene for resistance to *Pseudomonas syringae*), McDowell and Woffenden, (2003) *Trends Biotechnol.* 21(4):178-83 and Toyoda, *et al.*, (2002) *Transgenic Res.* 11(6):567-82. A plant resistant to a disease is one that is more resistant to a pathogen as compared to the wild type plant.

(B) Genes encoding a *Bacillus thuringiensis* protein, a derivative thereof or a synthetic polypeptide modeled thereon. See, for example, Geiser, *et al.*, (1986) *Gene* 48:109, who disclose the cloning and nucleotide sequence of a Bt delta-endotoxin gene. Moreover, DNA molecules encoding delta-endotoxin genes can be purchased from American Type Culture Collection (Rockville, Md.), for example, under ATCC® Accession Numbers 40098, 67136, 31995 and 31998. Other non-limiting examples of *Bacillus thuringiensis* transgenes being genetically engineered are given in the following patents and patent applications and hereby are incorporated by reference for this purpose: US

Patent Numbers 5,188,960; 5,689,052; 5,880,275; 5,986,177; 6,023,013, 6,060,594, 6,063,597, 6,077,824, 6,620,988, 6,642,030, 6,713,259, 6,893,826, 7,105,332; 7,179,965, 7,208,474; 7,227,056, 7,288,643, 7,323,556, 7,329,736, 7,449,552, 7,468,278, 7,510,878, 7,521,235, 7,544,862, 7,605,304, 7,696,412, 7,629,504, 7,705,216, 7,772,465, 7,790,846, 5 7,858,849 and WO 1991/14778; WO 1999/31248; WO 2001/12731; WO 1999/24581. WO 1997/40162, and WO2015/021139.

Genes encoding pesticidal proteins may also be stacked including but are not limited to: insecticidal proteins from *Pseudomonas* sp. such as PSEEN3174 (Monalysin, (2011) *PLoS Pathogens*, 7:1-13), from *Pseudomonas protegens* strain CHA0 and Pf-5 10 (previously *fluorescens*) (Pechy-Tarr, (2008) *Environmental Microbiology* 10:2368-2386: GenBank Accession No. EU400157); from *Pseudomonas Taiwanensis* (Liu, *et al.*, (2010) *J. Agric. Food Chem.* 58:12343-12349) and from *Pseudomonas pseudoalcaligenes* (Zhang, *et al.*, (2009) *Annals of Microbiology* 59:45-50 and Li, *et al.*, (2007) *Plant Cell Tiss. Organ Cult.* 89:159-168); insecticidal proteins from *Photorhabdus* sp. and 15 *Xenorhabdus* sp. (Hinchliffe, *et al.*, (2010) *The Open Toxinology Journal* 3:101-118 and Morgan, *et al.*, (2001) *Applied and Envir. Micro.* 67:2062-2069), US Patent Number 6,048,838, and US Patent Number 6,379,946; a PIP-1 polypeptide of US Serial Number 13792861; an AfIP-1A and/or AfIP-1B polypeptides of US Serial Number 13/800233; a PHI-4 polypeptide of US Serial Number 13/839702; PIP-47 polypeptides of PCT 20 Publication Number WO2015/023846; the insecticidal proteins of US Serial Number 61/863761 and 61/863763; and δ -endotoxins including, but not limited to, the Cry1, Cry2, Cry3, Cry4, Cry5, Cry6, Cry7, Cry8, Cry9, Cry10, Cry11, Cry12, Cry13, Cry14, Cry15, Cry16, Cry17, Cry18, Cry19, Cry20, Cry21, Cry22, Cry23, Cry24, Cry25, Cry26, Cry27, Cry 28, Cry 29, Cry 30, Cry31, Cry32, Cry33, Cry34, Cry35, Cry36, Cry37, Cry38, Cry39, 25 Cry40, Cry41, Cry42, Cry43, Cry44, Cry45, Cry 46, Cry47, Cry49, Cry 51, Cry52, Cry 53, Cry 54, Cry55, Cry56, Cry57, Cry58, Cry59, Cry60, Cry61, Cry62, Cry63, Cry64, Cry65, Cry66, Cry67, Cry68, Cry69, Cry70 and Cry71 classes of δ -endotoxin genes and the *B. thuringiensis* cytolytic Cyt1 and Cyt2 genes. Members of these classes of *B. thuringiensis* insecticidal proteins include, but are not limited to Cry1Aa1 (Accession # AAA22353); 30 Cry1Aa2 (Accession # Accession # AAA22552); Cry1Aa3 (Accession # BAA00257); Cry1Aa4 (Accession # CAA31886); Cry1Aa5 (Accession # BAA04468); Cry1Aa6 (Accession # AAA86265); Cry1Aa7 (Accession # AAD46139); Cry1Aa8 (Accession # I26149); Cry1Aa9 (Accession # BAA77213); Cry1Aa10 (Accession # AAD55382); Cry1Aa11 (Accession # CAA70856); Cry1Aa12 (Accession # AAP80146); Cry1Aa13 (Accession # AAM44305); Cry1Aa14 (Accession # AAP40639); Cry1Aa15 (Accession # 35 AAY66993); Cry1Aa16 (Accession # HQ439776); Cry1Aa17 (Accession # HQ439788);

Cry1Aa18 (Accession # HQ439790); Cry1Aa19 (Accession # HQ685121); Cry1Aa20
 (Accession # JF340156); Cry1Aa21 (Accession # JN651496); Cry1Aa22 (Accession #
 KC158223); Cry1Ab1 (Accession # AAA22330); Cry1Ab2 (Accession # AAA22613);
 Cry1Ab3 (Accession # AAA22561); Cry1Ab4 (Accession # BAA00071); Cry1Ab5
 5 (Accession # CAA28405); Cry1Ab6 (Accession # AAA22420); Cry1Ab7 (Accession #
 CAA31620); Cry1Ab8 (Accession # AAA22551); Cry1Ab9 (Accession # CAA38701);
 Cry1Ab10 (Accession # A29125); Cry1Ab11 (Accession # I12419); Cry1Ab12 (Accession
 # AAC64003); Cry1Ab13 (Accession # AAN76494); Cry1Ab14 (Accession # AAG16877);
 Cry1Ab15 (Accession # AAO13302); Cry1Ab16 (Accession # AAK55546); Cry1Ab17
 10 (Accession # AAT46415); Cry1Ab18 (Accession # AAQ88259); Cry1Ab19 (Accession #
 AAW31761); Cry1Ab20 (Accession # ABB72460); Cry1Ab21 (Accession # ABS18384);
 Cry1Ab22 (Accession # ABW87320); Cry1Ab23 (Accession # HQ439777); Cry1Ab24
 (Accession # HQ439778); Cry1Ab25 (Accession # HQ685122); Cry1Ab26 (Accession #
 HQ847729); Cry1Ab27 (Accession # JN135249); Cry1Ab28 (Accession # JN135250);
 15 Cry1Ab29 (Accession # JN135251); Cry1Ab30 (Accession # JN135252); Cry1Ab31
 (Accession # JN135253); Cry1Ab32 (Accession # JN135254); Cry1Ab33 (Accession #
 AAS93798); Cry1Ab34 (Accession # KC156668); Cry1Ab-like (Accession # AAK14336);
 Cry1Ab-like (Accession # AAK14337); Cry1Ab-like (Accession # AAK14338); Cry1Ab-like
 (Accession # ABG88858); Cry1Ac1 (Accession # AAA22331); Cry1Ac2 (Accession #
 20 AAA22338); Cry1Ac3 (Accession # CAA38098); Cry1Ac4 (Accession # AAA73077);
 Cry1Ac5 (Accession # AAA22339); Cry1Ac6 (Accession # AAA86266); Cry1Ac7
 (Accession # AAB46989); Cry1Ac8 (Accession # AAC44841); Cry1Ac9 (Accession #
 AAB49768); Cry1Ac10 (Accession # CAA05505); Cry1Ac11 (Accession # CAA10270);
 Cry1Ac12 (Accession # I12418); Cry1Ac13 (Accession # AAD38701); Cry1Ac14
 25 (Accession # AAQ06607); Cry1Ac15 (Accession # AAN07788); Cry1Ac16 (Accession #
 AAU87037); Cry1Ac17 (Accession # AAX18704); Cry1Ac18 (Accession # AAY88347);
 Cry1Ac19 (Accession # ABD37053); Cry1Ac20 (Accession # ABB89046); Cry1Ac21
 (Accession # AAY66992); Cry1Ac22 (Accession # ABZ01836); Cry1Ac23 (Accession #
 CAQ30431); Cry1Ac24 (Accession # ABL01535); Cry1Ac25 (Accession # FJ513324);
 30 Cry1Ac26 (Accession # FJ617446); Cry1Ac27 (Accession # FJ617447); Cry1Ac28
 (Accession # ACM90319); Cry1Ac29 (Accession # DQ438941); Cry1Ac30 (Accession #
 GQ227507); Cry1Ac31 (Accession # GU446674); Cry1Ac32 (Accession # HM061081);
 Cry1Ac33 (Accession # GQ866913); Cry1Ac34 (Accession # HQ230364); Cry1Ac35
 (Accession # JF340157); Cry1Ac36 (Accession # JN387137); Cry1Ac37 (Accession #
 35 JQ317685); Cry1Ad1 (Accession # AAA22340); Cry1Ad2 (Accession # CAA01880);
 Cry1Ae1 (Accession # AAA22410); Cry1Af1 (Accession # AAB82749); Cry1Ag1

(Accession # AAD46137); Cry1Ah1 (Accession # AAQ14326); Cry1Ah2 (Accession # ABB76664); Cry1Ah3 (Accession # HQ439779); Cry1Ai1 (Accession # AAO39719); Cry1Ai2 (Accession # HQ439780); Cry1A-like (Accession # AAK14339); Cry1Ba1 (Accession # CAA29898); Cry1Ba2 (Accession # CAA65003); Cry1Ba3 (Accession # AAK63251); Cry1Ba4 (Accession # AAK51084); Cry1Ba5 (Accession # ABO20894); Cry1Ba6 (Accession # ABL60921); Cry1Ba7 (Accession # HQ439781); Cry1Bb1 (Accession # AAA22344); Cry1Bb2 (Accession # HQ439782); Cry1Bc1 (Accession # CAA86568); Cry1Bd1 (Accession # AAD10292); Cry1Bd2 (Accession # AAM93496); Cry1Be1 (Accession # AAC32850); Cry1Be2 (Accession # AAQ52387); Cry1Be3 (Accession # ACV96720); Cry1Be4 (Accession # HM070026); Cry1Bf1 (Accession # CAC50778); Cry1Bf2 (Accession # AAQ52380); Cry1Bg1 (Accession # AAO39720); Cry1Bh1 (Accession # HQ589331); Cry1Bi1 (Accession # KC156700); Cry1Ca1 (Accession # CAA30396); Cry1Ca2 (Accession # CAA31951); Cry1Ca3 (Accession # AAA22343); Cry1Ca4 (Accession # CAA01886); Cry1Ca5 (Accession # CAA65457); Cry1Ca6 [1] (Accession # AAF37224); Cry1Ca7 (Accession # AAG50438); Cry1Ca8 (Accession # AAM00264); Cry1Ca9 (Accession # AAL79362); Cry1Ca10 (Accession # AAN16462); Cry1Ca11 (Accession # AAX53094); Cry1Ca12 (Accession # HM070027); Cry1Ca13 (Accession # HQ412621); Cry1Ca14 (Accession # JN651493); Cry1Cb1 (Accession # M97880); Cry1Cb2 (Accession # AAG35409); Cry1Cb3 (Accession # ACD50894); Cry1Cb-like (Accession # AAX63901); Cry1Da1 (Accession # CAA38099); Cry1Da2 (Accession # I76415); Cry1Da3 (Accession # HQ439784); Cry1Db1 (Accession # CAA80234); Cry1Db2 (Accession # AAK48937); Cry1Dc1 (Accession # ABK35074); Cry1Ea1 (Accession # CAA37933); Cry1Ea2 (Accession # CAA39609); Cry1Ea3 (Accession # AAA22345); Cry1Ea4 (Accession # AAD04732); Cry1Ea5 (Accession # A15535); Cry1Ea6 (Accession # AAL50330); Cry1Ea7 (Accession # AAW72936); Cry1Ea8 (Accession # ABX11258); Cry1Ea9 (Accession # HQ439785); Cry1Ea10 (Accession # ADR00398); Cry1Ea11 (Accession # JQ652456); Cry1Eb1 (Accession # AAA22346); Cry1Fa1 (Accession # AAA22348); Cry1Fa2 (Accession # AAA22347); Cry1Fa3 (Accession # HM070028); Cry1Fa4 (Accession # HM439638); Cry1Fb1 (Accession # CAA80235); Cry1Fb2 (Accession # BAA25298); Cry1Fb3 (Accession # AAF21767); Cry1Fb4 (Accession # AAC10641); Cry1Fb5 (Accession # AAO13295); Cry1Fb6 (Accession # ACD50892); Cry1Fb7 (Accession # ACD50893); Cry1Ga1 (Accession # CAA80233); Cry1Ga2 (Accession # CAA70506); Cry1Gb1 (Accession # AAD10291); Cry1Gb2 (Accession # AAO13756); Cry1Gc1 (Accession # AAQ52381); Cry1Ha1 (Accession # CAA80236); Cry1Hb1 (Accession # AAA79694); Cry1Hb2 (Accession # HQ439786); Cry1H-like (Accession # AAF01213); Cry1Ia1 (Accession #

CAA44633); Cry1Ia2 (Accession # AAA22354); Cry1Ia3 (Accession # AAC36999); Cry1Ia4 (Accession # AAB00958); Cry1Ia5 (Accession # CAA70124); Cry1Ia6 (Accession # AAC26910); Cry1Ia7 (Accession # AAM73516); Cry1Ia8 (Accession # AAK66742); Cry1Ia9 (Accession # AAQ08616); Cry1Ia10 (Accession # AAP86782); Cry1Ia11 (Accession # CAC85964); Cry1Ia12 (Accession # AAV53390); Cry1Ia13 (Accession # ABF83202); Cry1Ia14 (Accession # ACG63871); Cry1Ia15 (Accession # FJ617445); Cry1Ia16 (Accession # FJ617448); Cry1Ia17 (Accession # GU989199); Cry1Ia18 (Accession # ADK23801); Cry1Ia19 (Accession # HQ439787); Cry1Ia20 (Accession # JQ228426); Cry1Ia21 (Accession # JQ228424); Cry1Ia22 (Accession # JQ228427); Cry1Ia23 (Accession # JQ228428); Cry1Ia24 (Accession # JQ228429); Cry1Ia25 (Accession # JQ228430); Cry1Ia26 (Accession # JQ228431); Cry1Ia27 (Accession # JQ228432); Cry1Ia28 (Accession # JQ228433); Cry1Ia29 (Accession # JQ228434); Cry1Ia30 (Accession # JQ317686); Cry1Ia31 (Accession # JX944038); Cry1Ia32 (Accession # JX944039); Cry1Ia33 (Accession # JX944040); Cry1Ib1 (Accession # AAA82114); Cry1Ib2 (Accession # ABW88019); Cry1Ib3 (Accession # ACD75515); Cry1Ib4 (Accession # HM051227); Cry1Ib5 (Accession # HM070028); Cry1Ib6 (Accession # ADK38579); Cry1Ib7 (Accession # JN571740); Cry1Ib8 (Accession # JN675714); Cry1Ib9 (Accession # JN675715); Cry1Ib10 (Accession # JN675716); Cry1Ib11 (Accession # JQ228423); Cry1Ic1 (Accession # AAC62933); Cry1Ic2 (Accession # AAE71691); Cry1Id1 (Accession # AAD44366); Cry1Id2 (Accession # JQ228422); Cry1Ie1 (Accession # AAG43526); Cry1Ie2 (Accession # HM439636); Cry1Ie3 (Accession # KC156647); Cry1Ie4 (Accession # KC156681); Cry1If1 (Accession # AAQ52382); Cry1Ig1 (Accession # KC156701); Cry1I-like (Accession # AAC31094); Cry1I-like (Accession # ABG88859); Cry1Ja1 (Accession # AAA22341); Cry1Ja2 (Accession # HM070030); Cry1Ja3 (Accession # JQ228425); Cry1Jb1 (Accession # AAA98959); Cry1Jc1 (Accession # AAC31092); Cry1Jc2 (Accession # AAQ52372); Cry1Jd1 (Accession # CAC50779); Cry1Ka1 (Accession # AAB00376); Cry1Ka2 (Accession # HQ439783); Cry1La1 (Accession # AAS60191); Cry1La2 (Accession # HM070031); Cry1Ma1 (Accession # FJ884067); Cry1Ma2 (Accession # KC156659); Cry1Na1 (Accession # KC156648); Cry1Nb1 (Accession # KC156678); Cry1-like (Accession # AAC31091); Cry2Aa1 (Accession # AAA22335); Cry2Aa2 (Accession # AAA83516); Cry2Aa3 (Accession # D86064); Cry2Aa4 (Accession # AAC04867); Cry2Aa5 (Accession # CAA10671); Cry2Aa6 (Accession # CAA10672); Cry2Aa7 (Accession # CAA10670); Cry2Aa8 (Accession # AAO13734); Cry2Aa9 (Accession # AAO13750); Cry2Aa10 (Accession # AAQ04263); Cry2Aa11 (Accession # AAQ52384); Cry2Aa12 (Accession # ABI83671); Cry2Aa13 (Accession # ABL01536); Cry2Aa14 (Accession # ACF04939);

Cry2Aa15 (Accession # JN426947); Cry2Ab1 (Accession # AAA22342); Cry2Ab2
 (Accession # CAA39075); Cry2Ab3 (Accession # AAG36762); Cry2Ab4 (Accession #
 AAO13296); Cry2Ab5 (Accession # AAQ04609); Cry2Ab6 (Accession # AAP59457);
 Cry2Ab7 (Accession # AAZ66347); Cry2Ab8 (Accession # ABC95996); Cry2Ab9
 5 (Accession # ABC74968); Cry2Ab10 (Accession # EF157306); Cry2Ab11 (Accession #
 CAM84575); Cry2Ab12 (Accession # ABM21764); Cry2Ab13 (Accession # ACG76120);
 Cry2Ab14 (Accession # ACG76121); Cry2Ab15 (Accession # HM037126); Cry2Ab16
 (Accession # GQ866914); Cry2Ab17 (Accession # HQ439789); Cry2Ab18 (Accession #
 JN135255); Cry2Ab19 (Accession # JN135256); Cry2Ab20 (Accession # JN135257);
 10 Cry2Ab21 (Accession # JN135258); Cry2Ab22 (Accession # JN135259); Cry2Ab23
 (Accession # JN135260); Cry2Ab24 (Accession # JN135261); Cry2Ab25 (Accession #
 JN415485); Cry2Ab26 (Accession # JN426946); Cry2Ab27 (Accession # JN415764);
 Cry2Ab28 (Accession # JN651494); Cry2Ac1 (Accession # CAA40536); Cry2Ac2
 (Accession # AAG35410); Cry2Ac3 (Accession # AAQ52385); Cry2Ac4 (Accession #
 15 ABC95997); Cry2Ac5 (Accession # ABC74969); Cry2Ac6 (Accession # ABC74793);
 Cry2Ac7 (Accession # CAL18690); Cry2Ac8 (Accession # CAM09325); Cry2Ac9
 (Accession # CAM09326); Cry2Ac10 (Accession # ABN15104); Cry2Ac11 (Accession #
 CAM83895); Cry2Ac12 (Accession # CAM83896); Cry2Ad1 (Accession # AAF09583);
 Cry2Ad2 (Accession # ABC86927); Cry2Ad3 (Accession # CAK29504); Cry2Ad4
 20 (Accession # CAM32331); Cry2Ad5 (Accession # CAO78739); Cry2Ae1 (Accession #
 AAQ52362); Cry2Af1 (Accession # ABO30519); Cry2Af2 (Accession # GQ866915);
 Cry2Ag1 (Accession # ACH91610); Cry2Ah1 (Accession # EU939453); Cry2Ah2
 (Accession # ACL80665); Cry2Ah3 (Accession # GU073380); Cry2Ah4 (Accession #
 KC156702); Cry2Ai1 (Accession # FJ788388); Cry2Aj (Accession #); Cry2Ak1
 25 (Accession # KC156660); Cry2Ba1 (Accession # KC156658); Cry3Aa1 (Accession #
 AAA22336); Cry3Aa2 (Accession # AAA22541); Cry3Aa3 (Accession # CAA68482);
 Cry3Aa4 (Accession # AAA22542); Cry3Aa5 (Accession # AAA50255); Cry3Aa6
 (Accession # AAC43266); Cry3Aa7 (Accession # CAB41411); Cry3Aa8 (Accession #
 AAS79487); Cry3Aa9 (Accession # AAW05659); Cry3Aa10 (Accession # AAU29411);
 30 Cry3Aa11 (Accession # AAW82872); Cry3Aa12 (Accession # ABY49136); Cry3Ba1
 (Accession # CAA34983); Cry3Ba2 (Accession # CAA00645); Cry3Ba3 (Accession #
 JQ397327); Cry3Bb1 (Accession # AAA22334); Cry3Bb2 (Accession # AAA74198);
 Cry3Bb3 (Accession # I15475); Cry3Ca1 (Accession # CAA42469); Cry4Aa1 (Accession
 # CAA68485); Cry4Aa2 (Accession # BAA00179); Cry4Aa3 (Accession # CAD30148);
 35 Cry4Aa4 (Accession # AFB18317); Cry4A-like (Accession # AAY96321); Cry4Ba1
 (Accession # CAA30312); Cry4Ba2 (Accession # CAA30114); Cry4Ba3 (Accession #

AAA22337); Cry4Ba4 (Accession # BAA00178); Cry4Ba5 (Accession # CAD30095);
 Cry4Ba-like (Accession # ABC47686); Cry4Ca1 (Accession # EU646202); Cry4Cb1
 (Accession # FJ403208); Cry4Cb2 (Accession # FJ597622); Cry4Cc1 (Accession #
 FJ403207); Cry5Aa1 (Accession # AAA67694); Cry5Ab1 (Accession # AAA67693);
 5 Cry5Ac1 (Accession # I34543); Cry5Ad1 (Accession # ABQ82087); Cry5Ba1 (Accession
 # AAA68598); Cry5Ba2 (Accession # ABW88931); Cry5Ba3 (Accession # AFJ04417);
 Cry5Ca1 (Accession # HM461869); Cry5Ca2 (Accession # ZP_04123426); Cry5Da1
 (Accession # HM461870); Cry5Da2 (Accession # ZP_04123980); Cry5Ea1 (Accession #
 HM485580); Cry5Ea2 (Accession # ZP_04124038); Cry6Aa1 (Accession # AAA22357);
 10 Cry6Aa2 (Accession # AAM46849); Cry6Aa3 (Accession # ABH03377); Cry6Ba1
 (Accession # AAA22358); Cry7Aa1 (Accession # AAA22351); Cry7Ab1 (Accession #
 AAA21120); Cry7Ab2 (Accession # AAA21121); Cry7Ab3 (Accession # ABX24522);
 Cry7Ab4 (Accession # EU380678); Cry7Ab5 (Accession # ABX79555); Cry7Ab6
 (Accession # ACI44005); Cry7Ab7 (Accession # ADB89216); Cry7Ab8 (Accession #
 15 GU145299); Cry7Ab9 (Accession # ADD92572); Cry7Ba1 (Accession # ABB70817);
 Cry7Bb1 (Accession # KC156653); Cry7Ca1 (Accession # ABR67863); Cry7Cb1
 (Accession # KC156698); Cry7Da1 (Accession # ACQ99547); Cry7Da2 (Accession #
 HM572236); Cry7Da3 (Accession # KC156679); Cry7Ea1 (Accession # HM035086);
 Cry7Ea2 (Accession # HM132124); Cry7Ea3 (Accession # EEM19403); Cry7Fa1
 20 (Accession # HM035088); Cry7Fa2 (Accession # EEM19090); Cry7Fb1 (Accession #
 HM572235); Cry7Fb2 (Accession # KC156682); Cry7Ga1 (Accession # HM572237);
 Cry7Ga2 (Accession # KC156669); Cry7Gb1 (Accession # KC156650); Cry7Gc1
 (Accession # KC156654); Cry7Gd1 (Accession # KC156697); Cry7Ha1 (Accession #
 KC156651); Cry7Ia1 (Accession # KC156665); Cry7Ja1 (Accession # KC156671);
 25 Cry7Ka1 (Accession # KC156680); Cry7Kb1 (Accession # BAM99306); Cry7La1
 (Accession # BAM99307); Cry8Aa1 (Accession # AAA21117); Cry8Ab1 (Accession #
 EU044830); Cry8Ac1 (Accession # KC156662); Cry8Ad1 (Accession # KC156684);
 Cry8Ba1 (Accession # AAA21118); Cry8Bb1 (Accession # CAD57542); Cry8Bc1
 (Accession # CAD57543); Cry8Ca1 (Accession # AAA21119); Cry8Ca2 (Accession #
 30 AAR98783); Cry8Ca3 (Accession # EU625349); Cry8Ca4 (Accession # ADB54826);
 Cry8Da1 (Accession # BAC07226); Cry8Da2 (Accession # BD133574); Cry8Da3
 (Accession # BD133575); Cry8Db1 (Accession # BAF93483); Cry8Ea1 (Accession #
 AAQ73470); Cry8Ea2 (Accession # EU047597); Cry8Ea3 (Accession # KC855216);
 Cry8Fa1 (Accession # AAT48690); Cry8Fa2 (Accession # HQ174208); Cry8Fa3
 35 (Accession # AFH78109); Cry8Ga1 (Accession # AAT46073); Cry8Ga2 (Accession #
 ABC42043); Cry8Ga3 (Accession # FJ198072); Cry8Ha1 (Accession # AAW81032);

Cry8Ia1 (Accession # EU381044); Cry8Ia2 (Accession # GU073381); Cry8Ia3 (Accession # HM044664); Cry8Ia4 (Accession # KC156674); Cry8Ib1 (Accession # GU325772); Cry8Ib2 (Accession # KC156677); Cry8Ja1 (Accession # EU625348); Cry8Ka1 (Accession # FJ422558); Cry8Ka2 (Accession # ACN87262); Cry8Kb1 (Accession # HM123758); Cry8Kb2 (Accession # KC156675); Cry8La1 (Accession # GU325771); Cry8Ma1 (Accession # HM044665); Cry8Ma2 (Accession # EEM86551); Cry8Ma3 (Accession # HM210574); Cry8Na1 (Accession # HM640939); Cry8Pa1 (Accession # HQ388415); Cry8Qa1 (Accession # HQ441166); Cry8Qa2 (Accession # KC152468); Cry8Ra1 (Accession # AFP87548); Cry8Sa1 (Accession # JQ740599); Cry8Ta1 (Accession # KC156673); Cry8-like (Accession # FJ770571); Cry8-like (Accession # ABS53003); Cry9Aa1 (Accession # CAA41122); Cry9Aa2 (Accession # CAA41425); Cry9Aa3 (Accession # GQ249293); Cry9Aa4 (Accession # GQ249294); Cry9Aa5 (Accession # JX174110); Cry9Aa like (Accession # AAQ52376); Cry9Ba1 (Accession # CAA52927); Cry9Ba2 (Accession # GU299522); Cry9Bb1 (Accession # AAV28716); Cry9Ca1 (Accession # CAA85764); Cry9Ca2 (Accession # AAQ52375); Cry9Da1 (Accession # BAA19948); Cry9Da2 (Accession # AAB97923); Cry9Da3 (Accession # GQ249293); Cry9Da4 (Accession # GQ249297); Cry9Db1 (Accession # AAX78439); Cry9Dc1 (Accession # KC156683); Cry9Ea1 (Accession # BAA34908); Cry9Ea2 (Accession # AAO12908); Cry9Ea3 (Accession # ABM21765); Cry9Ea4 (Accession # ACE88267); Cry9Ea5 (Accession # ACF04743); Cry9Ea6 (Accession # ACG63872); Cry9Ea7 (Accession # FJ380927); Cry9Ea8 (Accession # GQ249292); Cry9Ea9 (Accession # JN651495); Cry9Eb1 (Accession # CAC50780); Cry9Eb2 (Accession # GQ249298); Cry9Eb3 (Accession # KC156646); Cry9Ec1 (Accession # AAC63366); Cry9Ed1 (Accession # AAX78440); Cry9Ee1 (Accession # GQ249296); Cry9Ee2 (Accession # KC156664); Cry9Fa1 (Accession # KC156692); Cry9Ga1 (Accession # KC156699); Cry9-like (Accession # AAC63366); Cry10Aa1 (Accession # AAA22614); Cry10Aa2 (Accession # E00614); Cry10Aa3 (Accession # CAD30098); Cry10Aa4 (Accession # AFB18318); Cry10A-like (Accession # DQ167578); Cry11Aa1 (Accession # AAA22352); Cry11Aa2 (Accession # AAA22611); Cry11Aa3 (Accession # CAD30081); Cry11Aa4 (Accession # AFB18319); Cry11Aa-like (Accession # DQ166531); Cry11Ba1 (Accession # CAA60504); Cry11Bb1 (Accession # AAC97162); Cry11Bb2 (Accession # HM068615); Cry12Aa1 (Accession # AAA22355); Cry13Aa1 (Accession # AAA22356); Cry14Aa1 (Accession # AAA21516); Cry14Ab1 (Accession # KC156652); Cry15Aa1 (Accession # AAA22333); Cry16Aa1 (Accession # CAA63860); Cry17Aa1 (Accession # CAA67841); Cry18Aa1 (Accession # CAA67506); Cry18Ba1 (Accession # AAF89667); Cry18Ca1 (Accession # AAF89668); Cry19Aa1 (Accession # CAA68875); Cry19Ba1

(Accession # BAA32397); Cry19Ca1 (Accession # AFM37572); Cry20Aa1 (Accession # AAB93476); Cry20Ba1 (Accession # ACS93601); Cry20Ba2 (Accession # KC156694); Cry20-like (Accession # GQ144333); Cry21Aa1 (Accession # I32932); Cry21Aa2 (Accession # I66477); Cry21Ba1 (Accession # BAC06484); Cry21Ca1 (Accession # JF521577); Cry21Ca2 (Accession # KC156687); Cry21Da1 (Accession # JF521578); Cry22Aa1 (Accession # I34547); Cry22Aa2 (Accession # CAD43579); Cry22Aa3 (Accession # ACD93211); Cry22Ab1 (Accession # AAK50456); Cry22Ab2 (Accession # CAD43577); Cry22Ba1 (Accession # CAD43578); Cry22Bb1 (Accession # KC156672); Cry23Aa1 (Accession # AAF76375); Cry24Aa1 (Accession # AAC61891); Cry24Ba1 (Accession # BAD32657); Cry24Ca1 (Accession # CAJ43600); Cry25Aa1 (Accession # AAC61892); Cry26Aa1 (Accession # AAD25075); Cry27Aa1 (Accession # BAA82796); Cry28Aa1 (Accession # AAD24189); Cry28Aa2 (Accession # AAG00235); Cry29Aa1 (Accession # CAC80985); Cry30Aa1 (Accession # CAC80986); Cry30Ba1 (Accession # BAD00052); Cry30Ca1 (Accession # BAD67157); Cry30Ca2 (Accession # ACU24781); Cry30Da1 (Accession # EF095955); Cry30Db1 (Accession # BAE80088); Cry30Ea1 (Accession # ACC95445); Cry30Ea2 (Accession # FJ499389); Cry30Fa1 (Accession # ACI22625); Cry30Ga1 (Accession # ACG60020); Cry30Ga2 (Accession # HQ638217); Cry31Aa1 (Accession # BAB11757); Cry31Aa2 (Accession # AAL87458); Cry31Aa3 (Accession # BAE79808); Cry31Aa4 (Accession # BAF32571); Cry31Aa5 (Accession # BAF32572); Cry31Aa6 (Accession # BAI44026); Cry31Ab1 (Accession # BAE79809); Cry31Ab2 (Accession # BAF32570); Cry31Ac1 (Accession # BAF34368); Cry31Ac2 (Accession # AB731600); Cry31Ad1 (Accession # BAI44022); Cry32Aa1 (Accession # AAG36711); Cry32Aa2 (Accession # GU063849); Cry32Ab1 (Accession # GU063850); Cry32Ba1 (Accession # BAB78601); Cry32Ca1 (Accession # BAB78602); Cry32Cb1 (Accession # KC156708); Cry32Da1 (Accession # BAB78603); Cry32Ea1 (Accession # GU324274); Cry32Ea2 (Accession # KC156686); Cry32Eb1 (Accession # KC156663); Cry32Fa1 (Accession # KC156656); Cry32Ga1 (Accession # KC156657); Cry32Ha1 (Accession # KC156661); Cry32Hb1 (Accession # KC156666); Cry32Ia1 (Accession # KC156667); Cry32Ja1 (Accession # KC156685); Cry32Ka1 (Accession # KC156688); Cry32La1 (Accession # KC156689); Cry32Ma1 (Accession # KC156690); Cry32Mb1 (Accession # KC156704); Cry32Na1 (Accession # KC156691); Cry32Oa1 (Accession # KC156703); Cry32Pa1 (Accession # KC156705); Cry32Qa1 (Accession # KC156706); Cry32Ra1 (Accession # KC156707); Cry32Sa1 (Accession # KC156709); Cry32Ta1 (Accession # KC156710); Cry32Ua1 (Accession # KC156655); Cry33Aa1 (Accession # AAL26871); Cry34Aa1 (Accession # AAG50341); Cry34Aa2 (Accession # AAK64560); Cry34Aa3 (Accession # AAT29032); Cry34Aa4 (Accession # AAT29030); Cry34Ab1

(Accession # AAG41671); Cry34Ac1 (Accession # AAG50118); Cry34Ac2 (Accession # AAK64562); Cry34Ac3 (Accession # AAT29029); Cry34Ba1 (Accession # AAK64565); Cry34Ba2 (Accession # AAT29033); Cry34Ba3 (Accession # AAT29031); Cry35Aa1 (Accession # AAG50342); Cry35Aa2 (Accession # AAK64561); Cry35Aa3 (Accession # AAT29028); Cry35Aa4 (Accession # AAT29025); Cry35Ab1 (Accession # AAG41672); Cry35Ab2 (Accession # AAK64563); Cry35Ab3 (Accession # AY536891); Cry35Ac1 (Accession # AAG50117); Cry35Ba1 (Accession # AAK64566); Cry35Ba2 (Accession # AAT29027); Cry35Ba3 (Accession # AAT29026); Cry36Aa1 (Accession # AAK64558); Cry37Aa1 (Accession # AAF76376); Cry38Aa1 (Accession # AAK64559); Cry39Aa1 (Accession # BAB72016); Cry40Aa1 (Accession # BAB72018); Cry40Ba1 (Accession # BAC77648); Cry40Ca1 (Accession # EU381045); Cry40Da1 (Accession # ACF15199); Cry41Aa1 (Accession # BAD35157); Cry41Ab1 (Accession # BAD35163); Cry41Ba1 (Accession # HM461871); Cry41Ba2 (Accession # ZP_04099652); Cry42Aa1 (Accession # BAD35166); Cry43Aa1 (Accession # BAD15301); Cry43Aa2 (Accession # BAD95474); Cry43Ba1 (Accession # BAD15303); Cry43Ca1 (Accession # KC156676); Cry43Cb1 (Accession # KC156695); Cry43Cc1 (Accession # KC156696); Cry43-like (Accession # BAD15305); Cry44Aa (Accession # BAD08532); Cry45Aa (Accession # BAD22577); Cry46Aa (Accession # BAC79010); Cry46Aa2 (Accession # BAG68906); Cry46Ab (Accession # BAD35170); Cry47Aa (Accession # AAY24695); Cry48Aa (Accession # CAJ18351); Cry48Aa2 (Accession # CAJ86545); Cry48Aa3 (Accession # CAJ86546); Cry48Ab (Accession # CAJ86548); Cry48Ab2 (Accession # CAJ86549); Cry49Aa (Accession # CAH56541); Cry49Aa2 (Accession # CAJ86541); Cry49Aa3 (Accession # CAJ86543); Cry49Aa4 (Accession # CAJ86544); Cry49Ab1 (Accession # CAJ86542); Cry50Aa1 (Accession # BAE86999); Cry50Ba1 (Accession # GU446675); Cry50Ba2 (Accession # GU446676); Cry51Aa1 (Accession # ABI14444); Cry51Aa2 (Accession # GU570697); Cry52Aa1 (Accession # EF613489); Cry52Ba1 (Accession # FJ361760); Cry53Aa1 (Accession # EF633476); Cry53Ab1 (Accession # FJ361759); Cry54Aa1 (Accession # ACA52194); Cry54Aa2 (Accession # GQ140349); Cry54Ba1 (Accession # GU446677); Cry55Aa1 (Accession # ABW88932); Cry54Ab1 (Accession # JQ916908); Cry55Aa2 (Accession # AAE33526); Cry56Aa1 (Accession # ACU57499); Cry56Aa2 (Accession # GQ483512); Cry56Aa3 (Accession # JX025567); Cry57Aa1 (Accession # ANC87261); Cry58Aa1 (Accession # ANC87260); Cry59Ba1 (Accession # JN790647); Cry59Aa1 (Accession # ACR43758); Cry60Aa1 (Accession # ACU24782); Cry60Aa2 (Accession # EAO57254); Cry60Aa3 (Accession # EEM99278); Cry60Ba1 (Accession # GU810818); Cry60Ba2 (Accession # EAO57253); Cry60Ba3 (Accession # EEM99279); Cry61Aa1 (Accession # HM035087); Cry61Aa2 (Accession # HM132125); Cry61Aa3

(Accession # EEM19308); Cry62Aa1 (Accession # HM054509); Cry63Aa1 (Accession # BAI44028); Cry64Aa1 (Accession # BAJ05397); Cry65Aa1 (Accession # HM461868); Cry65Aa2 (Accession # ZP_04123838); Cry66Aa1 (Accession # HM485581); Cry66Aa2 (Accession # ZP_04099945); Cry67Aa1 (Accession # HM485582); Cry67Aa2 (Accession # ZP_04148882); Cry68Aa1 (Accession # HQ113114); Cry69Aa1 (Accession # HQ401006); Cry69Aa2 (Accession # JQ821388); Cry69Ab1 (Accession # JN209957); Cry70Aa1 (Accession # JN646781); Cry70Ba1 (Accession # ADO51070); Cry70Bb1 (Accession # EEL67276); Cry71Aa1 (Accession # JX025568); Cry72Aa1 (Accession # JX025569).

Examples of δ -endotoxins also include but are not limited to Cry1A proteins of US Patent Numbers 5,880,275, 7,858,849 8,530,411, 8,575,433, and 8,686,233; a DIG-3 or DIG-11 toxin (N-terminal deletion of α -helix 1 and/or α -helix 2 variants of cry proteins such as Cry1A, Cry3A) of US Patent Numbers 8,304,604, 8,304,605 and 8,476,226; Cry1B of US Patent Application Serial Number 10/525,318; Cry1C of US Patent Number 6,033,874; Cry1F of US Patent Numbers 5,188,960 and 6,218,188; Cry1A/F chimeras of US Patent Numbers 7,070,982; 6,962,705 and 6,713,063); a Cry2 protein such as Cry2Ab protein of US Patent Number 7,064,249); a Cry3A protein including but not limited to an engineered hybrid insecticidal protein (eHIP) created by fusing unique combinations of variable regions and conserved blocks of at least two different Cry proteins (US Patent Application Publication Number 2010/0017914); a Cry4 protein; a Cry5 protein; a Cry6 protein; Cry8 proteins of US Patent Numbers 7,329,736, 7,449,552, 7,803,943, 7,476,781, 7,105,332, 7,378,499 and 7,462,760; a Cry9 protein such as such as members of the Cry9A, Cry9B, Cry9C, Cry9D, Cry9E and Cry9F families, including but not limited to the Cry9D protein of US Patent Number 8,802,933 and the Cry9B protein of US Patent Number 8,802,934; a Cry15 protein of Naimov, *et al.*, (2008) *Applied and Environmental Microbiology*, 74:7145-7151; a Cry22, a Cry34Ab1 protein of US Patent Numbers 6,127,180, 6,624,145 and 6,340,593; a CryET33 and cryET34 protein of US Patent Numbers 6,248,535, 6,326,351, 6,399,330, 6,949,626, 7,385,107 and 7,504,229; a CryET33 and CryET34 homologs of US Patent Publication Number 2006/0191034, 2012/0278954, and PCT Publication Number WO 2012/139004; a Cry35Ab1 protein of US Patent Numbers 6,083,499, 6,548,291 and 6,340,593; a Cry46 protein, a Cry 51 protein, a Cry binary toxin; a TIC901 or related toxin; TIC807 of US Patent Application Publication Number 2008/0295207; ET29, ET37, TIC809, TIC810, TIC812, TIC127, TIC128 of PCT US 2006/033867; TIC853 toxins of US Patent 8,513,494, AXMI-027, AXMI-036, and AXMI-038 of US Patent Number 8,236,757; AXMI-031, AXMI-039, AXMI-040, AXMI-049 of US Patent Number 7,923,602; AXMI-018, AXMI-020 and AXMI-021 of

WO 2006/083891; AXMI-010 of WO 2005/038032; AXMI-003 of WO 2005/021585; AXMI-008 of US Patent Application Publication Number 2004/0250311; AXMI-006 of US Patent Application Publication Number 2004/0216186; AXMI-007 of US Patent Application Publication Number 2004/0210965; AXMI-009 of US Patent Application Number 2004/0210964; AXMI-014 of US Patent Application Publication Number 2004/0197917; AXMI-004 of US Patent Application Publication Number 2004/0197916; AXMI-028 and AXMI-029 of WO 2006/119457; AXMI-007, AXMI-008, AXMI-0080rf2, AXMI-009, AXMI-014 and AXMI-004 of WO 2004/074462; AXMI-150 of US Patent Number 8,084,416; AXMI-205 of US Patent Application Publication Number 2011/0023184; AXMI-011, AXMI-012, AXMI-013, AXMI-015, AXMI-019, AXMI-044, AXMI-037, AXMI-043, AXMI-033, AXMI-034, AXMI-022, AXMI-023, AXMI-041, AXMI-063 and AXMI-064 of US Patent Application Publication Number 2011/0263488; AXMI-R1 and related proteins of US Patent Application Publication Number 2010/0197592; AXMI221Z, AXMI222z, AXMI223z, AXMI224z and AXMI225z of WO 2011/103248; AXMI218, AXMI219, AXMI220, AXMI226, AXMI227, AXMI228, AXMI229, AXMI230 and AXMI231 of WO 2011/103247 and US Patent Number 8,759,619; AXMI-115, AXMI-113, AXMI-005, AXMI-163 and AXMI-184 of US Patent Number 8,334,431; AXMI-001, AXMI-002, AXMI-030, AXMI-035 and AXMI-045 of US Patent Application Publication Number 2010/0298211; AXMI-066 and AXMI-076 of US Patent Application Publication Number 2009/0144852; AXMI128, AXMI130, AXMI131, AXMI133, AXMI140, AXMI141, AXMI142, AXMI143, AXMI144, AXMI146, AXMI148, AXMI149, AXMI152, AXMI153, AXMI154, AXMI155, AXMI156, AXMI157, AXMI158, AXMI162, AXMI165, AXMI166, AXMI167, AXMI168, AXMI169, AXMI170, AXMI171, AXMI172, AXMI173, AXMI174, AXMI175, AXMI176, AXMI177, AXMI178, AXMI179, AXMI180, AXMI181, AXMI182, AXMI185, AXMI186, AXMI187, AXMI188, AXMI189 of US Patent Number 8,318,900; AXMI079, AXMI080, AXMI081, AXMI082, AXMI091, AXMI092, AXMI096, AXMI097, AXMI098, AXMI099, AXMI100, AXMI101, AXMI102, AXMI103, AXMI104, AXMI107, AXMI108, AXMI109, AXMI110, AXMI111, AXMI112, AXMI114, AXMI116, AXMI117, AXMI118, AXMI119, AXMI120, AXMI121, AXMI122, AXMI123, AXMI124, AXMI1257, AXMI1268, AXMI127, AXMI129, AXMI164, AXMI151, AXMI161, AXMI183, AXMI132, AXMI138, AXMI137 of US Patent Application Publication Number 2010/0005543, AXMI270 of US Patent Application Publication US20140223598, AXMI279 of US Patent Application Publication US20140223599, cry proteins such as Cry1A and Cry3A having modified proteolytic sites of US Patent Number 8,319,019; a Cry1Ac, Cry2Aa and Cry1Ca toxin protein from *Bacillus thuringiensis* strain VBTS 2528 of US Patent Application Publication Number 2011/0064710. Other Cry proteins are well known to one skilled in the art (see, Crickmore, *et al.*, "Bacillus thuringiensis toxin nomenclature"

(2011), at lifesci.sussex.ac.uk/home/Neil_Crickmore/Bt/ which can be accessed on the world-wide web using the "www" prefix). The insecticidal activity of Cry proteins is well known to one skilled in the art (for review, see, van Franckenhuysen, (2009) *J. Invert. Path.* 101:1-16). The use of Cry proteins as transgenic plant traits is well known to one skilled in the art and Cry-transgenic plants including but not limited to plants expressing Cry1Ac, Cry1Ac+Cry2Ab, Cry1Ab, Cry1A.105, Cry1F, Cry1Fa2, Cry1F+Cry1Ac, Cry2Ab, Cry3A, mCry3A, Cry3Bb1, Cry34Ab1, Cry35Ab1, Vip3A, mCry3A, Cry9c and CBI-Bt have received regulatory approval (see, Sanahuja, (2011) *Plant Biotech Journal* 9:283-300 and the CERA (2010) GM Crop Database Center for Environmental Risk Assessment (CERA), ILSI Research Foundation, Washington D.C. at cera-gmc.org/index.php?action=gm_crop_database, which can be accessed on the world-wide web using the "www" prefix). More than one pesticidal proteins well known to one skilled in the art can also be expressed in plants such as Vip3Ab & Cry1Fa (US2012/0317682); Cry1BE & Cry1F (US2012/0311746); Cry1CA & Cry1AB (US2012/0311745); Cry1F & CryCa (US2012/0317681); Cry1DA & Cry1BE (US2012/0331590); Cry1DA & Cry1Fa (US2012/0331589); Cry1AB & Cry1BE (US2012/0324606); Cry1Fa & Cry2Aa and Cry1I & Cry1E (US2012/0324605); Cry34Ab/35Ab and Cry6Aa (US20130167269); Cry34Ab/VCry35Ab & Cry3Aa (US20130167268); Cry1Ab & Cry1F (US20140182018); and Cry3A and Cry1Ab or Vip3Aa (US20130116170). Pesticidal proteins also include insecticidal lipases including lipid acyl hydrolases of US Patent Number 7,491,869, and cholesterol oxidases such as from *Streptomyces* (Purcell et al. (1993) *Biochem Biophys Res Commun* 15:1406-1413). Pesticidal proteins also include VIP (vegetative insecticidal proteins) toxins of US Patent Numbers 5,877,012, 6,107,279, 6,137,033, 7,244,820, 7,615,686, and 8,237,020, and the like. Other VIP proteins are well known to one skilled in the art (see, lifesci.sussex.ac.uk/home/Neil_Crickmore/Bt/vip.html which can be accessed on the world-wide web using the "www" prefix). Pesticidal proteins also include toxin complex (TC) proteins, obtainable from organisms such as *Xenorhabdus*, *Photorhabdus* and *Paenibacillus* (see, US Patent Numbers 7,491,698 and 8,084,418). Some TC proteins have "stand alone" insecticidal activity and other TC proteins enhance the activity of the stand-alone toxins produced by the same given organism. The toxicity of a "stand-alone" TC protein (from *Photorhabdus*, *Xenorhabdus* or *Paenibacillus*, for example) can be enhanced by one or more TC protein "potentiators" derived from a source organism of a different genus. There are three main types of TC proteins. As referred to herein, Class A proteins ("Protein A") are stand-alone toxins. Class B proteins ("Protein B") and Class C proteins ("Protein C") enhance the toxicity of Class A proteins. Examples of Class A proteins are TcbA, TcdA, XptA1 and XptA2. Examples of Class B

proteins are TcaC, TcdB, XptB1Xb and XptC1Wi. Examples of Class C proteins are TccC, XptC1Xb and XptB1Wi. Pesticidal proteins also include spider, snake and scorpion venom proteins. Examples of spider venom peptides include but are not limited to lycotoxin-1 peptides and mutants thereof (US Patent Number 8,334,366).

5 (C) A polynucleotide encoding an insect-specific hormone or pheromone such as an ecdysteroid and juvenile hormone, a variant thereof, a mimetic based thereon or an antagonist or agonist thereof. See, for example, the disclosure by Hammock, *et al.*, (1990) *Nature* 344:458, of baculovirus expression of cloned juvenile hormone esterase, an inactivator of juvenile hormone.

10 (D) A polynucleotide encoding an insect-specific peptide which, upon expression, disrupts the physiology of the affected pest. For example, see the disclosures of, Regan, (1994) *J. Biol. Chem.* 269:9 (expression cloning yields DNA coding for insect diuretic hormone receptor); Pratt, *et al.*, (1989) *Biochem. Biophys. Res. Comm.* 163:1243 (an allostatin is identified in *Diploptera puntata*); Chattopadhyay, *et al.*, (2004) *Critical*
15 *Reviews in Microbiology* 30(1):33-54; Zjawiony, (2004) *J Nat Prod* 67(2):300-310; Carlini and Grossi-de-Sa, (2002) *Toxicon* 40(11):1515-1539; Ussuf, *et al.*, (2001) *Curr Sci.* 80(7):847-853 and Vasconcelos and Oliveira, (2004) *Toxicon* 44(4):385-403. See also, US Patent Number 5,266,317 to Tomalski, *et al.*, who disclose genes encoding insect-specific toxins.

20 (E) A polynucleotide encoding an enzyme responsible for a hyperaccumulation of a monoterpene, a sesquiterpene, a steroid, hydroxamic acid, a phenylpropanoid derivative or another non-protein molecule with insecticidal activity.

(F) A polynucleotide encoding an enzyme involved in the modification, including the post-translational modification, of a biologically active molecule; for example, a
25 glycolytic enzyme, a proteolytic enzyme, a lipolytic enzyme, a nuclease, a cyclase, a transaminase, an esterase, a hydrolase, a phosphatase, a kinase, a phosphorylase, a polymerase, an elastase, a chitinase and a glucanase, whether natural or synthetic. See, PCT Application WO 1993/02197 in the name of Scott, *et al.*, which discloses the nucleotide sequence of a callase gene. DNA molecules which contain chitinase-encoding
30 sequences can be obtained, for example, from the ATCC[®] under Accession Numbers 39637 and 67152. See also, Kramer, *et al.*, (1993) *Insect Biochem. Molec. Biol.* 23:691, who teach the nucleotide sequence of a cDNA encoding tobacco hookworm chitinase and Kawalleck, *et al.*, (1993) *Plant Molec. Biol.* 21:673, who provide the nucleotide sequence of the parsley ubi4-2 polyubiquitin gene, and US Patent Numbers 6,563,020; 7,145,060
35 and 7,087,810.

(G) A polynucleotide encoding a molecule that stimulates signal transduction. For example, see the disclosure by Botella, *et al.*, (1994) *Plant Molec. Biol.* 24:757, of nucleotide sequences for mung bean calmodulin cDNA clones, and Griess, *et al.*, (1994) *Plant Physiol.* 104:1467, who provide the nucleotide sequence of a maize calmodulin cDNA clone.

(H) A polynucleotide encoding a hydrophobic moment peptide. See, PCT Application WO 1995/16776 and US Patent Number 5,580,852 (disclosure of peptide derivatives of Tachyplesin which inhibit fungal plant pathogens) and PCT Application WO 1995/18855 and US Patent Number 5,607,914 (teaches synthetic antimicrobial peptides that confer disease resistance).

(I) A polynucleotide encoding a membrane permease, a channel former or a channel blocker. For example, see the disclosure by Jaynes, *et al.*, (1993) *Plant Sci.* 89:43, of heterologous expression of a cecropin-beta lytic peptide analog to render transgenic tobacco plants resistant to *Pseudomonas solanacearum*.

(J) A gene encoding a viral-invasive protein or a complex toxin derived therefrom. For example, the accumulation of viral coat proteins in transformed plant cells imparts resistance to viral infection and/or disease development effected by the virus from which the coat protein gene is derived, as well as by related viruses. See, Beachy, *et al.*, (1990) *Ann. Rev. Phytopathol.* 28:451. Coat protein-mediated resistance has been conferred upon transformed plants against alfalfa mosaic virus, cucumber mosaic virus, tobacco streak virus, potato virus X, potato virus Y, tobacco etch virus, tobacco rattle virus and tobacco mosaic virus. *Id.*

(K) A gene encoding an insect-specific antibody or an immunotoxin derived therefrom. Thus, an antibody targeted to a critical metabolic function in the insect gut would inactivate an affected enzyme, killing the insect. Cf. Taylor, *et al.*, Abstract #497, SEVENTH INT'L SYMPOSIUM ON MOLECULAR PLANT-MICROBE INTERACTIONS (Edinburgh, Scotland, 1994) (enzymatic inactivation in transgenic tobacco via production of single-chain antibody fragments).

(L) A gene encoding a virus-specific antibody. See, for example, Tavladoraki, *et al.*, (1993) *Nature* 366:469, who show that transgenic plants expressing recombinant antibody genes are protected from virus attack.

(M) A polynucleotide encoding a developmental-arrestive protein produced in nature by a pathogen or a parasite. Thus, fungal endo alpha-1,4-D-polygalacturonases facilitate fungal colonization and plant nutrient release by solubilizing plant cell wall homo-alpha-1,4-D-galacturonase. See, Lamb, *et al.*, (1992) *Bio/Technology* 10:1436. The

cloning and characterization of a gene which encodes a bean endopolygalacturonase-inhibiting protein is described by Toubart, *et al.*, (1992) *Plant J.* 2:367.

(N) A polynucleotide encoding a developmental-arrestive protein produced in nature by a plant. For example, Logemann, *et al.*, (1992) *Bio/Technology* 10:305, have
5 shown that transgenic plants expressing the barley ribosome-inactivating gene have an increased resistance to fungal disease.

(O) Genes involved in the Systemic Acquired Resistance (SAR) Response and/or the pathogenesis related genes. Briggs, (1995) *Current Biology* 5(2), Pieterse and Van Loon, (2004) *Curr. Opin. Plant Bio.* 7(4):456-64 and Somssich, (2003) *Cell* 113(7):815-6.

10 (P) Antifungal genes (Cornelissen and Melchers, (1993) *Pl. Physiol.* 101:709-712 and Parijs, *et al.*, (1991) *Planta* 183:258-264 and Bushnell, *et al.*, (1998) *Can. J. of Plant Path.* 20(2):137-149. Also see, US Patent Application Serial Numbers 09/950,933; 11/619,645; 11/657,710; 11/748,994; 11/774,121 and US Patent Numbers 6,891,085 and 7,306,946. LysM Receptor-like kinases for the perception of chitin fragments as a first
15 step in plant defense response against fungal pathogens (US 2012/0110696).

(Q) Detoxification genes, such as for fumonisin, beauvericin, moniliformin and zearalenone and their structurally related derivatives. For example, see, US Patent Numbers 5,716,820; 5,792,931; 5,798,255; 5,846,812; 6,083,736; 6,538,177; 6,388,171 and 6,812,380.

20 (R) A polynucleotide encoding a Cystatin and cysteine proteinase inhibitors. See, US Patent Number 7,205,453.

(S) Defensin genes. See, WO 2003/000863 and US Patent Numbers 6,911,577; 6,855,865; 6,777,592 and 7,238,781.

(T) Genes conferring resistance to nematodes. See, e.g., PCT Application WO
25 1996/30517; PCT Application WO 1993/19181, WO 2003/033651 and Urwin, *et al.*, (1998) *Planta* 204:472-479, Williamson, (1999) *Curr Opin Plant Bio.* 2(4):327-31; US Patent Numbers 6,284,948 and 7,301,069 and miR164 genes (WO 2012/058266).

(U) Genes that confer resistance to Phytophthora Root Rot, such as the Rps 1, Rps 1-a, Rps 1-b, Rps 1-c, Rps 1-d, Rps 1-e, Rps 1-k, Rps 2, Rps 3-a, Rps 3-b, Rps 3-c,
30 Rps 4, Rps 5, Rps 6, Rps 7 and other Rps genes. See, for example, Shoemaker, *et al.*, Phytophthora Root Rot Resistance Gene Mapping in Soybean, Plant Genome IV Conference, San Diego, Calif. (1995).

(V) Genes that confer resistance to Brown Stem Rot, such as described in US Patent Number 5,689,035 and incorporated by reference for this purpose.

(W) Genes that confer resistance to *Colletotrichum*, such as described in US Patent Application Publication US 2009/0035765 and incorporated by reference for this purpose. This includes the Rcg locus that may be utilized as a single locus conversion.

5 **2. Transgenes that Confer Resistance to a Herbicide, for Example:**

(A) A polynucleotide encoding resistance to a herbicide that inhibits the growing point or meristem, such as an imidazolinone or a sulfonylurea. Exemplary genes in this category code for mutant ALS and AHAS enzyme as described, for example, by Lee, *et al.*, (1988) *EMBO J.* 7:1241 and Miki, *et al.*, (1990) *Theor. Appl. Genet.* 80:449,
10 respectively. See also, US Patent Numbers 5,605,011; 5,013,659; 5,141,870; 5,767,361; 5,731,180; 5,304,732; 4,761,373; 5,331,107; 5,928,937 and 5,378,824; US Patent Application Serial Number 11/683,737 and International Publication WO 1996/33270.

(B) A polynucleotide encoding a protein for resistance to Glyphosate (resistance imparted by mutant 5-enolpyruvyl-3-phosphokimate synthase (EPSP) and *aroA* genes,
15 respectively) and other phosphono compounds such as glufosinate (phosphinothricin acetyl transferase (PAT) and *Streptomyces hygroscopicus* phosphinothricin acetyl transferase (*bar*) genes), and pyridinoxy or phenoxy proprionic acids and cyclohexones (ACCase inhibitor-encoding genes). See, for example, US Patent Number 4,940,835 to Shah, *et al.*, which discloses the nucleotide sequence of a form of EPSPS which can
20 confer glyphosate resistance. US Patent Number 5,627,061 to Barry, *et al.*, also describes genes encoding EPSPS enzymes. See also, US Patent Numbers 6,566,587; 6,338,961; 6,248,876 B1; 6,040,497; 5,804,425; 5,633,435; 5,145,783; 4,971,908; 5,312,910; 5,188,642; 5,094,945, 4,940,835; 5,866,775; 6,225,114 B1; 6,130,366; 5,310,667; 4,535,060; 4,769,061; 5,633,448; 5,510,471; Re. 36,449; RE 37,287 E and
25 5,491,288 and International Publications EP 1173580; WO 2001/66704; EP 1173581 and EP 1173582, which are incorporated herein by reference for this purpose. Glyphosate resistance is also imparted to plants that express a gene encoding a glyphosate oxidoreductase enzyme as described more fully in US Patent Numbers 5,776,760 and 5,463,175, which are incorporated herein by reference for this purpose. In addition
30 glyphosate resistance can be imparted to plants by the over expression of genes encoding glyphosate N-acetyltransferase. See, for example, US Patent Numbers 7,462,481; 7,405,074 and US Patent Application Publication Number US 2008/0234130. A DNA molecule encoding a mutant *aroA* gene can be obtained under ATCC® Accession Number 39256, and the nucleotide sequence of the mutant gene is disclosed in US
35 Patent Number 4,769,061 to Comai. EP Application Number 0 333 033 to Kumada, *et al.*, and US Patent Number 4,975,374 to Goodman, *et al.*, disclose nucleotide sequences of

glutamine synthetase genes which confer resistance to herbicides such as L-phosphinothricin. The nucleotide sequence of a phosphinothricin-acetyl-transferase gene is provided in EP Application Numbers 0 242 246 and 0 242 236 to Leemans, *et al.*; De Greef, *et al.*, (1989) *Bio/Technology* 7:61, describe the production of transgenic plants
 5 that express chimeric bar genes coding for phosphinothricin acetyl transferase activity. See also, US Patent Numbers 5,969,213; 5,489,520; 5,550,318; 5,874,265; 5,919,675; 5,561,236; 5,648,477; 5,646,024; 6,177,616 B1 and 5,879,903, which are incorporated herein by reference for this purpose. Exemplary genes conferring resistance to phenoxy
 10 propionic acids and cyclohexones, such as sethoxydim and haloxyfop, are the Acc1-S1, Acc1-S2 and Acc1-S3 genes described by Marshall, *et al.*, (1992) *Theor. Appl. Genet.* 83:435.

(C) A polynucleotide encoding a protein for resistance to herbicide that inhibits photosynthesis, such as a triazine (psbA and gs+genes) and a benzonitrile (nitrilase gene). Przibilla, *et al.*, (1991) *Plant Cell* 3:169, describe the transformation of
 15 *Chlamydomonas* with plasmids encoding mutant psbA genes. Nucleotide sequences for nitrilase genes are disclosed in US Patent Number 4,810,648 to Stalker and DNA molecules containing these genes are available under ATCC[®] Accession Numbers 53435, 67441 and 67442. Cloning and expression of DNA coding for a glutathione S-transferase is described by Hayes, *et al.*, (1992) *Biochem. J.* 285:173.

(D) A polynucleotide encoding a protein for resistance to Acetohydroxy acid synthase, which has been found to make plants that express this enzyme resistant to
 20 multiple types of herbicides, has been introduced into a variety of plants (see, e.g., Hattori, *et al.*, (1995) *Mol Gen Genet.* 246:419). Other genes that confer resistance to herbicides include: a gene encoding a chimeric protein of rat cytochrome P4507A1 and yeast NADPH-cytochrome P450 oxidoreductase (Shiota, *et al.*, (1994) *Plant Physiol*
 25 106:17), genes for glutathione reductase and superoxide dismutase (Aono, *et al.*, (1995) *Plant Cell Physiol* 36:1687) and genes for various phosphotransferases (Datta, *et al.*, (1992) *Plant Mol Biol* 20:619).

(E) A polynucleotide encoding resistance to a herbicide targeting
 30 Protoporphyrinogen oxidase (protox) which is necessary for the production of chlorophyll. The protox enzyme serves as the target for a variety of herbicidal compounds. These herbicides also inhibit growth of all the different species of plants present, causing their total destruction. The development of plants containing altered protox activity which are resistant to these herbicides are described in US Patent Numbers 6,288,306 B1;
 35 6,282,837 B1 and 5,767,373 and International Publication WO 2001/12825.

(F) The aad-1 gene (originally from *Sphingobium herbicidovorans*) encodes the aryloxyalkanoate dioxygenase (AAD-1) protein. The trait confers tolerance to 2,4-dichlorophenoxyacetic acid and aryloxyphenoxypropionate (commonly referred to as “fop” herbicides such as quizalofop) herbicides. The aad-1 gene, itself, for herbicide tolerance in plants was first disclosed in WO 2005/107437 (see also, US 2009/0093366). The aad-12 gene, derived from *Delftia acidovorans*, which encodes the aryloxyalkanoate dioxygenase (AAD-12) protein that confers tolerance to 2,4-dichlorophenoxyacetic acid and pyridyloxyacetate herbicides by deactivating several herbicides with an aryloxyalkanoate moiety, including phenoxy auxin (e.g., 2,4-D, MCPA), as well as pyridyloxy auxins (e.g., fluroxypyr, triclopyr).

(G) A polynucleotide encoding a herbicide resistant dicamba monooxygenase disclosed in US Patent Application Publication 2003/0135879 for imparting dicamba tolerance;

(H) A polynucleotide molecule encoding bromoxynil nitrilase (Bxn) disclosed in US Patent Number 4,810,648 for imparting bromoxynil tolerance;

(I) A polynucleotide molecule encoding phytoene (crtl) described in Misawa, *et al.*, (1993) *Plant J.* 4:833-840 and in Misawa, *et al.*, (1994) *Plant J.* 6:481-489 for norflurazon tolerance.

3. Transgenes that Confer or Contribute to an Altered Grain Characteristic

Such as:

(A) Altered fatty acids, for example, by

(1) Down-regulation of stearyl-ACP to increase stearic acid content of the plant. See, Knultzon, *et al.*, (1992) *Proc. Natl. Acad. Sci. USA* 89:2624 and WO 1999/64579 (Genes to Alter Lipid Profiles in Corn).

(2) Elevating oleic acid via FAD-2 gene modification and/or decreasing linolenic acid via FAD-3 gene modification (see, US Patent Numbers 6,063,947; 6,323,392; 6,372,965 and WO 1993/11245).

(3) Altering conjugated linolenic or linoleic acid content, such as in WO 2001/12800.

(4) Altering LEC1, AGP, Dek1, Superal1, mi1 ps, various lpa genes such as lpa1, lpa3, hpt or hgg. For example, see, WO 2002/42424, WO 1998/22604, WO 2003/011015, WO 2002/057439, WO 2003/011015, US Patent Numbers 6,423,886, 6,197,561, 6,825,397 and US Patent Application Publication Numbers US 2003/0079247, US 2003/0204870 and Rivera-Madrid, *et al.*, (1995) *Proc. Natl. Acad. Sci.* 92:5620-5624.

(5) Genes encoding delta-8 desaturase for making long-chain polyunsaturated fatty acids (US Patent Numbers 8,058,571 and 8,338,152), delta-9 desaturase for lowering saturated fats (US Patent Number 8,063,269), Primula Δ 6-desaturase for improving omega-3 fatty acid profiles.

5 (6) Isolated nucleic acids and proteins associated with lipid and sugar metabolism regulation, in particular, lipid metabolism protein (LMP) used in methods of producing transgenic plants and modulating levels of seed storage compounds including lipids, fatty acids, starches or seed storage proteins and use in methods of modulating the seed size, seed number, seed weights, root length and leaf size of plants (EP 2404499).

10 (7) Altering expression of a High-Level Expression of Sugar-Inducible 2 (HSI2) protein in the plant to increase or decrease expression of HSI2 in the plant. Increasing expression of HSI2 increases oil content while decreasing expression of HSI2 decreases abscisic acid sensitivity and/or increases drought resistance (US Patent Application Publication Number 2012/0066794).

15 (8) Expression of cytochrome b5 (Cb5) alone or with FAD2 to modulate oil content in plant seed, particularly to increase the levels of omega-3 fatty acids and improve the ratio of omega-6 to omega-3 fatty acids (US Patent Application Publication Number 2011/0191904).

20 (9) Nucleic acid molecules encoding wrinkled1-like polypeptides for modulating sugar metabolism (US Patent Number 8,217,223).

(B) Altered phosphorus content, for example, by the

(1) Introduction of a phytase-encoding gene would enhance breakdown of phytate, adding more free phosphate to the transformed plant. For example, see, Van Hartingsveldt, *et al.*, (1993) *Gene* 127:87, for a disclosure of the nucleotide sequence of
25 an *Aspergillus niger* phytase gene.

(2) Modulating a gene that reduces phytate content. In maize, this, for example, could be accomplished, by cloning and then re-introducing DNA associated with one or more of the alleles, such as the LPA alleles, identified in maize mutants characterized by low levels of phytic acid, such as in WO 2005/113778 and/or by altering inositol kinase
30 activity as in WO 2002/059324, US Patent Application Publication Number 2003/0009011, WO 2003/027243, US Patent Application Publication Number 2003/0079247, WO 1999/05298, US Patent Number 6,197,561, US Patent Number 6,291,224, US Patent Number 6,391,348, WO 2002/059324, US Patent Application Publication Number 2003/0079247, WO 1998/45448, WO 1999/55882, WO 2001/04147.

35 (C) Altered carbohydrates affected, for example, by altering a gene for an enzyme that affects the branching pattern of starch or, a gene altering thioredoxin such as NTR

and/or TRX (see, US Patent Number 6,531,648. which is incorporated by reference for this purpose) and/or a gamma zein knock out or mutant such as cs27 or TUSC27 or en27 (see, US Patent Number 6,858,778 and US Patent Application Publication Number 2005/0160488, US Patent Application Publication Number 2005/0204418, which are incorporated by reference for this purpose). See, Shiroza, *et al.*, (1988) *J. Bacteriol.* 170:810 (nucleotide sequence of *Streptococcus* mutant fructosyltransferase gene), Steinmetz, *et al.*, (1985) *Mol. Gen. Genet.* 200:220 (nucleotide sequence of *Bacillus subtilis* levansucrase gene), Pen, *et al.*, (1992) *Bio/Technology* 10:292 (production of transgenic plants that express *Bacillus licheniformis* alpha-amylase), Elliot, *et al.*, (1993) *Plant Molec. Biol.* 21:515 (nucleotide sequences of tomato invertase genes), Sogaard, *et al.*, (1993) *J. Biol. Chem.* 268:22480 (site-directed mutagenesis of barley alpha-amylase gene) and Fisher, *et al.*, (1993) *Plant Physiol.* 102:1045 (maize endosperm starch branching enzyme II), WO 1999/10498 (improved digestibility and/or starch extraction through modification of UDP-D-xylose 4-epimerase, Fragile 1 and 2, Ref1, HCHL, C4H), US Patent Number 6,232,529 (method of producing high oil seed by modification of starch levels (AGP)). The fatty acid modification genes mentioned herein may also be used to affect starch content and/or composition through the interrelationship of the starch and oil pathways.

(D) Altered antioxidant content or composition, such as alteration of tocopherol or tocotrienols. For example, see, US Patent Number 6,787,683, US Patent Application Publication Number 2004/0034886 and WO 2000/68393 involving the manipulation of antioxidant levels and WO 2003/082899 through alteration of a homogentisate geranyl geranyl transferase (hggt).

(E) Altered essential seed amino acids. For example, see, US Patent Number 6,127,600 (method of increasing accumulation of essential amino acids in seeds), US Patent Number 6,080,913 (binary methods of increasing accumulation of essential amino acids in seeds), US Patent Number 5,990,389 (high lysine), WO 1999/40209 (alteration of amino acid compositions in seeds), WO 1999/29882 (methods for altering amino acid content of proteins), US Patent Number 5,850,016 (alteration of amino acid compositions in seeds), WO 1998/20133 (proteins with enhanced levels of essential amino acids), US Patent Number 5,885,802 (high methionine), US Patent Number 5,885,801 (high threonine), US Patent Number 6,664,445 (plant amino acid biosynthetic enzymes), US Patent Number 6,459,019 (increased lysine and threonine), US Patent Number 6,441,274 (plant tryptophan synthase beta subunit), US Patent Number 6,346,403 (methionine metabolic enzymes), US Patent Number 5,939,599 (high sulfur), US Patent Number 5,912,414 (increased methionine), WO 1998/56935 (plant amino acid biosynthetic

enzymes), WO 1998/45458 (engineered seed protein having higher percentage of essential amino acids), WO 1998/42831 (increased lysine), US Patent Number 5,633,436 (increasing sulfur amino acid content), US Patent Number 5,559,223 (synthetic storage proteins with defined structure containing programmable levels of essential amino acids for improvement of the nutritional value of plants), WO 1996/01905 (increased threonine), WO 1995/15392 (increased lysine), US Patent Application Publication Number 2003/0163838, US Patent Application Publication Number 2003/0150014, US Patent Application Publication Number 2004/0068767, US Patent Number 6,803,498, WO 2001/79516.

4. Genes that Control Male-Sterility:

There are several methods of conferring genetic male sterility available, such as multiple mutant genes at separate locations within the genome that confer male sterility, as disclosed in US Patent Numbers 4,654,465 and 4,727,219 to Brar, *et al.*, and chromosomal translocations as described by Patterson in US Patent Numbers 3,861,709 and 3,710,511. In addition to these methods, Albertsen, *et al.*, US Patent Number 5,432,068, describe a system of nuclear male sterility which includes: identifying a gene which is critical to male fertility; silencing this native gene which is critical to male fertility; removing the native promoter from the essential male fertility gene and replacing it with an inducible promoter; inserting this genetically engineered gene back into the plant; and thus creating a plant that is male sterile because the inducible promoter is not "on" resulting in the male fertility gene not being transcribed. Fertility is restored by inducing or turning "on", the promoter, which in turn allows the gene that confers male fertility to be transcribed.

(A) Introduction of a deacetylase gene under the control of a tapetum-specific promoter and with the application of the chemical N-Ac-PPT (WO 2001/29237).

(B) Introduction of various stamen-specific promoters (WO 1992/13956, WO 1992/13957).

(C) Introduction of the barnase and the barstar gene (Paul, *et al.*, (1992) *Plant Mol. Biol.* 19:611-622).

For additional examples of nuclear male and female sterility systems and genes, see also, US Patent Numbers 5,859,341; 6,297,426; 5,478,369; 5,824,524; 5,850,014 and 6,265,640, all of which are hereby incorporated by reference.

5. Genes that create a site for site specific DNA integration.

This includes the introduction of FRT sites that may be used in the FLP/FRT system and/or Lox sites that may be used in the Cre/Loxp system. For example, see, Lyznik, *et al.*, (2003) *Plant Cell Rep* 21:925-932 and WO 1999/25821, which are hereby
 5 incorporated by reference. Other systems that may be used include the Gin recombinase of phage Mu (Maeser, *et al.*, (1991) Vicki Chandler, The Maize Handbook ch. 118 (Springer-Verlag 1994), the Pin recombinase of E. coli (Enomoto, *et al.*, 1983) and the R/RS system of the pSRi plasmid (Araki, *et al.*, 1992).

10 6. Genes that affect abiotic stress resistance

Including but not limited to flowering, ear and seed development, enhancement of nitrogen utilization efficiency, altered nitrogen responsiveness, drought resistance or tolerance, cold resistance or tolerance and salt resistance or tolerance and increased yield under stress.

15 (A) For example, see: WO 2000/73475 where water use efficiency is altered through alteration of malate; US Patent Numbers 5,892,009, 5,965,705, 5,929,305, 5,891,859, 6,417,428, 6,664,446, 6,706,866, 6,717,034, 6,801,104, WO 2000/060089, WO 2001/026459, WO 2001/035725, WO 2001/034726, WO 2001/035727, WO 2001/036444, WO 2001/036597, WO 2001/036598, WO 2002/015675, WO 2002/017430,
 20 WO 2002/077185, WO 2002/079403, WO 2003/013227, WO 2003/013228, WO 2003/014327, WO 2004/031349, WO 2004/076638, WO 199809521.

(B) WO 199938977 describing genes, including CBF genes and transcription factors effective in mitigating the negative effects of freezing, high salinity and drought on plants, as well as conferring other positive effects on plant phenotype.

25 (C) US Patent Application Publication Number 2004/0148654 and WO 2001/36596 where abscisic acid is altered in plants resulting in improved plant phenotype such as increased yield and/or increased tolerance to abiotic stress.

(D) WO 2000/006341, WO 2004/090143, US Patent Numbers 7,531,723 and 6,992,237 where cytokinin expression is modified resulting in plants with increased stress
 30 tolerance, such as drought tolerance, and/or increased yield. Also see, WO 2002/02776, WO 2003/052063, JP 2002/281975, US Patent Number 6,084,153, WO 2001/64898, US Patent Number 6,177,275 and US Patent Number 6,107,547 (enhancement of nitrogen utilization and altered nitrogen responsiveness).

(E) For ethylene alteration, see, US Patent Application Publication Number
 35 2004/0128719, US Patent Application Publication Number 2003/0166197 and WO 2000/32761.

(F) For plant transcription factors or transcriptional regulators of abiotic stress, see, e.g., US Patent Application Publication Number 2004/0098764 or US Patent Application Publication Number 2004/0078852.

(G) Genes that increase expression of vacuolar pyrophosphatase such as AVP1
 5 (US Patent Number 8,058,515) for increased yield; nucleic acid encoding a HSFA4 or a HSFA5 (Heat Shock Factor of the class A4 or A5) polypeptides, an oligopeptide transporter protein (OPT4-like) polypeptide; a plastochron2-like (PLA2-like) polypeptide or a Wuschel related homeobox 1-like (WOX1-like) polypeptide (U. Patent Application Publication Number US 2011/0283420).

10 (H) Down regulation of polynucleotides encoding poly (ADP-ribose) polymerase (PARP) proteins to modulate programmed cell death (US Patent Number 8,058,510) for increased vigor.

(I) Polynucleotide encoding DTP21 polypeptides for conferring drought resistance (US Patent Application Publication Number US 2011/0277181).

15 (J) Nucleotide sequences encoding ACC Synthase 3 (ACS3) proteins for modulating development, modulating response to stress, and modulating stress tolerance (US Patent Application Publication Number US 2010/0287669).

(K) Polynucleotides that encode proteins that confer a drought tolerance phenotype (DTP) for conferring drought resistance (WO 2012/058528).

20 (L) Tocopherol cyclase (TC) genes for conferring drought and salt tolerance (US Patent Application Publication Number 2012/0272352).

(M) CAAX amino terminal family proteins for stress tolerance (US Patent Number 8,338,661).

(N) Mutations in the SAL1 encoding gene have increased stress tolerance,
 25 including increased drought resistant (US Patent Application Publication Number 2010/0257633).

(O) Expression of a nucleic acid sequence encoding a polypeptide selected from the group consisting of: GRF polypeptide, RAA1-like polypeptide, SYR polypeptide, ARKL polypeptide, and YTP polypeptide increasing yield-related traits (US Patent Application
 30 Publication Number 2011/0061133).

(P) Modulating expression in a plant of a nucleic acid encoding a Class III Trehalose Phosphate Phosphatase (TPP) polypeptide for enhancing yield-related traits in plants, particularly increasing seed yield (US Patent Application Publication Number 2010/0024067).

(Q) Expression of a nucleic acid sequence encoding a Drought Tolerant Phenotype (DTP6) polypeptide, specifically AT-DTP6 of US Patent Application Publication Number US-2014/0223595.

Other genes and transcription factors that affect plant growth and agronomic traits
 5 such as yield, flowering, plant growth and/or plant structure, can be introduced or introgressed into plants, see e.g., WO 1997/49811 (LHY), WO 1998/56918 (ESD4), WO 1997/10339 and US Patent Number 6,573,430 (TFL), US Patent Number 6,713,663 (FT), WO 1996/14414 (CON), WO 1996/38560, WO 2001/21822 (VRN1), WO 2000/44918 (VRN2), WO 1999/49064 (GI), WO 2000/46358 (FR1), WO 1997/29123, US Patent
 10 Number 6,794,560, US Patent Number 6,307,126 (GAI), WO 1999/09174 (D8 and Rht) and WO 2004/076638 and WO 2004/031349 (transcription factors).

7. Genes that confer increased yield

(A) A transgenic crop plant transformed by a 1-AminoCyclopropane-1-
 15 Carboxylate Deaminase-like Polypeptide (ACCDP) coding nucleic acid, wherein expression of the nucleic acid sequence in the crop plant results in the plant's increased root growth, and/or increased yield, and/or increased tolerance to environmental stress as compared to a wild type variety of the plant (US Patent Number 8,097,769).

(B) Over-expression of maize zinc finger protein gene (Zm-ZFP1) using a seed
 20 preferred promoter has been shown to enhance plant growth, increase kernel number and total kernel weight per plant (US Patent Application Publication Number 2012/0079623).

(C) Constitutive over-expression of maize lateral organ boundaries (LOB) domain protein (Zm-LOBDP1) has been shown to increase kernel number and total kernel weight per plant (US Patent Application Publication Number 2012/0079622).

25 (D) Enhancing yield-related traits in plants by modulating expression in a plant of a nucleic acid encoding a VIM1 (Variant in Methylation 1)-like polypeptide or a VTC2-like (GDP-L-galactose phosphorylase) polypeptide or a DUF1685 polypeptide or an ARF6-like (Auxin Responsive Factor) polypeptide (WO 2012/038893).

(E) Modulating expression in a plant of a nucleic acid encoding a Ste20-like
 30 polypeptide or a homologue thereof gives plants having increased yield relative to control plants (EP 2431472).

(F) Genes encoding nucleoside diphosphatase kinase (NDK) polypeptides and homologs thereof for modifying the plant's root architecture (US Patent Application Publication Number 2009/0064373).

8. Genes that confer plant digestibility.

(A) Altering the level of xylan present in the cell wall of a plant by modulating expression of xylan synthase (US Patent Number 8,173,866).

5 In some embodiment the stacked trait may be a trait or event that has received regulatory approval including but not limited to the events in Table 4A -4F.

Table 4A *Oryza sativa* Rice

Event	Company	Description
CL121, CL141, CFX51	BASF Inc.	Tolerance to the imidazolinone herbicide, imazethapyr, induced by chemical mutagenesis of the acetolactate synthase (ALS) enzyme using ethyl methanesulfonate (EMS).
IMINTA-1, IMINTA-4	BASF Inc.	Tolerance to imidazolinone herbicides induced by chemical mutagenesis of the acetolactate synthase (ALS) enzyme using sodium azide.
LLRICE06, LLRICE62	Aventis CropScience	Glufosinate ammonium herbicide tolerant rice produced by inserting a modified phosphinothricin acetyltransferase (PAT) encoding gene from the soil bacterium <i>Streptomyces hygroscopicus</i> .
LLRICE601	Bayer CropScience (Aventis CropScience(AgrEvo))	Glufosinate ammonium herbicide tolerant rice produced by inserting a modified phosphinothricin acetyltransferase (PAT) encoding gene from the soil bacterium <i>Streptomyces hygroscopicus</i> .
PWC16	BASF Inc.	Tolerance to the imidazolinone herbicide, imazethapyr, induced by chemical mutagenesis of the acetolactate synthase (ALS) enzyme using ethyl methanesulfonate (EMS).

10 Table 4B *Medicago sativa* Alfalfa

Event	Company	Description
J101, J163	Monsanto Company and Forage Genetics International	Glyphosate herbicide tolerant alfalfa (lucerne) produced by inserting a gene encoding the enzyme 5-enolpyruvylshikimate-3-phosphate synthase (EPSPS) from the CP4 strain of <i>Agrobacterium tumefaciens</i> .

Table 4C *Triticum aestivum* Wheat

15

Event	Company	Description
AP205CL	BASF Inc.	Selection for a mutagenized version of the enzyme acetohydroxyacid synthase (AHAS), also known as acetolactate synthase (ALS) or acetolactate pyruvate- lyase.
AP602CL	BASF Inc.	Selection for a mutagenized version of the enzyme acetohydroxyacid synthase (AHAS), also known as acetolactate synthase (ALS) or acetolactate pyruvate- lyase.
BW255-2, BW238-3	BASF Inc.	Selection for a mutagenized version of the enzyme acetohydroxyacid synthase (AHAS), also known as acetolactate synthase (ALS) or acetolactate pyruvate- lyase.

Event	Company	Description
BW7	BASF Inc.	Tolerance to imidazolinone herbicides induced by chemical mutagenesis of the acetohydroxyacid synthase (AHAS) gene using sodium azide.
MON71800	Monsanto Company	Glyphosate tolerant wheat variety produced by inserting a modified 5-enolpyruvylshikimate-3-phosphate synthase (EPSPS) encoding gene from the soil bacterium <i>Agrobacterium tumefaciens</i> , strain CP4.
SWP965001	Cyanamid Crop Protection	Selection for a mutagenized version of the enzyme acetohydroxyacid synthase (AHAS), also known as acetolactate synthase (ALS) or acetolactate pyruvate- lyase.
Teal 11A	BASF Inc.	Selection for a mutagenized version of the enzyme acetohydroxyacid synthase (AHAS), also known as acetolactate synthase (ALS) or acetolactate pyruvate- lyase.

Table 4D *Helianthus annuus* Sunflower

Event	Company	Description
X81359	BASF Inc.	Tolerance to imidazolinone herbicides by selection of a naturally occurring mutant.

5

Table 4E *Glycine max* L. Soybean

Event	Company	Description
A2704-12, A2704-21, A5547-35	Bayer CropScience (Aventis CropScience (AgrEvo))	Glufosinate ammonium herbicide tolerant soybean produced by inserting a modified phosphinothricin acetyltransferase (PAT) encoding gene from the soil bacterium <i>Streptomyces viridochromogenes</i> .
A5547-127	Bayer CropScience (Aventis CropScience (AgrEvo))	Glufosinate ammonium herbicide tolerant soybean produced by inserting a modified phosphinothricin acetyltransferase (PAT) encoding gene from the soil bacterium <i>Streptomyces viridochromogenes</i> .
BPS-CV127-9	BASF Inc.	The introduced <i>csr1-2</i> gene from <i>Arabidopsis thaliana</i> encodes an acetohydroxyacid synthase protein that confers tolerance to imidazolinone herbicides due to a point mutation that results in a single amino acid substitution in which the serine residue at position 653 is replaced by asparagine (S653N).
DP-305423	Pioneer Hi-Bred International Inc.	High oleic acid soybean produced by inserting additional copies of a portion of the omega-6 desaturase encoding gene, <i>gm-fad2-1</i> resulting in silencing of the endogenous omega-6 desaturase gene (<i>FAD2-1</i>).
DP356043	Pioneer Hi-Bred International Inc.	Soybean event with two herbicide tolerance genes: glyphosate N-acetyltransferase, which detoxifies glyphosate, and a modified acetolactate synthase (ALS) gene which is tolerant to ALS-inhibiting herbicides.

Event	Company	Description
G94-1, G94-19, G168	DuPont Canada Agricultural Products	High oleic acid soybean produced by inserting a second copy of the fatty acid desaturase (GmFad2-1) encoding gene from soybean, which resulted in "silencing" of the endogenous host gene.
GTS 40-3-2	Monsanto Company	Glyphosate tolerant soybean variety produced by inserting a modified 5-enolpyruvylshikimate-3-phosphate synthase (EPSPS) encoding gene from the soil bacterium <i>Agrobacterium tumefaciens</i> .
GU262	Bayer CropScience (Aventis CropScience(AgrEvo))	Glufosinate ammonium herbicide tolerant soybean produced by inserting a modified phosphinothricin acetyltransferase (PAT) encoding gene from the soil bacterium <i>Streptomyces viridochromogenes</i> .
MON87701	Monsanto Company	Resistance to Lepidopteran pests of soybean including velvetbean caterpillar (<i>Anticarsia gemmatilis</i>) and soybean looper (<i>Pseudoplusia includens</i>).
MON87701 x MON89788	Monsanto Company	Glyphosate herbicide tolerance through expression of the EPSPS encoding gene from <i>A. tumefaciens</i> strain CP4, and resistance to Lepidopteran pests of soybean including velvetbean caterpillar (<i>Anticarsia gemmatilis</i>) and soybean looper (<i>Pseudoplusia includens</i>) via expression of the Cry1Ac encoding gene from <i>B. thuringiensis</i> .
MON89788	Monsanto Company	Glyphosate-tolerant soybean produced by inserting a modified 5-enolpyruvylshikimate-3-phosphate synthase (EPSPS) encoding <i>aroA</i> (<i>epsps</i>) gene from <i>Agrobacterium tumefaciens</i> CP4.
OT96-15	Agriculture & Agri-Food Canada	Low linolenic acid soybean produced through traditional cross-breeding to incorporate the novel trait from a naturally occurring <i>fan1</i> gene mutant that was selected for low linolenic acid.
W62, W98	Bayer CropScience (Aventis CropScience(AgrEvo))	Glufosinate ammonium herbicide tolerant soybean produced by inserting a modified phosphinothricin acetyltransferase (PAT) encoding gene from the soil bacterium <i>Streptomyces hygroscopicus</i> .

Table 4F *Zea mays* L. Maize

Event	Company	Description
176	Syngenta Seeds, Inc.	Insect-resistant maize produced by inserting the <i>Cry1Ab</i> gene from <i>Bacillus thuringiensis</i> subsp. <i>kurstaki</i> . The genetic modification affords resistance to attack by the European corn borer (ECB).
3751IR	Pioneer Hi-Bred International Inc.	Selection of somaclonal variants by culture of embryos on imidazolinone containing media.

Event	Company	Description
676, 678, 680	Pioneer Hi-Bred International Inc.	Male-sterile and glufosinate ammonium herbicide tolerant maize produced by inserting genes encoding DNA adenine methylase and phosphinothricin acetyltransferase (PAT) from <i>Escherichia coli</i> and <i>Streptomyces viridochromogenes</i> , respectively.
B16 (DLL25)	Dekalb Genetics Corporation	Glufosinate ammonium herbicide tolerant maize produced by inserting the gene encoding phosphinothricin acetyltransferase (PAT) from <i>Streptomyces hygroscopicus</i> .
BT11 (X4334CBR, X4734CBR)	Syngenta Seeds, Inc.	Insect-resistant and herbicide tolerant maize produced by inserting the <i>Cry1Ab</i> gene from <i>Bacillus thuringiensis</i> subsp. <i>kurstaki</i> , and the phosphinothricin N-acetyltransferase (PAT) encoding gene from <i>S. viridochromogenes</i> .
BT11 x GA21	Syngenta Seeds, Inc.	Stacked insect resistant and herbicide tolerant maize produced by conventional cross breeding of parental lines BT11 (OECD unique identifier: SYN-BTO11-1) and GA21 (OECD unique identifier: MON-OOO21-9).
BT11 x MIR162 x MIR604 x GA21	Syngenta Seeds, Inc.	Resistance to Coleopteran pests, particularly corn rootworm pests (<i>Diabrotica</i> spp.) and several Lepidopteran pests of corn, including European corn borer (ECB, <i>Ostrinia nubilalis</i>), corn earworm (CEW, <i>Helicoverpa zea</i>), fall army worm (FAW, <i>Spodoptera frugiperda</i>), and black cutworm (BCW, <i>Agrotis ipsilon</i>); tolerance to glyphosate and glufosinate-ammonium containing herbicides.
BT11 x MIR162	Syngenta Seeds, Inc.	Stacked insect resistant and herbicide tolerant maize produced by conventional cross breeding of parental lines BT11 (OECD unique identifier: SYN-BTO11-1) and MIR162 (OECD unique identifier: SYN-IR162-4). Resistance to the European Corn Borer and tolerance to the herbicide glufosinate ammonium (Liberty) is derived from BT11, which contains the <i>Cry1Ab</i> gene from <i>Bacillus thuringiensis</i> subsp. <i>kurstaki</i> , and the phosphinothricin N-acetyltransferase (PAT) encoding gene from <i>S. viridochromogenes</i> . Resistance to other Lepidopteran pests, including <i>H. zea</i> , <i>S. frugiperda</i> , <i>A. ipsilon</i> , and <i>S. albicosta</i> , is derived from MIR162, which contains the <i>vip3Aa</i> gene from <i>Bacillus thuringiensis</i> strain AB88.
BT11 x MIR162 x MIR604	Syngenta Seeds, Inc.	<i>Bacillus thuringiensis</i> Cry1Ab delta-endotoxin protein and the genetic material necessary for its production (via elements of vector pZO1502) in Event Bt11 corn (OECD Unique Identifier: SYN-BTO11-1) x <i>Bacillus thuringiensis</i> Vip3Aa20 insecticidal protein and the genetic material necessary for its production (via elements of vector pNOV1300) in Event MIR162 maize (OECD Unique Identifier: SYN-IR162-4) x modified Cry3A protein and the genetic material necessary for its production (via elements of vector pZM26) in Event MIR604 corn (OECD Unique Identifier: SYN-IR604-5).

Event	Company	Description
CBH-351	Aventis CropScience	Insect-resistant and glufosinate ammonium herbicide tolerant maize developed by inserting genes encoding Cry9C protein from <i>Bacillus thuringiensis</i> subsp <i>tolworthi</i> and phosphinothricin acetyltransferase (PAT) from <i>Streptomyces hygroscopicus</i> .
DAS-06275-8	DOW AgroSciences LLC	Lepidopteran insect resistant and glufosinate ammonium herbicide-tolerant maize variety produced by inserting the <i>Cry1F</i> gene from <i>Bacillus thuringiensis</i> var <i>aizawai</i> and the phosphinothricin acetyltransferase (PAT) from <i>Streptomyces hygroscopicus</i> .
BT11 x MIR604	Syngenta Seeds, Inc.	Stacked insect resistant and herbicide tolerant maize produced by conventional cross breeding of parental lines BT11 (OECD unique identifier: SYN-BTO11-1) and MIR604 (OECD unique identifier: SYN-IR6O5-5). Resistance to the European Corn Borer and tolerance to the herbicide glufosinate ammonium (Liberty) is derived from BT11, which contains the <i>Cry1Ab</i> gene from <i>Bacillus thuringiensis</i> subsp. <i>kurstaki</i> , and the phosphinothricin N-acetyltransferase (PAT) encoding gene from <i>S. viridochromogenes</i> . Corn rootworm-resistance is derived from MIR604 which contains the <i>mCry3A</i> gene from <i>Bacillus thuringiensis</i> .
BT11 x MIR604 x GA21	Syngenta Seeds, Inc.	Stacked insect resistant and herbicide tolerant maize produced by conventional cross breeding of parental lines BT11 (OECD unique identifier: SYN-BTO11-1), MIR604 (OECD unique identifier: SYN-IR6O5-5) and GA21 (OECD unique identifier: MON-OOO21-9). Resistance to the European Corn Borer and tolerance to the herbicide glufosinate ammonium (Liberty) is derived from BT11, which contains the <i>Cry1Ab</i> gene from <i>Bacillus thuringiensis</i> subsp. <i>kurstaki</i> , and the phosphinothricin N-acetyltransferase (PAT) encoding gene from <i>S. viridochromogenes</i> . Corn rootworm-resistance is derived from MIR604 which contains the <i>mCry3A</i> gene from <i>Bacillus thuringiensis</i> . Tolerance to glyphosate herbicide is derived from GA21 which contains a modified EPSPS gene from maize.
DAS-59122-7	DOW AgroSciences LLC and Pioneer Hi-Bred International Inc.	Corn rootworm-resistant maize produced by inserting the <i>Cry34Ab1</i> and <i>Cry35Ab1</i> genes from <i>Bacillus thuringiensis</i> strain PS149B1. The PAT encoding gene from <i>Streptomyces viridochromogenes</i> was introduced as a selectable marker.

Event	Company	Description
DAS-59122-7 x TC1507 x NK603	DOW AgroSciences LLC and Pioneer Hi-Bred International Inc.	Stacked insect resistant and herbicide tolerant maize produced by conventional cross breeding of parental lines DAS-59122-7 (OECD unique identifier: DAS-59122-7) and TC1507 (OECD unique identifier: DAS-O15O7-1) with NK603 (OECD unique identifier: MON-OO6O3-6). Corn rootworm-resistance is derived from DAS-59122-7 which contains the <i>Cry34Ab1</i> and <i>Cry35Ab1</i> genes from <i>Bacillus thuringiensis</i> strain PS149B1. Lepidopteran resistance and tolerance to glufosinate ammonium herbicide is derived from TC1507. Tolerance to glyphosate herbicide is derived from NK603.
DBT418	Dekalb Genetics Corporation	Insect-resistant and glufosinate ammonium herbicide tolerant maize developed by inserting genes encoding Cry1AC protein from <i>Bacillus thuringiensis</i> subsp kurstaki and phosphinothricin acetyltransferase (PAT) from <i>Streptomyces hygroscopicus</i>
MIR604 x GA21	Syngenta Seeds, Inc.	Stacked insect resistant and herbicide tolerant maize produced by conventional cross breeding of parental lines MIR604 (OECD unique identifier: SYN-IR6O5-5) and GA21 (OECD unique identifier: MON-OOO21-9). Corn rootworm-resistance is derived from MIR604 which contains the <i>mCry3A</i> gene from <i>Bacillus thuringiensis</i> . Tolerance to glyphosate herbicide is derived from GA21.
MON80100	Monsanto Company	Insect-resistant maize produced by inserting the <i>Cry1Ab</i> gene from <i>Bacillus thuringiensis</i> subsp. kurstaki. The genetic modification affords resistance to attack by the European corn borer (ECB).
MON802	Monsanto Company	Insect-resistant and glyphosate herbicide tolerant maize produced by inserting the genes encoding the Cry1Ab protein from <i>Bacillus thuringiensis</i> and the 5-enolpyruvylshikimate-3-phosphate synthase (EPSPS) from <i>A. tumefaciens</i> strain CP4.
MON809	Pioneer Hi-Bred International Inc.	Resistance to European corn borer (<i>Ostrinia nubilalis</i>) by introduction of a synthetic Cry1Ab gene. Glyphosate resistance via introduction of the bacterial version of a plant enzyme, 5-enolpyruvyl shikimate-3-phosphate synthase (EPSPS).
MON810	Monsanto Company	Insect-resistant maize produced by inserting a truncated form of the <i>Cry1Ab</i> gene from <i>Bacillus thuringiensis</i> subsp. kurstaki HD-1. The genetic modification affords resistance to attack by the European corn borer (ECB).
MON810 x LY038	Monsanto Company	Stacked insect resistant and enhanced lysine content maize derived from conventional cross-breeding of the parental lines MON810 (OECD identifier: MON-OO81O-6) and LY038 (OECD identifier: REN-OOO38-3).

Event	Company	Description
MON810 x MON88017	Monsanto Company	Stacked insect resistant and glyphosate tolerant maize derived from conventional cross-breeding of the parental lines MON810 (OECD identifier: MON-OO81O-6) and MON88017 (OECD identifier:MON-88O17-3). European corn borer (ECB) resistance is derived from a truncated form of the <i>Cry1Ab</i> gene from <i>Bacillus thuringiensis</i> subsp. <i>kurstaki</i> HD-1 present in MON810. Corn rootworm resistance is derived from the <i>Cry3Bb1</i> gene from <i>Bacillus thuringiensis</i> subspecies <i>kumamotoensis</i> strain EG4691 present in MON88017. Glyphosate tolerance is derived from a 5-enolpyruvylshikimate-3-phosphate synthase (EPSPS) encoding gene from <i>Agrobacterium tumefaciens</i> strain CP4 present in MON88017.
MON832	Monsanto Company	Introduction, by particle bombardment, of glyphosate oxidase (GOX) and a modified 5-enolpyruvyl shikimate-3-phosphate synthase (EPSPS), an enzyme involved in the shikimate biochemical pathway for the production of the aromatic amino acids.
MON863	Monsanto Company	Corn rootworm resistant maize produced by inserting the <i>Cry3Bb1</i> gene from <i>Bacillus thuringiensis</i> subsp. <i>kumamotoensis</i> .
MON863 x MON810	Monsanto Company	Stacked insect resistant corn hybrid derived from conventional cross-breeding of the parental lines MON863 (OECD identifier: MON-OO863-5) and MON810 (OECD identifier: MON-OO81O-6)
MON863 x MON810 x NK603	Monsanto Company	Stacked insect resistant and herbicide tolerant corn hybrid derived from conventional cross-breeding of the stacked hybrid MON-OO863-5 x MON-OO81O-6 and NK603 (OECD identifier:MON-OO6O3-6).
MON863 x NK603	Monsanto Company	Stacked insect resistant and herbicide tolerant corn hybrid derived from conventional cross-breeding of the parental lines MON863 (OECD identifier:MON-OO863-5) and NK603 (OECD identifier: MON-OO6O3-6).
MON87460	Monsanto Company	MON 87460 was developed to provide reduced yield loss under water-limited conditions compared to conventional maize. Efficacy in MON 87460 is derived by expression of the inserted <i>Bacillus subtilis</i> cold shock protein B (CspB).
MON88017	Monsanto Company	Corn rootworm-resistant maize produced by inserting the <i>Cry3Bb1</i> gene from <i>Bacillus thuringiensis</i> subspecies <i>kumamotoensis</i> strain EG4691. Glyphosate tolerance derived by inserting a 5-enolpyruvylshikimate-3-phosphate synthase (EPSPS) encoding gene from <i>Agrobacterium tumefaciens</i> strain CP4.
MON89034	Monsanto Company	Maize event expressing two different insecticidal proteins from <i>Bacillus thuringiensis</i> providing resistance to number of Lepidopteran pests.

Event	Company	Description
MON89034 x MON88017	Monsanto Company	Stacked insect resistant and glyphosate tolerant maize derived from conventional cross-breeding of the parental lines MON89034 (OECD identifier: MON-89O34-3) and MON88017 (OECD identifier: MON-88O17-3). Resistance to Lepidopteran insects is derived from two <i>Cry</i> genes present in MON89043. Corn rootworm resistance is derived from a single <i>Cry</i> genes and glyphosate tolerance is derived from the 5-enolpyruvylshikimate-3-phosphate synthase (EPSPS) encoding gene from <i>Agrobacterium tumefaciens</i> present in MON88017.
MON89034 x NK603	Monsanto Company	Stacked insect resistant and herbicide tolerant maize produced by conventional cross breeding of parental lines MON89034 (OECD identifier: MON-89O34-3) with NK603 (OECD unique identifier: MON-OO6O3-6). Resistance to Lepidopteran insects is derived from two <i>Cry</i> genes present in MON89043. Tolerance to glyphosate herbicide is derived from NK603.
NK603 x MON810	Monsanto Company	Stacked insect resistant and herbicide tolerant corn hybrid derived from conventional cross-breeding of the parental lines NK603 (OECD identifier: MON-OO6O3-6) and MON810 (OECD identifier: MON-OO81O-6).
MON89034 x TC1507 x MON88017 x DAS- 59122-7	Monsanto Company and Mycogen Seeds c/o Dow AgroSciences LLC	Stacked insect resistant and herbicide tolerant maize produced by conventional cross breeding of parental lines: MON89034, TC1507, MON88017, and DAS-59122. Resistance to the above-ground and below-ground insect pests and tolerance to glyphosate and glufosinate-ammonium containing herbicides.
MS3	Bayer CropScience (Aventis CropScience(AgrEvo))	Male sterility caused by expression of the barnase ribonuclease gene from <i>Bacillus amyloliquefaciens</i> ; PPT resistance was via PPT-acetyltransferase (PAT).
MS6	Bayer CropScience (Aventis CropScience(AgrEvo))	Male sterility caused by expression of the barnase ribonuclease gene from <i>Bacillus amyloliquefaciens</i> ; PPT resistance was via PPT-acetyltransferase (PAT).
NK603	Monsanto Company	Introduction, by particle bombardment, of a modified 5-enolpyruvyl shikimate-3-phosphate synthase (EPSPS), an enzyme involved in the shikimate biochemical pathway for the production of the aromatic amino acids.
NK603 x T25	Monsanto Company	Stacked glufosinate ammonium and glyphosate herbicide tolerant maize hybrid derived from conventional cross-breeding of the parental lines NK603 (OECD identifier: MON-OO6O3-6) and T25 (OECD identifier: ACS-ZM003-2).
T25 x MON810	Bayer CropScience (Aventis CropScience(AgrEvo))	Stacked insect resistant and herbicide tolerant corn hybrid derived from conventional cross-breeding of the parental lines T25 (OECD identifier: ACS-ZMOO3-2) and MON810 (OECD identifier: MON-OO81O-6).

Event	Company	Description
TC1507	Mycogen (c/o Dow AgroSciences); Pioneer (c/o DuPont)	Insect-resistant and glufosinate ammonium herbicide tolerant maize produced by inserting the <i>Cry1F</i> gene from <i>Bacillus thuringiensis</i> var. <i>aizawai</i> and the phosphinothricin N-acetyltransferase encoding gene from <i>Streptomyces viridochromogenes</i> .
TC1507 x NK603	DOW AgroSciences LLC	Stacked insect resistant and herbicide tolerant corn hybrid derived from conventional cross-breeding of the parental lines 1507 (OECD identifier: DAS-O15O7-1) and NK603 (OECD identifier: MON-OO6O3-6).
TC1507 x DAS-59122-7	DOW AgroSciences LLC and Pioneer Hi-Bred International Inc.	Stacked insect resistant and herbicide tolerant maize produced by conventional cross breeding of parental lines TC1507 (OECD unique identifier: DAS-O15O7-1) with DAS-59122-7 (OECD unique identifier: DAS-59122-7). Resistance to Lepidopteran insects is derived from TC1507 due the presence of the <i>Cry1F</i> gene from <i>Bacillus thuringiensis</i> var. <i>aizawai</i> . Corn rootworm-resistance is derived from DAS-59122-7 which contains the <i>Cry34Ab1</i> and <i>Cry35Ab1</i> genes from <i>Bacillus thuringiensis</i> strain PS149B1. Tolerance to glufosinate ammonium herbicide is derived from TC1507 from the phosphinothricin N-acetyltransferase encoding gene from <i>Streptomyces viridochromogenes</i> .

Other events with regulatory approval are well known to one skilled in the art and can be found at the Center for Environmental Risk Assessment (ceramc.org/?action=gm_crop_database, which can be accessed using the www prefix) and
5 at the International Service for the Acquisition of Agri-Biotech Applications (isaaa.org/gmapprovaldatabase/default.asp, which can be accessed using the www prefix).

Gene silencing

In some embodiments the stacked trait may be in the form of silencing of one or
10 more polynucleotides of interest resulting in suppression of one or more target pest polypeptides. In some embodiments the silencing is achieved through the use of a suppression DNA construct.

In some embodiments one or more polynucleotide encoding the polypeptides of the PIP-72 polypeptides or fragments or variants thereof may be stacked with one or more
15 polynucleotides encoding one or more polypeptides having insecticidal activity or agronomic traits as set forth supra and optionally may further include one or more polynucleotides providing for gene silencing of one or more target polynucleotides as discussed infra.

“Suppression DNA construct” is a recombinant DNA construct which when transformed or stably integrated into the genome of the plant, results in “silencing” of a target gene in the plant. The target gene may be endogenous or transgenic to the plant. “Silencing,” as used herein with respect to the target gene, refers generally to the suppression of levels of mRNA or protein/enzyme expressed by the target gene, and/or the level of the enzyme activity or protein functionality. The term “suppression” includes lower, reduce, decline, decrease, inhibit, eliminate and prevent. “Silencing” or “gene silencing” does not specify mechanism and is inclusive, and not limited to, anti-sense, cosuppression, viral-suppression, hairpin suppression, stem-loop suppression, RNAi-based approaches and small RNA-based approaches.

A suppression DNA construct may comprise a region derived from a target gene of interest and may comprise all or part of the nucleic acid sequence of the sense strand (or antisense strand) of the target gene of interest. Depending upon the approach to be utilized, the region may be 100% identical or less than 100% identical (e.g., at least 50% or any integer between 51% and 100% identical) to all or part of the sense strand (or antisense strand) of the gene of interest.

Suppression DNA constructs are well-known in the art, are readily constructed once the target gene of interest is selected, and include, without limitation, cosuppression constructs, antisense constructs, viral-suppression constructs, hairpin suppression constructs, stem-loop suppression constructs, double-stranded RNA-producing constructs, and more generally, RNAi (RNA interference) constructs and small RNA constructs such as siRNA (short interfering RNA) constructs and miRNA (microRNA) constructs.

“Antisense inhibition” refers to the production of antisense RNA transcripts capable of suppressing the expression of the target protein.

“Antisense RNA” refers to an RNA transcript that is complementary to all or part of a target primary transcript or mRNA and that blocks the expression of a target isolated nucleic acid fragment (US Patent Number 5,107,065). The complementarity of an antisense RNA may be with any part of the specific gene transcript, i.e., at the 5′ non-coding sequence, 3′ non-coding sequence, introns or the coding sequence.

“Cosuppression” refers to the production of sense RNA transcripts capable of suppressing the expression of the target protein. “Sense” RNA refers to RNA transcript that includes the mRNA and can be translated into protein within a cell or in vitro. Cosuppression constructs in plants have been previously designed by focusing on overexpression of a nucleic acid sequence having homology to a native mRNA, in the sense orientation, which results in the reduction of all RNA having homology to the

overexpressed sequence (see, Vaucheret, *et al.*, (1998) *Plant J.* 16:651-659 and Gura, (2000) *Nature* 404:804-808).

Another variation describes the use of plant viral sequences to direct the suppression of proximal mRNA encoding sequences (PCT Publication WO 1998/36083).

5 Recent work has described the use of “hairpin” structures that incorporate all or part, of an mRNA encoding sequence in a complementary orientation that results in a potential “stem-loop” structure for the expressed RNA (PCT Publication WO 1999/53050). In this case the stem is formed by polynucleotides corresponding to the gene of interest inserted in either sense or anti-sense orientation with respect to the promoter and the loop
10 is formed by some polynucleotides of the gene of interest, which do not have a complement in the construct. This increases the frequency of cosuppression or silencing in the recovered transgenic plants. For review of hairpin suppression, see, Wesley, *et al.*, (2003) *Methods in Molecular Biology, Plant Functional Genomics: Methods and Protocols* 236:273-286.

15 A construct where the stem is formed by at least 30 nucleotides from a gene to be suppressed and the loop is formed by a random nucleotide sequence has also effectively been used for suppression (PCT Publication WO 1999/61632).

The use of poly-T and poly-A sequences to generate the stem in the stem-loop structure has also been described (PCT Publication WO 2002/00894).

20 Yet another variation includes using synthetic repeats to promote formation of a stem in the stem-loop structure. Transgenic organisms prepared with such recombinant DNA fragments have been shown to have reduced levels of the protein encoded by the nucleotide fragment forming the loop as described in PCT Publication WO 2002/00904.

RNA interference refers to the process of sequence-specific post-transcriptional
25 gene silencing in animals mediated by short interfering RNAs (siRNAs) (Fire, *et al.*, (1998) *Nature* 391:806). The corresponding process in plants is commonly referred to as post-transcriptional gene silencing (PTGS) or RNA silencing and is also referred to as quelling in fungi. The process of post-transcriptional gene silencing is thought to be an evolutionarily-conserved cellular defense mechanism used to prevent the expression of
30 foreign genes and is commonly shared by diverse flora and phyla (Fire, *et al.*, (1999) *Trends Genet.* 15:358). Such protection from foreign gene expression may have evolved in response to the production of double-stranded RNAs (dsRNAs) derived from viral infection or from the random integration of transposon elements into a host genome via a cellular response that specifically destroys homologous single-stranded RNA of viral
35 genomic RNA. The presence of dsRNA in cells triggers the RNAi response through a mechanism that has yet to be fully characterized.

The presence of long dsRNAs in cells stimulates the activity of a ribonuclease III enzyme referred to as dicer. Dicer is involved in the processing of the dsRNA into short pieces of dsRNA known as short interfering RNAs (siRNAs) (Bernstein, *et al.*, (2001) *Nature* 409:363). Short interfering RNAs derived from dicer activity are typically about 21 to about 23 nucleotides in length and comprise about 19 base pair duplexes (Elbashir, *et al.*, (2001) *Genes Dev.* 15:188). Dicer has also been implicated in the excision of 21- and 22-nucleotide small temporal RNAs (stRNAs) from precursor RNA of conserved structure that are implicated in translational control (Hutvagner, *et al.*, (2001) *Science* 293:834). The RNAi response also features an endonuclease complex, commonly referred to as an RNA-induced silencing complex (RISC), which mediates cleavage of single-stranded RNA having sequence complementarity to the antisense strand of the siRNA duplex. Cleavage of the target RNA takes place in the middle of the region complementary to the antisense strand of the siRNA duplex (Elbashir, *et al.*, (2001) *Genes Dev.* 15:188). In addition, RNA interference can also involve small RNA (e.g., miRNA) mediated gene silencing, presumably through cellular mechanisms that regulate chromatin structure and thereby prevent transcription of target gene sequences (see, e.g., Allshire, (2002) *Science* 297:1818-1819; Volpe, *et al.*, (2002) *Science* 297:1833-1837; Jenuwein, (2002) *Science* 297:2215-2218 and Hall, *et al.*, (2002) *Science* 297:2232-2237). As such, miRNA molecules of the disclosure can be used to mediate gene silencing via interaction with RNA transcripts or alternately by interaction with particular gene sequences, wherein such interaction results in gene silencing either at the transcriptional or post-transcriptional level.

Methods and compositions are further provided which allow for an increase in RNAi produced from the silencing element. In such embodiments, the methods and compositions employ a first polynucleotide comprising a silencing element for a target pest sequence operably linked to a promoter active in the plant cell; and, a second polynucleotide comprising a suppressor enhancer element comprising the target pest sequence or an active variant or fragment thereof operably linked to a promoter active in the plant cell. The combined expression of the silencing element with suppressor enhancer element leads to an increased amplification of the inhibitory RNA produced from the silencing element over that achievable with only the expression of the silencing element alone. In addition to the increased amplification of the specific RNAi species itself, the methods and compositions further allow for the production of a diverse population of RNAi species that can enhance the effectiveness of disrupting target gene expression. As such, when the suppressor enhancer element is expressed in a plant cell in combination with the silencing element, the methods and composition can allow for the

systemic production of RNAi throughout the plant; the production of greater amounts of RNAi than would be observed with just the silencing element construct alone; and, the improved loading of RNAi into the phloem of the plant, thus providing better control of phloem feeding insects by an RNAi approach. Thus, the various methods and compositions provide improved methods for the delivery of inhibitory RNA to the target organism. See, for example, US Patent Application Publication 2009/0188008.

As used herein, a “suppressor enhancer element” comprises a polynucleotide comprising the target sequence to be suppressed or an active fragment or variant thereof. It is recognized that the suppressor enhancer element need not be identical to the target sequence, but rather, the suppressor enhancer element can comprise a variant of the target sequence, so long as the suppressor enhancer element has sufficient sequence identity to the target sequence to allow for an increased level of the RNAi produced by the silencing element over that achievable with only the expression of the silencing element. Similarly, the suppressor enhancer element can comprise a fragment of the target sequence, wherein the fragment is of sufficient length to allow for an increased level of the RNAi produced by the silencing element over that achievable with only the expression of the silencing element.

It is recognized that multiple suppressor enhancer elements from the same target sequence or from different target sequences or from different regions of the same target sequence can be employed. For example, the suppressor enhancer elements employed can comprise fragments of the target sequence derived from different region of the target sequence (i.e., from the 3'UTR, coding sequence, intron, and/or 5'UTR). Further, the suppressor enhancer element can be contained in an expression cassette, as described elsewhere herein, and in specific embodiments, the suppressor enhancer element is on the same or on a different DNA vector or construct as the silencing element. The suppressor enhancer element can be operably linked to a promoter as disclosed herein. It is recognized that the suppressor enhancer element can be expressed constitutively or alternatively, it may be produced in a stage-specific manner employing the various inducible or tissue-preferred or developmentally regulated promoters that are discussed elsewhere herein.

In specific embodiments, employing both a silencing element and the suppressor enhancer element the systemic production of RNAi occurs throughout the entire plant. In further embodiments, the plant or plant parts of the disclosure have an improved loading of RNAi into the phloem of the plant than would be observed with the expression of the silencing element construct alone and, thus provide better control of phloem feeding insects by an RNAi approach. In specific embodiments, the plants, plant parts and plant

cells of the disclosure can further be characterized as allowing for the production of a diversity of RNAi species that can enhance the effectiveness of disrupting target gene expression.

5 In specific embodiments, the combined expression of the silencing element and the suppressor enhancer element increases the concentration of the inhibitory RNA in the plant cell, plant, plant part, plant tissue or phloem over the level that is achieved when the silencing element is expressed alone.

10 As used herein, an “increased level of inhibitory RNA” comprises any statistically significant increase in the level of RNAi produced in a plant having the combined expression when compared to an appropriate control plant. For example, an increase in the level of RNAi in the plant, plant part or the plant cell can comprise at least about a 1%, about a 1%-5%, about a 5%-10%, about a 10%-20%, about a 20%-30%, about a 30%-40%, about a 40%-50%, about a 50%-60%, about 60-70%, about 70%-80%, about a 80%-90%, about a 90%-100% or greater increase in the level of RNAi in the plant, plant
15 part, plant cell or phloem when compared to an appropriate control. In other embodiments, the increase in the level of RNAi in the plant, plant part, plant cell or phloem can comprise at least about a 1 fold, about a 1 fold-5 fold, about a 5 fold-10 fold, about a 10 fold-20 fold, about a 20 fold-30 fold, about a 30 fold-40 fold, about a 40 fold-50 fold, about a 50 fold-60 fold, about 60 fold-70 fold, about 70 fold-80 fold, about a 80 fold-
20 90 fold, about a 90 fold-100 fold or greater increase in the level of RNAi in the plant, plant part, plant cell or phloem when compared to an appropriate control. Examples of combined expression of the silencing element with suppressor enhancer element for the control of Stinkbugs and Lygus can be found in US Patent Application Publication 2011/0301223 and US Patent Application Publication 2009/0192117.

25 Some embodiments relate to down-regulation of expression of target genes in insect pest species by interfering ribonucleic acid (RNA) molecules. PCT Publication WO 2007/074405 describes methods of inhibiting expression of target genes in invertebrate pests including Colorado potato beetle. PCT Publication WO 2005/110068 describes methods of inhibiting expression of target genes in invertebrate pests including in
30 particular Western corn rootworm as a means to control insect infestation. Furthermore, PCT Publication WO 2009/091864 describes compositions and methods for the suppression of target genes from insect pest species including pests from the Lygus genus. Nucleic acid molecules including RNAi for targeting the vacuolar ATPase H subunit, useful for controlling a coleopteran pest population and infestation as described
35 in US Patent Application Publication 2012/0198586. PCT Publication WO 2012/055982 describes ribonucleic acid (RNA or double stranded RNA) that inhibits or down regulates

the expression of a target gene that encodes: an insect ribosomal protein such as the ribosomal protein L19, the ribosomal protein L40 or the ribosomal protein S27A; an insect proteasome subunit such as the Rpn6 protein, the Pros 25, the Rpn2 protein, the proteasome beta 1 subunit protein or the Pros beta 2 protein; an insect β -coatamer of the COPI vesicle, the γ -coatamer of the COPI vesicle, the β' - coatamer protein or the ζ -coatamer of the COPI vesicle; an insect Tetraspanine 2 A protein which is a putative transmembrane domain protein; an insect protein belonging to the actin family such as Actin 5C; an insect ubiquitin-5E protein; an insect Sec23 protein which is a GTPase activator involved in intracellular protein transport; an insect crinkled protein which is an unconventional myosin which is involved in motor activity; an insect crooked neck protein which is involved in the regulation of nuclear alternative mRNA splicing; an insect vacuolar H⁺-ATPase G-subunit protein and an insect Tbp-1 such as Tat-binding protein. US Patent Application Publications 2012/029750, US 20120297501, and 2012/0322660 describe interfering ribonucleic acids (RNA or double stranded RNA) that functions upon uptake by an insect pest species to down-regulate expression of a target gene in said insect pest, wherein the RNA comprises at least one silencing element wherein the silencing element is a region of double-stranded RNA comprising annealed complementary strands, one strand of which comprises or consists of a sequence of nucleotides which is at least partially complementary to a target nucleotide sequence within the target gene. US Patent Application Publication 2012/0164205 describes potential targets for interfering double stranded ribonucleic acids for inhibiting invertebrate pests including: a Chd3 Homologous Sequence, a Beta-Tubulin Homologous Sequence, a 40 kDa V-ATPase Homologous Sequence, a EF1 α Homologous Sequence, a 26S Proteasome Subunit p28 Homologous Sequence, a Juvenile Hormone Epoxide Hydrolase Homologous Sequence, a Swelling Dependent Chloride Channel Protein Homologous Sequence, a Glucose-6-Phosphate 1-Dehydrogenase Protein Homologous Sequence, an Act42A Protein Homologous Sequence, a ADP-Ribosylation Factor 1 Homologous Sequence, a Transcription Factor IIB Protein Homologous Sequence, a Chitinase Homologous Sequences, a Ubiquitin Conjugating Enzyme Homologous Sequence, a Glyceraldehyde-3-Phosphate Dehydrogenase Homologous Sequence, an Ubiquitin B Homologous Sequence, a Juvenile Hormone Esterase Homolog, and an Alpha Tubulin Homologous Sequence. US Patent Application Publication 2009/0192117 describes suppression of target polynucleotides from *Lygus*.

Use in Pesticidal Control

General methods for employing strains comprising a nucleic acid sequence of the embodiments or a variant thereof, in pesticide control or in engineering other organisms as pesticidal agents are known in the art. See, for example US Patent Number 5,039,523 and EP 0480762A2.

Microorganism hosts that are known to occupy the "phytosphere" (phylloplane, phyllosphere, rhizosphere, and/or rhizoplane) of one or more crops of interest may be selected. These microorganisms are selected so as to be capable of successfully competing in the particular environment with the wild-type microorganisms, provide for stable maintenance and expression of the gene expressing the PIP-72 polypeptide, and desirably, provide for improved protection of the pesticide from environmental degradation and inactivation.

Such microorganisms include bacteria, algae, and fungi. Of particular interest are microorganisms such as bacteria, e.g., *Pseudomonas*, *Erwinia*, *Serratia*, *Klebsiella*, *Xanthomonas*, *Streptomyces*, *Rhizobium*, *Rhodopseudomonas*, *Methylius*, *Agrobacterium*, *Acetobacter*, *Lactobacillus*, *Arthrobacter*, *Azotobacter*, *Leuconostoc*, and *Alcaligenes*, fungi, particularly yeast, e.g., *Saccharomyces*, *Cryptococcus*, *Kluyveromyces*, *Sporobolomyces*, *Rhodotorula*, and *Aureobasidium*. Of particular interest are such phytosphere bacterial species as *Pseudomonas syringae*, *Pseudomonas fluorescens*, *Pseudomonas chlororaphis*, *Serratia marcescens*, *Acetobacter xylinum*, *Agrobacteria*, *Rhodopseudomonas spheroides*, *Xanthomonas campestris*, *Rhizobium melioli*, *Alcaligenes entrophus*, *Clavibacter xyli* and *Azotobacter vinelandii* and phytosphere yeast species such as *Rhodotorula rubra*, *R. glutinis*, *R. marina*, *R. aurantiaca*, *Cryptococcus albidus*, *C. diffluens*, *C. laurentii*, *Saccharomyces rosei*, *S. pretoriensis*, *S. cerevisiae*, *Sporobolomyces roseus*, *S. odoratus*, *Kluyveromyces veronae*, and *Aureobasidium pollulans*. Of particular interest are the pigmented microorganisms. Host organisms of particular interest include yeast, such as *Rhodotorula* spp., *Aureobasidium* spp., *Saccharomyces* spp. (such as *S. cerevisiae*), *Sporobolomyces* spp., phylloplane organisms such as *Pseudomonas* spp. (such as *P. aeruginosa*, *P. fluorescens*, *P. chlororaphis*), *Erwinia* spp., and *Flavobacterium* spp., and other such organisms, including *Agrobacterium tumefaciens*, *E. coli*, *Bacillus subtilis*, *Bacillus cereus* and the like.

Genes encoding the PIP-72 polypeptides of the embodiments can be introduced into microorganisms that multiply on plants (epiphytes) to deliver PIP-72 polypeptides to potential target pests. Epiphytes, for example, can be gram-positive or gram-negative bacteria.

Root-colonizing bacteria, for example, can be isolated from the plant of interest by methods known in the art. Specifically, a *Bacillus cereus* strain that colonizes roots can be isolated from roots of a plant (see, for example, Handelsman *et al.* (1991) *Appl. Environ. Microbiol.* 56:713-718). Genes encoding the PIP-72 polypeptides of the
5 embodiments can be introduced into a root-colonizing *Bacillus cereus* by standard methods known in the art.

Genes encoding PIP-72 polypeptides can be introduced, for example, into the root-colonizing *Bacillus* by means of electro transformation. Specifically, genes encoding the PIP-72 polypeptides can be cloned into a shuttle vector, for example, pHT3101
10 (Lerecius, *et al.*, (1989) *FEMS Microbiol. Letts.* 60:211-218. The shuttle vector pHT3101 containing the coding sequence for the particular PIP-72 polypeptide gene can, for example, be transformed into the root-colonizing *Bacillus* by means of electroporation (Lerecius, *et al.*, (1989) *FEMS Microbiol. Letts.* 60:211-218).

Expression systems can be designed so that PIP-72 polypeptides are secreted
15 outside the cytoplasm of gram-negative bacteria, such as *E. coli*, for example. Advantages of having PIP-72 polypeptides secreted are: (1) avoidance of potential cytotoxic effects of the PIP-72 polypeptide expressed; and (2) improvement in the efficiency of purification of the PIP-72 polypeptide, including, but not limited to, increased efficiency in the recovery and purification of the protein per volume cell broth and
20 decreased time and/or costs of recovery and purification per unit protein.

PIP-72 polypeptides can be made to be secreted in *E. coli*, for example, by fusing an appropriate *E. coli* signal peptide to the amino-terminal end of the PIP-72 polypeptide. Signal peptides recognized by *E. coli* can be found in proteins already known to be secreted in *E. coli*, for example the OmpA protein (Ghrayeb, *et al.*, (1984) *EMBO J*,
25 3:2437-2442). OmpA is a major protein of the *E. coli* outer membrane, and thus its signal peptide is thought to be efficient in the translocation process. Also, the OmpA signal peptide does not need to be modified before processing as may be the case for other signal peptides, for example lipoprotein signal peptide (Duffaud, *et al.*, (1987) *Meth. Enzymol.* 153:492).

PIP-72 polypeptides of the embodiments can be fermented in a bacterial host and the resulting bacteria processed and used as a microbial spray in the same manner that *Bt* strains have been used as insecticidal sprays. In the case of a PIP-72 polypeptide(s) that is secreted from *Bacillus*, the secretion signal is removed or mutated using procedures known in the art. Such mutations and/or deletions prevent secretion of the
35 PIP-72 polypeptide(s) into the growth medium during the fermentation process. The PIP-72 polypeptides are retained within the cell, and the cells are then processed to yield the

encapsulated PIP-72 polypeptides. Any suitable microorganism can be used for this purpose. *Pseudomonas* has been used to express *Bt* toxins as encapsulated proteins and the resulting cells processed and sprayed as an insecticide (Gaertner, *et al.*, (1993), in: *Advanced Engineered Pesticides*, ed. Kim).

5 Alternatively, the PIP-72 polypeptides are produced by introducing a heterologous gene into a cellular host. Expression of the heterologous gene results, directly or indirectly, in the intracellular production and maintenance of the pesticide. These cells are then treated under conditions that prolong the activity of the toxin produced in the cell when the cell is applied to the environment of target pest(s). The resulting product retains
10 the toxicity of the toxin. These naturally encapsulated PIP-72 polypeptides may then be formulated in accordance with conventional techniques for application to the environment hosting a target pest, e.g., soil, water, and foliage of plants. See, for example EPA 0192319, and the references cited therein.

15 Pesticidal Compositions

In some embodiments the active ingredients can be applied in the form of compositions and can be applied to the crop area or plant to be treated, simultaneously or in succession, with other compounds. These compounds can be fertilizers, weed killers, Cryoprotectants, surfactants, detergents, pesticidal soaps, dormant oils, polymers, and/or
20 time-release or biodegradable carrier formulations that permit long-term dosing of a target area following a single application of the formulation. They can also be selective herbicides, chemical insecticides, virucides, microbicides, amoebicides, pesticides, fungicides, bacteriocides, nematocides, molluscicides or mixtures of several of these preparations, if desired, together with further agriculturally acceptable carriers, surfactants
25 or application-promoting adjuvants customarily employed in the art of formulation. Suitable carriers and adjuvants can be solid or liquid and correspond to the substances ordinarily employed in formulation technology, e.g. natural or regenerated mineral substances, solvents, dispersants, wetting agents, tackifiers, binders or fertilizers. Likewise the formulations may be prepared into edible "baits" or fashioned into pest
30 "traps" to permit feeding or ingestion by a target pest of the pesticidal formulation.

Methods of applying an active ingredient or an agrochemical composition that contains at least one of the PIP-72 polypeptides produced by the bacterial strains include leaf application, seed coating and soil application. The number of applications and the rate of application depend on the intensity of infestation by the corresponding pest.

35 The composition may be formulated as a powder, dust, pellet, granule, spray, emulsion, colloid, solution or such like, and may be prepared by such conventional means

as desiccation, lyophilization, homogenation, extraction, filtration, centrifugation, sedimentation or concentration of a culture of cells comprising the polypeptide. In all such compositions that contain at least one such pesticidal polypeptide, the polypeptide may be present in a concentration of from about 1% to about 99% by weight.

5 Lepidopteran, Dipteran, Heteropteran, nematode, Hemiptera or Coleopteran pests may be killed or reduced in numbers in a given area by the methods of the disclosure or may be prophylactically applied to an environmental area to prevent infestation by a susceptible pest. Preferably the pest ingests or is contacted with, a pesticidally-effective amount of the polypeptide. "Pesticidally-effective amount" as used herein refers to an
10 amount of the pesticide that is able to bring about death to at least one pest or to noticeably reduce pest growth, feeding or normal physiological development. This amount will vary depending on such factors as, for example, the specific target pests to be controlled, the specific environment, location, plant, crop or agricultural site to be treated, the environmental conditions and the method, rate, concentration, stability, and quantity of
15 application of the pesticidally-effective polypeptide composition. The formulations may also vary with respect to climatic conditions, environmental considerations, and/or frequency of application and/or severity of pest infestation.

 The pesticide compositions described may be made by formulating either the bacterial cell, Crystal and/or spore suspension or isolated protein component with the
20 desired agriculturally-acceptable carrier. The compositions may be formulated prior to administration in an appropriate means such as lyophilized, freeze-dried, desiccated or in an aqueous carrier, medium or suitable diluent, such as saline or other buffer. The formulated compositions may be in the form of a dust or granular material or a suspension in oil (vegetable or mineral) or water or oil/water emulsions or as a wettable powder or in
25 combination with any other carrier material suitable for agricultural application. Suitable agricultural carriers can be solid or liquid and are well known in the art. The term "agriculturally-acceptable carrier" covers all adjuvants, inert components, dispersants, surfactants, tackifiers, binders, etc. that are ordinarily used in pesticide formulation technology; these are well known to those skilled in pesticide formulation. The
30 formulations may be mixed with one or more solid or liquid adjuvants and prepared by various means, e.g., by homogeneously mixing, blending and/or grinding the pesticidal composition with suitable adjuvants using conventional formulation techniques. Suitable formulations and application methods are described in US Patent Number 6,468,523, herein incorporated by reference. The plants can also be treated with one or more
35 chemical compositions, including one or more herbicide, insecticides or fungicides. Exemplary chemical compositions include: Fruits/Vegetables Herbicides: Atrazine,

Bromacil, Diuron, Glyphosate, Linuron, Metribuzin, Simazine, Trifluralin, Fluazifop, Glufosinate, Halo sulfuron Gowan, Paraquat, Propyzamide, Sethoxydim, Butafenacil, Halosulfuron, Indaziflam; Fruits/Vegetables Insecticides: Aldicarb, *Bacillus thuriangiensis*, Carbaryl, Carbofuran, Chlorpyrifos, Cypermethrin, Deltamethrin, Diazinon, Malathion,

5 Abamectin, Cyfluthrin/beta-cyfluthrin, Esfenvalerate, Lambda-cyhalothrin, Acequinocyl, Bifenazate, Methoxyfenozide, Novaluron, Chromafenozide, Thiacloprid, Dinotefuran, FluaCrypyrim, Tolfenpyrad, Clothianidin, Spirodiclofen, Gamma-cyhalothrin, Spiromesifen, Spinosad, Rynaxypyr, Cyazypyr, Spinoteram, Triflumuron, Spirotetramat, Imidacloprid, Flubendiamide, Thiodicarb, Metaflumizone, Sulfoxaflor, Cyflumetofen, Cyanopyrafen,

10 Imidacloprid, Clothianidin, Thiamethoxam, Spinotoram, Thiodicarb, Flonicamid, Methiocarb, Emamectin-benzoate, Indoxacarb, Forthiazate, Fenamiphos, Cadusaphos, Pyriproxifen, Fenbutatin-oxid, Hexthiazox, Methomyl, 4-[[[(6-Chlorpyridin-3-yl)methyl](2,2-difluorethyl)amino]furan-2(5H)-on; Fruits/Vegetables Fungicides: Carbendazim, Chlorothalonil, EBDCs, Sulphur, Thiophanate-methyl, Azoxystrobin, Cymoxanil,

15 Fluazinam, Fosetyl, Iprodione, Kresoxim-methyl, Metalaxyl/mefenoxam, Trifloxystrobin, Ethaboxam, Iprovalicarb, Trifloxystrobin, Fenhexamid, Oxpoconazole fumarate, Cyazofamid, Fenamidone, Zoxamide, Picoxystrobin, Pyraclostrobin, Cyflufenamid, Boscalid; Cereals Herbicides: Isoproturon, Bromoxynil, Ioxynil, Phenoxies, Chlorsulfuron, Clodinafop, Diclofop, Diflufenican, Fenoxaprop, Florasulam, Fluoroxypyr, Metsulfuron,

20 Triasulfuron, Flucarbazone, Iodosulfuron, Propoxycarbazon, Picolinafen, Mesosulfuron, Beflubutamid, Pinoxaden, Amidosulfuron, Thifensulfuron Methyl, Tribenuron, Flupyrsulfuron, Sulfosulfuron, Pyrasulfotole, Pyroxsulam, Flufenacet, Tralkoxydim, Pyroxasulfon; Cereals Fungicides: Carbendazim, Chlorothalonil, Azoxystrobin, Cyproconazole, Cyprodinil, Fenpropimorph, Epoxiconazole, Kresoxim-methyl,

25 Quinoxifen, Tebuconazole, Trifloxystrobin, Simeconazole, Picoxystrobin, Pyraclostrobin, Dimoxystrobin, Prothioconazole, Fluoxastrobin; Cereals Insecticides: Dimethoate, Lambda-cyhalothrin, Deltamethrin, alpha-Cypermethrin, beta-cyfluthrin, Bifenthrin, Imidacloprid, Clothianidin, Thiamethoxam, Thiacloprid, Acetamiprid, Dinotefuran, Clorphyriphos, Metamidophos, Oxidemethon-methyl, Pirimicarb, Methiocarb; Maize

30 Herbicides: Atrazine, Alachlor, Bromoxynil, Acetochlor, Dicamba, Clopyralid, (S-) Dimethenamid, Glufosinate, Glyphosate, Isoxaflutole, (S-)Metolachlor, Mesotrione, Nicosulfuron, Primisulfuron, Rimsulfuron, Sulcotrione, Foramsulfuron, Topramezone, Tembotrione, Saflufenacil, Thiencarbazon, Flufenacet, Pyroxasulfon; Maize Insecticides: Carbofuran, Chlorpyrifos, Bifenthrin, Fipronil, Imidacloprid, Lambda-Cyhalothrin,

35 Tefluthrin, Terbufos, Thiamethoxam, Clothianidin, Spiromesifen, Flubendiamide, Triflumuron, Rynaxypyr, Deltamethrin, Thiodicarb, beta-Cyfluthrin, Cypermethrin, Bifenthrin,

Lufenuron, Triflumuron, Tefluthrin, Tebupirimphos, Ethiprole, Cyazypyr, Thiacloprid, Acetamiprid, Dinotofuran, Avermectin, Methiocarb, Spirodiclofen, Spirotetramat; Maize Fungicides: Fenitropan, Thiram, Prothioconazole, Tebuconazole, Trifloxystrobin; Rice Herbicides: Butachlor, Propanil, Azimsulfuron, Bensulfuron, Cyhalofop, Daimuron, Fentrazamide, Imazosulfuron, Mefenacet, Oxaziclomefone, Pyrazosulfuron, Pyributicarb, Quinclorac, Thiobencarb, Indanofan, Flufenacet, Fentrazamide, Halosulfuron, Oxaziclomefone, Benzobicyclon, Pyriftalid, Penoxsulam, Bispyribac, Oxadiargyl, Ethoxysulfuron, Pretilachlor, Mesotrione, Tefuryltrione, Oxadiazon, Fenoxaprop, Pyrimisulfan; Rice Insecticides: Diazinon, Fenitrothion, Fenobucarb, Monocrotophos, Benfuracarb, Buprofezin, Dinotofuran, Fipronil, Imidacloprid, Isoprocarb, Thiacloprid, Chromafenozide, Thiacloprid, Dinotofuran, Clothianidin, Ethiprole, Flubendiamide, Rynaxypyr, Deltamethrin, Acetamiprid, Thiamethoxam, Cyazypyr, Spinosad, Spinotoram, Emamectin-Benzoate, Cypermethrin, Chlorpyrifos, Cartap, Methamidophos, Etofenprox, Triazophos, 4-[[[(6-Chlorpyridin-3-yl)methyl](2,2-difluorethyl)amino]furan-2(5H)-on, Carbofuran, Benfuracarb; Rice Fungicides: Thiophanate-methyl, Azoxystrobin, Carpropamid, Edifenphos, Ferimzone, Iprobenfos, Isoprothiolane, Pencycuron, Probenazole, Pyroquilon, Tricyclazole, Trifloxystrobin, Diclocymet, Fenoxanil, Simeconazole, Tiadinil; Cotton Herbicides: Diuron, Fluometuron, MSMA, Oxyfluorfen, Prometryn, Trifluralin, Carfentrazone, Clethodim, Fluazifop-butyl, Glyphosate, Norflurazon, Pendimethalin, Pyriithiobac-sodium, Trifloxysulfuron, Tepraloxymdim, Glufosinate, Flumioxazin, Thidiazuron; Cotton Insecticides: Acephate, Aldicarb, Chlorpyrifos, Cypermethrin, Deltamethrin, Malathion, Monocrotophos, Abamectin, Acetamiprid, Emamectin Benzoate, Imidacloprid, Indoxacarb, Lambda-Cyhalothrin, Spinosad, Thiodicarb, Gamma-Cyhalothrin, Spiromesifen, Pyridalyl, Flonicamid, Flubendiamide, Triflumuron, Rynaxypyr, Beta-Cyfluthrin, Spirotetramat, Clothianidin, Thiamethoxam, Thiacloprid, Dinotofuran, Flubendiamide, Cyazypyr, Spinosad, Spinotoram, gamma Cyhalothrin, 4-[[[(6-Chlorpyridin-3-yl)methyl](2,2-difluorethyl)amino]furan-2(5H)-on, Thiodicarb, Avermectin, Flonicamid, Pyridalyl, Spiromesifen, Sulfoxaflor, Profenophos, Thiazophos, Endosulfan; Cotton Fungicides: Etridiazole, Metalaxyl, Quintozene; Soybean Herbicides: Alachlor, Bentazone, Trifluralin, Chlorimuron-Ethyl, Cloransulam-Methyl, Fenoxaprop, Fomesafen, Fluazifop, Glyphosate, Imazamox, Imazaquin, Imazethapyr, (S-)Metolachlor, Metribuzin, Pendimethalin, Tepraloxymdim, Glufosinate; Soybean Insecticides: Lambda-cyhalothrin, Methomyl, Parathion, Thiocarb, Imidacloprid, Clothianidin, Thiamethoxam, Thiacloprid, Acetamiprid, Dinotofuran, Flubendiamide, Rynaxypyr, Cyazypyr, Spinosad, Spinotoram, Emamectin-Benzoate, Fipronil, Ethiprole, Deltamethrin, β -Cyfluthrin, gamma and lambda Cyhalothrin,

4-[[[(6-Chlorpyridin-3-yl)methyl](2,2-difluorethyl)amino]furan-2(5H)-on, Spirotetramat, Spinodiclofen, Triflumuron, Flonicamid, Thiodicarb, beta-Cyfluthrin; Soybean Fungicides: Azoxystrobin, Cyproconazole, Epoxiconazole, Flutriafol, Pyraclostrobin, Tebuconazole, Trifloxystrobin, Prothioconazole, Tetraconazole; Sugarbeet Herbicides: Chloridazon, Desmedipham, Ethofumesate, Phenmedipham, Triallate, Clopyralid, Fluazifop, Lenacil, Metamitron, Quinmerac, Cycloxydim, Triflusulfuron, Tepraloxydim, Quizalofop; Sugarbeet Insecticides: Imidacloprid, Clothianidin, Thiamethoxam, Thiacloprid, Acetamiprid, Dinetofuran, Deltamethrin, β -Cyfluthrin, gamma/lambda Cyhalothrin, 4-[[[(6-Chlorpyridin-3-yl)methyl](2,2-difluorethyl)amino]furan-2(5H)-on, Tefluthrin, Rynaxypyr, Cyaxypyr, Fipronil, Carbofuran; Canola Herbicides: Clopyralid, Diclofop, Fluazifop, Glufosinate, Glyphosate, Metazachlor, Trifluralin Ethametsulfuron, Quinmerac, Quizalofop, Clethodim, Tepraloxydim; Canola Fungicides: Azoxystrobin, Carbendazim, Fludioxonil, Iprodione, Prochloraz, Vinclozolin; Canola Insecticides: Carbofuran organophosphates, Pyrethroids, Thiacloprid, Deltamethrin, Imidacloprid, Clothianidin, Thiamethoxam, Acetamiprid, Dinetofuran, β -Cyfluthrin, gamma and lambda Cyhalothrin, tau-Fluvalerate, Ethiprole, Spinosad, Spinotoram, Flubendiamide, Rynaxypyr, Cyazypyr, 4-[[[(6-Chlorpyridin-3-yl)methyl](2,2-difluorethyl)amino]furan-2(5H)-on.

In some embodiments the herbicide is Atrazine, Bromacil, Diuron, Chlorsulfuron, Metsulfuron, Thifensulfuron Methyl, Tribenuron, Acetochlor, Dicamba, Isoxaflutole, Nicosulfuron, Rimsulfuron, Pyriithiobac-sodium, Flumioxazin, Chlorimuron-Ethyl, Metribuzin, Quizalofop, S-metolachlor, Hexazinone or combinations thereof.

In some embodiments the insecticide is Esfenvalerate, Chlorantraniliprole, Methomyl, Indoxacarb, Oxamyl or combinations thereof.

In some embodiment the herbicide is a homogentisate solanesyltransferase (HST) inhibiting herbicide and/or hydroxyphenyl pyruvate dioxygenase (HPPD) inhibiting herbicide of US Patent Publication US2011173718.

Pesticidal and insecticidal activity

“Pest” includes but is not limited to, insects, fungi, bacteria, nematodes, mites, ticks and the like. Insect pests include insects selected from the orders Coleoptera, Diptera, Hymenoptera, Lepidoptera, Mallophaga, Homoptera, Hemiptera Orthoptera, Thysanoptera, Dermaptera, Isoptera, Anoplura, Siphonaptera, Trichoptera, etc., particularly Lepidoptera and Coleoptera.

Those skilled in the art will recognize that not all compounds are equally effective against all pests. Compounds of the embodiments display activity against insect pests, which may include economically important agronomic, forest, greenhouse, nursery

ornamentals, food and fiber, public and animal health, domestic and commercial structure, household and stored product pests.

Larvae of the order Lepidoptera include, but are not limited to, armyworms, cutworms, loopers and heliothines in the family Noctuidae *Spodoptera frugiperda* JE
 5 Smith (fall armyworm); *S. exigua* Hübner (beet armyworm); *S. litura* Fabricius (tobacco cutworm, cluster caterpillar); *Mamestra configurata* Walker (bertha armyworm); *M. brassicae* Linnaeus (cabbage moth); *Agrotis ipsilon* Hufnagel (black cutworm); *A. orthogonia* Morrison (western cutworm); *A. subterranea* Fabricius (granulate cutworm);
 10 *Alabama argillacea* Hübner (cotton leaf worm); *Trichoplusia ni* Hübner (cabbage looper); *Pseudoplusia includens* Walker (soybean looper); *Anticarsia gemmatilis* Hübner (velvetbean caterpillar); *Hypena scabra* Fabricius (green cloverworm); *Heliothis virescens* Fabricius (tobacco budworm); *Pseudaletia unipuncta* Haworth (armyworm); *Athetis mindara* Barnes and McDunnough (rough skinned cutworm); *Euxoa messoria* Harris (darksided cutworm); *Earias insulana* Boisduval (spiny bollworm); *E. vittella* Fabricius
 15 (spotted bollworm); *Helicoverpa armigera* Hübner (American bollworm); *H. zea* Boddie (corn earworm or cotton bollworm); *Melanchra picta* Harris (zebra caterpillar); *Egira (Xylomyges) curialis* Grote (citrus cutworm); borers, casebearers, webworms, coneworms, and skeletonizers from the family Pyralidae *Ostrinia nubilalis* Hübner (European corn borer); *Amyelois transitella* Walker (naval orangeworm); *Anagasta kuehniella* Zeller
 20 (Mediterranean flour moth); *Cadra cautella* Walker (almond moth); *Chilo suppressalis* Walker (rice stem borer); *C. partellus*, (sorghum borer); *Corcyra cephalonica* Stainton (rice moth); *Crambus caliginosellus* Clemens (corn root webworm); *C. teterrellus* Zincken (bluegrass webworm); *Cnaphalocrocis medinalis* Guenée (rice leaf roller); *Desmia funeralis* Hübner (grape leaf folder); *Diaphania hyalinata* Linnaeus (melon worm); *D. nitidalis* Stoll (pickleworm); *Diatraea grandiosella* Dyar (southwestern corn borer), *D. saccharalis* Fabricius (surgarcane borer); *Eoreuma loftini* Dyar (Mexican rice borer); *Ephestia elutella* Hübner (tobacco (cacao) moth); *Galleria mellonella* Linnaeus (greater wax moth); *Herpetogramma licarsisalis* Walker (sod webworm); *Homoeosoma electellum* Hulst (sunflower moth); *Elasmopalpus lignosellus* Zeller (lesser cornstalk borer); *Achroia*
 30 *grisella* Fabricius (lesser wax moth); *Loxostege sticticalis* Linnaeus (beet webworm); *Orthaga thyrisalis* Walker (tea tree web moth); *Maruca testulalis* Geyer (bean pod borer); *Plodia interpunctella* Hübner (Indian meal moth); *Scirpophaga incertulas* Walker (yellow stem borer); *Udea rubigalis* Guenée (celery leaftier); and leafrollers, budworms, seed worms and fruit worms in the family Tortricidae *Accleris gloverana* Walsingham (Western blackheaded budworm); *A. variana* Fernald (Eastern blackheaded budworm); *Archips argyrospila* Walker (fruit tree leaf roller); *A. rosana* Linnaeus (European leaf roller); and

other *Archips* species, *Adoxophyes orana* Fischer von Rösslerstamm (summer fruit tortrix moth); *Cochylis hospes* Walsingham (banded sunflower moth); *Cydia latiferreana* Walsingham (filbertworm); *C. pomonella* Linnaeus (coding moth); *Platynota flavedana* Clemens (variegated leafroller); *P. stultana* Walsingham (omnivorous leafroller); *Lobesia botrana* Denis & Schiffermüller (European grape vine moth); *Spilonota ocellana* Denis & Schiffermüller (eyespotted bud moth); *Endopiza viteana* Clemens (grape berry moth); *Eupoecilia ambiguella* Hübner (vine moth); *Bonagota salubricola* Meyrick (Brazilian apple leafroller); *Grapholita molesta* Busck (oriental fruit moth); *Suleima helianthana* Riley (sunflower bud moth); *Argyrotaenia* spp.; *Choristoneura* spp..

10 Selected other agronomic pests in the order Lepidoptera include, but are not limited to, *Alsophila pometaria* Harris (fall cankerworm); *Anarsia lineatella* Zeller (peach twig borer); *Anisota senatoria* J.E. Smith (orange striped oakworm); *Antheraea pernyi* Guérin-Méneville (Chinese Oak Tussah Moth); *Bombyx mori* Linnaeus (Silkworm); *Bucculatrix thurberiella* Busck (cotton leaf perforator); *Colias eurytheme* Boisduval (alfalfa caterpillar); *Datana integerrima* Grote & Robinson (walnut caterpillar); *Dendrolimus sibiricus* Tschetwerikov (Siberian silk moth), *Ennomos subsignaria* Hübner (elm spanworm); *Erannis tiliaria* Harris (linden looper); *Euproctis chrysorrhoea* Linnaeus (browntail moth); *Harrisina americana* Guérin-Méneville (grapeleaf skeletonizer); *Hemileuca oliviae* Cockrell (range caterpillar); *Hyphantria cunea* Drury (fall webworm); *Keiferia lycopersicella* Walsingham (tomato pinworm); *Lambdina fiscellaria fiscellaria* Hulst (Eastern hemlock looper); *L. fiscellaria lugubrosa* Hulst (Western hemlock looper); *Leucoma salicis* Linnaeus (satin moth); *Lymantria dispar* Linnaeus (gypsy moth); *Manduca quinquemaculata* Haworth (five spotted hawk moth, tomato hornworm); *M. sexta* Haworth (tomato hornworm, tobacco hornworm); *Operophtera brumata* Linnaeus (winter moth); *Paleacrita vernata* Peck (spring cankerworm); *Papilio cresphontes* Cramer (giant swallowtail orange dog); *Phryganidia californica* Packard (California oakworm); *Phyllocnistis citrella* Stainton (citrus leafminer); *Phyllonorycter blancardella* Fabricius (spotted tentiform leafminer); *Pieris brassicae* Linnaeus (large white butterfly); *P. rapae* Linnaeus (small white butterfly); *P. napi* Linnaeus (green veined white butterfly); *Platyptilia carduidactyla* Riley (artichoke plume moth); *Plutella xylostella* Linnaeus (diamondback moth); *Pectinophora gossypiella* Saunders (pink bollworm); *Pontia protodice* Boisduval and Leconte (Southern cabbageworm); *Sabulodes aegrotata* Guenée (omnivorous looper); *Schizura concinna* J.E. Smith (red humped caterpillar); *Sitotroga cerealella* Olivier (Angoumois grain moth); *Thaumetopoea pityocampa* Schiffermuller (pine processionary caterpillar); *Tineola bisselliella* Hummel (webbing clothesmoth); *Tuta absoluta* Meyrick

(tomato leafminer); *Yponomeuta padella* Linnaeus (ermine moth); *Heliothis subflexa* Guenée; *Malacosoma* spp. and *Orgyia* spp.

Of interest are larvae and adults of the order Coleoptera including weevils from the families Anthribidae, Bruchidae and Curculionidae (including, but not limited to:

5 *Anthonomus grandis* Boheman (boll weevil); *Lissorhoptrus oryzophilus* Kuschel (rice water weevil); *Sitophilus granarius* Linnaeus (granary weevil); *S. oryzae* Linnaeus (rice weevil); *Hypera punctata* Fabricius (clover leaf weevil); *Cylindrocopturus adspersus* LeConte (sunflower stem weevil); *Smicronyx fulvus* LeConte (red sunflower seed weevil); *S. sordidus* LeConte (gray sunflower seed weevil); *Sphenophorus maidis* Chittenden

10 (maize billbug)); flea beetles, cucumber beetles, rootworms, leaf beetles, potato beetles and leafminers in the family Chrysomelidae (including, but not limited to: *Leptinotarsa decemlineata* Say (Colorado potato beetle); *Diabrotica virgifera virgifera* LeConte (western corn rootworm); *D. barberi* Smith and Lawrence (northern corn rootworm); *D. undecimpunctata howardi* Barber (southern corn rootworm); *Chaetocnema pulicaria*

15 Melsheimer (corn flea beetle); *Phyllotreta cruciferae* Goeze (Crucifer flea beetle); *Phyllotreta striolata* (stripped flea beetle); *Colaspis brunnea* Fabricius (grape colaspis); *Oulema melanopus* Linnaeus (cereal leaf beetle); *Zygogramma exclamationis* Fabricius (sunflower beetle)); beetles from the family Coccinellidae (including, but not limited to: *Epilachna varivestis* Mulsant (Mexican bean beetle)); chafers and other beetles from the

20 family Scarabaeidae (including, but not limited to: *Popillia japonica* Newman (Japanese beetle); *Cyclocephala borealis* Arrow (northern masked chafer, white grub); *C. immaculata* Olivier (southern masked chafer, white grub); *Rhizotrogus majalis* Razoumowsky (European chafer); *Phyllophaga crinita* Burmeister (white grub); *Ligyrus gibbosus* De Geer (carrot beetle)); carpet beetles from the family Dermestidae; wireworms

25 from the family Elateridae, *Eleodes* spp., *Melanotus* spp.; *Conoderus* spp.; *Limonius* spp.; *Agriotes* spp.; *Ctenicera* spp.; *Aeolus* spp.; bark beetles from the family Scolytidae and beetles from the family Tenebrionidae.

Adults and immatures of the order Diptera are of interest, including leafminers *Agromyza parvicornis* Loew (corn blotch leafminer); midges (including, but not limited to:

30 *Contarinia sorghicola* Coquillett (sorghum midge); *Mayetiola destructor* Say (Hessian fly); *Sitodiplosis mosellana* Géhin (wheat midge); *Neolasioptera murtfeldtiana* Felt, (sunflower seed midge)); fruit flies (Tephritidae), *Oscinella frit* Linnaeus (fruit flies); maggots (including, but not limited to: *Delia platura* Meigen (seedcorn maggot); *D. coarctata* Fallen (wheat bulb fly) and other *Delia* spp., *Meromyza americana* Fitch (wheat stem maggot);

35 *Musca domestica* Linnaeus (house flies); *Fannia canicularis* Linnaeus, *F. femoralis* Stein (lesser house flies); *Stomoxys calcitrans* Linnaeus (stable flies)); face flies, horn flies,

blow flies, *Chrysomya* spp.; *Phormia* spp. and other muscoid fly pests, horse flies *Tabanus* spp.; bot flies *Gastrophilus* spp.; *Oestrus* spp.; cattle grubs *Hypoderma* spp.; deer flies *Chrysops* spp.; *Melophagus ovinus* Linnaeus (keds) and other *Brachycera*, mosquitoes *Aedes* spp.; *Anopheles* spp.; *Culex* spp.; black flies *Prosimulium* spp.;
 5 *Simulium* spp.; biting midges, sand flies, sciarids, and other *Nematocera*.

Included as insects of interest are adults and nymphs of the orders Hemiptera and Homoptera such as, but not limited to, adelgids from the family Adelgidae, plant bugs from the family Miridae, cicadas from the family Cicadidae, leafhoppers, *Empoasca* spp.; from the family Cicadellidae, planthoppers from the families Cixiidae, Flatidae, Fulgoroidea,
 10 Issidae and Delphacidae, treehoppers from the family Membracidae, psyllids from the family Psyllidae, whiteflies from the family Aleyrodidae, aphids from the family Aphididae, phylloxera from the family Phylloxeridae, mealybugs from the family Pseudococcidae, scales from the families Asterolecanidae, Coccidae, Dactylopiidae, Diaspididae, Eriococcidae Ortheziidae, Phoenicococcidae and Margarodidae, lace bugs from the
 15 family Tingidae, stink bugs from the family Pentatomidae, cinch bugs, *Blissus* spp.; and other seed bugs from the family Lygaeidae, spittlebugs from the family Cercopidae squash bugs from the family Coreidae and red bugs and cotton stainers from the family Pyrrhocoridae.

Agronomically important members from the order Homoptera further include, but
 20 are not limited to: *Acyrtosiphon pisum* Harris (pea aphid); *Aphis craccivora* Koch (cowpea aphid); *A. fabae* Scopoli (black bean aphid); *A. gossypii* Glover (cotton aphid, melon aphid); *A. maidiradicis* Forbes (corn root aphid); *A. pomi* De Geer (apple aphid); *A. spiraecola* Patch (spirea aphid); *Aulacorthum solani* Kaltenbach (foxglove aphid); *Chaetosiphon fragaefolii* Cockerell (strawberry aphid); *Diuraphis noxia*
 25 Kurdjumov/Mordvilko (Russian wheat aphid); *Dysaphis plantaginea* Paaserini (rosy apple aphid); *Eriosoma lanigerum* Hausmann (woolly apple aphid); *Brevicoryne brassicae* Linnaeus (cabbage aphid); *Hyalopterus pruni* Geoffroy (mealy plum aphid); *Lipaphis erysimi* Kaltenbach (turnip aphid); *Metopolophium dirrhodum* Walker (cereal aphid); *Macrosiphum euphorbiae* Thomas (potato aphid); *Myzus persicae* Sulzer (peach-potato
 30 aphid, green peach aphid); *Nasonovia ribisnigri* Mosley (lettuce aphid); *Pemphigus* spp. (root aphids and gall aphids); *Rhopalosiphum maidis* Fitch (corn leaf aphid); *R. padi* Linnaeus (bird cherry-oat aphid); *Schizaphis graminum* Rondani (greenbug); *Sipha flava* Forbes (yellow sugarcane aphid); *Sitobion avenae* Fabricius (English grain aphid); *Therioaphis maculata* Buckton (spotted alfalfa aphid); *Toxoptera aurantii* Boyer de
 35 Fonscolombe (black citrus aphid) and *T. citricida* Kirkaldy (brown citrus aphid); *Melanaphis sacchari* (sugarcane aphid); *Adelges* spp. (adelgids); *Phylloxera devastatrix*

Pergande (pecan phylloxera); *Bemisia tabaci* Gennadius (tobacco whitefly, sweetpotato whitefly); *B. argentifolii* Bellows & Perring (silverleaf whitefly); *Dialeurodes citri* Ashmead (citrus whitefly); *Trialeurodes abutiloneus* (bandedwinged whitefly) and *T. vaporariorum* Westwood (greenhouse whitefly); *Empoasca fabae* Harris (potato leafhopper);
 5 *Laodelphax striatellus* Fallen (smaller brown planthopper); *Macrolestes quadrilineatus* Forbes (aster leafhopper); *Nephotettix cincticeps* Uhler (green leafhopper); *N. nigropictus* Stål (rice leafhopper); *Nilaparvata lugens* Stål (brown planthopper); *Peregrinus maidis* Ashmead (corn planthopper); *Sogatella furcifera* Horvath (white-backed planthopper); *Sogatodes orizicola* Muir (rice delphacid); *Typhlocyba pomaria* McAtee (white apple
 10 leafhopper); *Erythroneoura* spp. (grape leafhoppers); *Magicicada septendecim* Linnaeus (periodical cicada); *Icerya purchasi* Maskell (cottony cushion scale); *Quadraspidiotus perniciosus* Comstock (San Jose scale); *Planococcus citri* Risso (citrus mealybug); *Pseudococcus* spp. (other mealybug complex); *Cacopsylla pyricola* Foerster (pear psylla); *Trioza diospyri* Ashmead (persimmon psylla).

15 Agronomically important species of interest from the order Hemiptera include, but are not limited to: *Acrosternum hilare* Say (green stink bug); *Anasa tristis* De Geer (squash bug); *Blissus leucopterus leucopterus* Say (chinch bug); *Corythuca gossypii* Fabricius (cotton lace bug); *Cyrtopeltis modesta* Distant (tomato bug); *Dysdercus suturellus* Herrich-Schäffer (cotton stainer); *Euschistus servus* Say (brown stink bug); *E.*
 20 *variolaris* Palisot de Beauvois (one-spotted stink bug); *Graptostethus* spp. (complex of seed bugs); *Leptoglossus corculus* Say (leaf-footed pine seed bug); *Lygus lineolaris* Palisot de Beauvois (tarnished plant bug); *L. hesperus* Knight (Western tarnished plant bug); *L. pratensis* Linnaeus (common meadow bug); *L. rugulipennis* Poppius (European tarnished plant bug); *Lygocoris pabulinus* Linnaeus (common green capsid); *Nezara viridula* Linnaeus (southern green stink bug); *Oebalus pugnax* Fabricius (rice stink bug);
 25 *Oncopeltus fasciatus* Dallas (large milkweed bug); *Pseudatomoscelis seriatus* Reuter (cotton fleahopper).

Furthermore, embodiments may be effective against Hemiptera such, *Calocoris norvegicus* Gmelin (strawberry bug); *Orthops campestris* Linnaeus; *Plesiocoris rugicollis*
 30 Fallen (apple capsid); *Cyrtopeltis modestus* Distant (tomato bug); *Cyrtopeltis notatus* Distant (suckfly); *Spanagonicus albofasciatus* Reuter (whitemarked fleahopper); *Diaphnocoris chlorionis* Say (honeylocust plant bug); *Labopidicola allii* Knight (onion plant bug); *Pseudatomoscelis seriatus* Reuter (cotton fleahopper); *Adelphocoris rapidus* Say (rapid plant bug); *Poecilocapsus lineatus* Fabricius (four-lined plant bug); *Nysius ericae*
 35 Schilling (false chinch bug); *Nysius raphanus* Howard (false chinch bug); *Nezara viridula*

Linnaeus (Southern green stink bug); *Eurygaster* spp.; *Coreidae* spp.; *Pyrrhocoridae* spp.; *Tinidae* spp.; *Blattellidae* spp.; *Reduviidae* spp. and *Cimicidae* spp.

Also included are adults and larvae of the order Acari (mites) such as *Aceria tosichella* Keifer (wheat curl mite); *Petrobia latens* Müller (brown wheat mite); spider mites and red mites in the family Tetranychidae, *Panonychus ulmi* Koch (European red mite); *Tetranychus urticae* Koch (two spotted spider mite); (*T. mcdanieli* McGregor (McDaniel mite); *T. cinnabarinus* Boisduval (carmine spider mite); *T. turkestanii* Ugarov & Nikolski (strawberry spider mite); flat mites in the family Tenuipalpidae, *Brevipalpus lewisi* McGregor (citrus flat mite); rust and bud mites in the family Eriophyidae and other foliar feeding mites and mites important in human and animal health, i.e., dust mites in the family Epidermoptidae, follicle mites in the family Demodicidae, grain mites in the family Glycyphagidae, ticks in the order Ixodidae. *Ixodes scapularis* Say (deer tick); *I. holocyclus* Neumann (Australian paralysis tick); *Dermacentor variabilis* Say (American dog tick); *Amblyomma americanum* Linnaeus (lone star tick) and scab and itch mites in the families Psoroptidae, Pyemotidae and Sarcoptidae.

Insect pests of the order Thysanura are of interest, such as *Lepisma saccharina* Linnaeus (silverfish); *Thermobia domestica* Packard (firebrat).

Additional arthropod pests covered include: spiders in the order Araneae such as *Loxosceles reclusa* Gertsch and Mulaik (brown recluse spider) and the *Latrodectus mactans* Fabricius (black widow spider) and centipedes in the order Scutigleromorpha such as *Scutigera coleoptrata* Linnaeus (house centipede).

Insect pest of interest include the superfamily of stink bugs and other related insects including but not limited to species belonging to the family Pentatomidae (*Nezara viridula*, *Halyomorpha halys*, *Piezodorus guildini*, *Euschistus servus*, *Acrosternum hilare*, *Euschistus heros*, *Euschistus tristigmus*, *Acrosternum hilare*, *Dichelops furcatus*, *Dichelops melacanthus*, and *Bagrada hilaris* (Bagrada Bug)), the family Plataspididae (*Megacopta cribraria* - Bean plataspid) and the family Cydnidae (*Scaptocoris castanea* - Root stink bug) and Lepidoptera species including but not limited to: diamond-back moth, e.g., *Helicoverpa zea* Boddie; soybean looper, e.g., *Pseudoplusia includens* Walker and velvet bean caterpillar e.g., *Anticarsia gemmatilis* Hübner.

Methods for measuring pesticidal activity are well known in the art. See, for example, Czapla and Lang, (1990) *J. Econ. Entomol.* 83:2480-2485; Andrews, et al., (1988) *Biochem. J.* 252:199-206; Marrone, et al., (1985) *J. of Economic Entomology* 78:290-293 and US Patent Number 5,743,477, all of which are herein incorporated by reference in their entirety. Generally, the protein is mixed and used in feeding assays. See, for example Marrone, et al., (1985) *J. of Economic Entomology* 78:290-293. Such

assays can include contacting plants with one or more pests and determining the plant's ability to survive and/or cause the death of the pests.

Nematodes include parasitic nematodes such as root-knot, cyst and lesion nematodes, including *Heterodera* spp., *Meloidogyne* spp. and *Globodera* spp.; particularly members of the cyst nematodes, including, but not limited to, *Heterodera glycines* (soybean cyst nematode); *Heterodera schachtii* (beet cyst nematode); *Heterodera avenae* (cereal cyst nematode) and *Globodera rostochiensis* and *Globodera pallida* (potato cyst nematodes). Lesion nematodes include *Pratylenchus* spp.

10 Seed Treatment

To protect and to enhance yield production and trait technologies, seed treatment options can provide additional crop plan flexibility and cost effective control against insects, weeds and diseases. Seed material can be treated, typically surface treated, with a composition comprising combinations of chemical or biological herbicides, herbicide safeners, insecticides, fungicides, germination inhibitors and enhancers, nutrients, plant growth regulators and activators, bactericides, nematocides, avicides and/or molluscicides. These compounds are typically formulated together with further carriers, surfactants or application-promoting adjuvants customarily employed in the art of formulation. The coatings may be applied by impregnating propagation material with a liquid formulation or by coating with a combined wet or dry formulation. Examples of the various types of compounds that may be used as seed treatments are provided in The Pesticide Manual: A World Compendium, C.D.S. Tomlin Ed., Published by the British Crop Production Council, which is hereby incorporated by reference.

Some seed treatments that may be used on crop seed include, but are not limited to, one or more of abscisic acid, acibenzolar-S-methyl, avermectin, amitrol, azaconazole, azospirillum, azadirachtin, azoxystrobin, *Bacillus* spp. (including one or more of cereus, firmus, megaterium, pumilis, sphaericus, subtilis and/or thuringiensis species), bradyrhizobium spp. (including one or more of betae, canariense, elkanii, iriomotense, japonicum, liaonigense, pachyrhizi and/or yuanmingense), captan, carboxin, chitosan, clothianidin, copper, cyazypyr, difenoconazole, etidiazole, fipronil, fludioxonil, fluoxastrobin, fluquinconazole, flurazole, fluxofenim, harpin protein, imazalil, imidacloprid, ipconazole, isoflavenoids, lipo-chitooligosaccharide, mancozeb, manganese, maneb, mefenoxam, metalaxyl, metconazole, myclobutanil, PCNB, penflufen, penicillium, penthiopyrad, permethrine, picoxystrobin, prothioconazole, pyraclostrobin, rynaxypyr, S-metolachlor, saponin, sedaxane, TCMTB, tebuconazole, thiabendazole, thiamethoxam, thiocarb, thiram, tolclofos-methyl, triadimenol, trichoderma, trifloxystrobin, triticonazole

and/or zinc. PCNB seed coat refers to EPA Registration Number 00293500419, containing quitozen and terrazole. TCMTB refers to 2-(thiocyanomethylthio) benzothiazole.

Seed varieties and seeds with specific transgenic traits may be tested to determine which seed treatment options and application rates may complement such varieties and transgenic traits in order to enhance yield. For example, a variety with good yield potential but head smut susceptibility may benefit from the use of a seed treatment that provides protection against head smut, a variety with good yield potential but cyst nematode susceptibility may benefit from the use of a seed treatment that provides protection against cyst nematode, and so on. Likewise, a variety encompassing a transgenic trait conferring insect resistance may benefit from the second mode of action conferred by the seed treatment, a variety encompassing a transgenic trait conferring herbicide resistance may benefit from a seed treatment with a safener that enhances the plants resistance to that herbicide, etc. Further, the good root establishment and early emergence that results from the proper use of a seed treatment may result in more efficient nitrogen use, a better ability to withstand drought and an overall increase in yield potential of a variety or varieties containing a certain trait when combined with a seed treatment.

20 **Methods for killing an insect pest and controlling an insect population**

In some embodiments methods are provided for killing an insect pest, comprising contacting the insect pest with an insecticidally-effective amount of a recombinant PIP-72 polypeptide of the disclosure. In some embodiments methods are provided for killing an insect pest, comprising contacting the insect pest with an insecticidally-effective amount of a recombinant pesticidal protein of SEQ ID NO: 2, SEQ ID NO: 4, SEQ ID NO: 6, SEQ ID NO: 8, SEQ ID NO: 10, SEQ ID NO: 12, SEQ ID NO: 14, SEQ ID NO: 18, SEQ ID NO: 28, SEQ ID NO: 32, any one of SEQ ID NO: 528 - SEQ ID NO: 768, any one of SEQ ID NO: 825 - SEQ ID NO: 844, SEQ ID NO: 771, SEQ ID NO: 772 or SEQ ID NO: 852 or a variant thereof.

In some embodiments methods are provided for controlling an insect pest population, comprising contacting the insect pest population with an insecticidally-effective amount of a recombinant PIP-72 polypeptide of the disclosure. In some embodiments methods are provided for controlling an insect pest population, comprising contacting the insect pest population with an insecticidally-effective amount of a recombinant pesticidal protein of SEQ ID NO: 2, SEQ ID NO: 4, SEQ ID NO: 6, SEQ ID NO: 8, SEQ ID NO: 10, SEQ ID NO: 12, SEQ ID NO: 14, SEQ ID NO: 18, SEQ ID NO: 28,

SEQ ID NO: 32, any one of SEQ ID NO: 528 - SEQ ID NO: 768, any one of SEQ ID NO: 825 – SEQ ID NO: 844, SEQ ID NO: 771, SEQ ID NO: 772 or SEQ ID NO: 852 or a variant thereof. As used herein, “controlling a pest population” or “controls a pest” refers to any effect on a pest that results in limiting the damage that the pest causes.

5 Controlling a pest includes, but is not limited to, killing the pest, inhibiting development of the pest, altering fertility or growth of the pest in such a manner that the pest provides less damage to the plant, decreasing the number of offspring produced, producing less fit pests, producing pests more susceptible to predator attack or deterring the pests from eating the plant.

10 In some embodiments methods are provided for controlling an insect pest population resistant to a pesticidal protein, comprising contacting the insect pest population with an insecticidally-effective amount of a recombinant PIP-72 polypeptide of the disclosure. In some embodiments methods are provided for controlling an insect pest population resistant to a pesticidal protein, comprising contacting the insect pest
15 population with an insecticidally-effective amount of a recombinant pesticidal protein of SEQ ID NO: 2, SEQ ID NO: 4, SEQ ID NO: 6, SEQ ID NO: 8, SEQ ID NO: 10, SEQ ID NO: 12, SEQ ID NO: 14, SEQ ID NO: 18, SEQ ID NO: 28, SEQ ID NO: 32, any one of SEQ ID NO: 528 - SEQ ID NO: 768, any one of SEQ ID NO: 825 – SEQ ID NO: 844, SEQ ID NO: 771, SEQ ID NO: 772 or SEQ ID NO: 852 or a variant thereof.

20 In some embodiments methods are provided for protecting a plant from an insect pest, comprising expressing in the plant or cell thereof a recombinant polynucleotide encoding a PIP-72 polypeptide of the disclosure. In some embodiments methods are provided for protecting a plant from an insect pest, comprising expressing in the plant or cell thereof a recombinant polynucleotide encoding pesticidal protein of SEQ ID NO: 2,
25 SEQ ID NO: 4, SEQ ID NO: 6, SEQ ID NO: 8, SEQ ID NO: 10, SEQ ID NO: 12, SEQ ID NO: 14, SEQ ID NO: 18, SEQ ID NO: 28, SEQ ID NO: 32, any one of SEQ ID NO: 528 - SEQ ID NO: 768, any one of SEQ ID NO: 825 – SEQ ID NO: 844, SEQ ID NO: 771, SEQ ID NO: 772 or SEQ ID NO: 852 or variants thereof.

In some embodiments methods are provided for killing an insect pest, comprising
30 contacting the insect pest with an insecticidally-effective amount of a recombinant polypeptide of SEQ ID NO: 20, SEQ ID NO: 22, SEQ ID NO: 24, SEQ ID NO: 26, SEQ ID NO: 30, SEQ ID NO: 34, SEQ ID NO: 36, SEQ ID NO: 929, SEQ ID NO: 930, SEQ ID NO: 931, SEQ ID NO: 937, SEQ ID NO: 938, SEQ ID NO: 942, SEQ ID NO: 947, or SEQ ID NO: 948 or a variant thereof.

35 In some embodiments methods are provided for controlling an insect pest population, comprising contacting the insect pest population with an effective amount of a

recombinant polypeptide of SEQ ID NO: 20, SEQ ID NO: 22, SEQ ID NO: 24, SEQ I NO: 26, SEQ ID NO: 30, SEQ ID NO: 34, SEQ ID NO: 36, SEQ ID NO: 929, SEQ ID NO: 930, SEQ ID NO: 931, SEQ ID NO: 937, SEQ ID NO: 938, SEQ ID NO: 942, SEQ ID NO: 947, or SEQ ID NO: 948 or a variant thereof. As used herein, “controlling a pest population” or “controls a pest” refers to any effect on a pest that results in limiting the damage that the pest causes. Controlling a pest includes, but is not limited to, killing the pest, inhibiting development of the pest, altering fertility or growth of the pest in such a manner that the pest provides less damage to the plant, decreasing the number of offspring produced, producing less fit pests, producing pests more susceptible to predator attack or deterring the pests from eating the plant.

In some embodiments methods are provided for controlling an insect pest population resistant to a pesticidal protein, comprising contacting the insect pest population with an effective amount of a recombinant polypeptide of SEQ ID NO: 20, SEQ ID NO: 22, SEQ ID NO: 24, SEQ I NO: 26, SEQ ID NO: 30, SEQ ID NO: 34, SEQ ID NO: 36, SEQ ID NO: 929, SEQ ID NO: 930, SEQ ID NO: 931, SEQ ID NO: 937, SEQ ID NO: 938, SEQ ID NO: 942, SEQ ID NO: 947, or SEQ ID NO: 948 or a variant thereof.

In some embodiments methods are provided for protecting a plant from an insect pest, comprising expressing in the plant or cell thereof a recombinant polynucleotide encoding a pesticidal protein of SEQ ID NO: 20, SEQ ID NO: 22, SEQ ID NO: 24, SEQ I NO: 26, SEQ ID NO: 30, SEQ ID NO: 34, SEQ ID NO: 36, SEQ ID NO: 929, SEQ ID NO: 930, SEQ ID NO: 931, SEQ ID NO: 937, SEQ ID NO: 938, SEQ ID NO: 942, SEQ ID NO: 947, or SEQ ID NO: 948 or variants thereof.

Insect Resistance Management (IRM) Strategies

Expression of *B. thuringiensis* δ -endotoxins in transgenic corn plants has proven to be an effective means of controlling agriculturally important insect pests (Perak, *et al.*, 1990; 1993). However, insects have evolved that are resistant to *B. thuringiensis* δ -endotoxins expressed in transgenic plants. Such resistance, should it become widespread, would clearly limit the commercial value of germplasm containing genes encoding such *B. thuringiensis* δ -endotoxins.

One way to increasing the effectiveness of the transgenic insecticides against target pests and contemporaneously reducing the development of insecticide-resistant pests is to use provide non-transgenic (i.e., non-insecticidal protein) refuges (a section of non-insecticidal crops/ corn) for use with transgenic crops producing a single insecticidal protein active against target pests. The United States Environmental Protection Agency (epa.gov/oppbppdl/biopesticides/pips/bt_corn_refuge_2006.htm, which can be accessed

using the www prefix) publishes the requirements for use with transgenic crops producing a single Bt protein active against target pests. In addition, the National Corn Growers Association, on their website: (ncga.com/insect-resistance-management-fact-sheet-bt-corn, which can be accessed using the www prefix) also provides similar guidance
5 regarding refuge requirements. Due to losses to insects within the refuge area, larger refuges may reduce overall yield.

Another way of increasing the effectiveness of the transgenic insecticides against target pests and contemporaneously reducing the development of insecticide-resistant pests would be to have a repository of insecticidal genes that are effective against groups
10 of insect pests and which manifest their effects through different modes of action.

Expression in a plant of two or more insecticidal compositions toxic to the same insect species, each insecticide being expressed at efficacious levels would be another way to achieve control of the development of resistance. This is based on the principle that evolution of resistance against two separate modes of action is far more unlikely than
15 only one. Roush, for example, outlines two-toxin strategies, also called "pyramiding" or "stacking," for management of insecticidal transgenic crops. (The Royal Society. Phil. Trans. R. Soc. Lond. B. (1998) 353:1777-1786). Stacking or pyramiding of two different proteins each effective against the target pests and with little or no cross-resistance can allow for use of a smaller refuge. The US Environmental Protection Agency requires
20 significantly less (generally 5%) structured refuge of non-Bt corn be planted than for single trait products (generally 20%). There are various ways of providing the IRM effects of a refuge, including various geometric planting patterns in the fields and in-bag seed mixtures, as discussed further by Roush.

In some embodiments the PIP-72 polypeptides of the disclosure are useful as an
25 insect resistance management strategy in combination (i.e., pyramided) with other pesticidal proteins include but are not limited to Bt toxins, *Xenorhabdus* sp. or *Photorhabdus* sp. insecticidal proteins, and the like.

Provided are methods of controlling Lepidoptera and/or Coleoptera insect infestation(s) in a transgenic plant that promote insect resistance management,
30 comprising expressing in the plant at least two different insecticidal proteins having different modes of action.

In some embodiments the methods of controlling Lepidoptera and/or Coleoptera insect infestation in a transgenic plant and promoting insect resistance management the at least one of the insecticidal proteins comprise a PIP-72 polypeptide insecticidal to
35 insects in the order Lepidoptera and/or Coleoptera.

In some embodiments the methods of controlling Lepidoptera and/or Coleoptera insect infestation in a transgenic plant and promoting insect resistance management the at least one of the insecticidal proteins comprises a protein of SEQ ID NO: 2, SEQ ID NO: 4, SEQ ID NO: 6, SEQ ID NO: 8, SEQ ID NO: 10, SEQ ID NO: 12, SEQ ID NO: 14, SEQ ID NO: 18, SEQ ID NO: 28, SEQ ID NO: 32, any one of SEQ ID NO: 528 - SEQ ID NO: 768, any one of SEQ ID NO: 825 – SEQ ID NO: 844, SEQ ID NO: 771, SEQ ID NO: 772, SEQ ID NO: 852, any one of SEQ ID NO: 903 – SEQ ID NO: 914, SEQ ID NO: 927, SEQ ID NO: 928, SEQ ID NO: 932, SEQ ID NO: 933, SEQ ID NO: 934, SEQ ID NO: 935, SEQ ID NO: 936, SEQ ID NO: 939, SEQ ID NO: 940, SEQ ID NO: 941, SEQ ID NO: 943, SEQ ID NO: 944, SEQ ID NO: 945, or SEQ ID NO: 946 or variants thereof, insecticidal to insects in the order Lepidoptera and/or Coleoptera.

In some embodiments the methods of controlling Lepidoptera and/or Coleoptera insect infestation in a transgenic plant and promoting insect resistance management comprise expressing in the transgenic plant a PIP-72 polypeptide and a Cry protein insecticidal to insects in the order Lepidoptera and/or Coleoptera having different modes of action.

In some embodiments the methods of controlling Lepidoptera and/or Coleoptera insect infestation in a transgenic plant and promoting insect resistance management comprise in the transgenic plant a protein of SEQ ID NO: 2, SEQ ID NO: 4, SEQ ID NO: 6, SEQ ID NO: 8, SEQ ID NO: 10, SEQ ID NO: 12, SEQ ID NO: 14, SEQ ID NO: 18, SEQ ID NO: 28, SEQ ID NO: 32, any one of SEQ ID NO: 528 - SEQ ID NO: 768, any one of SEQ ID NO: 825 – SEQ ID NO: 844, SEQ ID NO: 771, SEQ ID NO: 772, SEQ ID NO: 852, any one of SEQ ID NO: 903 – SEQ ID NO: 914, SEQ ID NO: 927, SEQ ID NO: 928, SEQ ID NO: 932, SEQ ID NO: 933, SEQ ID NO: 934, SEQ ID NO: 935, SEQ ID NO: 936, SEQ ID NO: 939, SEQ ID NO: 940, SEQ ID NO: 941, SEQ ID NO: 943, SEQ ID NO: 944, SEQ ID NO: 945, or SEQ ID NO: 946 or variants thereof and a Cry protein insecticidal to insects in the order Lepidoptera and/or Coleoptera having different modes of action.

Also provided are methods of reducing likelihood of emergence of Lepidoptera and/or Coleoptera insect resistance to transgenic plants expressing in the plants insecticidal proteins to control the insect species, comprising expression of a PIP-72 polypeptide insecticidal to the insect species in combination with a second insecticidal protein to the insect species having different modes of action.

Also provided are methods of reducing likelihood of emergence of Lepidoptera and/or Coleoptera insect resistance to transgenic plants expressing in the plants insecticidal proteins to control the insect species, comprising expression of a protein of SEQ ID NO: 2, SEQ ID NO: 4, SEQ ID NO: 6, SEQ ID NO: 8, SEQ ID NO: 10, SEQ ID

NO: 12, SEQ ID NO: 14, SEQ ID NO: 18, SEQ ID NO: 28, SEQ ID NO: 32, any one of
 SEQ ID NO: 528 - SEQ ID NO: 768, any one of SEQ ID NO: 825 – SEQ ID NO: 844, SEQ
 ID NO: 771, SEQ ID NO: 772, SEQ ID NO: 852, any one of SEQ ID NO: 903 – SEQ ID
 NO: 914, SEQ ID NO: 927, SEQ ID NO: 928, SEQ ID NO: 932, SEQ ID NO: 933, SEQ ID
 5 NO: 934, SEQ ID NO: 935, SEQ ID NO: 936, SEQ ID NO: 939, SEQ ID NO: 940, SEQ ID
 NO: 941, SEQ ID NO: 943, SEQ ID NO: 944, SEQ ID NO: 945, or SEQ ID NO: 946 or
 variants thereof, insecticidal to the insect species in combination with a second
 insecticidal protein to the insect species having different modes of action.

Also provided are means for effective Lepidoptera and/or Coleoptera insect
 10 resistance management of transgenic plants, comprising co-expressing at high levels in
 the plants two or more insecticidal proteins toxic to Lepidoptera and/or Coleoptera insects
 but each exhibiting a different mode of effectuating its killing activity, wherein the two or
 more insecticidal proteins comprise a PIP-72 polypeptide and a Cry protein. Also
 provided are means for effective Lepidoptera and/or Coleoptera insect resistance
 15 management of transgenic plants, comprising co-expressing at high levels in the plants
 two or more insecticidal proteins toxic to Lepidoptera and/or Coleoptera insects but each
 exhibiting a different mode of effectuating its killing activity, wherein the two or more
 insecticidal proteins comprise a protein of SEQ ID NO: 2, SEQ ID NO: 4, SEQ ID NO: 6,
 SEQ ID NO: 8, SEQ ID NO: 10, SEQ ID NO: 12, SEQ ID NO: 14, SEQ ID NO: 18, SEQ ID
 20 NO: 28, SEQ ID NO: 32, any one of SEQ ID NO: 528 - SEQ ID NO: 768, any one of SEQ
 ID NO: 825 – SEQ ID NO: 844, SEQ ID NO: 771, SEQ ID NO: 772, SEQ ID NO: 852, any
 one of SEQ ID NO: 903 – SEQ ID NO: 914, SEQ ID NO: 927, SEQ ID NO: 928, SEQ ID
 NO: 932, SEQ ID NO: 933, SEQ ID NO: 934, SEQ ID NO: 935, SEQ ID NO: 936, SEQ ID
 NO: 939, SEQ ID NO: 940, SEQ ID NO: 941, SEQ ID NO: 943, SEQ ID NO: 944, SEQ ID
 25 NO: 945, or SEQ ID NO: 946 or variants thereof and a Cry protein.

In addition, methods are provided for obtaining regulatory approval for planting or
 commercialization of plants expressing proteins insecticidal to insects in the order
 Lepidoptera and/or Coleoptera, comprising the step of referring to, submitting or relying
 on insect assay binding data showing that the PIP-72 polypeptide does not compete with
 30 binding sites for Cry proteins in such insects. In addition, methods are provided for
 obtaining regulatory approval for planting or commercialization of plants expressing
 proteins insecticidal to insects in the order Lepidoptera and/or Coleoptera, comprising the
 step of referring to, submitting or relying on insect assay binding data showing that the
 protein of SEQ ID NO: 2, SEQ ID NO: 4, SEQ ID NO: 6, SEQ ID NO: 8, SEQ ID NO: 10,
 35 SEQ ID NO: 12, SEQ ID NO: 14, SEQ ID NO: 18, SEQ ID NO: 28, SEQ ID NO: 32, any
 one of SEQ ID NO: 528 - SEQ ID NO: 768, any one of SEQ ID NO: 825 – SEQ ID NO:

844, SEQ ID NO: 771, SEQ ID NO: 772 or SEQ ID NO: 852 or variant thereof does not compete with binding sites for Cry proteins in such insects.

Methods for Increasing Plant Yield

5 Methods for increasing plant yield are provided. The methods comprise providing a plant or plant cell expressing a polynucleotide encoding the pesticidal polypeptide sequence disclosed herein and growing the plant or a seed thereof in a field infested with a pest against which the polypeptide has pesticidal activity. In some embodiments, the polypeptide has pesticidal activity against a Lepidopteran, Coleopteran, Dipteran,
10 Hemipteran or nematode pest, and the field is infested with a Lepidopteran, Hemipteran, Coleopteran, Dipteran or nematode pest.

As defined herein, the “yield” of the plant refers to the quality and/or quantity of biomass produced by the plant. “Biomass” as used herein refers to any measured plant product. An increase in biomass production is any improvement in the yield of the
15 measured plant product. Increasing plant yield has several commercial applications. For example, increasing plant leaf biomass may increase the yield of leafy vegetables for human or animal consumption. Additionally, increasing leaf biomass can be used to increase production of plant-derived pharmaceutical or industrial products. An increase in yield can comprise any statistically significant increase including, but not limited to, at
20 least a 1% increase, at least a 3% increase, at least a 5% increase, at least a 10% increase, at least a 20% increase, at least a 30%, at least a 50%, at least a 70%, at least a 100% or a greater increase in yield compared to a plant not expressing the pesticidal sequence.

In specific methods, plant yield is increased as a result of improved pest
25 resistance of a plant expressing a PIP-72 polypeptide disclosed herein. Expression of the PIP-72 polypeptide results in a reduced ability of a pest to infest or feed on the plant, thus improving plant yield.

Methods of Processing

30 Further provided are methods of processing a plant, plant part or seed to obtain a food or feed product from a plant, plant part or seed comprising a PIP-72 polypeptide. The plants, plant parts or seeds provided herein, can be processed to yield oil, protein products and/or by-products that are derivatives obtained by processing that have commercial value. Non-limiting examples include transgenic seeds comprising a nucleic
35 acid molecule encoding a PIP-72 polypeptide which can be processed to yield soy oil, soy products and/or soy by-products.

"Processing" refers to any physical and chemical methods used to obtain any soy product and includes, but is not limited to, heat conditioning, flaking and grinding, extrusion, solvent extraction or aqueous soaking and extraction of whole or partial seeds

The following examples are offered by way of illustration and not by way of limitation.

EXPERIMENTALS

Example 1 - Identification of a insecticidal protein active against Western Corn Root Worm (WCRW) from strain SS143D5

The WCRW (*Diabrotica virgifera virgifera*) active protein PIP-72Aa was identified by protein purification, liquid chromatography mass spectrometry (LC-MS/MS) and PCR cloning from *Pseudomonas chlororaphis* strain SS143D5 as follows:

Insecticidal activity against WCRW (*Diabrotica virgifera virgifera*) was observed from a clear cell lysate of SS143D5 grown in Trypticase soy medium (Tryptone 17 g/L, enzymatic digest of soy meal 3 g/L, Dextrose 2.5 g/L, Sodium Chloride 5 g/L, K₂HPO₄ 2.5g/L) and cultured overnight at 26°C with shaking at 250rpm. This insecticidal activity exhibited heat and proteinase sensitivity indicating proteinaceous nature. For protein extraction, cells were thawed and re-suspended in 50 mM sodium acetate buffer, pH 5 (buffer A) containing protease inhibitor cocktail V from CalBiochem. A crude cleared lysate was obtained by passing the cells through a homogenizer at 30,000 psi, followed by centrifugation at 13,800 x g for 20 min.

WCRW bioassays were conducted using 10 microliter cell lysate samples mixed with molten low-melt WCRW diet (Southland Products Inc., Lake Village, Arkansas) in a 96 well format. *Diabrotica virgifera virgifera* neonates were placed into each well of a 96 well plate. The assay was run for 4 days at 25°C and then was scored for insect mortality and stunting of insect growth. The scores were noted as dead, severely stunted (little or no growth but alive), stunted (growth to second instar but not equivalent to controls) or no activity.

Genomic DNA from strain SS143D5 was extracted with a Sigma-Aldrich® Bacterial Genomic DNA Extraction Kit (Cat # NA2110-KT, Sigma-Aldrich, PO Box 14508, St. Louis, MO 63178) according to the manufactures' instructions. The DNA concentration was determined using a NanoDrop® Spectrophotometer (Thermo Fisher Scientific®, 3411 Silverside Road, Bancroft Building, Suite 100, Willmington, DE 19810) and the genomic DNA was diluted to 40ng/ul with sterile water. A 25 ul PCR reaction was set up by combining 80 ng genomic DNA, 2 ul (5 uM) 16S ribosomal DNA primers

TACCTTGTTACGACTT (SEQ ID NO: 285) and AGAGTTTGATCMTGGCTCAG (SEQ ID NO: 286), 1 ul 10mM dNTP, 1x Phusion[®] HF[™] buffer, and 1 unit of Phusion[®] High-Fidelity DNA Polymerase (New England Biolabs[®], Cat #M0530L, 240 County Road, Ipswich, MA 01938-2723). The PCR reaction was run in a MJ Research PTC-200

5 Thermo Cycler (Bio-Rad[®] Laboratories, Inc., 1000 Alfred Nobel Drive, Hercules, California, 94547, USA) with the following program: 96°C 1 min; 30 cycles of 96°C 15 seconds, 52°C 2 minutes and 72°C 2 minutes; 72°C 10 minutes; and hold on 4°C. The PCR products were purified with QiaQuick[®] DNA purification Kit (Cat # 28104, QIAGEN[®] Inc., 27220 Turnberry Lane, Valencia, CA 91355). The purified PCR sample was DNA

10 sequenced and the resulting 16S ribosomal DNA sequence was BLAST searched against the NCBI database which indicated that SS143D5 is a *Pseudomonas chlororaphis* strain. The *Pseudomonas chlororaphis* strain SS143D5 was deposited on February 7, 2013 under accession # NRRL B-50810 with the Agricultural Research Service Culture Collection (NRRL), 1815 North University Street, Peoria, Illinois 61604,

15 (nrri.ncaur.usda.gov, which can be accessed on the world-wide web using the "www" prefix).

Isolated strain SS143D5 genomic DNA was also prepared according to a library construction protocol developed by Illumina and sequenced using the Illumina[®] Genome Analyzer[®] IIx (Cat# SY-301-1301, Illumina Inc., 9885 Towne Center Drive, San Diego,

20 CA92121).. The nucleic acid contig sequences were assembled and open reading frames were generated.

Cell pellet of an overnight culture of SS143D5 grown in 2x YT broth at 26°C with shaking at 250 rpm was lysed at ~20,000 psi after resuspension in acetate buffer, pH 5. The crude lysate was cleared by centrifugation and loaded onto a HiTrap[™] S-HP column

25 (GE Healthcare, 800 Centennial Avenue, P.O. Box 1327, Piscataway, NJ 08855). Bound protein was eluted with a linear sodium chloride gradient and fractionated. Fractions containing protein of interest were pooled and buffer exchanged for loading onto a MonoQ[™] column (GE Healthcare), run at pH 8. PIP-72Aa (SEQ ID NO: 2) was eluted with a linear sodium chloride gradient and after activity confirmation further purified by

30 hydrophobic interaction chromatography. For this the protein was adjusted to 0.8 M ammonium sulfate, loaded onto a HiTrap[™] Butyl-HP column (GE Healthcare) and active protein was recovered in the unbound fraction. SDS-PAGE analysis showed a single band after staining with Coomassie[™] Blue dye. The protein band was excised , digested with trypsin and analyzed by nano-liquid chromatography/electrospray tandem mass

35 spectrometry (nano-LC/ESI-MS/MS) on a Thermo Q Exactive[™] Orbitrap[™] mass spectrometer (Thermo Fisher Scientific[®], 81 Wyman Street, Waltham, MA 02454)

interfaced with an Eksigent NanoLC 1-D Plus nano-Ic system (AB Sciex™, 500 Old Connecticut Path, Framingham, MA 01701, USA). Ten product ion spectra were collected in an information dependent acquisition mode after a MS1 survey scan.

Protein identification was done by database searches using Mascot® (Matrix Science, 10 Perrins Lane, London NW3 1QY, UK). The search against the in-house database Bacteria-Plus, which combines all bacterial protein sequences and keratin sequences derived from the NCBI non-redundant database (nr) as well as in-house protein sequences, identified a novel gene encoded by strain SS143D5, which was designated as PIP-72Aa (SEQ ID NO: 1).

Example 2 - Identification of homologs of PIP-72Aa

Gene identities may be determined by conducting BLAST (Basic Local Alignment Search Tool; Altschul, *et al.*, (1993) *J. Mol. Biol.* 215:403-410; see also ncbi.nlm.nih.gov/BLAST/, which can be accessed using the www prefix) searches under default parameters for similarity to sequences contained in the publically available BLAST "nr" database (comprising all non-redundant GenBank CDS translations, sequences derived from the 3-dimensional structure Brookhaven Protein Data Bank, the last major release of the SWISS-PROT protein sequence database, EMBL, and DDBJ databases. In addition to public databases, internal DuPont Pioneer databases were searched. The polynucleotide sequences SEQ ID NO: 1 was analyzed.

The search identified several homologs of PIP-72Aa (SEQ ID NO: 2) having varying percent identity to PIP-72Aa (SEQ ID NO: 2). Insecticidal active PIP-72Aa homologs designated herein as: PIP-72Ba (SEQ ID NO: 4); PIP-72Ca (SEQ ID NO: 6); PIP-72Cb (SEQ ID NO: 8); PIP-72Da (SEQ ID NO: 10); PIP-72Db (SEQ ID NO: 12); PIP-72Dc (SEQ ID NO: 14); PIP-72Fa (SEQ ID NO: 18); PIP-72Ff (SEQ ID NO: 28) and PIP-72Gb (SEQ ID NO: 32) were identified from a DuPont Pioneer internal bacterial genome database from: *Pseudomonas rhodesiae*; *Pseudomonas chlororaphis*; *Pseudomonas mandelii*; *Pseudomonas congelans*; *Pseudomonas mandelii*; *Pseudomonas ficuserectae*; *Pseudomonas mosselii*; *Pseudomonas chlororaphis*; and *Pseudomonas chlororaphis* respectively. PIP-72Ba (SEQ ID NO: 4); PIP-72Ca (SEQ ID NO: 6); PIP-72Cb (SEQ ID NO: 8); PIP-72Da (SEQ ID NO: 10); PIP-72Db (SEQ ID NO: 12); PIP-72Dc (SEQ ID NO: 14); PIP-72Fa (SEQ ID NO: 18); PIP-72Ff (SEQ ID NO: 28) and PIP-72Gb (SEQ ID NO: 32) are encoded by SEQ ID NO: 3; SEQ ID NO: 5; SEQ ID NO: 7; SEQ ID NO: 9; SEQ ID NO: 11; SEQ ID NO: 13; SEQ ID NO: 17; SEQ ID NO: 27 and SEQ ID NO: 31, respectively. The inactive low identity homologs designated herein as PIP-72Ea (SEQ ID NO: 16) and PIP-72Ge (SEQ ID NO: 38) were identified from a DuPont Pioneer internal

bacterial genome database from *Pseudomonas congelans* and *Pseudomonas chlororaphis* respectively. PIP-72Ea and PIP-72Ge are encoded by SEQ ID NO: 15 and SEQ ID NO: 37, respectively.

The more distant insecticidal active homologs designated herein as: GBP_A3175
 5 (SEQ ID NO: 20 – Hypothetical Protein GBP346_A3175, Accession # YP_002897852);
 JG43047 (SEQ ID NO: 24 – Hypothetical Protein, Accession # JGI - 2165143047) and
 PFL_6283 (SEQ ID NO: 30 – Hypothetical Protein, Accession # YP_004842361.1) were
 identified from external public databases from: *Burkholderia pseudomallei* MSHR346;
Pseudomonas sp. and *Pseudomonas protegens* Pf-5, respectively. GBP_A3175 (SEQ ID
 10 NO: 20); JG43047 (SEQ ID NO: 24) and PFL_6283 (SEQ ID NO: 30) are encoded by
 SEQ ID NO: 19, SEQ ID NO: 23 and SEQ ID NO: 29, respectively.

The more distant homologs, which were not expressed or were inactive at the
 concentrations tested were designated as SRBS_294080 (SEQ ID NO: 22 – Hypothetical
 Protein from a Switchgrass rhizosphere MC, Accession # JGI 2021745495); SwiRh_4910
 15 (SEQ ID NO: 26 – Hypothetical Protein from Switchgrass rhizosphere, Accession # JGI -
 SwiRh_1014910); XBJ1_1078 (SEQ ID NO: 34 – Hypothetical Protein XBJ1_1078 from
Xenorhabdus bovienii SS-2004, Accession # YP_003467009) and plu2373 (SEQ ID NO:
 36 – Hypothetical Protein plu2373 from *Photorhabdus luminescens subsp. laumondii*
 TTO1, Accession # NP_929618) were identified from external public databases;
 20 *Xenorhabdus* encoded by SEQ ID NO: 21; SEQ ID NO: 25; SEQ ID NO: 33 and SEQ ID
 NO: 35, respectively.

Additional PIP-72 homologs were identified from BLAST searching public
 databases and internal DuPont Pioneer databases basically as described above. Table 5
 shows the PIP-72 polypeptide designation, percent identity to IPD072Aa (SEQ ID NO: 2),
 25 source of the bacterial strain, and bacterial species. Table 6 shows the PIP-72
 polypeptide designation, polypeptide sequence identifier, and polynucleotide sequence
 identifier.

Table 5

PIP-72 homolog	Identity to PIP-72Aa SEQ ID NO: 2	Source	Species
PIP-72Ab	94.2%	internal active strain - SSP587D6-1	<i>Pseudomonas chlororaphis</i>
PIP-72Bb	87.4%	internal collection - SSP555A5b; JH54973-1	<i>Pseudomonas brassicacearum</i>
WP_030131237	77.9%	NCBI-WP_030131237-hypothetical protein	<i>Pseudomonas sp.</i> QTF5
WP_016417435	50.6%	NCBI-hypothetical protein WP_016417435.1	<i>Halomonas anticariensis</i>
BDL_2850	41.1%	NCBI hypothetical protein BDL_2850 (AHE26696)	<i>Burkholderia pseudomallei</i>
PIP-72Fh	41.9%	internal active strain SSP533D8d; SS143C5; SSP436A3a; SSP535F2a; SSP429C9a	<i>Pseudomonas entomophila</i> L48
PIP-72Fi	41.9%	internal active strain SSP533G1a	<i>Pseudomonas entomophila</i>
PIP-72Fj	39.5%	internal active strain JH44835-2; JH59153-1	<i>Pseudomonas chlororaphis</i>
PIP-72Fk	41.9%	internal active strain JH52442-1; JH52448-2	<i>Pseudomonas chlororaphis</i>
PIP-72Fl	44.9%	internal active strain JH59178-1; JH59094-1	<i>Burkholderia multivorans</i>
BBK_2354	43.0%	NCBI hypothetical protein WP_023360071.1 BBK_2354	<i>Burkholderia pseudomallei</i>
D512_15386	38.6%	NCBI hypothetical protein D512_15386 ZP_23811189.1	<i>Burkholderia pseudomallei</i> MSHR1043
PIP-72Gg	33%	internal collection - SSP459B9-3; SSP541A11-3; SSP560B2a; SSP560B12c	<i>Pseudomonas chlororaphis</i>
PIP-72Gh	38.4%	internal collection - SSP469F1d	<i>Pseudomonas chlororaphis</i>
PIP-72Gi	39.5%	internal collection - SSP471D1a; SSP471D1c; SSP4G8; SSP514E4-3; SSP514E2-1;	<i>Pseudomonas mosselii</i>
BTI_1023	37.5%	hypothetical protein BTI_1023, YP_007917531; EMBL-N0ALH1 BURTH	<i>Burkholderia thailandensis</i>
PIP-72Gk	37.5%	internal collection - JH34931-1	<i>Pseudomonas protegens</i>
PIP-72Gl	39.5%	internal collection - SSP490B11a; SSP514E2-1; SSP341E4-3	<i>Pseudomonas plecoglossicida</i>
PIP-72Gm	37.8%	internal collection- JH23445-2	
PIP-72Gn	38.4%	internal collection- SSP579D5-2, SSP581D7-1; SSP579D8-1	<i>Pseudomonas chlororaphis</i>
WP_028536646	39.5%	NCBI-WP_028536646.1-hypothetical protein	<i>Paludibacterium yongneupense</i>
BTRA_1468	38.9%	NCBI-AIC88674.1-hypothetical protein BTRA_1468	<i>Burkholderia thailandensis</i>

Table 6

PIP-72 homolog	Polypeptide	Polynucleotide
PIP-72Ab	SEQ ID NO: 927	SEQ ID NO: 949
PIP-72Bb	SEQ ID NO: 928	SEQ ID NO: 950
WP_030131237	SEQ ID NO: 929	SEQ ID NO: 951
WP_016417435	SEQ ID NO: 930	SEQ ID NO: 952
BDL_2850	SEQ ID NO: 931	SEQ ID NO: 953
PIP-72Fh	SEQ ID NO: 932	SEQ ID NO: 954
PIP-72Fi	SEQ ID NO: 933	SEQ ID NO: 955
PIP-72Fj	SEQ ID NO: 934	SEQ ID NO: 956
PIP-72Fk	SEQ ID NO: 935	SEQ ID NO: 957
PIP-72Fl	SEQ ID NO: 936	SEQ ID NO: 958
BBK_2354	SEQ ID NO: 937	SEQ ID NO: 959
D512_15386	SEQ ID NO: 938	SEQ ID NO: 960
PIP-72Gg	SEQ ID NO: 939	SEQ ID NO: 961
PIP-72Gh	SEQ ID NO: 940	SEQ ID NO: 962
PIP-72Gi	SEQ ID NO: 941	SEQ ID NO: 963
BTI_1023	SEQ ID NO: 942	SEQ ID NO: 964
PIP-72Gk	SEQ ID NO: 943	SEQ ID NO: 965
PIP-72Gl	SEQ ID NO: 944	SEQ ID NO: 966
PIP-72Gm	SEQ ID NO: 945	SEQ ID NO: 967
PIP-72Gn	SEQ ID NO: 946	SEQ ID NO: 968
WP_028536646	SEQ ID NO: 947	SEQ ID NO: 969
BTRA_1468	SEQ ID NO: 948	SEQ ID NO: 970

Figure 1 shows the amino acid sequence alignment of PIP-72Aa (SEQ ID NO: 2), PIP-72Ba (SEQ ID NO: 4); PIP-72Ca (SEQ ID NO: 6); PIP-72Cb (SEQ ID NO: 8); PIP-72Da (SEQ ID NO: 10); PIP-72Db (SEQ ID NO: 12); PIP-72Dc (SEQ ID NO: 14); PIP-72Ea (SEQ ID NO: 16), PIP-72Fa (SEQ ID NO: 18); GBP_A3175 (SEQ ID NO: 20), SRBS_294080 (SEQ ID NO: 22); JG43047 (SEQ ID NO: 24); SwiRh_4910 (SEQ ID NO: 26); PIP-72Ff (SEQ ID NO: 28), PFL_6283 (SEQ ID NO: 30); PIP-72Gb (SEQ ID NO: 32); XBJ1_1078 (SEQ ID NO: 34); plu2373 (SEQ ID NO: 36); and PIP-72Ge (SEQ ID NO: 38). The amino acid sequence diversity is highlighted. Amino acids 37-51 (Motif 1) relative to PIP-72Aa (SEQ ID NO: 2) are underlined.

Figure 2 shows an alignment of the amino acid sequences of PIP-72Aa (SEQ ID NO: 2), PIP-72Ab (SEQ ID NO: 927); PIP-72Ba (SEQ ID NO: 4); PIP-72Bb (SEQ ID NO: 928); PIP-72Ca (SEQ ID NO: 6); PIP-72Cb (SEQ ID NO: 8); WP_030131237 (SEQ ID NO: 929); PIP-72Da (SEQ ID NO: 10); PIP-72Db (SEQ ID NO: 12); PIP-72Dc (SEQ ID NO: 14); PIP-72Fa (SEQ ID NO: 18); and GBP_A3175 (SEQ ID NO: 20). The amino acid sequence diversity between PIP-72Aa (SEQ ID NO: 2) and the other homologs is indicated with shading.

Figure 3 shows the amino acid sequence alignment of PIP-72Aa (SEQ ID NO: 2), PIP-72Ba (SEQ ID NO: 4); PIP-72Ca (SEQ ID NO: 6); PIP-72Cb (SEQ ID NO: 8); PIP-72Da (SEQ ID NO: 10); PIP-72Db (SEQ ID NO: 12); and PIP-72Dc (SEQ ID NO: 14). The amino acid sequence diversity between PIP-72Aa (SEQ ID NO: 2) and the other
5 homologs is indicated with shading.

Figure 4 shows the amino acid sequence alignment of WP_030131237 (SEQ ID NO: 929) PIP-72Ca (SEQ ID NO: 6); PIP-72Cb (SEQ ID NO: 8); PIP-72Da (SEQ ID NO: 10); PIP-72Db (SEQ ID NO: 12); and PIP-72Dc (SEQ ID NO: 14). The amino acid sequence diversity between PIP-72Da (SEQ ID NO: 10) and the other homologs is
10 indicated with shading.

Figure 5 shows an alignment of the amino acid sequences of PIP-72Fh (SEQ ID NO: 932), PIP-72Gi (SEQ ID NO: 941); PIP-72Fi (SEQ ID NO: 933); PIP-72GI (SEQ ID NO: 944); PIP-72Fa (SEQ ID NO: 14). The amino acid diversity between PIP-72Ca (SEQ ID NO: 2) and the other homologs is indicated with shading.

15 Table 7 shows the sequence identity between the PIP-72 homologs.

Table 7

.	GBP_A3175 SEQ ID NO: 20	PIP-72Ab SEQ ID NO: 927	PIP-72Bb SEQ ID NO: 928	WP_030131237 SEQ ID NO: 929	WP_016417435 SEQ ID NO: 930	BDL_2850 SEQ ID NO: 931	PIP-72Fh SEQ ID NO: 932	PIP-72Fi SEQ ID NO: 933	PIP-72Fj SEQ ID NO: 934	PIP-72Fk SEQ ID NO: 935
PIP-72Aa (SEQ ID NO: 2)	42.2	94.2	88.4	77.9	51.2	41.1	39.6	39.6	35.4	37.5
GBP_A3175	-	43.3	46.7	46.7	47.8	97.8	34.4	38.7	38.1	41.2
PIP-72Ab	-	-	87.2	75.6	48.8	42.2	39.6	39.6	33.3	35.4
PIP-72Bb	-	-	-	80.2	48.8	45.6	40.7	40.7	31.2	33.3
WP_030131237	-	-	-	-	52.3	45.6	37.4	37.4	34.4	35.4
WP_016417435	-	-	-	-	-	46.7	33.0	33.0	35.4	37.4
BDL_2850	-	-	-	-	-	-	33.3	37.6	38.1	41.2
PIP-72Fh	-	-	-	-	-	-	-	93.4	52.1	55.2
PIP-72Fi	-	-	-	-	-	-	-	-	53.1	56.2
PIP-72Fj	-	-	-	-	-	-	-	-	-	80.2
PIP-72Fk	-	-	-	-	-	-	-	-	-	-
PIP-72Fl	-	-	-	-	-	-	-	-	-	-
BBK_2354	-	-	-	-	-	-	-	-	-	-
D512_15386	-	-	-	-	-	-	-	-	-	-
PIP-72Gg	-	-	-	-	-	-	-	-	-	-
PIP-72Gh	-	-	-	-	-	-	-	-	-	-
PIP-72Gi	-	-	-	-	-	-	-	-	-	-
BTI_1023	-	-	-	-	-	-	-	-	-	-
PIP-72Gk	-	-	-	-	-	-	-	-	-	-
PIP-72Gl	-	-	-	-	-	-	-	-	-	-
PIP-72Gm	-	-	-	-	-	-	-	-	-	-
PIP-72Gn	-	-	-	-	-	-	-	-	-	-
WP_028536646	-	-	-	-	-	-	-	-	-	-
BTRA_1468	-	-	-	-	-	-	-	-	-	-
JG43047	-	-	-	-	-	-	-	-	-	-
PFL_6283	-	-	-	-	-	-	-	-	-	-
PIP-72Ba	-	-	-	-	-	-	-	-	-	-
PIP-72Ca	-	-	-	-	-	-	-	-	-	-
PIP-72Cb	-	-	-	-	-	-	-	-	-	-
PIP-72Da	-	-	-	-	-	-	-	-	-	-
PIP-72Db	-	-	-	-	-	-	-	-	-	-
PIP-72Dc	-	-	-	-	-	-	-	-	-	-
PIP-72Ea	-	-	-	-	-	-	-	-	-	-
PIP-72Fa	-	-	-	-	-	-	-	-	-	-
PIP-72Ff	-	-	-	-	-	-	-	-	-	-
PIP-72Gb	-	-	-	-	-	-	-	-	-	-
PIP-72Ge	-	-	-	-	-	-	-	-	-	-
Plu2373	-	-	-	-	-	-	-	-	-	-
SRBS_294080	-	-	-	-	-	-	-	-	-	-
SwiRh_4910	-	-	-	-	-	-	-	-	-	-
XBJ1_1078	-	-	-	-	-	-	-	-	-	-

WO 2016/144686

PCT/US2016/020634

.	PIP-72Fl SEQ ID NO: 936	BBK_2354 SEQ ID NO: 937	D512_15386 SEQ ID NO: 938	PIP-72Gg SEQ ID NO: 939	PIP-72Gh SEQ ID NO: 940	PIP-72Gi SEQ ID NO: 941	BTI_1023 SEQ ID NO: 942	PIP-72Gk SEQ ID NO: 943	PIP-72Gl SEQ ID NO: 944	PIP-72Gm SEQ ID NO: 945
PIP-72Aa (SEQ ID NO: 2)	44.9	41.1	37.0	33.7	34.4	37.4	30.0	37.4	39.6	37.8
GBP_A3175	42.9	98.9	89.1	34.7	38.1	37.6	77.8	43.2	37.6	39.1
PIP-72Ab	46.1	42.2	38.0	31.6	32.3	37.4	30.0	38.5	39.6	35.6
PIP-72Bb	43.8	45.6	41.3	33.7	30.2	38.5	32.2	39.6	40.7	36.7
WP_030131237	47.2	45.6	42.4	31.6	33.3	35.2	34.4	37.4	37.4	35.6
WP_016417435	36.0	46.7	42.4	35.8	34.3	33.0	35.6	34.1	33.0	35.5
BDL_2850	41.8	98.9	91.3	33.7	38.1	36.6	80.0	42.1	36.6	38.0
PIP-72Fh	28.3	33.3	32.6	43.4	52.1	94.5	29.0	53.3	94.5	56.0
PIP-72Fi	27.2	37.6	36.8	41.7	53.1	94.5	32.3	53.3	98.9	56.0
PIP-72Fj	34.0	38.1	38.4	48.5	92.7	55.2	29.9	48.5	52.1	59.4
PIP-72Fk	32.0	41.2	39.4	42.6	80.2	58.3	33.0	50.5	55.2	53.1
PIP-72Fl	-	41.8	37.6	35.4	36.1	29.3	31.9	28.3	27.2	35.9
BBK_2354	-	-	90.2	34.7	38.1	36.6	78.9	43.2	36.6	39.1
D512_15386	-	-	-	33.7	38.4	35.8	73.9	41.2	35.8	36.2
PIP-72Gg	-	-	-	-	50.5	43.8	28.1	46.9	41.7	67.4
PIP-72Gh	-	-	-	-	-	55.2	29.9	48.5	52.1	59.4
PIP-72Gi	-	-	-	-	-	-	31.2	53.3	95.6	58.2
BTI_1023	-	-	-	-	-	-	-	34.7	31.2	30.4
PIP-72Gk	-	-	-	-	-	-	-	-	52.2	51.6
PIP-72Gl	-	-	-	-	-	-	-	-	-	56.0
PIP-72Gm	-	-	-	-	-	-	-	-	-	-
PIP-72Gn	-	-	-	-	-	-	-	-	-	-
WP_028536646	-	-	-	-	-	-	-	-	-	-
BTRA_1468	-	-	-	-	-	-	-	-	-	-
JG43047	-	-	-	-	-	-	-	-	-	-
PFL_6283	-	-	-	-	-	-	-	-	-	-
PIP-72Ba	-	-	-	-	-	-	-	-	-	-
PIP-72Ca	-	-	-	-	-	-	-	-	-	-
PIP-72Cb	-	-	-	-	-	-	-	-	-	-
PIP-72Da	-	-	-	-	-	-	-	-	-	-
PIP-72Db	-	-	-	-	-	-	-	-	-	-
PIP-72Dc	-	-	-	-	-	-	-	-	-	-
PIP-72Ea	-	-	-	-	-	-	-	-	-	-
PIP-72Fa	-	-	-	-	-	-	-	-	-	-
PIP-72Ff	-	-	-	-	-	-	-	-	-	-
PIP-72Gb	-	-	-	-	-	-	-	-	-	-
PIP-72Ge	-	-	-	-	-	-	-	-	-	-
Plu2373	-	-	-	-	-	-	-	-	-	-
SRBS_294080	-	-	-	-	-	-	-	-	-	-
SwiRh_4910	-	-	-	-	-	-	-	-	-	-
XBJ1_1078	-	-	-	-	-	-	-	-	-	-

WO 2016/144686

PCT/US2016/020634

.	PIP-72Gn SEQ ID NO: 946	WP_028536646 SEQ ID NO: 947	BTRA_1468 SEQ ID NO: 948	JG43047 SEQ ID NO: 24	PFL_6283 SEQ ID NO: 30	PIP-72Ba SEQ ID NO: 4	PIP-72Ca SEQ ID NO: 6	PIP-72Cb SEQ ID NO: 8	PIP-72Da SEQ ID NO: 10	PIP-72Db SEQ ID NO: 12
PIP-72Aa (SEQ ID NO: 2)	33.7	40.0	31.1	35.7	34.8	83.7	72.1	69.8	68.6	69.8
GBP_A3175	37.4	34.4	77.8	37.4	35.1	45.6	44.4	43.3	45.6	44.4
PIP-72Ab	31.6	35.2	32.2	33.7	32.6	82.6	69.8	67.4	66.3	67.4
PIP-72Bb	29.6	36.7	33.3	31.6	35.9	91.9	68.6	70.9	67.4	68.6
WP_030131237	32.7	36.4	35.6	34.7	34.8	77.9	68.6	68.6	67.4	68.6
WP_016417435	33.7	35.6	36.7	34.7	35.9	51.7	47.7	46.5	47.7	46.5
BDL_2850	37.4	34.4	80.0	37.4	34.0	44.4	43.3	42.2	44.4	43.3
PIP-72Fh	52.0	24.2	30.1	52.0	47.3	40.7	35.2	37.4	36.3	37.4
PIP-72Fi	54.1	24.2	33.3	53.1	44.1	40.7	36.3	38.5	37.4	38.5
PIP-72Fj	90.8	25.0	30.9	96.9	48.0	33.3	35.4	34.4	36.5	35.4
PIP-72Fk	77.6	21.9	35.4	79.6	43.9	35.4	34.4	33.3	35.4	34.4
PIP-72Fl	34.3	30.9	34.1	32.3	29.0	44.9	51.7	49.4	48.3	48.3
BBK_2354	37.4	33.3	78.9	37.4	35.1	44.4	43.3	42.2	44.4	43.3
D512_15386	37.6	29.3	73.9	37.6	35.1	40.2	39.1	38.0	40.2	39.1
PIP-72Gg	48.5	21.2	28.4	48.5	69.5	35.8	31.6	32.6	32.3	31.2
PIP-72Gh	91.8	24.0	30.9	89.8	48.0	31.2	33.3	32.3	34.4	33.3
PIP-72Gi	55.1	23.1	32.3	55.1	46.2	38.5	34.1	36.3	35.2	36.3
BTI_1023	29.3	28.1	94.7	29.3	27.7	31.1	33.3	32.2	35.6	34.4
PIP-72Gk	48.5	30.2	34.0	50.0	47.3	40.7	39.6	41.8	40.7	39.6
PIP-72Gl	53.1	24.2	32.3	52.0	45.2	40.7	36.3	38.5	37.4	38.5
PIP-72Gm	56.1	22.8	32.3	59.2	66.3	37.8	37.4	38.5	39.6	38.5
PIP-72Gn	-	22.4	30.3	90.8	46.0	31.6	33.7	32.7	34.7	33.7
WP_028536646	-	-	29.2	23.5	24.5	36.3	38.5	38.5	36.0	37.2
BTRA_1468	-	-	-	30.3	28.7	32.2	34.4	33.3	35.6	34.4
JG43047	-	-	-	-	48.0	33.7	33.7	32.7	34.7	33.7
PFL_6283	-	-	-	-	-	35.9	33.7	34.8	34.8	33.7
PIP-72Ba	-	-	-	-	-	-	72.1	74.4	69.8	70.9
PIP-72Ca	-	-	-	-	-	-	-	97.7	93.0	93.0
PIP-72Cb	-	-	-	-	-	-	-	-	93.0	93.0
PIP-72Da	-	-	-	-	-	-	-	-	-	97.7
PIP-72Db	-	-	-	-	-	-	-	-	-	-
PIP-72Dc	-	-	-	-	-	-	-	-	-	-
PIP-72Ea	-	-	-	-	-	-	-	-	-	-
PIP-72Fa	-	-	-	-	-	-	-	-	-	-
PIP-72Ff	-	-	-	-	-	-	-	-	-	-
PIP-72Gb	-	-	-	-	-	-	-	-	-	-
PIP-72Ge	-	-	-	-	-	-	-	-	-	-
Plu2373	-	-	-	-	-	-	-	-	-	-
SRBS_294080	-	-	-	-	-	-	-	-	-	-
SwiRh_4910	-	-	-	-	-	-	-	-	-	-
XBJ1_1078	-	-	-	-	-	-	-	-	-	-

.	PIP-72Dc SEQ ID NO: 14	PIP-72Ea SEQ ID NO: 16	PIP-72Fa SEQ ID NO: 18	PIP-72Ff SEQ ID NO: 28	PIP-72Gb SEQ ID NO: 32	PIP-72Ge SEQ ID NO: 38	Plu2373 SEQ ID NO: 36	SRBS_294080 SEQ ID NO: 22	SwiRh_4910 SEQ ID NO: 26	XBJ1_1078 SEQ ID NO: 34
PIP-72Aa (SEQ ID NO: 2)	69.8	51.7	38.5	36.7	34.4	33.7	38.9	41.1	38.9	36.7
GBP_A3175	45.6	46.7	36.6	40.4	40.6	37.4	41.8	39.1	39.1	43.3
PIP-72Ab	67.4	52.9	38.5	34.7	32.3	31.6	39.4	38.9	36.7	35.6
PIP-72Bb	68.6	52.9	39.6	32.7	30.2	29.6	40.4	40.0	37.8	36.7
WP_030131237	67.4	50.6	36.3	34.7	33.3	32.7	42.6	38.9	36.7	38.9
WP_016417435	47.7	43.7	31.9	36.6	34.3	33.7	31.2	37.6	35.5	36.7
BDL_2850	44.4	46.7	35.5	40.4	40.6	37.4	43.9	38.0	38.0	45.6
PIP-72Fh	36.3	35.2	95.6	54.1	53.1	52.0	24.0	56.0	57.1	31.5
PIP-72Fi	37.4	35.2	97.8	55.1	54.2	53.1	25.3	56.0	57.1	30.4
PIP-72Fj	36.5	35.4	52.1	79.6	94.8	90.8	31.7	58.3	59.4	28.1
PIP-72Fk	35.4	35.4	55.2	96.9	78.1	80.6	32.7	54.2	54.2	28.1
PIP-72Fl	48.3	40.4	27.2	32.3	35.1	35.4	32.3	34.1	35.9	31.5
BBK_2354	44.4	46.7	35.5	40.4	40.6	37.4	42.9	39.1	39.1	44.4
D512_15386	40.2	45.7	34.7	38.6	40.8	37.6	38.0	36.2	36.2	40.2
PIP-72Gg	32.3	34.4	41.7	42.7	49.5	49.5	27.9	63.2	67.4	28.4
PIP-72Gh	34.4	35.4	52.1	79.6	92.7	95.9	30.8	58.3	59.4	28.1
PIP-72Gi	35.2	33.0	96.7	57.1	56.2	55.1	24.0	58.2	59.3	29.3
BTI_1023	35.6	36.7	31.2	32.3	32.3	29.3	36.1	30.4	30.4	37.5
PIP-72Gk	40.7	33.7	52.2	52.0	49.5	50.0	33.3	50.5	51.6	31.9
PIP-72Gl	37.4	35.2	98.9	54.1	53.1	52.0	24.0	56.0	57.1	30.4
PIP-72Gm	39.6	37.4	56.0	53.1	59.4	58.2	31.3	93.3	98.9	31.9
PIP-72Gn	34.7	34.7	53.1	79.6	92.9	94.9	30.2	55.1	56.1	27.6
WP_028536646	36.0	30.1	24.2	21.4	24.0	23.5	34.7	23.3	22.8	37.1
BTRA_1468	35.6	37.8	32.3	34.7	30.9	30.3	37.1	32.3	32.3	38.6
JG43047	34.7	34.7	52.0	82.7	91.8	91.8	32.1	58.2	59.2	27.6
PFL_6283	34.8	35.9	45.2	44.0	48.0	47.0	22.9	63.0	67.4	29.0
PIP-72Ba	70.9	51.7	39.6	34.7	32.3	31.6	41.5	41.1	38.9	35.6
PIP-72Ca	91.9	46.0	35.2	33.7	34.4	33.7	40.4	35.6	37.4	37.8
PIP-72Cb	91.9	44.8	37.4	32.7	33.3	32.7	40.4	36.7	38.5	37.8
PIP-72Da	98.8	44.8	36.3	34.7	35.4	34.7	41.5	37.8	39.6	34.4
PIP-72Db	97.7	46.0	37.4	33.7	34.4	33.7	39.4	36.7	38.5	35.6
PIP-72Dc	—	44.8	36.3	34.7	35.4	34.7	41.5	37.8	39.6	34.4
PIP-72Ea	—	—	34.1	34.7	35.4	34.7	35.8	35.6	37.4	35.6
PIP-72Fa	—	—	—	54.1	53.1	52.0	24.0	56.0	57.1	30.4
PIP-72Ff	—	—	—	—	77.6	83.7	32.1	54.1	54.1	27.6
PIP-72Gb	—	—	—	—	—	92.9	30.8	58.3	59.4	28.1
PIP-72Ge	—	—	—	—	—	—	30.2	57.1	58.2	27.6
Plu2373	—	—	—	—	—	—	—	31.6	31.3	41.2
SRBS_294080	—	—	—	—	—	—	—	—	94.4	33.0
SwiRh_4910	—	—	—	—	—	—	—	—	—	31.9
XBJ1_1078	—	—	—	—	—	—	—	—	—	—

Example 3 - E. coli expression of PIP-72Aa and homologs

The PIP-72Aa gene was amplified by PCR using genomic DNA isolated from strain SS143D5: forward primer (SEQ ID NO: 39) and reverse primer (SEQ ID NO: 40). The resulting PCR product was DNA sequence verified and subcloned into pCOLD™ 1 (Takara Bio Inc., Seta 3-4-1, Otsu, Shiga, Japan 520-2193) in frame with an N-terminal His-6 tag followed by a Factor Xa cleavage site. The polynucleotides encoding PIP-72Aa homologs identified from internal strains (PIP-72Ba, PIP-72Ca, PIP-72Cb, PIP-72Da, PIP-72Db, PIP-72Dc, PIP-72Db, PIP-72Ea, PIP-72Fa, JG43047, IDP072Ff, PFL_6283, PIP-72Gb, PIP-72Ge) were cloned as described above, using their respective genomic DNA preparation as template for gene amplification by PCR and the primer sequences indicated in Table 8.

Homologs of PIP-72Aa which were identified from external databases (GBP_A3175, SRBS_294080, SwiRh_4910, XBJ1_1078, Plu2373, WP_030131237, and WP_016417435) were obtained through gene synthesis with compatible 5' and 3' ends for downstream cloning into pCOLD™-1.

Table 8

gene	forward primer	reverse primer
PIP-72Ba	SEQ ID NO: 41	SEQ ID NO: 42
PIP-72Ca	SEQ ID NO: 43	SEQ ID NO: 44
PIP-72Cb	SEQ ID NO: 45	SEQ ID NO: 46
PIP-72Da	SEQ ID NO: 47	SEQ ID NO: 48
PIP-72Dc	SEQ ID NO: 49	SEQ ID NO: 50
PIP-72Db	SEQ ID NO: 51	SEQ ID NO: 52
PIP-72Ea	SEQ ID NO: 53	SEQ ID NO: 54
PIP-72Fa	SEQ ID NO: 55	SEQ ID NO: 56
JG43047	SEQ ID NO: 57	SEQ ID NO: 58
PIP-72Ff	SEQ ID NO: 59	SEQ ID NO: 60
PFL_6283	SEQ ID NO: 61	SEQ ID NO: 62
PIP-72Gb	SEQ ID NO: 63	SEQ ID NO: 64
PIP-72Ge	SEQ ID NO: 65	SEQ ID NO: 66
PIP-72Ge	SEQ ID NO: 67	SEQ ID NO: 68
PIP-72Ab	SEQ ID NO: 971	SEQ ID NO: 972
PIP-72Bb	SEQ ID NO: 973	SEQ ID NO: 974
PIP-72Fi	SEQ ID NO: 975	SEQ ID NO: 976
PIP-72Gh	SEQ ID NO: 977	SEQ ID NO: 978
PIP-72Gg	SEQ ID NO: 979	SEQ ID NO: 980

Competent BL21-DE3 *E. coli* cells were transformed with pCOLD™ -1 plasmid DNA, containing the respective PIP-72 gene insert for recombinant protein expression. The transformed *E. coli* cells were grown overnight at 37°C with carbenicillin selection and then inoculated to a fresh 2xYT medium (1:25) and further grown to an optical density of about 0.8. The cells were then chilled in the presence of 1 mM IPTG and further grown at

16°C for 16 hours to induce protein expression. The *E. coli* expressed proteins were purified by immobilized metal ion chromatography using Ni-NTA agarose (Qiagen®, Germany) according to the manufacturer's protocols.

5 **Example 4 - Insect activity of PIP-72Aa and homologs**

A series of concentrations of the purified protein sample was assayed against Coleoptera insects and concentrations for 50% mortality (LC50) or inhibition of 50% of the individuals (IC50) were calculated in two independent experiments. The WCRW and Northern corn root worm (NCRW) results for PIP-72Aa (SEQ ID NO: 2) are shown in
10 Table 9.

Table 9

insect	effect	ppm	95% confidence interval (ppm)
WCRW	LC50	80	30-130
	IC50	20	10-40
NCRW	LC50	>442	
	IC50	232	159-437

To measure insecticidal activities of other PIP-72 polypeptides, WCRW (*Diabrotica virgifera virgifera*) and NCRW (*Diabrotica barberi*) bioassays were conducted using 20 ul
15 of the purified protein samples applied topically over 75 ul artificial WCRW diet (Bio-Serv F9800B based) in each of a 96 well bioassay plate (BD Falcon 353910) then air dried. For diet incorporation assays 10 ul of test sample were mixed with 50 ul of artificial diet. Independent of the assay format a variable number of neonate *Diabrotica virgifera virgifera* or *Diabrotica barberi* neonates (3 to 9) were placed into each well of the 96 well
20 plate. The assay was run for 4 days at 25°C with no light and then scored for mortality and stunting. The WCRW insecticidal activity for the various PIP-72 polypeptides is shown in Table 10.

PIP-72Aa (SEQ ID NO: 2) was further tested against Southern Corn Root Worm (*Diabrotica undecimpunctata howardi*) and San Antonio beetle (*Diabrotica speciosa*) as
25 well as against the sucking insect *Lygus hesperus*. PIP-72Aa (SEQ ID NO: 2) was not insecticidal against these pests at the concentrations tested (up to 875 ppm of purified protein).

Several other PIP-72 polypeptides were also tested against SCRW (*Diabrotica undecimpunctata howardi*). Bioassays were conducted using 10 ul of the purified protein
30 samples mixed with 50 ul artificial SCRW diet (Bio-Serv F9800B based) in each of a 96 well bioassay plate (BD Falcon 353910). A variable number of neonate *Diabrotica undecimpunctata howardi* neonates (3 to 5) were placed into each well of the 96 well

plate. The assay was run for 4 days at 25°C with no light and then scored for mortality and stunting.

Table 10

	WCRW activity, effect	highest conc. tested, ug/cm2 (ppm)	IC50, ug/cm2	IC50, ppm
PIP-72Aa SEQ ID NO: 2	active , death	300	5-15	10-40
PIP-72Ab SEQ ID NO: 927	active , death	1000		50
PIP-72Ba SEQ ID NO: 4	active , death	(1900)		10-40
PIP-72Bb SEQ ID NO: 928	active , death	1000		50
PIP-72Ca SEQ ID NO: 6	active , death	1500	10-30	70
PIP-72Cb SEQ ID NO: 8	active , death	1000	10-30	84
PIP-72Da SEQ ID NO: 10	active , death	(1666)	not tested in overlay format	40-80
PIP-72Db SEQ ID NO: 12	active , death	750	10-30	95
PIP-72Dc SEQ ID NO: 14	active , death	450	5-15	~100
PIP-72Ea SEQ ID NO: 16	Inactive at concentration tested	(2150)		
PIP-72Fa SEQ ID NO: 18	active , severe stunting	1132	141	
PIP-72Fi SEQ ID NO: 933	active , severe stunting	1000		
PIP-72Gg SEQ ID NO: 939	active , severe stunting	1000		500
PIP-72Gh SEQ ID NO: 940	active , severe stunting	1000		
GBP_A3175 SEQ ID NO: 20	active , death	224	15-30	
SRBS_294080 SEQ ID NO: 22	not expressed	--	--	
JG43047 SEQ ID NO: 24	weakly active , mild stunting	218	>218	
SwiRh_4910 SEQ ID NO: 26	Inactive at concentration tested	708	--	
WP_030131237 SEQ ID NO: 929	active , death			400

	WCRW activity, effect	highest conc. tested, ug/cm2 (ppm)	IC50, ug/cm2	IC50, ppm
WP_016417435 SEQ ID NO: 930	inactive, low expression			
PIP-72Ff SEQ ID NO: 28	weakly active, stunting	565	~ 500	
PFL_6283 SEQ ID NO: 30	weakly active, mild stunting	414	> 414	
PIP-72Gb SEQ ID NO: 32	active, severe stunting	571	71	
XBJ1_1078 SEQ ID NO: 34	inactive	97	--	
Plu2373 SEQ ID NO: 36	not expressed	--	--	
PIP-72Ge SEQ ID NO: 38	inactive	457	--	

Lepidoptera feeding assays were conducted on an artificial diet in a 96 well plate set up. The purified protein was incorporated with the Lepidopteran-specific artificial diet in a ratio of 10 ul cleared lysate and 40 ul of diet mixture. Two to five neonate larvae were placed in each well to feed *ad libitum* for 5 days. Results were expressed as positive for larvae reactions such as stunting and or mortality. Results were expressed as negative if the larvae were similar to the negative control that is feeding diet to which the above buffer only has been applied.

PIP-72Aa (SEQ ID NO: 2), PFL_6283 (SEQ ID NO: 30), PIP-72Da (SEQ ID NO: 10), PIP-72Fa (SEQ ID NO: 18) and PIP-72Gb (SEQ ID NO: 32) were assayed on European corn borer (*Ostrinia nubilalis*), corn earworm (*Helicoverpa zea*), black cutworm (*Agrotis ipsilon*), fall armyworm (*Spodoptera frugiperda*) and Soybean looper (*Pseudoplusia includens*). No activity against the *Lepidoptera* species was seen for any of the PIP-72 polypeptides tested at protein concentrations up to 800 ppm.

Example 5 - Lack of Cross Resistance of PIP-72Aa in mCry3A resistant strain of WCRW

The WCRW strain resistant to mCry3A was developed by selections of WCRW on mCry3A transgenic maize plants with T0 expression level of mCry3A at >10,000 ppm of total proteins in roots. Seven selections were made on F3, F6, F7, F8, F10, F12, F14 larvae. F16 eggs of the Cry3A - resistant insects had a resistance ratio (RR) of >46-fold to mCry3A compared with the susceptible laboratory colony, and were used for cross

resistance testing of PIP-72Aa (SEQ ID NO: 2). Standardized WCRW diet incorporation bioassays were utilized to evaluate the effects of PIP-72Aa (SEQ ID NO: 2) on WCRW larvae. WCRW neonate larvae were placed on the plates containing the bioassay diet and insecticidal protein with 4 replicates for each concentration treatment for 3 days after initiation of each bioassay. Insect mortality and severe stunting was scored and used to calculate inhibitory concentrations (IC₅₀ and LC₅₀) based on probit analysis. The resistance ratio (RR) was calculated as follows: $RR = (LC/IC_{50} \text{ of resistant WCRW}) / (LC/IC_{50} \text{ of susceptible WCRW})$. As shown in Table 11 Cry3A-resistant WCRW insects were sensitive to PIP-72Aa (SEQ ID NO: 2).

10

Table 11

WCRW colony	LC/IC	PIP-72Aa (SEQ ID NO: 2), ppm	95%CL	Resistance Ratio
Cry3A sensitive	LC50	168.9	97.81-429.5	1
	IC50	15.38	11.64-19.68	1
Cry3A resistant	LC50	212.3	102.9-1071	1.3
	IC50	25.97	17.71-38.35	1.7

Example 6 – *Agrobacterium*-mediated Stable Transformation of Maize

For *Agrobacterium*-mediated maize transformation PIP-72 polypeptides, the method of Zhao was employed (US Patent Number 5,981,840 and International Patent Publication Number WO 1998/32326, the contents of which are hereby incorporated by reference). Briefly, immature embryos were isolated from maize and the embryos contacted with an *Agrobacterium* Suspension, where the bacteria were capable of transferring a polynucleotide encoding a PIP-72 polypeptide to at least one cell of at least one of the immature embryos (step 1: the infection step). In this step the immature embryos were immersed in an *Agrobacterium* suspension for the initiation of inoculation. The embryos were co-cultured for a time with the *Agrobacterium* (step 2: the co-cultivation step). The immature embryos were cultured on solid medium with antibiotic, but without a selecting agent, for *Agrobacterium* elimination and for a resting phase for the infected cells. Next, inoculated embryos were cultured on medium containing a selective agent and growing transformed callus is recovered (step 4: the selection step). The immature embryos were cultured on solid medium with a selective agent resulting in the selective growth of transformed cells. The callus was then regenerated into plants (step 5: the regeneration step), and calli grown on selective medium were cultured on solid medium to regenerate the plants.

For detection of the PIP-72 polypeptide in leaf tissue 4 lyophilized leaf punches/sample were pulverized and resuspended in 100 μ L PBS containing 0.1% TWEEN™ 20 (PBST), 1% beta-mercaptoethanol containing 1 tablet/7 mL complete Mini proteinase inhibitor (Roche 1183615301). The suspension was sonicated for 2 min and then centrifuged at 4°C, 20,000 g for 15 min. To a supernatant aliquot 1/3 volume of 3X NuPAGE® LDS Sample Buffer (Invitrogen™ (CA, USA), 1% B-ME containing 1 tablet/7 mL complete Mini proteinase inhibitor was added. The reaction was heated at 80°C for 10 min and then centrifuged. A supernatant sample was loaded on 4-12% Bis-Tris Midi gels with MES running buffer as per manufacturer's (Invitrogen™) instructions and transferred onto a nitrocellulose membrane using an iBlot® apparatus (Invitrogen™). The nitrocellulose membrane was incubated in PBST containing 5% skim milk powder for 2 hours before overnight incubation in affinity-purified rabbit anti-PIP-72Aa in PBST overnight. The membrane was rinsed three times with PBST and then incubated in PBST for 15 min and then two times 5 min before incubating for 2 hours in PBST with goat anti-rabbit-HRP for 3 hours. The detected proteins were visualized using ECL Western Blotting Reagents (GE Healthcare cat # RPN2106) and Kodak® Biomax® MR film. For detection of the PIP-72Aa protein in roots the roots were lyophilized and 2 mg powder per sample was resuspended in LDS, 1% beta-mercaptoethanol containing 1 tablet/7 mL Complete Mini proteinase inhibitor was added. The reaction was heated at 80° C for 10 min and then centrifuged at 4°C, 20,000g for 15 min. A supernatant sample was loaded on 4-12% Bis-Tris Midi gels with MES running buffer as per manufacturer's (Invitrogen™) instructions and transferred onto a nitrocellulose membrane using an iBlot® apparatus (Invitrogen™). The nitrocellulose membrane was incubated in PBST containing 5% skim milk powder for 2 hours before overnight incubation in affinity-purified polyclonal rabbit anti-PIP-72Aa antibody in PBST overnight. The membrane was rinsed three times with PBST and then incubated in PBST for 15 min and then two times 5 min before incubating for 2 hours in PBST with goat anti-rabbit-HRP for 3 hrs. The antibody bound insecticidal proteins were detected using ECL™ Western Blotting Reagents (GE Healthcare cat # RPN2106) and Kodak® Biomax® MR film.

Transgenic maize plants positive for expression of the insecticidal proteins are tested for pesticidal activity using standard bioassays known in the art. Such methods include, for example, root excision bioassays and whole plant bioassays. See, e.g., US Patent Application Publication Number US 2003/0120054 and International Publication Number WO 2003/018810.

Example 7 – Expression Vector constructs for expression of PIP-72Aa in plants

The plant expression vectors, PHP61666, PHP61668, PHP61664 were constructed to include a transgene cassette containing the native PIP-72Aa (SEQ ID NO: 1), PIP-72Aa maize optimized variant 1 (SEQ ID NO: 850) and PIP-72Aa maize optimized variant 2 (SEQ ID NO: 851), respectively, under control of the Mirabilis Mosaic Virus (MMV) promoter [Dey N and Maiti IB, 1999, *Plant Mol. Biol.* 40(5):771-82] in combination with an enhancer element. Additional vectors, PHP64465, PHP64471, and PHP64468 expressing the PIP-72Aa (maize optimized Variant 1) under different promoter, intron and terminator combinations were also tested in transgenic maize events. PHP64465 expresses PIP-72Aa (Variant 1) under control of the maize polyubiquitin promoter and associated 5'UTR and intron (Christensen AH and Quail RH, 1996, *Transgenic Res* 5:213-218) combined with the 35S enhancer (Kay et al., 1987, *Science* 236(4806):1299-1302. PHP64471 and PHP64468 express Variant 1 under control of the Banana Streak Virus [BSV(AY)TR] promoter (Diehn S, Lu AL and Simmons CR, 2012, US patent 8338662B2) with either the ZM-HPLV9 (Diehn S et al., 2011, *US2011039696*) or ZM-ADH1 intron (Callis et al, 1987, *Genes Develop* 1:1183-1200), respectively. PHP69828 expresses PIP-72Aa maize optimized variant 3 (SEQ ID NO: 853) with the same regulatory elements as in PHP64471.

These constructs were used to generate transgenic maize events to test for efficacy against corn rootworm provided by expression of PIP-72Aa (SEQ ID NO: 2).

T0 greenhouse efficacy results for events generated from these constructs are shown in Figure 8. Efficacy for events derived from each of the constructs was observed relative to negative control events as measured by root protection from Western corn root worm. Root protection was measured according to the number of nodes of roots injured (CRWNIS = corn rootworm node injury score) using the method developed by Oleson, et al. (2005) [*J. Econ Entomol.* 98(1):1-8]. The root injury score is measured from "0" to "3" with "0" indicating no visible root injury, "1" indicating 1 node of root damage, "2" indicating 2 nodes or root damage, and "3" indicating a maximum score of 3 nodes of root damage. Intermediate scores (e.g. 1.5) indicate additional fractions of nodes of damage (e.g. one and a half nodes injured).

Figure 8 shows that the majority of events from the test constructs (each represents a single event from the construct) performed better than the negative control with rootworm injury scores of < 1.0. Several constructs such as PHP64471 and PHP64468 showed rootworm injury scores that averaged <0.2 across all events tested.

Example 8 – PIP-72Aa variants with multiple amino acid substitutions

To create variants of PIP-72Aa (SEQ ID NO: 2) with multiple amino acid changes, variant libraries were generated by synthetic DNA shuffling (Ness et al, 2002, *Nature Biotechnology* **20**, 1251-5) of PIP-72Aa (SEQ ID NO: 1) and GBP_A3175 (SEQ ID NO: 19) or by site-directed mutagenesis (QuikChange™ Lightning technique or QuikChange™ II technique, Agilent, Santa Clara CA). An amino acid sequence alignment of PIP-72Aa (SEQ ID NO: 2) and GBP_A3175 (SEQ ID NO: 20) is shown in Figure 5. Briefly, gene synthesis reactions were performed with oligonucleotides listed in Table 12.

Table 12

Name	Sequence	Name	Sequence
oligo 10	SEQ ID NO: 69	oligo 139	SEQ ID NO: 106
oligo 103	SEQ ID NO: 70	oligo 140	SEQ ID NO: 107
oligo 104	SEQ ID NO: 71	oligo 141	SEQ ID NO: 108
oligo 105	SEQ ID NO: 72	oligo 142	SEQ ID NO: 109
oligo 106	SEQ ID NO: 73	oligo 143	SEQ ID NO: 110
oligo 107	SEQ ID NO: 74	oligo 144	SEQ ID NO: 111
oligo 108	SEQ ID NO: 75	oligo 145	SEQ ID NO: 112
oligo 109	SEQ ID NO: 76	oligo 146	SEQ ID NO: 113
oligo 110	SEQ ID NO: 77	oligo 147	SEQ ID NO: 114
oligo 111	SEQ ID NO: 78	oligo 148	SEQ ID NO: 115
oligo 112	SEQ ID NO: 79	oligo 149	SEQ ID NO: 116
oligo 113	SEQ ID NO: 80	oligo 150	SEQ ID NO: 117
oligo 114	SEQ ID NO: 81	oligo 151	SEQ ID NO: 118
oligo 115	SEQ ID NO: 82	oligo 152	SEQ ID NO: 119
oligo 116	SEQ ID NO: 83	oligo 153	SEQ ID NO: 120
oligo 117	SEQ ID NO: 84	oligo 154	SEQ ID NO: 121
oligo 118	SEQ ID NO: 85	oligo 155	SEQ ID NO: 122
oligo 119	SEQ ID NO: 86	oligo 156	SEQ ID NO: 123
oligo 120	SEQ ID NO: 87	oligo 157	SEQ ID NO: 124
oligo 121	SEQ ID NO: 88	oligo 158	SEQ ID NO: 125
oligo 122	SEQ ID NO: 89	oligo 159	SEQ ID NO: 126
oligo 123	SEQ ID NO: 90	oligo 160	SEQ ID NO: 127
oligo 124	SEQ ID NO: 91	oligo 161	SEQ ID NO: 128
oligo 125	SEQ ID NO: 92	oligo 162	SEQ ID NO: 129
oligo 126	SEQ ID NO: 93	oligo 163	SEQ ID NO: 130
oligo 127	SEQ ID NO: 94	oligo 164	SEQ ID NO: 131
oligo 128	SEQ ID NO: 95	oligo 165	SEQ ID NO: 132
oligo 129	SEQ ID NO: 96	oligo 166	SEQ ID NO: 133
oligo 130	SEQ ID NO: 97	oligo 167	SEQ ID NO: 134
oligo 131	SEQ ID NO: 98	oligo 168	SEQ ID NO: 135
oligo 132	SEQ ID NO: 99	oligo 169	SEQ ID NO: 136
oligo 133	SEQ ID NO: 100	oligo 170	SEQ ID NO: 137
oligo 134	SEQ ID NO: 101	oligo 171	SEQ ID NO: 138
oligo 135	SEQ ID NO: 102	oligo 172	SEQ ID NO: 139
oligo 136	SEQ ID NO: 103	oligo 173	SEQ ID NO: 140
oligo 137	SEQ ID NO: 104	oligo 174	SEQ ID NO: 141
oligo 138	SEQ ID NO: 105	oligo 175	SEQ ID NO: 142

Several synthetic genes were generated using different primer sets as indicated in Table 13. Gene synthesis reactions F46, F31 and F39 each utilized sets of 10 discrete

oligonucleotide primers. Gene synthesis reactions deg7, deg15, deg20 utilized sets of oligonucleotide primers with sequence degeneracy, resulting in libraries of sequences. Gene synthesis reactions F46, F31, F39, deg7, deg15 and deg20 were combined and screened as a single library.

5

Table 13

Reaction	Primers
F46	10, 103, 104, 105, 106, 107, 108, 109, 110, 111
deg7	10, 112, 113, 114, 115, 116, 117, 118, 119, 120
deg15	10, 121, 122, 123, 124, 125, 126, 127, 128, 129
F31	10, 130, 131, 132, 133, 134, 135, 136, 137, 138
deg20	10, 139,140, 141, 142, 143, 144, 145, 146, 147, 148, 149, 150, 151, 152, 153, 154, 155, 156, 157, 158, 159, 160, 161, 162, 163, 164, 165, 166
F39	10, 167, 168, 169, 170, 171, 172, 173, 174, 175

Synthetic gene fragments were subcloned in expression vector pCOLD™1 as described in Example 3. The resulting plasmid DNAs were transformed into *E. coli*, and protein was expressed as described in Example 3. Bioassays were performed on Western Corn Root Worm as described in Example 4 to determine which gene variants retained insecticidal activity. DNA sequencing was performed on the active gene variants. The nucleotide and amino acid sequences of the resulting active PIP-72 polypeptide variants are listed in Table 14. Five active variants were recovered from 59 unique variants that were screened. Table 15 shows the amino acid substitutions of the resulting active PIP-72 polypeptide variants compared to PIP-72Aa (SEQ ID NO: 2).

10

15

Table 14

% Identity to PIP72Aa SEQ ID NO: 2	Clone designation	Polynucleotide SEQ ID NO	Polypeptide SEQ ID NO
53%	PIP-72Aa-Fb-01	SEQ ID NO: 287	SEQ ID NO: 528
48%	PIP-72Aa-Fb-09	SEQ ID NO: 288	SEQ ID NO: 529
56%	PIP-72Aa-Fb-27	SEQ ID NO: 289	SEQ ID NO: 530
57%	PIP-72Aa-Fb-28	SEQ ID NO: 290	SEQ ID NO: 531
67%	PIP-72Aa-Fb-33	SEQ ID NO: 291	SEQ ID NO: 532

20

Table 15

Clone Designation	Polypeptide	Amino acid substitutions compared to PIP-72Aa (SEQ ID NO: 2)
-------------------	-------------	---

PIP-72Aa-Fb-01	SEQ ID NO: 528	G002A, T004S, T006K, S009A, I013V, S022T, S027K, F028P, G032A, N033P, K035A, Q036S, E037D, T038S, S042N, S044L, L049M, S050Y, L051V, K052Q, K053L, N054G, A056S, Q057A, Q063L, A064S, S065T, K067N, E069V, V070I, D071Y, N072D, N073D, A074K, K076T, Q078S, R080Q, L081T, I082L, E083L
PIP-72Aa-Fb-09	SEQ ID NO: 529	G002A, T004S, T006K, N008S, S009A, P012T, I013V, A016S, S022T, S027K, F028P, S030K, V031M, G032A, N033P, K035A, Q036S, E037D, S042N, S044L, L049M, S050Y, L051V, K052Q, K053L, N054G, A056S, Q057A, H058T, Q063L, A064S, S065T, K067N, E069V, V070I, D071Y, N072D, N073D, A074K, K076T, Q078S, R080Q, L081T, I082L, E083L
PIP-72Aa-Fb-27	SEQ ID NO: 530	G002A, T006K, N008S, S009A, P012T, A016S, S022T, S027K, F028P, S030K, G032A, N033P, K035A, Q036S, S042N, S044L, S050Y, L051V, K052Q, K053L, N054G, A056S, Q057A, H058T, Q063L, A064S, K067N, E069V, V070I, D071Y, N072D, N073D, A074K, K076T, Q078S, R080Q, L081T, E083L
PIP-72Aa-Fb-28	SEQ ID NO: 531	G002A, T006K, N008S, S009A, P012T, A016S, S027K, F028P, S030K, G032A, N033P, K035A, Q036S, S042N, S044L, S050Y, K052Q, K053L, N054G, A056S, Q057A, H058T, Q063L, A064S, S065T, K067N, E069V, V070I, D071Y, N072D, N073D, A074K, K076T, Q078S, R080Q, L081T, E083L
PIP-72Aa-Fb-33	SEQ ID NO: 532	G002A, T004S, S009A, I013V, S022T, G032A, E037D, T038S, S044L, L049M, L051V, K052Q, Q063L, A064S, S065T, K067N, E069V, V070I, D071Y, N072D, N073D, A074K, K076T, Q078S, R080Q, L081T, I082L, E083L

To generate additional active PIP-72 polypeptides, further site-directed mutagenesis was performed using the polynucleotide sequences PIP-72Aa-Fb-9 (SEQ ID NO: 288), PIP-72Aa-Fb-27 (SEQ ID NO: 289) and PIP-72Aa-Fb-33 (SEQ ID NO: 291) as the templates by the QuikChange™ technique (Agilent, 5301 Stevens Creek Blvd., Santa Clara CA) using oligonucleotide primers listed in Table 16. Primers PIP-72Aa-Fb_9-27_1 (SEQ ID NO: 143), PIP-72Aa-Fb_9-27_2 (SEQ ID NO: 144), PIP-72Aa-Fb_9-27_3 (SEQ ID NO: 145), PIP-72Aa-Fb_9-27_12 (SEQ ID NO: 146), PIP-72Aa-Fb_9-27_13 (SEQ ID NO: 147), and PIP-72Aa-Fb_9-27_14 (SEQ ID NO: 148) were used for mutagenesis of plasmid DNA templates PIP-72Aa-Fb-09 (SEQ ID NO: 288) and PIP-72Aa-Fb-27 (SEQ ID NO: 289). Primers PIP-72Aa-Fb_33_1 through PIP-72Aa-Fb_33_11 (SEQ ID NO: 149 through SEQ ID NO: 159) were used for mutagenesis of plasmid DNA template PIP-72Aa-Fb-33 (SEQ ID NO: 291).

Table 16

Primer Name	Sequence identifier		Primer Name	Sequence identifier
PIP-72Aa-Fb_9-27_1	SEQ ID NO: 143		PIP-72Aa-Fb_33_10	SEQ ID NO: 158
PIP-72Aa-Fb_9-27_2	SEQ ID NO: 144		PIP-72Aa-Fb_33_11	SEQ ID NO: 159

PIP-72Aa-Fb 9-27 3	SEQ ID NO: 145		PIP-72Aa-Fb 33 12	SEQ ID NO: 160
PIP-72Aa-Fb 9-27 12	SEQ ID NO: 146		PIP-72Aa-Fb 33 13	SEQ ID NO: 161
PIP-72Aa-Fb 9-27 13	SEQ ID NO: 147		PIP-72Aa-Fb 33 14	SEQ ID NO: 162
PIP-72Aa-Fb 9-27 14	SEQ ID NO: 148		PIP-72Aa-Fb 33 15	SEQ ID NO: 163
PIP-72Aa-Fb 33 1	SEQ ID NO: 149		PIP-72Aa-Fb 33 16	SEQ ID NO: 164
PIP-72Aa-Fb 33 2	SEQ ID NO: 150		PIP-72Aa-Fb 33 17	SEQ ID NO: 165
PIP-72Aa-Fb 33 3	SEQ ID NO: 151		PIP-72Aa-Fb 33 18	SEQ ID NO: 166
PIP-72Aa-Fb 33 4	SEQ ID NO: 152		PIP-72Aa-Fb 33 19	SEQ ID NO: 167
PIP-72Aa-Fb 33 5	SEQ ID NO: 153		PIP-72Aa-Fb 33 20	SEQ ID NO: 168
PIP-72Aa-Fb 33 6	SEQ ID NO: 154		PIP-72Aa-Fb 33 21	SEQ ID NO: 169
PIP-72Aa-Fb 33 7	SEQ ID NO: 155		PIP-72Aa-Fb 33 22	SEQ ID NO: 170
PIP-72Aa-Fb 33 8	SEQ ID NO: 156		PIP-72Aa-Fb 33 9	SEQ ID NO: 157
PIP-72Aa-Fb 33 9	SEQ ID NO: 157		PIP-72Aa-Fb 33 10	SEQ ID NO: 158

The resulting plasmid DNAs were transformed into *E. coli*, and protein was expressed as described in Example 3. Bioassays were performed on Western Corn Root Worm as described in Example 4 to determine which gene variants retained insecticidal activity. DNA sequencing was performed on the active gene variants. The percent identity compared to PIP-72Aa (SEQ ID NO: 2), clone identification, polynucleotide and polypeptide sequences of the resulting active variants are listed in Table 17. The PIP-72 polypeptide variants from PIP-72Aa-Fb-9 (SEQ ID NO: 530) yielded 33 active variants out of 72 that were screened. The PIP-72 polypeptide variants from PIP-72Aa-Fb-27 (SEQ ID NO: 530) yielded 11 active variants out of 52 that were screened. PIP-72 polypeptide variants from PIP-72Aa-Fb-33 (SEQ ID NO: 532) yielded 47 active variants out of 79 that were screened. Table 18 shows the amino acid substitutions of the resulting active PIP-72 polypeptide variants compared to PIP-72Aa (SEQ ID NO: 2).

Table 17

% Identity to PIP-72Aa	Clone designation	Polynucleotide SEQ ID NO	Polypeptide SEQ ID NO:
55%	D_D0414317	SEQ ID NO: 292	SEQ ID NO: 533
56%	D_D0414326	SEQ ID NO: 293	SEQ ID NO: 534
57%	D_D0414327	SEQ ID NO: 294	SEQ ID NO: 535
55%	D_D0414355	SEQ ID NO: 295	SEQ ID NO: 536
53%	D_D0414366	SEQ ID NO: 296	SEQ ID NO: 537
57%	D_D0414388	SEQ ID NO: 297	SEQ ID NO: 538
52%	D_D0414411	SEQ ID NO: 298	SEQ ID NO: 539
53%	D_D0414412	SEQ ID NO: 299	SEQ ID NO: 540
49%	D_D0414416	SEQ ID NO: 300	SEQ ID NO: 541
48%	D_D0414422	SEQ ID NO: 301	SEQ ID NO: 542
50%	D_D0414424	SEQ ID NO: 302	SEQ ID NO: 543
49%	D_D0414425	SEQ ID NO: 303	SEQ ID NO: 544
53%	D_D0414427	SEQ ID NO: 304	SEQ ID NO: 545
46%	D_D0414430	SEQ ID NO: 305	SEQ ID NO: 546

WO 2016/144686

PCT/US2016/020634

51%	D_D0414433	SEQ ID NO: 306	SEQ ID NO: 547
50%	D_D0414439	SEQ ID NO: 307	SEQ ID NO: 548
49%	D_D0414449	SEQ ID NO: 308	SEQ ID NO: 549
49%	D_D0414450	SEQ ID NO: 309	SEQ ID NO: 550
49%	D_D0414453	SEQ ID NO: 310	SEQ ID NO: 551
48%	D_D0414454	SEQ ID NO: 311	SEQ ID NO: 552
52%	D_D0414455	SEQ ID NO: 312	SEQ ID NO: 553
50%	D_D0414459	SEQ ID NO: 313	SEQ ID NO: 554
48%	D_D0414462	SEQ ID NO: 314	SEQ ID NO: 555
50%	D_D0414466	SEQ ID NO: 315	SEQ ID NO: 556
51%	D_D0414470	SEQ ID NO: 316	SEQ ID NO: 557
49%	D_D0414471	SEQ ID NO: 317	SEQ ID NO: 558
51%	D_D0414475	SEQ ID NO: 318	SEQ ID NO: 559
50%	D_D0414479	SEQ ID NO: 319	SEQ ID NO: 560
51%	D_D0414486	SEQ ID NO: 320	SEQ ID NO: 561
50%	D_D0414489	SEQ ID NO: 321	SEQ ID NO: 562
50%	D_D0414493	SEQ ID NO: 322	SEQ ID NO: 563
69%	D_D0419050	SEQ ID NO: 323	SEQ ID NO: 564
70%	D_D0419051	SEQ ID NO: 324	SEQ ID NO: 565
70%	D_D0419053	SEQ ID NO: 325	SEQ ID NO: 566
69%	D_D0419057	SEQ ID NO: 326	SEQ ID NO: 567
71%	D_D0419058	SEQ ID NO: 327	SEQ ID NO: 568
66%	D_D0419060	SEQ ID NO: 328	SEQ ID NO: 569
71%	D_D0419062	SEQ ID NO: 329	SEQ ID NO: 570
70%	D_D0419064	SEQ ID NO: 330	SEQ ID NO: 571
66%	D_D0419066	SEQ ID NO: 331	SEQ ID NO: 572
69%	D_D0419071	SEQ ID NO: 332	SEQ ID NO: 573
70%	D_D0419072	SEQ ID NO: 333	SEQ ID NO: 574
69%	D_D0419075	SEQ ID NO: 334	SEQ ID NO: 575
72%	D_D0419077	SEQ ID NO: 335	SEQ ID NO: 576
71%	D_D0419082	SEQ ID NO: 336	SEQ ID NO: 577
69%	D_D0419083	SEQ ID NO: 337	SEQ ID NO: 578
66%	D_D0419084	SEQ ID NO: 338	SEQ ID NO: 579
70%	D_D0419087	SEQ ID NO: 339	SEQ ID NO: 580
69%	D_D0419091	SEQ ID NO: 340	SEQ ID NO: 581
73%	D_D0419093	SEQ ID NO: 341	SEQ ID NO: 582
70%	D_D0419095	SEQ ID NO: 342	SEQ ID NO: 583
71%	D_D0419096	SEQ ID NO: 343	SEQ ID NO: 584
70%	D_D0419098	SEQ ID NO: 344	SEQ ID NO: 585
70%	D_D0419099	SEQ ID NO: 345	SEQ ID NO: 586
70%	D_D0419101	SEQ ID NO: 346	SEQ ID NO: 587
69%	D_D0419102	SEQ ID NO: 347	SEQ ID NO: 588
71%	D_D0419106	SEQ ID NO: 348	SEQ ID NO: 589
70%	D_D0419108	SEQ ID NO: 349	SEQ ID NO: 590
67%	D_D0419109	SEQ ID NO: 350	SEQ ID NO: 591
67%	D_D0419110	SEQ ID NO: 351	SEQ ID NO: 592
69%	D_D0419111	SEQ ID NO: 352	SEQ ID NO: 593
67%	D_D0419114	SEQ ID NO: 353	SEQ ID NO: 594
70%	D_D0419115	SEQ ID NO: 354	SEQ ID NO: 595
72%	D_D0419117	SEQ ID NO: 355	SEQ ID NO: 596
74%	D_D0419118	SEQ ID NO: 356	SEQ ID NO: 597
67%	D_D0419119	SEQ ID NO: 357	SEQ ID NO: 598
69%	D_D0419120	SEQ ID NO: 358	SEQ ID NO: 599
72%	D_D0419124	SEQ ID NO: 359	SEQ ID NO: 600
72%	D_D0419126	SEQ ID NO: 360	SEQ ID NO: 601
71%	D_D0419127	SEQ ID NO: 361	SEQ ID NO: 602

70%	D_D0419128	SEQ ID NO: 362	SEQ ID NO: 603
71%	D_D0419132	SEQ ID NO: 363	SEQ ID NO: 604
69%	D_D0419138	SEQ ID NO: 364	SEQ ID NO: 605
65%	D_D0419142	SEQ ID NO: 365	SEQ ID NO: 606
69%	D_D0419145	SEQ ID NO: 366	SEQ ID NO: 607

Table 18

Clone Designation	Polypeptide	Amino acid substitutions compared to PIP-72Aa (SEQ ID NO: 2)
D_D0414317	SEQ ID NO: 533	G002A, T004S, T006K, N008S, S009A, P012T, I013V, S022T, S027K, F028P, S030K, G032A, N033P, K035A, Q036S, S042N, S044L, S050Y, L051V, K052Q, K053L, N054G, A056S, Q057A, H058T, Q063L, A064S, K067N, E069V, V070I, D071Y, N072D, N073D, A074K, K076T, Q078S, R080Q, L081T, E083L
D_D0414326	SEQ ID NO: 534	G002A, T006K, N008S, S009A, P012T, I013V, S022T, S027K, F028P, S030K, G032A, N033P, K035A, Q036S, S042N, S044L, S050Y, L051V, K052Q, K053L, N054G, A056S, Q057A, H058T, Q063L, A064S, K067N, E069V, V070I, D071Y, N072D, N073D, A074K, K076T, Q078S, R080Q, L081T, E083L
D_D0414327	SEQ ID NO: 535	G002A, T006K, N008S, S009A, P012T, S022T, S027K, F028P, S030K, G032A, N033P, K035A, Q036S, S042N, S044L, L049M, S050Y, L051V, K053L, N054G, A056S, Q057A, H058T, Q063L, A064S, K067N, E069V, V070I, D071Y, N072D, N073D, A074K, K076T, Q078S, R080Q, L081T, E083L
D_D0414355	SEQ ID NO: 536	G002A, T006K, N008S, S009A, P012T, A016S, S022T, S027K, F028P, S030K, G032A, N033P, K035A, Q036S, S042N, S044L, L049M, S050Y, L051V, K052Q, K053L, N054G, A056S, Q057A, H058T, Q063L, A064S, K067N, E069V, V070I, D071Y, N072D, N073D, A074K, K076T, Q078S, R080Q, L081T, E083L
D_D0414366	SEQ ID NO: 537	G002A, T006K, N008S, S009A, P012T, A016S, S022T, S027K, F028P, S030K, G032A, N033P, K035A, Q036S, E037D, T038S, S042N, S044L, S050Y, L051V, K052Q, K053L, N054G, A056S, Q057A, H058T, Q063L, A064S, K067N, E069V, V070I, D071Y, N072D, N073D, A074K, K076T, Q078S, R080Q, L081T, E083L
D_D0414388	SEQ ID NO: 538	G002A, T004S, T006K, N008S, P012T, S022T, S027K, F028P, S030K, G032A, N033P, K035A, Q036S, S042N, S044L, S050Y, L051V, K052Q, K053L, N054G, A056S, Q057A, H058T, Q063L, A064S, K067N, E069V, V070I, D071Y, N072D, N073D, A074K, K076T, Q078S, R080Q, L081T, E083L
D_D0414411	SEQ ID NO: 539	G002A, T006K, P012T, A016S, S022T, S027K, F028P, S030K, V031M, G032A, N033P, K035A, Q036S, T038S, S042N, S044L, L049M, S050Y, L051V, K052Q, K053L, N054G, A056S, Q057A, H058T, Q063L, A064S, S065T, K067N, E069V, V070I, D071Y, N072D, N073D, A074K, K076T, Q078S, R080Q, L081T, I082L, E083L

Clone Designation	Polypeptide	Amino acid substitutions compared to PIP-72Aa (SEQ ID NO: 2)
D_D0414412	SEQ ID NO: 540	G002A, T006K, S009A, P012T, S022T, S027K, F028P, S030K, V031M, G032A, N033P, K035A, Q036S, T038S, S042N, S044L, S050Y, L051V, K052Q, K053L, N054G, A056S, Q057A, H058T, Q063L, A064S, S065T, K067N, E069V, V070I, D071Y, N072D, N073D, A074K, K076T, Q078S, R080Q, L081T, I082L, E083L
D_D0414416	SEQ ID NO: 541	G002A, T004S, T006K, S009A, P012T, I013V, A016S, S022T, S027K, F028P, S030K, V031M, G032A, N033P, K035A, Q036S, E037D, S042N, S044L, L049M, S050Y, L051V, K052Q, K053L, N054G, A056S, Q057A, H058T, Q063L, A064S, S065T, K067N, E069V, V070I, D071Y, N072D, N073D, A074K, K076T, Q078S, R080Q, L081T, I082L, E083L
D_D0414422	SEQ ID NO: 542	G002A, T004S, T006K, N008S, S009A, P012T, I013V, A016S, S022T, S027K, F028P, S030K, V031M, G032A, N033P, K035A, Q036S, T038S, S042N, S044L, L049M, S050Y, L051V, K052Q, K053L, N054G, A056S, Q057A, H058T, Q063L, A064S, S065T, K067N, E069V, V070I, D071Y, N072D, N073D, A074K, K076T, Q078S, R080Q, L081T, I082L, E083L
D_D0414424	SEQ ID NO: 543	G002A, T004S, T006K, N008S, P012T, A016S, S022T, S027K, F028P, S030K, V031M, G032A, N033P, K035A, Q036S, E037D, S042N, S044L, L049M, S050Y, L051V, K052Q, K053L, N054G, A056S, Q057A, H058T, Q063L, A064S, S065T, K067N, E069V, V070I, D071Y, N072D, N073D, A074K, K076T, Q078S, R080Q, L081T, I082L, E083L
D_D0414425	SEQ ID NO: 544	G002A, T004S, T006K, N008S, S009A, P012T, I013V, A016S, S022T, S027K, F028P, S030K, V031M, G032A, N033P, K035A, Q036S, E037D, S042N, S044L, S050Y, L051V, K052Q, K053L, N054G, A056S, Q057A, H058T, Q063L, A064S, S065T, K067N, E069V, V070I, D071Y, N072D, N073D, A074K, K076T, Q078S, R080Q, L081T, I082L, E083L
D_D0414427	SEQ ID NO: 545	G002A, T006K, N008S, P012T, S022T, S027K, F028P, S030K, V031M, G032A, N033P, K035A, Q036S, S042N, S044L, L049M, S050Y, L051V, K052Q, K053L, N054G, A056S, Q057A, H058T, Q063L, A064S, S065T, K067N, E069V, V070I, D071Y, N072D, N073D, A074K, K076T, Q078S, R080Q, L081T, I082L, E083L
D_D0414430	SEQ ID NO: 546	G002A, T004S, T006K, N008S, S009A, P012T, I013V, A016S, S022T, S027K, F028P, S030K, V031M, G032A, N033P, K035A, Q036S, E037D, T038S, S042N, S044L, L049M, S050Y, L051V, K052Q, K053L, N054G, A056S, Q057A, H058T, Q063L, A064S, S065T, K067N, E069V, V070I, D071Y, N072D, N073D, A074K, K076T, Q078S, R080Q, L081T, I082L, E083L
D_D0414433	SEQ ID NO: 547	G002A, T004S, T006K, N008S, P012T, A016S, S022T, S027K, F028P, S030K, V031M, G032A, N033P, K035A, Q036S, S042N, S044L, L049M, S050Y, L051V, K052Q, K053L, N054G, A056S, Q057A, H058T, Q063L, A064S, S065T, K067N, E069V, V070I, D071Y, N072D, N073D, A074K, K076T, Q078S, R080Q, L081T, I082L, E083L

Clone Designation	Polypeptide	Amino acid substitutions compared to PIP-72Aa (SEQ ID NO: 2)
D_D0414439	SEQ ID NO: 548	G002A, T004S, T006K, N008S, S009A, P012T, I013V, A016S, S022T, S027K, F028P, S030K, V031M, G032A, N033P, K035A, Q036S, S042N, S044L, S050Y, L051V, K052Q, K053L, N054G, A056S, Q057A, H058T, Q063L, A064S, S065T, K067N, E069V, V070I, D071Y, N072D, N073D, A074K, K076T, Q078S, R080Q, L081T, I082L, E083L
D_D0414449	SEQ ID NO: 549	G002A, T006K, N008S, S009A, P012T, I013V, A016S, S022T, S027K, F028P, S030K, V031M, G032A, N033P, K035A, Q036S, T038S, S042N, S044L, L049M, S050Y, L051V, K052Q, K053L, N054G, A056S, Q057A, H058T, Q063L, A064S, S065T, K067N, E069V, V070I, D071Y, N072D, N073D, A074K, K076T, Q078S, R080Q, L081T, I082L, E083L
D_D0414450	SEQ ID NO: 550	G002A, T004S, T006K, N008S, S009A, P012T, A016S, S022T, S027K, F028P, S030K, V031M, G032A, N033P, K035A, Q036S, T038S, S042N, S044L, L049M, S050Y, L051V, K052Q, K053L, N054G, A056S, Q057A, H058T, Q063L, A064S, S065T, K067N, E069V, V070I, D071Y, N072D, N073D, A074K, K076T, Q078S, R080Q, L081T, I082L, E083L
D_D0414453	SEQ ID NO: 551	G002A, T004S, T006K, N008S, S009A, P012T, I013V, A016S, S022T, S027K, F028P, S030K, V031M, G032A, N033P, K035A, Q036S, S042N, S044L, L049M, S050Y, L051V, K052Q, K053L, N054G, A056S, Q057A, H058T, Q063L, A064S, S065T, K067N, E069V, V070I, D071Y, N072D, N073D, A074K, K076T, Q078S, R080Q, L081T, I082L, E083L
D_D0414454	SEQ ID NO: 552	G002A, T004S, T006K, N008S, S009A, P012T, I013V, A016S, S022T, S027K, F028P, S030K, V031M, G032A, N033P, K035A, Q036S, E037D, T038S, S042N, S044L, S050Y, L051V, K052Q, K053L, N054G, A056S, Q057A, H058T, Q063L, A064S, S065T, K067N, E069V, V070I, D071Y, N072D, N073D, A074K, K076T, Q078S, R080Q, L081T, I082L, E083L
D_D0414455	SEQ ID NO: 553	G002A, T006K, S009A, P012T, I013V, S022T, S027K, F028P, S030K, V031M, G032A, N033P, K035A, Q036S, S042N, S044L, L049M, S050Y, L051V, K052Q, K053L, N054G, A056S, Q057A, H058T, Q063L, A064S, S065T, K067N, E069V, V070I, D071Y, N072D, N073D, A074K, K076T, Q078S, R080Q, L081T, I082L, E083L
D_D0414459	SEQ ID NO: 554	G002A, T004S, T006K, P012T, A016S, S022T, S027K, F028P, S030K, V031M, G032A, N033P, K035A, Q036S, E037D, T038S, S042N, S044L, L049M, S050Y, L051V, K052Q, K053L, N054G, A056S, Q057A, H058T, Q063L, A064S, S065T, K067N, E069V, V070I, D071Y, N072D, N073D, A074K, K076T, Q078S, R080Q, L081T, I082L, E083L
D_D0414462	SEQ ID NO: 555	G002A, T004S, T006K, N008S, S009A, P012T, A016S, S022T, S027K, F028P, S030K, V031M, G032A, N033P, K035A, Q036S, E037D, T038S, S042N, S044L, L049M, S050Y, L051V, K052Q, K053L, N054G, A056S, Q057A, H058T, Q063L, A064S, S065T, K067N, E069V, V070I, D071Y, N072D, N073D, A074K, K076T, Q078S, R080Q, L081T, I082L, E083L

Clone Designation	Polypeptide	Amino acid substitutions compared to PIP-72Aa (SEQ ID NO: 2)
D_D0414466	SEQ ID NO: 556	G002A, T004S, T006K, N008S, P012T, I013V, S022T, S027K, F028P, S030K, V031M, G032A, N033P, K035A, Q036S, E037D, T038S, S042N, S044L, S050Y, L051V, K052Q, K053L, N054G, A056S, Q057A, H058T, Q063L, A064S, S065T, K067N, E069V, V070I, D071Y, N072D, N073D, A074K, K076T, Q078S, R080Q, L081T, I082L, E083L
D_D0414470	SEQ ID NO: 557	G002A, T006K, N008S, S009A, P012T, S022T, S027K, F028P, S030K, V031M, G032A, N033P, K035A, Q036S, E037D, S042N, S044L, L049M, S050Y, L051V, K052Q, K053L, N054G, A056S, Q057A, H058T, Q063L, A064S, S065T, K067N, E069V, V070I, D071Y, N072D, N073D, A074K, K076T, Q078S, R080Q, L081T, I082L, E083L
D_D0414471	SEQ ID NO: 558	G002A, T004S, T006K, N008S, S009A, P012T, I013V, A016S, S022T, S027K, F028P, S030K, V031M, G032A, N033P, K035A, Q036S, E037D, S042N, S044L, S050Y, L051V, K052Q, K053L, N054G, A056S, Q057A, H058T, Q063L, A064S, S065T, K067N, E069V, V070I, D071Y, N072D, N073D, A074K, K076T, Q078S, R080Q, L081T, I082L, E083L
D_D0414475	SEQ ID NO: 559	G002A, T004S, T006K, P012T, I013V, S022T, S027K, F028P, S030K, V031M, G032A, N033P, K035A, Q036S, T038S, S042N, S044L, L049M, S050Y, L051V, K052Q, K053L, N054G, A056S, Q057A, H058T, Q063L, A064S, S065T, K067N, E069V, V070I, D071Y, N072D, N073D, A074K, K076T, Q078S, R080Q, L081T, I082L, E083L
D_D0414479	SEQ ID NO: 560	G002A, T004S, T006K, N008S, P012T, I013V, S022T, S027K, F028P, S030K, V031M, G032A, N033P, K035A, Q036S, T038S, S042N, S044L, L049M, S050Y, L051V, K052Q, K053L, N054G, A056S, Q057A, H058T, Q063L, A064S, S065T, K067N, E069V, V070I, D071Y, N072D, N073D, A074K, K076T, Q078S, R080Q, L081T, I082L, E083L
D_D0414486	SEQ ID NO: 561	G002A, T006K, N008S, S009A, P012T, I013V, S022T, S027K, F028P, S030K, V031M, G032A, N033P, K035A, Q036S, E037D, S042N, S044L, L049M, S050Y, L051V, K053L, N054G, A056S, Q057A, H058T, Q063L, A064S, S065T, K067N, E069V, V070I, D071Y, N072D, N073D, A074K, K076T, Q078S, R080Q, L081T, I082L, E083L
D_D0414489	SEQ ID NO: 562	G002A, T004S, T006K, N008S, S009A, P012T, I013V, A016S, S022T, S027K, F028P, S030K, V031M, G032A, N033P, K035A, Q036S, E037D, S042N, S044L, S050Y, L051V, K053L, N054G, A056S, Q057A, H058T, Q063L, A064S, S065T, K067N, E069V, V070I, D071Y, N072D, N073D, A074K, K076T, Q078S, R080Q, L081T, I082L, E083L
D_D0414493	SEQ ID NO: 563	G002A, T004S, T006K, N008S, P012T, I013V, A016S, S022T, S027K, F028P, S030K, V031M, G032A, N033P, K035A, Q036S, E037D, S042N, S044L, S050Y, L051V, K052Q, K053L, N054G, A056S, Q057A, H058T, Q063L, A064S, S065T, K067N, E069V, V070I, D071Y, N072D, N073D, A074K, K076T, Q078S, R080Q, L081T, I082L, E083L

Clone Designation	Polypeptide	Amino acid substitutions compared to PIP-72Aa (SEQ ID NO: 2)
D_D0419050	SEQ ID NO: 564	G002A, T004S, N008S, S009A, I013V, S022T, G032A, T038S, S044L, L049M, L051V, Q063L, A064S, S065T, K067N, E069V, V070I, D071Y, N072D, N073D, A074K, K076T, Q078S, R080Q, L081T, I082L, E083L
D_D0419051	SEQ ID NO: 565	G002A, T004S, S009A, I013V, S022T, G032A, E037D, T038S, S044L, L049M, L051V, K052Q, Q063L, A064S, S065T, K067N, E069V, V070I, D071Y, N072D, N073D, A074K, K076T, Q078S, R080Q, E083L
D_D0419053	SEQ ID NO: 566	G002A, T004S, S009A, S022T, G032A, T038S, S044L, L049M, L051V, K052Q, Q063L, A064S, S065T, K067N, E069V, V070I, D071Y, N072D, N073D, A074K, K076T, Q078S, R080Q, L081T, I082L, E083L
D_D0419057	SEQ ID NO: 567	G002A, T004S, S009A, I013V, S022T, G032A, E037D, T038S, S044L, L049M, L051V, Q063L, A064S, S065T, K067N, E069V, V070I, D071Y, N072D, N073D, A074K, K076T, Q078S, R080Q, L081T, I082L, E083L
D_D0419058	SEQ ID NO: 568	G002A, T004S, S009A, S022T, G032A, S044L, L049M, L051V, K052Q, Q063L, A064S, S065T, K067N, E069V, V070I, D071Y, N072D, N073D, A074K, K076T, Q078S, R080Q, L081T, I082L, E083L
D_D0419060	SEQ ID NO: 569	G002A, T004S, N008S, S009A, I013V, S022T, G032A, E037D, T038S, S044L, L049M, L051V, K052Q, Q063L, A064S, S065T, K067N, E069V, V070I, D071Y, N072D, N073D, A074K, K076T, Q078S, R080Q, L081T, I082L, E083L
D_D0419062	SEQ ID NO: 570	G002A, T004S, S009A, I013V, S022T, G032A, S044L, L051V, K052Q, Q063L, A064S, S065T, K067N, E069V, V070I, D071Y, N072D, N073D, A074K, K076T, Q078S, R080Q, L081T, I082L, E083L
D_D0419064	SEQ ID NO: 571	G002A, T004S, S009A, I013V, S022T, G032A, T038S, S044L, L051V, K052Q, Q063L, A064S, S065T, K067N, E069V, V070I, D071Y, N072D, N073D, A074K, K076T, Q078S, R080Q, L081T, I082L, E083L
D_D0419066	SEQ ID NO: 572	G002A, T004S, S009A, I013V, A016S, S022T, G032A, E037D, T038S, S044L, L049M, L051V, K052Q, Q063L, A064S, S065T, K067N, E069V, V070I, D071Y, N072D, N073D, A074K, K076T, Q078S, R080Q, L081T, I082L, E083L
D_D0419071	SEQ ID NO: 573	G002A, T004S, S009A, I013V, S022T, G032A, E037D, T038S, S044L, L049M, L051V, K052Q, Q063L, A064S, S065T, K067N, E069V, V070I, D071Y, N072D, N073D, A074K, K076T, Q078S, R080Q, L081T, I082L
D_D0419072	SEQ ID NO: 574	G002A, T004S, S009A, I013V, S022T, G032A, S044L, L049M, L051V, K052Q, Q063L, A064S, S065T, K067N, E069V, V070I, D071Y, N072D, N073D, A074K, K076T, Q078S, R080Q, L081T, I082L, E083L
D_D0419075	SEQ ID NO: 575	G002A, T004S, S009A, I013V, S022T, G032A, T038S, S044L, L049M, L051V, K052Q, Q063L, A064S, S065T, K067N, E069V, V070I, D071Y, N072D, N073D, A074K, K076T, Q078S, R080Q, L081T, I082L, E083L
D_D0419077	SEQ ID NO: 576	G002A, T004S, S022T, G032A, E037D, T038S, S044L, L051V, Q063L, A064S, S065T, K067N, E069V, V070I, D071Y, N072D, N073D, A074K, K076T, Q078S, R080Q, L081T, I082L, E083L

Clone Designation	Polypeptide	Amino acid substitutions compared to PIP-72Aa (SEQ ID NO: 2)
D_D0419082	SEQ ID NO: 577	G002A, T004S, S022T, G032A, E037D, S044L, L049M, L051V, K052Q, Q063L, A064S, S065T, K067N, E069V, V070I, D071Y, N072D, N073D, A074K, K076T, Q078S, R080Q, L081T, I082L, E083L
D_D0419083	SEQ ID NO: 578	G002A, T004S, S009A, S022T, G032A, E037D, T038S, S044L, L049M, L051V, K052Q, Q063L, A064S, S065T, K067N, E069V, V070I, D071Y, N072D, N073D, A074K, K076T, Q078S, R080Q, L081T, I082L, E083L
D_D0419084	SEQ ID NO: 579	G002A, T004S, N008S, S009A, I013V, A016S, S022T, G032A, E037D, S044L, L049M, L051V, K052Q, Q063L, A064S, S065T, K067N, E069V, V070I, D071Y, N072D, N073D, A074K, K076T, Q078S, R080Q, L081T, I082L, E083L
D_D0419087	SEQ ID NO: 580	G002A, T004S, S009A, I013V, A016S, S022T, G032A, S044L, L049M, L051V, K052Q, Q063L, A064S, S065T, K067N, E069V, V070I, D071Y, N072D, N073D, A074K, K076T, Q078S, R080Q, L081T, E083L
D_D0419091	SEQ ID NO: 581	G002A, T004S, S009A, I013V, S022T, G032A, T038S, S044L, L049M, L051V, K052Q, Q063L, A064S, S065T, K067N, E069V, V070I, D071Y, N072D, N073D, A074K, K076T, Q078S, R080Q, L081T, I082L, E083L
D_D0419093	SEQ ID NO: 582	G002A, I013V, S022T, G032A, S044L, L051V, Q063L, A064S, S065T, K067N, E069V, V070I, D071Y, N072D, N073D, A074K, K076T, Q078S, R080Q, L081T, I082L, E083L, L085A
D_D0419095	SEQ ID NO: 583	G002A, T004S, S009A, I013V, A016S, S022T, G032A, S044L, L049M, L051V, Q063L, A064S, S065T, K067N, E069V, V070I, D071Y, N072D, N073D, A074K, K076T, Q078S, R080Q, L081T, I082L, E083L
D_D0419096	SEQ ID NO: 584	G002A, T004S, S009A, S022T, G032A, T038S, S044L, L049M, L051V, K052Q, Q063L, A064S, S065T, K067N, E069V, V070I, D071Y, N072D, N073D, A074K, K076T, Q078S, R080Q, E083L, L085A
D_D0419098	SEQ ID NO: 585	G002A, T004S, S009A, I013V, A016S, S022T, G032A, E037D, T038S, S044L, L049M, L051V, K052Q, Q063L, A064S, S065T, K067N, E069V, V070I, D071Y, N072D, N073D, A074K, K076T, Q078S, R080Q
D_D0419099	SEQ ID NO: 586	G002A, T004S, S022T, G032A, E037D, T038S, S044L, L049M, L051V, K052Q, Q063L, A064S, S065T, K067N, E069V, V070I, D071Y, N072D, N073D, A074K, K076T, Q078S, R080Q, L081T, I082L, E083L
D_D0419101	SEQ ID NO: 587	G002A, T004S, S009A, S022T, G032A, T038S, S044L, L049M, L051V, K052Q, Q063L, A064S, S065T, K067N, E069V, V070I, D071Y, N072D, N073D, A074K, K076T, Q078S, R080Q, L081T, I082L, E083L
D_D0419102	SEQ ID NO: 588	G002A, T004S, N008S, S009A, I013V, S022T, G032A, S044L, L049M, L051V, K052Q, Q063L, A064S, S065T, K067N, E069V, V070I, D071Y, N072D, N073D, A074K, K076T, Q078S, R080Q, L081T, I082L, E083L
D_D0419106	SEQ ID NO: 589	G002A, T004S, S009A, A016S, S022T, G032A, S044L, L049M, L051V, K052Q, Q063L, A064S, S065T, K067N, E069V, V070I, D071Y, N072D, N073D, A074K, K076T, Q078S, R080Q, L081T, I082L

Clone Designation	Polypeptide	Amino acid substitutions compared to PIP-72Aa (SEQ ID NO: 2)
D_D0419108	SEQ ID NO: 590	G002A, T004S, S009A, I013V, S022T, G032A, E037D, T038S, S044L, L049M, L051V, Q063L, A064S, S065T, K067N, E069V, V070I, D071Y, N072D, N073D, A074K, K076T, Q078S, R080Q, L081T, E083L
D_D0419109	SEQ ID NO: 591	G002A, T004S, S009A, I013V, S022T, G032A, E037D, S044L, L049M, L051V, K052Q, Q063L, A064S, S065T, K067N, E069V, V070I, D071Y, N072D, N073D, A074K, K076T, Q078S, R080Q, L081T, I082F, E083V, L085V
D_D0419110	SEQ ID NO: 592	G002A, N008S, S009A, I013V, S022T, G032A, E037D, T038S, S044L, L049M, L051V, K052Q, Q063L, A064S, S065T, K067N, E069V, V070I, D071Y, N072D, N073D, A074K, K076T, Q078S, R080Q, L081T, I082L, E083L
D_D0419111	SEQ ID NO: 593	G002A, T004S, S009A, I013V, S022T, G032A, E037D, S044L, L049M, L051V, K052Q, Q063L, A064S, S065T, K067N, E069V, V070I, D071Y, N072D, N073D, A074K, K076T, Q078S, R080Q, L081T, I082L, E083L
D_D0419114	SEQ ID NO: 594	G002A, T004S, N008S, I013V, S022T, G032A, E037D, T038S, S044L, L049M, L051V, K052Q, Q063L, A064S, S065T, K067N, E069V, V070I, D071Y, N072D, N073D, A074K, K076T, Q078S, R080Q, L081T, I082L, E083L
D_D0419115	SEQ ID NO: 595	G002A, T004S, S009A, S022T, G032A, E037D, T038S, S044L, L049M, L051V, Q063L, A064S, S065T, K067N, E069V, V070I, D071Y, N072D, N073D, A074K, K076T, Q078S, R080Q, L081T, I082L, E083L
D_D0419117	SEQ ID NO: 596	G002A, T004S, S009A, I013V, S022T, G032A, T038S, S044L, L049M, L051V, K052Q, Q063L, A064S, S065T, K067N, E069V, V070I, D071Y, N072D, N073D, A074K, K076T, Q078S, R080Q
D_D0419118	SEQ ID NO: 597	G002A, T004S, S009A, I013V, S022T, G032A, T038S, S044L, L051V, Q063L, A064S, S065T, K067N, E069V, V070I, D071Y, N072D, N073D, A074K, K076T, Q078S, R080Q
D_D0419119	SEQ ID NO: 598	G002A, S009A, I013V, A016S, S022T, G032A, T038S, S044L, L049M, L051V, K052Q, Q063L, A064S, S065T, K067N, E069V, V070I, D071Y, N072D, N073D, A074K, K076T, Q078S, R080Q, L081T, I082L, E083L, S086N
D_D0419120	SEQ ID NO: 599	G002A, N008S, S009A, I013V, S022T, G032A, E037D, T038S, S044L, L049M, L051V, Q063L, A064S, S065T, K067N, E069V, V070I, D071Y, N072D, N073D, A074K, K076T, Q078S, R080Q, L081T, I082L, E083L
D_D0419124	SEQ ID NO: 600	G002A, T004S, S009A, I013V, S022T, G032A, S044L, L051V, Q063L, A064S, S065T, K067N, E069V, V070I, D071Y, N072D, N073D, A074K, K076T, Q078S, R080Q, L081T, I082L, E083L
D_D0419126	SEQ ID NO: 601	G002A, T004S, S022T, G032A, E037D, T038S, S044L, L049M, L051V, K052Q, Q063L, A064S, S065T, K067N, E069V, V070I, D071Y, N072D, N073D, A074K, K076T, Q078S, R080Q, L081T
D_D0419127	SEQ ID NO: 602	G002A, T004S, S009A, I013V, S022T, G032A, E037D, S044L, L049M, L051V, Q063L, A064S, S065T, K067N, E069V, V070I, D071Y, N072D, N073D, A074K, K076T, Q078S, R080Q, I082L, E083L

Clone Designation	Polypeptide	Amino acid substitutions compared to PIP-72Aa (SEQ ID NO: 2)
D_D0419128	SEQ ID NO: 603	G002A, T004S, S009A, I013V, S022T, G032A, S044L, L049M, L051V, K052Q, Q063L, A064S, S065T, K067N, E069V, V070I, D071Y, N072D, N073D, A074K, K076T, Q078S, R080Q, L081T, E083L, S086N
D_D0419132	SEQ ID NO: 604	G002A, T004S, S009A, I013V, S022T, G032A, E037D, T038S, S044L, L049M, L051V, Q063L, A064S, S065T, K067N, E069V, V070I, D071Y, N072D, N073D, A074K, K076T, Q078S, R080Q, I082L
D_D0419138	SEQ ID NO: 605	G002A, T004S, S009A, I013V, A016S, S022T, G032A, E037D, T038S, S044L, L049M, L051V, K052Q, Q063L, A064S, S065T, K067N, E069V, V070I, D071Y, N072D, N073D, A074K, K076T, Q078S, R080Q, I082L
D_D0419142	SEQ ID NO: 606	G002A, T004S, N008S, I013V, A016S, S022T, G032A, E037D, T038S, S044L, L049M, L051V, K052Q, Q063L, A064S, S065T, K067N, E069V, V070I, D071Y, N072D, N073D, A074K, K076T, Q078S, R080Q, L081T, I082L, E083L, L085A
D_D0419145	SEQ ID NO: 607	G002A, T004S, S009A, I013V, S022T, G032A, E037D, T038S, S044L, L051V, K052Q, Q063L, A064S, S065T, K067N, E069V, V070I, D071Y, N072D, N073D, A074K, K076T, Q078S, R080Q, L081T, I082L, E083L

Example 9 – PIP-72Aa variants with multiple amino acid substitutions

To generate further PIP-72 polypeptide variants site-directed mutagenesis was performed using the oligonucleotide primers listed in Table 19 to introduce amino acid substitutions from PIP-72Da (SEQ ID NO: 10) into PIP-72Aa (SEQ ID NO: 2) or from PIP-72Aa (SEQ ID NO: 2) into PIP-72Da (SEQ ID NO: 845 – resynthesized to facilitate mutagenesis). An amino acid sequence alignment of PIP-72Aa (SEQ ID NO: 2) and PIP-72Da (SEQ ID NO: 10) is shown in Figure 6. Synthetic gene fragments were subcloned in expression vector pCOLD™1 as described in Example 3.

Table 19

Primer	Sequence identifier		Primer	Sequence identifier
72_DG_1aF	SEQ ID NO: 171		72_DG_5aF-2	SEQ ID NO: 181
72_DG_1bF	SEQ ID NO: 172		72_DG_5bF-2	SEQ ID NO: 182
72_DG_1cF	SEQ ID NO: 173		72_DG_5cF-2	SEQ ID NO: 183
72_DG_1dF	SEQ ID NO: 174		72_DG_5dF-2	SEQ ID NO: 184
72_DG_2F	SEQ ID NO: 175		72c_Div_1F	SEQ ID NO: 185
72_DG_3aF	SEQ ID NO: 176		72c_Div_2F	SEQ ID NO: 186

72_DG_3bF	SEQ ID NO: 177		72c_Div_3F	SEQ ID NO: 187
72_DG_3cF	SEQ ID NO: 178		72c_Div_4F	SEQ ID NO: 188
72_DG_3dF	SEQ ID NO: 179		72c_Div_5F-2	SEQ ID NO: 189
72_DG_4F	SEQ ID NO: 180			

The resulting plasmid DNAs were transformed into *E. coli*, and the insecticidal protein was expressed as described in Example 3. Bioassays were performed on Western Corn Root Worm as described in Example 4 to determine which gene variants retained insecticidal activity. DNA sequencing was performed on the active gene variants. The percent identity compared to PIP-72Aa (SEQ ID NO: 2), clone designation, nucleotide and amino acid sequences of the resulting active PIP-72 polypeptide variants are listed in Table 20. Out of approximately 180 unique PIP-72 polypeptide variants that were screened, 156 active variants were identified. Table 21 summarizes the % identity of the active variants compared to PIP-72Aa (SEQ ID NO: 17), the number of clones with each % identity and the clone identification. Table 22 shows the amino acid substitutions of the resulting active PIP-72 polypeptide variants compared to PIP-72Aa (SEQ ID NO: 2).

15

Table 20

% Identity to PIP-72Aa SEQ ID NO: 2	Clone designations	Polynucleotide	Polypeptide
86%	D_D0403719	SEQ ID NO: 367	SEQ ID NO: 608
86%	D_D0403734	SEQ ID NO: 368	SEQ ID NO: 609
86%	D_D0403823	SEQ ID NO: 369	SEQ ID NO: 610
86%	D_D0403844	SEQ ID NO: 370	SEQ ID NO: 611
86%	D_D0403865	SEQ ID NO: 371	SEQ ID NO: 612
86%	D_D0403897	SEQ ID NO: 372	SEQ ID NO: 613
86%	D_D0403907	SEQ ID NO: 373	SEQ ID NO: 614
95%	D_D0404048	SEQ ID NO: 374	SEQ ID NO: 615
98%	D_D0404051	SEQ ID NO: 375	SEQ ID NO: 616
96%	D_D0404052	SEQ ID NO: 376	SEQ ID NO: 617
98%	D_D0404054	SEQ ID NO: 377	SEQ ID NO: 618
95%	D_D0404056	SEQ ID NO: 378	SEQ ID NO: 619
98%	D_D0404057	SEQ ID NO: 379	SEQ ID NO: 620
96%	D_D0404062	SEQ ID NO: 380	SEQ ID NO: 621
95%	D_D0404066	SEQ ID NO: 381	SEQ ID NO: 622
96%	D_D0404067	SEQ ID NO: 382	SEQ ID NO: 623
95%	D_D0404068	SEQ ID NO: 383	SEQ ID NO: 624
95%	D_D0404073	SEQ ID NO: 384	SEQ ID NO: 625
98%	D_D0404074	SEQ ID NO: 385	SEQ ID NO: 626
95%	D_D0404078	SEQ ID NO: 386	SEQ ID NO: 627
88%	D_D0404079	SEQ ID NO: 387	SEQ ID NO: 628
98%	D_D0404098	SEQ ID NO: 388	SEQ ID NO: 629
92%	D_D0404103	SEQ ID NO: 389	SEQ ID NO: 630

WO 2016/144686

PCT/US2016/020634

% Identity to PIP-72Aa SEQ ID NO: 2	Clone designations	Polynucleotide	Polypeptide
98%	D_D0404111	SEQ ID NO: 390	SEQ ID NO: 631
99%	D_D0404113	SEQ ID NO: 391	SEQ ID NO: 632
99%	D_D0404116	SEQ ID NO: 392	SEQ ID NO: 633
98%	D_D0404119	SEQ ID NO: 393	SEQ ID NO: 634
96%	D_D0404120	SEQ ID NO: 394	SEQ ID NO: 635
96%	D_D0404121	SEQ ID NO: 395	SEQ ID NO: 636
96%	D_D0404122	SEQ ID NO: 396	SEQ ID NO: 637
96%	D_D0404128	SEQ ID NO: 397	SEQ ID NO: 638
98%	D_D0404130	SEQ ID NO: 398	SEQ ID NO: 639
95%	D_D0404135	SEQ ID NO: 399	SEQ ID NO: 640
91%	D_D0405129	SEQ ID NO: 400	SEQ ID NO: 641
92%	D_D0405130	SEQ ID NO: 401	SEQ ID NO: 642
94%	D_D0405132	SEQ ID NO: 402	SEQ ID NO: 643
95%	D_D0405135	SEQ ID NO: 403	SEQ ID NO: 644
90%	D_D0405137	SEQ ID NO: 404	SEQ ID NO: 645
94%	D_D0405139	SEQ ID NO: 405	SEQ ID NO: 646
87%	D_D0405141	SEQ ID NO: 406	SEQ ID NO: 647
85%	D_D0405142	SEQ ID NO: 407	SEQ ID NO: 648
92%	D_D0405145	SEQ ID NO: 408	SEQ ID NO: 649
99%	D_D0405148	SEQ ID NO: 409	SEQ ID NO: 650
98%	D_D0405151	SEQ ID NO: 410	SEQ ID NO: 651
98%	D_D0405153	SEQ ID NO: 411	SEQ ID NO: 652
98%	D_D0405157	SEQ ID NO: 412	SEQ ID NO: 653
96%	D_D0405159	SEQ ID NO: 413	SEQ ID NO: 654
99%	D_D0405163	SEQ ID NO: 414	SEQ ID NO: 655
87%	D_D0405169	SEQ ID NO: 415	SEQ ID NO: 656
99%	D_D0405174	SEQ ID NO: 416	SEQ ID NO: 657
90%	D_D0405177	SEQ ID NO: 417	SEQ ID NO: 658
93%	D_D0405183	SEQ ID NO: 418	SEQ ID NO: 659
88%	D_D0405187	SEQ ID NO: 419	SEQ ID NO: 660
95%	D_D0405191	SEQ ID NO: 420	SEQ ID NO: 661
93%	D_D0405192	SEQ ID NO: 421	SEQ ID NO: 662
93%	D_D0405193	SEQ ID NO: 422	SEQ ID NO: 663
94%	D_D0405199	SEQ ID NO: 423	SEQ ID NO: 664
91%	D_D0405204	SEQ ID NO: 424	SEQ ID NO: 665
93%	D_D0405205	SEQ ID NO: 425	SEQ ID NO: 666
98%	D_D0405213	SEQ ID NO: 426	SEQ ID NO: 667
82%	D_D0405218	SEQ ID NO: 427	SEQ ID NO: 668
82%	D_D0405219	SEQ ID NO: 428	SEQ ID NO: 669
98%	D_D0405227	SEQ ID NO: 429	SEQ ID NO: 670
96%	D_D0405228	SEQ ID NO: 430	SEQ ID NO: 671
99%	D_D0405230	SEQ ID NO: 431	SEQ ID NO: 672
96%	D_D0405231	SEQ ID NO: 432	SEQ ID NO: 673
99%	D_D0405233	SEQ ID NO: 433	SEQ ID NO: 674
94%	D_D0405238	SEQ ID NO: 434	SEQ ID NO: 675
94%	D_D0405239	SEQ ID NO: 435	SEQ ID NO: 676
96%	D_D0405241	SEQ ID NO: 436	SEQ ID NO: 677
96%	D_D0405242	SEQ ID NO: 437	SEQ ID NO: 678
98%	D_D0405243	SEQ ID NO: 438	SEQ ID NO: 679
96%	D_D0405244	SEQ ID NO: 439	SEQ ID NO: 680
99%	D_D0405249	SEQ ID NO: 440	SEQ ID NO: 681
96%	D_D0405251	SEQ ID NO: 441	SEQ ID NO: 682
98%	D_D0405252	SEQ ID NO: 442	SEQ ID NO: 683
99%	D_D0405254	SEQ ID NO: 443	SEQ ID NO: 684

% Identity to PIP-72Aa SEQ ID NO: 2	Clone designations	Polynucleotide	Polypeptide
99%	D_D0405258	SEQ ID NO: 444	SEQ ID NO: 685
98%	D_D0405260	SEQ ID NO: 445	SEQ ID NO: 686
98%	D_D0405261	SEQ ID NO: 446	SEQ ID NO: 687
98%	D_D0405281	SEQ ID NO: 447	SEQ ID NO: 688
93%	D_D0405282	SEQ ID NO: 448	SEQ ID NO: 689
94%	D_D0405284	SEQ ID NO: 449	SEQ ID NO: 690
96%	D_D0405285	SEQ ID NO: 450	SEQ ID NO: 691
95%	D_D0405288	SEQ ID NO: 451	SEQ ID NO: 692
95%	D_D0405289	SEQ ID NO: 452	SEQ ID NO: 693
95%	D_D0405290	SEQ ID NO: 453	SEQ ID NO: 694
98%	D_D0405291	SEQ ID NO: 454	SEQ ID NO: 695
95%	D_D0405292	SEQ ID NO: 455	SEQ ID NO: 696
99%	D_D0405294	SEQ ID NO: 456	SEQ ID NO: 697
94%	D_D0405297	SEQ ID NO: 457	SEQ ID NO: 698
95%	D_D0405299	SEQ ID NO: 458	SEQ ID NO: 699
94%	D_D0405300	SEQ ID NO: 459	SEQ ID NO: 700
99%	D_D0405302	SEQ ID NO: 460	SEQ ID NO: 701
94%	D_D0405307	SEQ ID NO: 461	SEQ ID NO: 702
91%	D_D0405309	SEQ ID NO: 462	SEQ ID NO: 703
99%	D_D0405310	SEQ ID NO: 463	SEQ ID NO: 704
94%	D_D0405311	SEQ ID NO: 464	SEQ ID NO: 705
96%	D_D0405312	SEQ ID NO: 465	SEQ ID NO: 706
94%	D_D0405313	SEQ ID NO: 466	SEQ ID NO: 707
96%	D_D0405320	SEQ ID NO: 467	SEQ ID NO: 708
70%	D_D0408199	SEQ ID NO: 468	SEQ ID NO: 709
70%	D_D0408201	SEQ ID NO: 469	SEQ ID NO: 710
71%	D_D0408212	SEQ ID NO: 470	SEQ ID NO: 711
76%	D_D0408220	SEQ ID NO: 471	SEQ ID NO: 712
77%	D_D0408221	SEQ ID NO: 472	SEQ ID NO: 713
73%	D_D0408223	SEQ ID NO: 473	SEQ ID NO: 714
77%	D_D0408226	SEQ ID NO: 474	SEQ ID NO: 715
73%	D_D0408229	SEQ ID NO: 475	SEQ ID NO: 716
72%	D_D0408231	SEQ ID NO: 476	SEQ ID NO: 717
73%	D_D0408234	SEQ ID NO: 477	SEQ ID NO: 718
72%	D_D0408238	SEQ ID NO: 478	SEQ ID NO: 719
72%	D_D0408241	SEQ ID NO: 479	SEQ ID NO: 720
71%	D_D0408246	SEQ ID NO: 480	SEQ ID NO: 721
76%	D_D0408250	SEQ ID NO: 481	SEQ ID NO: 722
73%	D_D0408253	SEQ ID NO: 482	SEQ ID NO: 723
72%	D_D0408254	SEQ ID NO: 483	SEQ ID NO: 724
71%	D_D0408261	SEQ ID NO: 484	SEQ ID NO: 725
70%	D_D0408267	SEQ ID NO: 485	SEQ ID NO: 726
72%	D_D0408268	SEQ ID NO: 486	SEQ ID NO: 727
73%	D_D0408270	SEQ ID NO: 487	SEQ ID NO: 728
70%	D_D0408275	SEQ ID NO: 488	SEQ ID NO: 729
72%	D_D0408276	SEQ ID NO: 489	SEQ ID NO: 730
74%	D_D0408277	SEQ ID NO: 490	SEQ ID NO: 731
78%	D_D0408283	SEQ ID NO: 491	SEQ ID NO: 732
74%	D_D0408284	SEQ ID NO: 492	SEQ ID NO: 733
73%	D_D0408286	SEQ ID NO: 493	SEQ ID NO: 734
76%	D_D0408287	SEQ ID NO: 494	SEQ ID NO: 735
77%	D_D0408294	SEQ ID NO: 495	SEQ ID NO: 736
73%	D_D0408295	SEQ ID NO: 496	SEQ ID NO: 737
79%	D_D0408296	SEQ ID NO: 497	SEQ ID NO: 738

% Identity to PIP-72Aa SEQ ID NO: 2	Clone designations	Polynucleotide	Polypeptide
74%	D_D0408297	SEQ ID NO: 498	SEQ ID NO: 739
71%	D_D0408298	SEQ ID NO: 499	SEQ ID NO: 740
74%	D_D0408302	SEQ ID NO: 500	SEQ ID NO: 741
74%	D_D0408308	SEQ ID NO: 501	SEQ ID NO: 742
73%	D_D0408309	SEQ ID NO: 502	SEQ ID NO: 743
72%	D_D0408314	SEQ ID NO: 503	SEQ ID NO: 744
74%	D_D0408318	SEQ ID NO: 504	SEQ ID NO: 745
73%	D_D0408319	SEQ ID NO: 505	SEQ ID NO: 746
72%	D_D0408322	SEQ ID NO: 506	SEQ ID NO: 747
79%	D_D0408329	SEQ ID NO: 507	SEQ ID NO: 748
78%	D_D0408331	SEQ ID NO: 508	SEQ ID NO: 749
74%	D_D0408338	SEQ ID NO: 509	SEQ ID NO: 750
78%	D_D0408340	SEQ ID NO: 510	SEQ ID NO: 751
70%	D_D0408353	SEQ ID NO: 511	SEQ ID NO: 752
78%	D_D0408357	SEQ ID NO: 512	SEQ ID NO: 753
76%	D_D0408359	SEQ ID NO: 513	SEQ ID NO: 754
73%	D_D0408361	SEQ ID NO: 514	SEQ ID NO: 755
78%	D_D0408366	SEQ ID NO: 515	SEQ ID NO: 756
74%	D_D0408368	SEQ ID NO: 516	SEQ ID NO: 757
73%	D_D0408370	SEQ ID NO: 517	SEQ ID NO: 758
73%	D_D0408372	SEQ ID NO: 518	SEQ ID NO: 759
74%	D_D0408373	SEQ ID NO: 519	SEQ ID NO: 760
72%	D_D0408374	SEQ ID NO: 520	SEQ ID NO: 761
73%	D_D0408377	SEQ ID NO: 521	SEQ ID NO: 762
72%	D_D0408381	SEQ ID NO: 522	SEQ ID NO: 763
74%	D_D0408382	SEQ ID NO: 523	SEQ ID NO: 764
73%	D_D0408384	SEQ ID NO: 524	SEQ ID NO: 765
76%	D_D0408385	SEQ ID NO: 525	SEQ ID NO: 766
72%	D_D0408386	SEQ ID NO: 526	SEQ ID NO: 767
74%	D_D0408387	SEQ ID NO: 527	SEQ ID NO: 768
78%	D_D0348839	SEQ ID NO: 770	SEQ ID NO: 772
85%	D_D0347298	SEQ ID NO: 769	SEQ ID NO: 771

Table 21

Identity to PIP-72Aa (%)	# of variants	Variants name
46%	1	D_D0414430
48%	4	D_D0407437, D_D0414422, D_D0414454, D_D0414462
49%	6	D_D0414416, D_D0414425, D_D0414449, D_D0414450, D_D0414453, D_D0414471
50%	7	D_D0414424, D_D0414439, D_D0414459, D_D0414466, D_D0414479, D_D0414489, D_D0414493
51%	4	D_D0414433, D_D0414470, D_D0414475, D_D0414486
52%	2	D_D0414411, D_D0414455
53%	4	D_D0407429, D_D0414366, D_D0414412, D_D0414427
55%	2	D_D0414317, D_D0414355

Identity to PIP-72Aa (%)	# of variants	Variants name
56%	2	D_D0407455, D_D0414326
57%	3	D_D0407456, D_D0414327, D_D0414388
65%	1	D_D0419142
66%	3	D_D0419060, D_D0419066, D_D0419084
67%	5	D_D0407461, D_D0419109, D_D0419110, D_D0419114, D_D0419119
69%	11	D_D0419050, D_D0419057, D_D0419071, D_D0419075, D_D0419083, D_D0419091, D_D0419102, D_D0419111, D_D0419120, D_D0419138, D_D0419145
70%	17	D_D0419051, D_D0419053, D_D0419064, D_D0419072, D_D0419087, D_D0419095, D_D0419098, D_D0419099, D_D0419101, D_D0419108, D_D0419115, D_D0419128, D_D0408199, D_D0408201, D_D0408267, D_D0408275, D_D0408353
71%	11	D_D0419058, D_D0419062, D_D0419082, D_D0419096, D_D0419106, D_D0419127, D_D0419132, D_D0408212, D_D0408246, D_D0408261, D_D0408298
72%	15	D_D0419077, D_D0419117, D_D0419124, D_D0419126, D_D0408231, D_D0408238, D_D0408241, D_D0408254, D_D0408268, D_D0408276, D_D0408314, D_D0408322, D_D0408374, D_D0408381, D_D0408386
73%	15	D_D0419093, D_D0408223, D_D0408229, D_D0408234, D_D0408253, D_D0408270, D_D0408286, D_D0408295, D_D0408309, D_D0408319, D_D0408361, D_D0408370, D_D0408372, D_D0408377, D_D0408384
74%	12	D_D0419118, D_D0408277, D_D0408284, D_D0408297, D_D0408302, D_D0408308, D_D0408318, D_D0408338, D_D0408368, D_D0408373, D_D0408382, D_D0408387
76%	5	D_D0408220, D_D0408250, D_D0408287, D_D0408359, D_D0408385
77%	3	D_D0408221, D_D0408226, D_D0408294
78%	6	D_D0408283, D_D0408331, D_D0408340, D_D0408357, D_D0408366, D_D0348839
79%	2	D_D0408296, D_D0408329
82%	2	D_D0405218, D_D0405219
85%	2	D_D0405142, D_D0347298
86%	7	D_D0403719, D_D0403734, D_D0403823, D_D0403844, D_D0403865, D_D0403897, D_D0403907
87%	2	D_D0405141, D_D0405169
88%	2	D_D0404079, D_D0405187
90%	2	D_D0405137, D_D0405177
91%	3	D_D0405129, D_D0405204, D_D0405309

Identity to PIP-72Aa (%)	# of variants	Variants name
92%	3	D_D0404103, D_D0405130, D_D0405145
93%	5	D_D0405183, D_D0405192, D_D0405193, D_D0405205, D_D0405282
94%	11	D_D0405132, D_D0405139, D_D0405199, D_D0405238, D_D0405239, D_D0405284, D_D0405297, D_D0405300, D_D0405307, D_D0405311, D_D0405313
95%	14	D_D0404048, D_D0404056, D_D0404066, D_D0404068, D_D0404073, D_D0404078, D_D0404135, D_D0405135, D_D0405191, D_D0405288, D_D0405289, D_D0405290, D_D0405292, D_D0405299
96%	17	D_D0404052, D_D0404062, D_D0404067, D_D0404120, D_D0404121, D_D0404122, D_D0404128, D_D0405159, D_D0405228, D_D0405231, D_D0405241, D_D0405242, D_D0405244, D_D0405251, D_D0405285, D_D0405312, D_D0405320
98%	19	D_D0404051, D_D0404054, D_D0404057, D_D0404074, D_D0404098, D_D0404111, D_D0404119, D_D0404130, D_D0405151, D_D0405153, D_D0405157, D_D0405213, D_D0405227, D_D0405243, D_D0405252, D_D0405260, D_D0405261, D_D0405281, D_D0405291
99%	13	D_D0404113, D_D0404116, D_D0405148, D_D0405163, D_D0405174, D_D0405230, D_D0405233, D_D0405249, D_D0405254, D_D0405258, D_D0405294, D_D0405302, D_D0405310

Table 22

Clone Designation	Polypeptide	Amino Acid Substitutions compared to PIP- 72Aa (SEQ ID NO: 2)
D_D0403719	SEQ ID NO: 608	N011G, S027Q, S030P, N033S, T038S, S044D, K053N, D071E, A074Y, Q078S, R080E, E083L
D_D0403734	SEQ ID NO: 609	N011G, P012D, S027Q, S030K, G032A, N033P, T038S, S044A, K053N, D071E, R080Q, E083L
D_D0403823	SEQ ID NO: 610	N011G, P012D, S030K, G032A, N033P, S044D, K053N, D071E, N073D, A074Y, R080Q, E083L
D_D0403844	SEQ ID NO: 611	S009L, P012D, S027Q, S030K, N033P, T038S, S044A, D071E, N073D, Q078S, R080E, E083L
D_D0403865	SEQ ID NO: 612	N008S, N011G, P012D, S030K, N033S, T038S, S044D, K053N, D071E, A074Y, Q078S, R080E
D_D0403897	SEQ ID NO: 613	N011G, S027Q, S030K, G032A, N033P, T038S, S044D, K053N, D071E, N073D, Q078S, R080E
D_D0403907	SEQ ID NO: 614	N008S, N011G, P012D, S027Q, S030K, N033S, S044D, K053N, D071E, N073D, Q078S, R080Q
D_D0404048	SEQ ID NO: 615	N011K, V015A, K053R, H058A
D_D0404051	SEQ ID NO: 616	T038S, K053R
D_D0404052	SEQ ID NO: 617	N011K, R080Q, E083Q
D_D0404054	SEQ ID NO: 618	N011K, T038S
D_D0404056	SEQ ID NO: 619	V015A, H019K, K053R, H058A
D_D0404057	SEQ ID NO: 620	N011K, A074T
D_D0404062	SEQ ID NO: 621	K053R, E083H, L085V
D_D0404066	SEQ ID NO: 622	K053R, H058A, E083H, L085V
D_D0404067	SEQ ID NO: 623	N011K, V015A, K053R

Clone Designation	Polypeptide	Amino Acid Substitutions compared to PIP-72Aa (SEQ ID NO: 2)
D_D0404068	SEQ ID NO: 624	N033S, K053R, A074T, R080E
D_D0404073	SEQ ID NO: 625	T038S, K053R, H058A, L085V
D_D0404074	SEQ ID NO: 626	K053R, E083H
D_D0404078	SEQ ID NO: 627	N011K, P012K, H019K, H058A
D_D0404079	SEQ ID NO: 628	N011K, S030G, G032D, T038S, K053R, S065T, D071E, A074T, L085V, S086A
D_D0404098	SEQ ID NO: 629	S065T, V070I
D_D0404103	SEQ ID NO: 630	V015A, H019K, V031I, G032D, N033S, T038S, K053R
D_D0404111	SEQ ID NO: 631	T038S, K053R
D_D0404113	SEQ ID NO: 632	K053N
D_D0404116	SEQ ID NO: 633	E083H
D_D0404119	SEQ ID NO: 634	P012K, H019K
D_D0404120	SEQ ID NO: 635	S030G, N033S, T038S
D_D0404121	SEQ ID NO: 636	H058A, R080E, L085V
D_D0404122	SEQ ID NO: 637	E083H, L085V, S086A
D_D0404128	SEQ ID NO: 638	N011K, V015A, E083H
D_D0404130	SEQ ID NO: 639	N011K, H019K
D_D0404135	SEQ ID NO: 640	S030G, V031I, N033S, T038S
D_D0405129	SEQ ID NO: 641	N011K, P012K, V015A, H019K, S065T, V070I, D071E, A074T
D_D0405130	SEQ ID NO: 642	H019K, K053R, H058A, S065T, V070I, D071E, A074T
D_D0405132	SEQ ID NO: 643	S030G, V031I, G032D, N033S, T038S
D_D0405135	SEQ ID NO: 644	N011K, P012K, V015A, H019K
D_D0405137	SEQ ID NO: 645	N011K, P012K, V015A, H019K, S030G, V031I, G032D, N033S, T038S
D_D0405139	SEQ ID NO: 646	N011K, P012K, V015A, H019K, K053S
D_D0405141	SEQ ID NO: 647	N011K, P012K, V015A, H019K, T038S, K053R, H058A, S065T, V070I, D071E, A074T
D_D0405142	SEQ ID NO: 648	N011K, P012K, V015A, H019K, S030G, V031I, G032D, N033S, T038S, S065T, V070I, D071E, A074T
D_D0405145	SEQ ID NO: 649	S030G, V031I, G032D, N033S, T038S, K053R, H058A
D_D0405148	SEQ ID NO: 650	T038S
D_D0405151	SEQ ID NO: 651	V015A, H019K
D_D0405153	SEQ ID NO: 652	K053R, H058A
D_D0405157	SEQ ID NO: 653	T038S, H058A
D_D0405159	SEQ ID NO: 654	K053R, H058A, A074T
D_D0405163	SEQ ID NO: 655	K053R
D_D0405169	SEQ ID NO: 656	N011K, P012K, V015A, H019K, S030G, V031I, G032D, N033S, T038S, K053R, H058A
D_D0405174	SEQ ID NO: 657	H058A
D_D0405177	SEQ ID NO: 658	S030G, V031I, G032D, N033S, T038S, S065T, V070I, D071E, A074T
D_D0405183	SEQ ID NO: 659	N011K, P012K, V015A, H019K, T038S, H058A
D_D0405187	SEQ ID NO: 660	N011K, P012K, V015A, H019K, S030G, V031I, G032D, N033S, K053R, H058A
D_D0405191	SEQ ID NO: 661	S065T, V070I, D071E, A074T

Clone Designation	Polypeptide	Amino Acid Substitutions compared to PIP-72Aa (SEQ ID NO: 2)
D_D0405192	SEQ ID NO: 662	K053R, H058A, S065T, V070I, D071E, A074T
D_D0405193	SEQ ID NO: 663	N011K, P012K, V015A, H019K, N033S, T038S
D_D0405199	SEQ ID NO: 664	K053R, H058A, V070I, D071E, A074T
D_D0405204	SEQ ID NO: 665	S030G, V031I, G032D, N033S, T038S, K053R, H058A, A074T
D_D0405205	SEQ ID NO: 666	N011K, P012K, V015A, H019K, K053R, H058A
D_D0405213	SEQ ID NO: 667	K053S, H058A
D_D0405218	SEQ ID NO: 668	N011K, P012K, V015A, H019K, S030G, V031I, G032D, N033S, T038S, K053R, H058A, R080E, E083H, L085V, S086A
D_D0405219	SEQ ID NO: 669	N011K, P012K, V015A, H019K, S030G, V031I, G032D, N033S, T038S, K053R, H058A, S065T, V070I, D071E, A074T
D_D0405227	SEQ ID NO: 670	R080E, S086A
D_D0405228	SEQ ID NO: 671	N011K, V015A, L085V
D_D0405230	SEQ ID NO: 672	H019K
D_D0405231	SEQ ID NO: 673	N011K, E083H, L085V
D_D0405233	SEQ ID NO: 674	N011K
D_D0405238	SEQ ID NO: 675	N011K, V015A, E083H, L085V, S086A
D_D0405239	SEQ ID NO: 676	N011K, H058A, R080E, L085V, S086A
D_D0405241	SEQ ID NO: 677	N011K, P012K, V015A
D_D0405242	SEQ ID NO: 678	N011K, R080E, S086A
D_D0405243	SEQ ID NO: 679	N011K, V015A
D_D0405244	SEQ ID NO: 680	N011K, V015A, H019K
D_D0405249	SEQ ID NO: 681	P012K
D_D0405251	SEQ ID NO: 682	P012K, V015A, H019K
D_D0405252	SEQ ID NO: 683	P012K, V015A
D_D0405254	SEQ ID NO: 684	V015A
D_D0405258	SEQ ID NO: 685	R080E
D_D0405260	SEQ ID NO: 686	H019K, K053R
D_D0405261	SEQ ID NO: 687	E083H, L085V
D_D0405281	SEQ ID NO: 688	N033S, T038S
D_D0405282	SEQ ID NO: 689	S030G, V031I, G032D, N033S, T038S, K053R
D_D0405284	SEQ ID NO: 690	V031I, G032D, T038S, R080E, L085V
D_D0405285	SEQ ID NO: 691	K053R, R080E, S086A
D_D0405288	SEQ ID NO: 692	S030G, N033S, R080E, S086A
D_D0405289	SEQ ID NO: 693	G032D, K053R, R080E, E083H
D_D0405290	SEQ ID NO: 694	S030G, V031I, G032D, N033S
D_D0405291	SEQ ID NO: 695	S030G, K053R
D_D0405292	SEQ ID NO: 696	N033S, K053R, R080E, S086A
D_D0405294	SEQ ID NO: 697	S030G
D_D0405297	SEQ ID NO: 698	S030G, V031I, G032D, N033S, K053R
D_D0405299	SEQ ID NO: 699	K053H, H058P, E083H, S086A
D_D0405300	SEQ ID NO: 700	G032D, N033S, T038S, L085V, S086A
D_D0405302	SEQ ID NO: 701	N033S

Clone Designation	Polypeptide	Amino Acid Substitutions compared to PIP-72Aa (SEQ ID NO: 2)
D_D0405307	SEQ ID NO: 702	N033S, T038S, K053R, H058A, R080E
D_D0405309	SEQ ID NO: 703	S030G, V031I, N033S, T038S, K053R, H058A, R080E, L085V
D_D0405310	SEQ ID NO: 704	G032D
D_D0405311	SEQ ID NO: 705	S030G, G032D, N033S, L085V, S086A
D_D0405312	SEQ ID NO: 706	S030G, V031I, T038S
D_D0405313	SEQ ID NO: 707	S030G, G032D, N033S, T038S, H058A
D_D0405320	SEQ ID NO: 708	S030G, N033S, H058A
D_D0408199	SEQ ID NO: 709	N008K, N011K, P012K, V015A, A016S, H019K, S027K, S030G, V031I, G032D, N033S, T038S, S044D, K053R, H058A, S065T, V070I, D071E, N073S, A074T, Q078H, R080E, L081T, E083H, L085V, S086A
D_D0408201	SEQ ID NO: 710	N008K, N011K, P012K, V015A, A016S, H019K, S027K, S030G, V031I, G032D, N033S, T038S, S044D, A056T, H058A, S065T, V070I, D071E, N073S, A074T, Q078H, R080E, L081T, E083H, L085V, S086A
D_D0408212	SEQ ID NO: 711	N008K, N011K, P012K, V015A, A016S, H019K, S027K, S030G, V031I, G032D, N033S, T038S, S044D, H058A, S065T, V070I, D071E, N073S, A074T, Q078H, R080E, L081T, E083H, L085V, S086A
D_D0408220	SEQ ID NO: 712	N008K, N011K, P012K, V015A, A016S, H019K, S027K, S030G, V031I, G032D, N033S, T038S, S044D, H058A, S065T, V070I, D071E, N073S, A074T, E083H, L085V
D_D0408221	SEQ ID NO: 713	N011K, V015A, S027K, S030G, V031I, G032D, N033S, T038S, S044D, S065T, V070I, D071E, N073S, A074T, Q078H, R080E, L081T, E083H, L085V, S086A
D_D0408223	SEQ ID NO: 714	N011K, V015A, H019K, S027K, S030G, V031I, G032D, N033S, T038S, S044D, K053R, H058A, S065T, V070I, D071E, N073S, A074T, Q078H, R080E, L081T, E083H, L085V, S086A
D_D0408226	SEQ ID NO: 715	N011K, V015A, H019K, S027K, S030G, V031I, G032D, N033S, T038S, S044D, K053R, H058A, S065T, V070I, D071E, N073S, A074T, R080E, E083H, L085V
D_D0408229	SEQ ID NO: 716	N008K, N011K, P012K, V015A, A016S, H019K, S027K, S030G, V031I, G032D, N033S, T038S, S044D, K053R, S065T, V070I, D071E, N073S, A074T, Q078H, R080E, L085V, S086A
D_D0408231	SEQ ID NO: 717	N008K, N011K, P012K, V015A, A016S, H019K, S027K, S030G, V031I, G032D, N033S, T038S, S044D, S065T, V070I, D071E, N073S, A074T, Q078H, R080E, L081T, E083H, L085V, S086A
D_D0408234	SEQ ID NO: 718	N008K, N011K, P012K, V015A, A016S, H019K, S027K, S030G, V031I, G032D, N033S, T038S, S044D, K053R, A056T, H058A, S065T, V070I, D071E, N073S, A074T, R080E, S086A
D_D0408238	SEQ ID NO: 719	P012K, V015A, H019K, S027K, S030G, V031I, G032D, N033S, T038S, S044D, K053R, A056T, H058A, S065T, V070I, D071E, N073S, A074T, Q078H, R080E, L081T, E083H, L085V, S086A
D_D0408241	SEQ ID NO: 720	N008K, N011K, P012K, V015A, A016S, H019K, S027K, S030G, V031I, G032D, N033S, T038S, S044D, K053R, H058A, S065T, V070I, D071E, N073S, A074T, R080E, E083H, L085V, S086A

Clone Designation	Polypeptide	Amino Acid Substitutions compared to PIP-72Aa (SEQ ID NO: 2)
D_D0408246	SEQ ID NO: 721	N008K, N011K, P012K, V015A, A016S, H019K, S022R, S027K, S030G, V031I, G032D, N033S, T038S, S044D, K053R, A056T, H058A, S065T, V070I, D071E, N073S, A074T, E083H, L085V, S086A
D_D0408250	SEQ ID NO: 722	N008K, N011K, P012K, V015A, A016S, H019K, V031I, N033S, S044D, K053R, S065T, V070I, D071E, N073S, A074T, Q078H, R080E, L081T, E083H, L085V, S086A
D_D0408253	SEQ ID NO: 723	N008K, N011K, P012K, V015A, A016S, H019K, S030G, N033S, S044D, K053R, A056T, H058A, S065T, V070I, D071E, N073S, A074T, Q078H, R080E, L081T, E083H, L085V, S086A
D_D0408254	SEQ ID NO: 724	N008K, N011K, P012K, V015A, A016S, H019K, S030G, G032D, N033S, S044D, K053R, A056T, H058A, S065T, V070I, D071E, N073S, A074T, Q078H, R080E, L081T, E083H, L085V, S086A
D_D0408261	SEQ ID NO: 725	N008K, N011K, P012K, V015A, A016S, H019K, S030G, G032D, N033S, T038S, S044D, K053R, A056T, H058A, S065T, V070I, D071E, N073S, A074T, Q078H, R080E, L081T, E083H, L085V, S086A
D_D0408267	SEQ ID NO: 726	N008K, N011K, P012K, V015A, A016S, H019K, S027K, S030G, V031I, G032D, N033S, T038S, K053R, A056T, H058A, S065T, V070I, D071E, N073S, A074T, Q078H, R080E, L081T, E083H, L085V, S086A
D_D0408268	SEQ ID NO: 727	N008K, N011K, P012K, V015A, A016S, H019K, S030G, N033S, T038S, S044D, K053R, A056T, H058A, S065T, V070I, D071E, N073S, A074T, Q078H, R080E, L081T, E083H, L085V, S086A
D_D0408270	SEQ ID NO: 728	N008K, N011K, P012K, V015A, A016S, H019K, V031I, G032D, N033S, S044D, K053R, S065T, S066N, V070I, D071E, N073S, A074T, Q078H, R080E, L081T, E083H, L085V, S086A
D_D0408275	SEQ ID NO: 729	N008K, N011K, P012K, V015A, A016S, H019K, S027K, S030G, V031I, G032D, N033S, S044D, K053R, A056T, H058A, S065T, V070I, D071E, N073S, A074T, Q078H, R080E, L081T, E083H, L085V, S086A
D_D0408276	SEQ ID NO: 730	N008K, N011K, P012K, V015A, A016S, H019K, S027K, S030G, V031I, G032D, N033S, K053R, H058A, S065T, V070I, D071E, N073S, A074T, Q078H, R080E, L081T, E083H, L085V, S086A
D_D0408277	SEQ ID NO: 731	N008K, N011K, P012K, V015A, A016S, H019K, S027K, S030G, V031I, G032D, N033S, S044D, K053R, H058A, S065T, V070I, D071E, N073S, A074T, R080E, E083H, L085V
D_D0408283	SEQ ID NO: 732	N008K, N011K, P012K, V015A, A016S, H019K, S027K, S030G, N033S, S044D, K053R, A056T, H058A, S065T, V070I, D071E, N073S, A074T, R080E
D_D0408284	SEQ ID NO: 733	N008K, N011K, P012K, V015A, A016S, H019K, S030G, G032D, N033S, S044D, K053R, S065T, V070I, D071E, N073S, A074T, Q078H, R080E, L081T, E083H, L085V, S086A
D_D0408286	SEQ ID NO: 734	N008K, N011K, P012K, V015A, A016S, H019K, S027K, S030G, V031I, G032D, N033S, T038S, S044D, K053R, S065T, V070I, D071E, N073S, A074T, R080E, E083H, L085V, S086A
D_D0408287	SEQ ID NO: 735	N008K, N011K, P012K, V015A, A016S, H019K, N033S, S044D, K053R, H058A, S065T, V070I, D071E, N073S, A074T, Q078H, R080E, L081T, E083H, L085V, S086A

Clone Designation	Polypeptide	Amino Acid Substitutions compared to PIP-72Aa (SEQ ID NO: 2)
D_D0408294	SEQ ID NO: 736	H019K, S027K, S030G, V031I, G032D, N033S, T038S, S044D, K053R, S065T, V070I, D071E, N073S, A074T, Q078H, R080E, L081T, E083H, L085V, S086A
D_D0408295	SEQ ID NO: 737	P012K, V015A, H019K, S027K, S030G, V031I, G032D, N033S, T038S, S044D, K053R, H058A, S065T, V070I, D071E, N073S, A074T, Q078H, R080E, L081T, E083H, L085V, S086A
D_D0408296	SEQ ID NO: 738	H019K, S027K, S030G, V031I, G032D, N033S, T038S, S044D, K053R, A056T, H058A, V070I, D071E, R080E, L081T, E083H, L085V, S086A
D_D0408297	SEQ ID NO: 739	N008K, N011K, P012K, V015A, A016S, H019K, S027K, S030G, V031I, G032D, N033S, T038S, S044D, H058A, S065T, V070I, D071E, N073S, A074T, R080E, E083H, S086A
D_D0408298	SEQ ID NO: 740	N008K, N011K, P012K, V015A, A016S, H019K, S027K, S030G, V031I, G032D, N033S, T038S, S044D, K053R, S065T, V070I, D071E, N073S, A074T, Q078H, R080E, L081T, E083H, L085V, S086A
D_D0408302	SEQ ID NO: 741	N011K, P012K, V015A, H019K, S027K, S030G, V031I, G032D, N033S, T038S, S044D, S065T, V070I, D071E, N073S, A074T, Q078H, R080E, L081T, E083H, L085V, S086A
D_D0408308	SEQ ID NO: 742	N011K, V015A, S027K, S030G, V031I, G032D, N033S, T038S, S044D, K053R, H058A, S065T, V070I, D071E, N073S, A074T, Q078H, R080E, L081T, E083H, L085V, S086A
D_D0408309	SEQ ID NO: 743	N011K, V015A, S027K, S030G, V031I, G032D, N033S, T038S, S044D, K053R, A056T, H058A, S065T, V070I, D071E, N073S, A074T, Q078H, R080E, L081T, E083H, L085V, S086A
D_D0408314	SEQ ID NO: 744	N008K, N011K, P012K, V015A, A016S, H019K, S030G, V031I, G032D, N033S, T038S, S044D, H058A, S065T, V070I, D071E, N073S, A074T, Q078H, R080E, L081T, E083H, L085V, S086A
D_D0408318	SEQ ID NO: 745	N008K, N011K, P012K, V015A, A016S, H019K, S027K, S030G, V031I, G032D, N033S, T038S, S044D, K053R, S065T, D071E, Q078H, R080E, L081T, E083H, L085V, S086A
D_D0408319	SEQ ID NO: 746	N008K, N011K, P012K, V015A, A016S, H019K, S027K, S030G, V031I, G032D, N033S, T038S, S044D, K053R, S065T, V070I, A074T, Q078H, R080E, L081T, E083H, L085V, S086A
D_D0408322	SEQ ID NO: 747	N011K, P012K, V015A, S027K, S030G, V031I, G032D, N033S, T038S, S044D, K053R, A056T, H058A, S065T, V070I, D071E, N073S, A074T, Q078H, R080E, L081T, E083H, L085V, S086A
D_D0408329	SEQ ID NO: 748	N011K, V015A, H019K, S027K, S030G, V031I, G032D, N033S, T038S, S044D, K053R, H058A, S065T, V070I, D071E, N073S, A074T, E083H
D_D0408331	SEQ ID NO: 749	N011K, V015A, H019K, G032D, N033S, S044D, K053R, H058A, S065T, V070I, D071E, N073S, A074T, Q078H, R080E, L081T, E083H, L085V, S086A
D_D0408338	SEQ ID NO: 750	N008K, N011K, P012K, V015A, H019K, S030G, N033S, S044D, K053R, A056T, H058A, S065T, V070I, D071E, N073S, A074T, Q078H, R080E, L081T, E083H, L085V, S086A
D_D0408340	SEQ ID NO: 751	H019K, S027K, S030G, V031I, N033S, T038S, S044D, K053R, S065T, V070I, D071E, N073S, A074T, Q078H, R080E, L081T, E083H, L085V, S086A

Clone Designation	Polypeptide	Amino Acid Substitutions compared to PIP-72Aa (SEQ ID NO: 2)
D_D0408353	SEQ ID NO: 752	N008K, N011K, P012K, V015A, A016S, H019K, S027K, S030G, V031I, G032D, N033S, T038S, S044D, K053S, H058A, S065T, V070I, D071E, N073S, A074T, Q078H, R080E, L081T, E083H, L085V, S086A
D_D0408357	SEQ ID NO: 753	N008K, N011K, P012K, V015A, A016S, H019K, S030G, N033S, S044D, S065T, V070I, D071E, N073S, A074T, R080E, L081T, E083H, L085V, S086A
D_D0408359	SEQ ID NO: 754	N008K, N011K, P012K, V015A, H019K, S027K, S030G, V031I, G032D, N033S, T038S, S044D, V070I, D071E, A074T, Q078H, R080E, L081T, E083H, L085V, S086A
D_D0408361	SEQ ID NO: 755	N008K, N011K, P012K, V015A, A016S, S030G, V031I, G032D, N033S, T038S, S044D, K053R, S065T, V070I, D071E, N073S, A074T, Q078H, R080E, L081T, E083H, L085V, S086A
D_D0408366	SEQ ID NO: 756	N008K, N011K, P012K, V015A, A016S, H019K, S027K, S030G, V031I, G032D, N033S, T038S, S044D, K053R, S065T, V070I, D071E, L085V, S086A
D_D0408368	SEQ ID NO: 757	N011K, S027K, S030G, V031I, G032D, N033S, T038S, S044D, K053R, A056T, H058A, S065T, V070I, D071E, N073S, A074T, Q078H, R080E, L081T, E083H, L085V, S086A
D_D0408370	SEQ ID NO: 758	N008K, N011K, P012K, V015A, H019K, S027K, S030G, V031I, G032D, N033S, T038S, S044D, S065T, V070I, D071E, N073S, A074T, Q078H, R080E, L081T, E083H, L085V, S086A
D_D0408372	SEQ ID NO: 759	N011K, V015A, H019K, S027K, S030G, V031I, G032D, N033S, T038S, S044D, K053R, H058A, S065T, V070I, D071E, N073S, A074T, Q078H, R080E, L081T, E083H, L085V, S086A
D_D0408373	SEQ ID NO: 760	N008K, N011K, P012K, V015A, A016S, H019K, S027K, S030G, V031I, G032D, N033S, T038S, S044D, K053R, S065T, V070I, D071E, N073S, A074T, R080E, E083H, L085V
D_D0408374	SEQ ID NO: 761	N008K, N011K, P012K, V015A, A016S, H019K, S027K, S030G, V031I, G032D, N033S, S044D, K053R, S065T, V070I, D071E, N073S, A074T, Q078H, R080E, L081T, E083H, L085V, S086A
D_D0408377	SEQ ID NO: 762	N011K, P012K, S027K, S030G, V031I, G032D, N033S, T038S, S044D, K053R, A056T, H058A, S065T, V070I, D071E, N073S, A074T, Q078H, R080E, L081T, E083H, L085V, S086A
D_D0408381	SEQ ID NO: 763	N008K, N011K, P012K, V015A, A016S, H019K, S027K, S030G, V031I, G032D, N033S, T038S, S044D, S065T, V070I, D071E, N073S, A074T, Q078H, R080E, L081T, E083H, L085V, S086A
D_D0408382	SEQ ID NO: 764	N011K, P012K, H019K, S027K, S030G, V031I, G032D, N033S, T038S, S044D, K053R, S065T, V070I, D071E, N073S, A074T, Q078H, R080E, L081T, E083H, L085V, S086A
D_D0408384	SEQ ID NO: 765	N008K, N011K, P012K, V015A, A016S, S027K, S030G, V031I, G032D, N033S, T038S, S044D, S065T, V070I, D071E, N073S, A074T, Q078H, R080E, L081T, E083H, L085V, S086A
D_D0408385	SEQ ID NO: 766	N011K, P012K, H019K, S027K, S030G, V031I, G032D, N033S, T038S, S044D, S065T, V070I, D071E, N073S, A074T, Q078H, R080E, L081T, E083H, L085V, S086A
D_D0408386	SEQ ID NO: 767	N008K, N011K, P012K, V015A, A016S, H019K, S027K, S030G, V031I, G032D, N033S, S044D, H058A, S065T, V070I, D071E, N073S, A074T, Q078H, R080E, L081T, E083H, L085V, S086A

Clone Designation	Polypeptide	Amino Acid Substitutions compared to PIP-72Aa (SEQ ID NO: 2)
D_D0408387	SEQ ID NO: 768	N008K, N011K, P012K, S027K, S030G, V031I, G032D, N033S, T038S, S044D, K053R, S065T, V070I, D071E, N073S, A074T, Q078H, R080E, L081T, E083H, L085V, S086A
D_D0348839	SEQ ID NO: 772	N008K, N011K, P012K, V015A, A016S, H019K, S027K, S030G, V031I, G032D, N033S, T038S, S044D, Q078H, R080E, L081T, E083H, L085V, S086A
D_D0347298	SEQ ID NO: 771	N008K, N011K, P012K, V015A, A016S, H019K, S027K, S030G, V031I, G032D, N033S, T038S, S044D

Example 10 - Identification of amino acid positions affecting the function of PIP-72Aa

The protein sequence alignment of PIP-72Aa (SEQ ID NO: 2) and other active family members PIP-72Da (SEQ ID NO: 10), PIP-72Fa (SEQ ID NO: 18), GBP_A3175 (SEQ ID NO: 20) and PIP-72Gb (SEQ ID NO: 32) is shown in Figure 2. From the alignment, conserved amino acid positions 7, 10, 20, 23, 24, 34, 60, 61, 66, 68, 75, 77, 79, 84 were selected for saturation mutagenesis using the oligonucleotide primers indicated in Table 23 (QuikChange™ technique, Agilent, 5301 Stevens Creek Blvd, Santa Clara CA). In addition, positions 8, 11, 12, 15, 16, 19, 27, 30, 31, 32, 33, 53, 56, 58, 65, 70, 71, 73, 74, 78, 80, 81, 83, 85, 86, which differ between PIP-72Aa (SEQ ID NO: 2) and PIP-72Da (SEQ ID NO: 10) were subjected to saturation mutagenesis using a modification of the QuikChange™ method with Phusion® High Fidelity DNA Polymerase (New England Biolabs®, Cat #M0530L, 240 County Road, Ipswich, MA 01938-2723), with the oligonucleotide primers indicated in Table 23. The resulting plasmid DNAs were transformed into *E. coli*, and protein was expressed as described in Example 3. Bioassays were performed on Western Corn Root Worm as described in Example 4 to determine which gene variants retained insecticidal activity. Table 23 lists the positions that were addressed and summarizes the data that was obtained. The amino acid substitutions that were identified by DNA sequence analysis are shown. For each position, the amino acid substitutions which yielded PIP-72Aa variants that retained Western Corn Root Worm activity are shown.

Table 23

Position	Oligo Name	Oligo sequence identifier	Identified Substitutions	Active Substitutions
N7	NNK7_F	SEQ ID NO: 190	A, V, C, E, F, G, H, I, K, L, M, P, Q, R, S, T, W, Y	A, V
	MNN7_R	SEQ ID NO: 191		
N8	N8N_F	SEQ ID NO: 192	A, C, D, E, G, H, I, K, L, M, Q, R, S, T, V, F, P, W, Y	A, C, D, E, G, H, I, K, L, M, Q, R, S, T, V
	N8N_R	SEQ ID NO: 193		
S10	NNK10_F	SEQ ID NO: 194	A, E, F, G, H, I, K, L,	A, E, F, G, H, I, K, L

Position	Oligo Name	Oligo sequence identifier	Identified Substitutions	Active Substitutions
	MNN10_R	SEQ ID NO: 195	N,P,Q,R,T,W	,N,P,Q,R,T,W
N11	N11N_F	SEQ ID NO: 196	A,C,D,E,G,H,I,K, L,M,Q,S,T,V,Y,P, R,W	A,C,D,E,G,H,I,K ,L,M,Q,S,T,V,Y
	N11N_R	SEQ ID NO: 197		
P12	P12N_F	SEQ ID NO: 198	A,C,D,E,G,H,K,L, N,Q,R,S,T,V,W,Y, I	A,C,D,E,G,H,K,L ,N,Q,R,S,T,V,W, Y
	P12N_R	SEQ ID NO: 199		
V15	V15N_F	SEQ ID NO: 200	A,C,I,M,R,D,F,G, H,L,P,Q,S,T,W,Y	A,C,I,M,R
	V15N_R	SEQ ID NO: 201		
A16	A16N_F	SEQ ID NO: 202	C,D,E,F,G,H,I,K, L,M,N,P,Q,R,S,T, V,W,Y	none
	A16N_R	SEQ ID NO: 203		
H19	H19N_F	SEQ ID NO: 204	A,E,K,L,P,R,S,Y, C,D,F,G,I,M,N,T, V,W	A,E,K,L,P,R,S,Y
	H19N_R	SEQ ID NO: 205		
W20	NNK20_F	SEQ ID NO: 206	A,T,D,E,G,I,K,L, M,N,P,Q,R,S,V,Y	A,T
	MNN20_R	SEQ ID NO: 207		
D23	NNK23_F	SEQ ID NO: 208	A,G,H,K,M,N,Q,S, T,V,C,L,P,R,W,Y	A,G,H,K,M,N,Q,S ,T,V
	MNN23_R	SEQ ID NO: 209		
G24	NNK24_F	SEQ ID NO: 210	D,F,A,E,H,I,L,M, N,P,R,S,T,V,W,Y	D,F
	MNN24_R	SEQ ID NO: 211		
S27	S27N_F	SEQ ID NO: 212	A,C,D,E,F,G,H,N, Q,R,T,I,K,L,M,P, W,Y	A,C,D,E,F,G,H,N ,Q,R,T
	S27N_R	SEQ ID NO: 213		
S30	S30N_F	SEQ ID NO: 214	A,C,D,E,F,G,H,K, L,M,N,P,Q,R,T,V, W,Y	A,C,D,E,F,G,H,K ,L,M,N,P,Q,R,T, V,W,Y
	S30N_R	SEQ ID NO: 215		
V31	V31N_F	SEQ ID NO: 216	I,L,A,C,D,E,F,G, H,K,N,P,Q,R,S,T, W,Y	I,L
	V31N_R	SEQ ID NO: 217		
G32	G32N_F	SEQ ID NO: 218	A,D,E,F,H,K,L,M, N,P,Q,R,S,T,V,W, Y	A,D,E,F,H,K,L,M ,N,P,Q,R,S,T,V, W,Y
	G32N_R	SEQ ID NO: 219		
N33	N33N_F	SEQ ID NO: 220	A,C,D,E,F,G,H,I, K,L,P,Q,R,S,T,V, Y,W	A,C,D,E,F,G,H,I ,K,L,P,Q,R,S,T, V,Y
	N33N_R	SEQ ID NO: 221		
G34	NNK34_F	SEQ ID NO: 222	E,F,H,K,L,M,N,Q, R,S,T,Y,I,P,V,W	E,F,H,K,L,M,N,Q ,R,S,T,Y
	MNN34_R	SEQ ID NO: 223		
K53	K53N_F	SEQ ID NO: 224	A,C,D,E,F,H,I,L, M,N,p,Q,R,S,T,V, Y,G,W	A,C,D,E,F,H,I,L ,M,N,Q,R,S,T,V, Y
	K53N_R	SEQ ID NO: 225		
A56	A56N_F	SEQ ID NO: 226	G,L,N,P,Q,R,S,T, C,D,E,F,H,I,K,Y	G,L,N,P,Q,R,S,T
	A56N_R	SEQ ID NO: 227		
H58	H58N_F	SEQ ID NO: 228	A,D,F,L,M,N,R,W, Y,C,G,I,K,P,S,T, V	A,D,F,L,M,N,R,W ,Y
	H58N_R	SEQ ID NO: 229		
Y60	NNK60_F	SEQ ID NO: 230	E,F,A,D,G,I,K,L, M,N,P,Q,R,S,T,V	E,F
	MNN60_R	SEQ ID NO: 231		
Y61	NNK61_F	SEQ ID NO: 232	A,C,D,G,I,K,L,N, P,R,S,T,V,W	none
	MNN61_R	SEQ ID NO: 233		
S65	S65N_F	SEQ ID NO: 234	A,C,D,E,F,G,H,I, L,N,T,V,P,R,Y	A,C,D,E,F,G,H,I ,L,N,T,V
	S65N_R	SEQ ID NO: 235		
S66	NNK66_F	SEQ ID NO: 236	A,G,C,D,E,I,K,L, M,N,P,R,T,V,W	A,G
	MNN66_R	SEQ ID NO: 237		

Position	Oligo Name	Oligo sequence identifier	Identified Substitutions	Active Substitutions
I68	NNK68_F	SEQ ID NO: 238	D,L,V,A,C,E,F,G, H,K,M,N,P,Q,R,T, W,Y	D,L,V
	MNN68_R	SEQ ID NO: 239		
V70	V70N_F	SEQ ID NO: 240	C,I,A,D,F,G,H,L, M,N,P,Q,R,S,T,Y	C,I
	V70N_R	SEQ ID NO: 241		
D71	D71N_F	SEQ ID NO: 242	A,C,G,H,I,L,M,N, S,T,V,Y,F,P,R	A,C,G,H,I,L,M,N ,S,T,V,Y
	D71N_R	SEQ ID NO: 243		
N73	N73N_F	SEQ ID NO: 244	A,C,D,F,G,H,I,L, R,S,T,V,Y,P	A,C,D,F,G,H,I,L ,R,S,T,V,Y
	N73N_R	SEQ ID NO: 245		
A74	A74N_F	SEQ ID NO: 246	C,D,F,G,H,I,L,N, Q,R,S,T,V,Y,P	C,D,F,G,H,I,L,N ,Q,R,S,T,V,Y
	A74N_R	SEQ ID NO: 247		
V75	NNK75_F	SEQ ID NO: 248	C,I,L,A,D,F,G,H, K,M,P,Q,R,S,T,W, Y	C,I,L
	MNN75_R	SEQ ID NO: 249		
D77	NNK77_F	SEQ ID NO: 250	Y,A,E,F,G,H,K,L, M,N,P,Q,R,T,V,W	Y
	MNN77_R	SEQ ID NO: 251		
Q78	Q78N_F	SEQ ID NO: 252	A,C,D,F,G,H,I,L, M,N,R,S,T,V,Y,P	A,C,D,F,G,H,I,L ,M,N,R,S,T,V,Y
	Q78N_R	SEQ ID NO: 253		
R79	NNK79_F	SEQ ID NO: 254	A,C,D,E,F,H,K,L, N,Q,R,S,T,W,Y,I, P,V	A,C,D,E,F,H,K,L ,N,Q,R,S,T,W,Y
	MNN79_R	SEQ ID NO: 255		
R80	R80N_F	SEQ ID NO: 256	A,C,D,F,G,H,I,L, N,S,T,V,Y,P	A,C,D,F,G,H,I,L ,N,S,T,V,Y
	R80N_R	SEQ ID NO: 257		
L81	L81N_F	SEQ ID NO: 258	A,C,D,F,G,H,I,N, P,R,S,T,V,Y	A,C,D,F,G,H,I,N ,P,R,S,T,V
	L81N_R	SEQ ID NO: 259		
E83	E83N_F	SEQ ID NO: 260	A,C,D,F,G,H,I,K, L,N,P,R,S,T,V,Y	A,C,D,F,G,H,I,K ,L,N,P,R,S,T,V, Y
	E83N_R	SEQ ID NO: 261		
P84	NNK84_F	SEQ ID NO: 262	A,C,E,I,S,V,W,Y, F,G,H,L,N,R,T	A,C,E,I,S,V,W,Y
	MNN84_R	SEQ ID NO: 263		
L85	L85N_F	SEQ ID NO: 264	C,G,V,A,D,E,F,H, I,N,P,Q,R,S,T,Y	C,G,V
	L85N_R	SEQ ID NO: 265		
S86	S86N_F	SEQ ID NO: 266	A,I,T,V,C,D,F,G, H,L,M,N,P,Q,R,Y	A,I,T,V
	S86N_R	SEQ ID NO: 267		

Example 11 - Identification of Motif 1 and analysis of amino acid positions affecting the function of PIP-72Aa

From the protein sequence alignment of PIP-72Aa (SEQ ID NO: 2) and other active family members including PIP-72Da (SEQ ID NO: 10), PIP-72Fa (SEQ ID NO: 18), GBP_A3175 (SEQ ID NO: 20) and PIP-72Gb (SEQ ID NO: 32) shown in Figure 2, the conserved Motif 1 was identified as potentially important for function (underlined in Figure 2 relative to PIP-72Aa (SEQ ID NO: 2). Each position within Motif 1 (37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50 and 51) was subjected to saturation mutagenesis using the oligonucleotide primers indicated in Table 24. The resulting plasmid DNAs were transformed into *E. coli* and protein was expressed as described in Example 3. Bioassays

were performed on Western Corn Root Worm as described in Example 4 to determine which gene variants retained insecticidal activity. Table 24 lists the positions that were mutagenized and summarizes the data that was obtained. For each position, the amino acid substitutions which yielded PIP-72A polypeptide variants that retained Western Corn

5 Root Worm activity are shown. Also, the amino acid substitutions associated with soluble protein expression in *E. coli* are noted.

Table 24

Residue	Oligo Name	Sequence identifier	Identified Substitutions	Active Substitutions	Soluble Expression
E37	37nnk_F	SEQ ID NO: 268	A, C, D, E, F, G, I, K, L, M, N, S, T, V, H, P, R, W, Y	A, C, D, F, G, I, K, L, M, N, S, T, V	A, C, D, E, F, G, I, K, L, M, N, S, T, V, H, R, W, Y
T38	T38N_F	SEQ ID NO: 269	A, C, D, E, F, G, H, I, L, M, N, Q, R, S, V, W, Y, K, P	A, C, D, E, F, G, H, I, L, M, N, Q, R, S, V, W, Y	A, C, D, E, F, G, H, I, L, M, N, Q, R, S, V, W, Y
	T38N_R	SEQ ID NO: 270			
W39	39nnk_F	SEQ ID NO: 271	F, A, C, D, E, G, H, I, K, L, M, N, P, Q, R, S, T, V, Y	F	F, W, Y
D40	40nnk_F	SEQ ID NO: 272	A, C, E, F, G, H, I, K, L, M, N, Q, R, S, T, V, W, Y, P	A, C, E, F, G, H, I, K, L, M, N, Q, R, S, T, V, W, Y	A, C, D, E, F, G, H, I, K, L, M, N, Q, R, S, T, V, W, Y, P
R41	41nnk_F	SEQ ID NO: 273	A, C, D, E, F, G, I, K, L, M, N, P, Q, S, T, V, W, Y	none	F, I, L, N, V
S42	42nnk_F	SEQ ID NO: 274	A, C, D, E, F, G, I, K, L, M, N, Q, R, S, T, V, W, Y, P	A, C, D, E, F, G, I, K, L, M, N, Q, R, T, V, W, Y	A, C, D, E, F, G, I, K, L, M, N, Q, R, S, T, V, W, Y, P
D43	43nnk_F	SEQ ID NO: 275	A, C, E, F, G, H, I, K, L, N, P, Q, R, S, T, V, W, Y	none	
S44	S44N_F	SEQ ID NO: 276	A, D, E, G, L, M, N, P, Q, T, V, Y, H, I, K, R, W	A, D, E, G, L, M, N, P, Q, T, V, Y	A, D, E, G, L, M, N, P, Q, T, V, Y, H, I, K, R, W
	S44N_R	SEQ ID NO: 277			
R45	45nnk_F	SEQ ID NO: 278	K, R, S, A, C, D, E, F, G, H, L, M, N, P, Q, T, V, W, Y	K, S	K, R, L, M, Q, S, Y
G46	46nnk_F	SEQ ID NO: 279	A, Q, C, D, E, F, H, I, K, L, M, N, P, R, S, T, V, W, Y	A, Q	A, G, Q

Residue	Oligo Name	Sequence identifier	Identified Substitutions	Active Substitutions	Soluble Expression
F47	47nnk_F	SEQ ID NO: 280	C, V, Y, A, D, E, G, H, I, K, L, M, N, P, Q, R, S, T, W	C, V, Y	C, F, V, Y, H, L, M
V48	48nnk_F	SEQ ID NO: 281	I, L, A, C, D, E, F, G, H, K, M, N, P, Q, R, S, W	I, L,	I, L, V
L49	49nnk_F	SEQ ID NO: 282	C, F, M, R, Y, A, D, E, G, H, I, K, N, P, Q, S, T, V, W	C, F, M, R, Y	C, F, L, M, R, Y
S50	50nnk_F	SEQ ID NO: 283	A, C, D, I, M, P, Q, S, T, V, F, G, H, K, L, N, R, W, Y	A, C, D, I, M, P, Q, T, V	A, C, D, I, M, Q, S, T, V, F, H, L, N, R, W, Y
L51	51nnk_F	SEQ ID NO: 284	A, C, M, V, D, E, F, G, H, K, N, P, Q, R, S, T, W, Y	A, C, M, V	A, C, L, M, V

Example 12 – PIP-72Aa variants with multiple amino acid substitutions in Motif 1

PIP-72Aa variants with multiple selected amino acid substitutions in Motif 1 were generated by the QuikChange™ technique (Agilent, Santa Clara CA) using a combination of the oligonucleotide primers indicated in Table 25. The resulting plasmid DNAs were transformed into *E. coli*, and protein was expressed as described in Example 3. Bioassays were performed on Western Corn Root Worm as described in Example 4 to determine which gene variants retained insecticidal activity. DNA sequencing was performed on the active gene variants. The nucleotide and amino acid sequences of active variants are listed in Table 26. Out of 78 variants screened, 20 had detectable Western Corn Root Worm activity. The active variants contained between 2 and 7 amino acid substitutions relative to PIP-72Aa (SEQ ID NO: 2). Table 27 shows the amino acid substitutions of the resulting active PIP-72 polypeptide variants compared to PIP-72Aa (SEQ ID NO: 2).

Table 25

primer	Sequence identifier		primer	Sequence identifier
CombiMM1:1_T	SEQ ID NO: 773		CombiMM1:17_T	SEQ ID NO: 789
CombiMM1:2_T	SEQ ID NO: 774		CombiMM1:18_T	SEQ ID NO: 790
CombiMM1:3_T	SEQ ID NO: 775		CombiMM1:19_T	SEQ ID NO: 791
CombiMM1:4_T	SEQ ID NO: 776		CombiMM1:20_T	SEQ ID NO: 792
CombiMM1:5_T	SEQ ID NO: 777		CombiMM1:21_T	SEQ ID NO: 793
CombiMM1:6_T	SEQ ID NO: 778		CombiMM1:22_T	SEQ ID NO: 794
CombiMM1:7_T	SEQ ID NO: 779		CombiMM1:23_T	SEQ ID NO: 795
CombiMM1:8_T	SEQ ID NO: 780		CombiMM1:24_T	SEQ ID NO: 796

CombiMM1:9_T	SEQ ID NO: 781		CombiMM1:25_T	SEQ ID NO: 797
CombiMM1:10_T	SEQ ID NO: 782		CombiMM1:26_T	SEQ ID NO: 798
CombiMM1:11_T	SEQ ID NO: 783		CombiMM1:27_T	SEQ ID NO: 799
CombiMM1:12_T	SEQ ID NO: 784		CombiMM1:28_T	SEQ ID NO: 800
CombiMM1:13_T	SEQ ID NO: 785		CombiMM1:29_T	SEQ ID NO: 801
CombiMM1:14_T	SEQ ID NO: 786		CombiMM1:30_T	SEQ ID NO: 802
CombiMM1:15_T	SEQ ID NO: 787		CombiMM1:31_T	SEQ ID NO: 803
CombiMM1:16_T	SEQ ID NO: 788		CombiMM1:32_T	SEQ ID NO: 804

Table 26

% ID PIP-72Aa	Clone Designation	Polynucleotide	Polypeptide
95.35%	D_D0416473	SEQ ID NO: 805	SEQ ID NO: 825
95.35%	D_D0416474	SEQ ID NO: 806	SEQ ID NO: 826
96.51%	D_D0416483	SEQ ID NO: 807	SEQ ID NO: 827
94.19%	D_D0416488	SEQ ID NO: 808	SEQ ID NO: 828
95.35%	D_D0416490	SEQ ID NO: 809	SEQ ID NO: 829
97.67%	D_D0416492	SEQ ID NO: 810	SEQ ID NO: 830
97.67%	D_D0416493	SEQ ID NO: 811	SEQ ID NO: 831
95.35%	D_D0416502	SEQ ID NO: 812	SEQ ID NO: 832
96.51%	D_D0416506	SEQ ID NO: 813	SEQ ID NO: 833
94.19%	D_D0416507	SEQ ID NO: 814	SEQ ID NO: 834
94.19%	D_D0416514	SEQ ID NO: 815	SEQ ID NO: 835
94.19%	D_D0416520	SEQ ID NO: 816	SEQ ID NO: 836
91.86%	D_D0416521	SEQ ID NO: 817	SEQ ID NO: 837
96.51%	D_D0416527	SEQ ID NO: 818	SEQ ID NO: 838
94.19%	D_D0416528	SEQ ID NO: 819	SEQ ID NO: 839
95.35%	D_D0416542	SEQ ID NO: 820	SEQ ID NO: 840
94.19%	D_D0416543	SEQ ID NO: 821	SEQ ID NO: 841
95.35%	D_D0416551	SEQ ID NO: 822	SEQ ID NO: 842
91.86%	D_D0416552	SEQ ID NO: 823	SEQ ID NO: 843
95.35%	D_D0416555	SEQ ID NO: 824	SEQ ID NO: 844

5

Table 27

Clone des.	polypeptide	Substitutions relative to SEQ ID NO: 2
D_D0416473	SEQ ID NO: 825	E037V, T038S, D040E, S044A
D_D0416474	SEQ ID NO: 826	E037V, D040G, S044A, S050G
D_D0416483	SEQ ID NO: 827	L049M, S050C, L051M
D_D0416488	SEQ ID NO: 828	T038G, S044A, L049M, S050C, L051M
D_D0416490	SEQ ID NO: 829	D040G, S042T, S044N, S050C
D_D0416492	SEQ ID NO: 830	S050C, L051M
D_D0416493	SEQ ID NO: 831	S044N, L049M
D_D0416502	SEQ ID NO: 832	E037V, T038S, D040A, S050C
D_D0416506	SEQ ID NO: 833	E037C, T038G, S050C
D_D0416507	SEQ ID NO: 834	E037V, T038G, S044A, L049M, S050A
D_D0416514	SEQ ID NO: 835	E037V, T038G, D040E, S044N, S050C

D_D0416520	SEQ ID NO: 836	E037C, T038G, S042T, S044N, L049M
D_D0416521	SEQ ID NO: 837	E037V, T038S, D040G, S044A, V048I, S050C, L051M
D_D0416527	SEQ ID NO: 838	T038G, S042T, S050C
D_D0416528	SEQ ID NO: 839	E037D, D040A, S042T, L049M, S050C
D_D0416542	SEQ ID NO: 840	E037C, D040G, L049M, S050A
D_D0416543	SEQ ID NO: 841	E037C, T038S, D040E, S042T, S050C
D_D0416551	SEQ ID NO: 842	E037V, T038S, D040A, S042N
D_D0416552	SEQ ID NO: 843	E037V, D040E, S042T, S044N, L049M, S050C, L051M
D_D0416555	SEQ ID NO: 844	E037D, T038S, S044A, S050C

Example 13 - Identification of additional amino acid positions affecting the function of PIP-72Aa

The remaining amino acid positions 2, 3, 4, 5, 6, 9, 13, 14, 17, 18, 21, 22, 25, 26, 28, 29, 35, 36, 52, 54, 55, 57, 59, 62, 63, 64, 67, 69, 72, 76, 82 were subjected to saturation mutagenesis as described in Example 11, using the oligonucleotide primers indicated in Table 27. The resulting plasmid DNAs were transformed into *E. coli*, and protein was expressed as described in Example 3. Bioassays were performed on Western Corn Root Worm as described in Example 4 to determine which gene variants retained insecticidal activity. Table 28 lists the positions that were mutagenized and summarizes the amino acid substitutions identified by DNA sequencing and the amino acid substitutions which yielded PIP-72Aa variants that retained Western Corn Root Worm activity are shown.

15

Table 28

POSITION	OLIGO NAME	SEQUENCE IDENTIFIER	IDENTIFIED SUBSTITUTIONS	ACTIVE SUBSTITUTIONS
G2	NNK2_HM	SEQ ID NO: 865	A, C, D, E, I, K, L, N, R, S, T, V, W, Y	A, C, D, E, I, K, L, N, R, S, T, V, W, Y
I3	NNK3_HM	SEQ ID NO: 866	A, C, D, E, F, G, H, L, N, P, Q, R, S, V, W, Y	W
T4	NNK4_HM	SEQ ID NO: 867	A, D, E, F, G, H, I, K, L, P, R, S, V, W, Y	A, D, E, H, I, K, L, R, S, V, W, Y
V5	NNK5_HM	SEQ ID NO: 868	A, C, E, G, H, I, K, L, N, Q, R, S, T, W, Y	A, C, G, H, I, Y
T6	NNK6_HM	SEQ ID NO: 869	A, C, D, E, F, G, H, I, K, L, M, N, P, Q, R, S, V, W, Y	A, C, F, G, H, I, K, M, P, Q, R, S, W, Y
S9	NNK9	SEQ ID NO: 889	A, C, D, E, F, G, H, I, K, L, M, P, Q, R, T, V, W, Y	A, C, G, T
	MNN9	SEQ ID NO: 890		
I13	NNK13_HM	SEQ ID NO: 870	A, C, D, F, G, H, K, L, M, N, P, Q, R, S, T, V, W, Y	N, Q, V
E14	NNK14_HM	SEQ ID NO: 871	A, C, D, F, G, H, K, L, M, N, P, Q, R, S, T, V, W, Y	A, C, F, H, K, Q

POSITION	OLIGO NAME	SEQUENCE IDENTIFIER	IDENTIFIED SUBSTITUTIONS	ACTIVE SUBSTITUTIONS
I17	NNK17_HM	SEQ ID NO: 872	A, C, D, E, F, G, H, K, L, M, N, P, Q, R, S, T, V, W, Y	E, V
N18	NNK18_HM	SEQ ID NO: 873	A, C, D, E, F, G, H, I, K, L, M, Q, R, S, T, V, Y	S
G21	NNK21_HM	SEQ ID NO: 874	A, D, F, I, L, M, P, R, S, T, V, W	NONE
S22	NNK22_HM	SEQ ID NO: 875	A, C, D, E, F, G, H, I, K, L, M, N, P, Q, R, T, V, W, Y	A, D, F, G, H, I, K, L, M, N, P, Q, R, T, V, Y
D25	NNK25_HM	SEQ ID NO: 876	A, C, E, F, G, H, L, N, P, Q, R, S, V, W	A, E, F, N, Q
T26	NNK26_HM	SEQ ID NO: 877	A, C, D, E, F, G, H, I, K, L, M, N, P, Q, R, S, V, W, Y	E, P
F28	NNK28	SEQ ID NO: 891	A, C, D, E, G, H, I, K, L, M, N, P, Q, R, S, T, V, W, Y	P, W, Y
	MNN28	SEQ ID NO: 892		
F29	NNK29	SEQ ID NO: 893	A, C, D, E, G, H, I, K, L, M, N, P, S, T, V, W, Y	A, C, I, L, Q, R, W, Y
	MNN29	SEQ ID NO: 894		
K35	NNK35	SEQ ID NO: 895	A, C, D, G, H, I, L, M, N, P, Q, R, S, T, V, W, Y	A, C, D, G, H, I, L, M, N, Q, R, S, T, V
	MNN35	SEQ ID NO: 896		
Q36	NNK36_HM	SEQ ID NO: 878	A, C, E, G, H, I, K, L, M, N, P, R, S, T, V, W, Y	A, C, E, G, H, I, K, L, N, P, R, S, T, V
K52	NNK52	SEQ ID NO: 897	A, C, D, E, F, G, H, I, L, M, N, P, R, S, T, V, W, Y	C, F, H, I, L, M, N, R, S, T, W, Y
	MNN52	SEQ ID NO: 898		
N54	NNK54_HM	SEQ ID NO: 879	A, C, D, E, F, G, I, K, L, M, P, Q, R, S, T, V, W, Y	C, D, E, F, G, K, M, Q, R, S, W
G55	NNK55_HM	SEQ ID NO: 880	A, C, D, E, F, H, I, K, L, M, N, P, Q, R, S, T, V, W, Y	NONE
Q57	NNK57_HM	SEQ ID NO: 881	A, C, D, E, F, G, H, I, K, L, M, P, R, S, T, V, W	E, L, M, S, T
P59	NNK59_HM	SEQ ID NO: 882	A, C, D, E, F, G, H, I, K, L, M, N, Q, R, S, T, V, W, Y	NONE
V62	NNK62_HM	SEQ ID NO: 883	A, C, D, E, F, G, H, K, L, M, N, P, Q, R, S, T, W, Y	NONE
Q63	NNK63_HM	SEQ ID NO: 884	A, C, D, E, F, G, H, I, K, L, M, N, P, R, S, T, V, W, Y	C, G, I, L, M, N, T, V, Y
A64	NNK64_HM	SEQ ID NO: 885	C, D, E, F, G, H, I, K, L, M, N, P, Q, R, S, T, V, W, Y	F, G, H, R, S, Y
K67	NNK67	SEQ ID NO: 899	A, C, D, F, G, H, I, L, M, N, P, Q, R, S, T, V, W, Y	A, C, D, F, H, I, L, M, N, Q, R, S, T, V, W, Y
	MNN67	SEQ ID NO: 900		
E69	NNK69_HM	SEQ ID NO: 886	A, C, D, F, G, H, I, K, L, M, N, P, Q, R, S, T, V, Y	A, C, D, F, H, I, L, M, Q, R, S, T, V, Y

POSITION	OLIGO NAME	SEQUENCE IDENTIFIER	IDENTIFIED SUBSTITUTIONS	ACTIVE SUBSTITUTIONS
N72	NNK72_HM	SEQ ID NO: 887	A, C, D, E, F, G, I, K, L, M, P, Q, R, S, T, V, W, Y	A, C, D, E, G, K, M, P, Q, R, S, T, V, W
K76	NNK76	SEQ ID NO: 901	A, C, D, E, F, G, H, I, L, N, P, Q, R, S, T, V, W, Y	A, C, F, H, I, L, Q, R, S, T, V, W, Y
	MNN76	SEQ ID NO: 902		
I82	NNK82_HM	SEQ ID NO: 888	A, D, E, F, G, H, K, L, M, N, P, Q, R, S, T, V, W, Y	A, L, M, R, V

Example 14 - PIP-72Aa variants with improved activity against Western corn rootworm

5 To create variants of PIP-72Aa (SEQ ID NO: 2) with increased Western corn rootworm activity, libraries were generated by synthetic DNA shuffling (Ness et al, 2002, *Nature Biotechnology* **20**, 1251-5) of PIP-72Aa (SEQ ID NO: 1) and by site-directed mutagenesis (QuikChange™ Lightning technique or QuikChange™ II technique, Agilent, Santa Clara CA). Twelve PIP-72 variant polypeptides with increased specific activity

10 against Western corn rootworm were identified. The PIP-72 variant polypeptides A5, A5:10E, A5:10T, A5:10V, A5:10A, A5:10L, A5:10E/78H, A5:8M, A5:71H/83F, A5:4S/54Q/78H, A5:71H and 3_68 exhibited between about 1.2 and 2-fold improved insecticidal activity against Western corn rootworm compared to PIP-72Aa (SEQ ID NO: 2). Table 29 shows the amino acid substitutions compared to PIP-72Aa (SEQ ID NO: 2)

15 for each of the PIP-72 variant polypeptides, the corresponding amino acid sequence identifier, and the corresponding nucleic acid sequence identifier. Amino acid substitutions compared to A5 (SEQ ID NO: **) are bolded.

Table 29

Variant	a.a. substitutions compared to SEQ ID NO: 2	Polypeptide sequence	Polynucleotide sequence
72Aa		SEQ ID NO: 2	SEQ ID NO: 1
Combi3_68	S10E, L49M, E83Y	SEQ ID NO: 903	SEQ ID NO: 915
A5	S30G, V31I, G32D, N33S, T38S, K53R, H57A	SEQ ID NO: 904	SEQ ID NO: 916
A5:10E	S10E , S30G, V31I, G32D, N33S, T38S, K53R, H57A	SEQ ID NO: 905	SEQ ID NO: 917
A5:10T	S10T , S30G, V31I, G32D, N33S, T38S, K53R, H57A	SEQ ID NO: 906	SEQ ID NO: 918
A5:10V	S10V , S30G, V31I, G32D, N33S, T38S, K53R, H57A	SEQ ID NO: 907	SEQ ID NO: 919
A5:10A	S10A , S30G, V31I, G32D, N33S, T38S, K53R, H57A	SEQ ID NO: 908	SEQ ID NO: 920
A5:10L	S10L , S30G, V31I, G32D, N33S, T38S, K53R, H57A	SEQ ID NO: 909	SEQ ID NO: 921

A5:10E/78H	S10E , S30G, V31I, G32D, N33S, T38S, K53R, H57A, Q78H	SEQ ID NO: 910	SEQ ID NO: 922
A5:8M	N8M , S30G, V31I, G32D, N33S, T38S, K53R, H57A	SEQ ID NO: 911	SEQ ID NO: 923
A5:71H/83F	S30G, V31I, G32D, N33S, T38S, K53R, H57A, D71H , E83F	SEQ ID NO: 912	SEQ ID NO: 924
A5:4S/54Q/78H	S30G, V31I, G32D, N33S, T38S, K53R, N54Q , H57A, Q78H	SEQ ID NO: 913	SEQ ID NO: 925
A5:71H	S30G, V31I, G32D, N33S, T38S, K53R, H57A, D71H	SEQ ID NO: 914	SEQ ID NO: 926

To determine Western corn rootworm activity, test proteins were assayed as described in Example 4. A 0-3 numerical scoring system based on the size and mortality was used. If no response or normal growth was seen, Score 0 was given. When the growth was somewhat retarded without any mortality, it was Score 1. Score 2 meant partial death (multiple insects were used in each well) and strong growth inhibition. Score 3 indicated the complete mortality. Each treatment was repeated 6 times for possible highest score of 18. In this scoring system, Score 9 with 6 repeats of one treatment means the 50% response (9 out of 18) of the treatment and called ILC50 (growth Inhibition and Lethal Concentration for 50% response). Activity data is shown in Table 30. Converted ILC50 numbers represent averages of between 2 and 20 experiments.

Table 30

Variant	converted ILC50	converted lower range	converted upper range	fold improvement	
PIP-72Aa SEQ ID NO: 2	56.68	48.32	66.69	1	n = 18
3_68 SEQ ID NO: 903	48.86	40.78	58.22	1.16	n = 4
A5 SEQ ID NO: 904	36.68	30.76	43.24	1.55	n = 20
A5:10E SEQ ID NO: 905	33.96	27.78	41.01	1.67	n = 10
A5:10T SEQ ID NO: 906	30.54	23.78	38.48	1.86	n = 4
A5:10V SEQ ID NO: 907	31.35	25.69	37.87	1.81	n = 4
A5:10A SEQ ID NO: 908	42.38	35.61	50.27	1.34	n = 2
A5:10L SEQ ID NO: 909	39.05	31.87	47.78	1.45	n = 2
A5:10E/78H SEQ ID NO: 910	36.04	28.64	44.66	1.57	n = 10
A5:8M SEQ ID NO: 911	25.02	19.34	30.90	2.27	n = 6
A5:71H/83F	32.24	26.72	38.44	1.78	n = 4

SEQ ID NO: 912					
A5:4S/54Q/78H SEQ ID NO: 913	29.01	23.42	35.20	1.95	n = 4
A5:71H SEQ ID NO: 914	26.82	20.57	33.75	2.1	n = 2

Example 15 – Three-dimensional structure determination of PIP-72Aa by NMR

Uniformly ^{15}N , ^{13}C isotope labeled PIP-72a was produced in *E.coli* strain Shuffle™ T7 (New England Biolabs) as described (Jansson, M. et al. 1996, J Biomol NMR 7:131). In brief, a modified minimal medium (MJ9) consisting of a strong buffering system, supplemental vitamins, and trace elements was employed. *E. coli* cells harboring the expression plasmid encoding PIP-72Aa (SEQ ID NO: 2) with an N-terminal His tag described in Example 3 were harvested and lysed by homogenization at 25,000 psi. Cleared, crude lysate was incubated with Ni-NTA resin (Qiagen) and highly enriched PIP-72Aa was eluted with imidazole as suggested by the manufacturer. The N-terminal purification tag was removed by proteolysis and further purification of untagged PIP-72Aa was achieved by anion exchange chromatography using Q-HP Sepharose (GE Healthcare). The final PIP-72Aa preparation was submitted to mass spectrometry to confirm uniform double labeling with both ^{15}N and ^{13}C isotopes.

For NMR data collection PIP-72Aa (SEQ ID NO: 2) was used at 0.7 mM formulated in 20 mM MES, pH 6.5, 100 mM NaCl, and 5 mM CaCl_2 . D_2O and DSS (4,4-dimethyl-4-silapentane-1-sulfonic acid) were added to 10% and 50 μM final concentrations, respectively. This was then loaded into a 4 mm NMR tube (Shigemi). Data collection was at 25°C on a Bruker 800 MHz spectrometer equipped with a cryo-probe (Monleon, D. et al. 2002, J Struct Funct Genomics 2: 93).

NMR data were processed and referenced to external DSS (800.1899152 at 25 °C). Sequence specific backbone assignments (HN, $\text{H}\alpha$, N, $\text{C}\alpha$) were obtained in a largely automated manner with the program AUTOASSIGN (Gardner, K.H. et al, 1997, Biochemistry 36:1389) using peak lists from 2D ^1H - ^{15}N HSQC and 3D HNCO, HNCA, HN(CO)CA, HN(CO)CACB and HNCACB NMR spectra. Sequential assignments and a 3D HAHB(CO)HN spectrum were then used to manually assign $\text{H}\beta/\text{C}\beta$ resonances. The CCH-TOCSY and simultaneous NOESY were analyzed manually to obtain nearly complete side-chain assignment. Assignments were obtained for 96% of backbone and 93% of side-chain chemical shifts assignable.

Structure determination utilized standard published protocols (Baran, M.C. et al. 2004, Chemical Reviews 104:3451; Huang, Y.J. et al. 2005 Methods in Enzymology

394:111, Liu, G.H. et al. 2005 Proceedings of the National Academy of Sciences of the United States of America 102:10487; Huang, Y.J. et al. 2006 Proteins-Structure Function and Bioinformatics 62: 587). Based on chemical shifts, the locations of regular secondary structure elements were identified as described (Wishart, D.S. et al, 1994 J of Biomol NMR 4:171).

A NOESY peak list containing expected intra-residue, sequential and α -helical medium range NOE peaks was initially generated and manually edited by visual inspection of the simultaneous NOESY (100 ms mixing time) and ^{13}C -edited aromatic NOESY (100 ms mixing time) spectra. NOEs were assigned using matching tolerances of 0.030, 0.025 and 0.40 ppm for indirect ^1H , direct ^1H and heavy atom $^{13}\text{C}/^{15}\text{N}$, respectively. Subsequent manual peak picking was used to identify remaining, primarily long-range NOEs. In addition, backbone dihedral angle constraints were derived from chemical shifts (Shen, Y. et al. 2009 J Biomol NMR 44:213) for residues located in well-defined secondary structure elements. The initial structure was refined in explicit solvent using standard methods (Linge, J.P. et al. 2003 Proteins-Structure Function and Bioinformatics 50:496).

Structure quality factors were assessed with the PSVS 1.3 software package A. Bhattacharya, R. et al. 2007 Proteins-Structure Function and Bioinformatics 66:778). Fit of the structure to the NMR restraint data was analyzed using PDBStat (Tejero, R. et al. 2013 J. Biomol. NMR 56:337). The global goodness-of-fit of the final structure ensembles with the NOESY peak list data were determined using the RPF analysis program (Huang, Y.J. et al. 2005 Journal of the American Chemical Society 127:1665).

Resonance assignments were validated with the Assignment Validation Software (AVS) suite (Moseley, H.N. et al. 2004 J Biomol NMR 28:341).

Example 16 –3-dimensional structure of PIP-72Aa

The overall structure of PIP-72Aa monomer is a flat β -sandwich approximately $35\text{\AA} \times 28\text{\AA} \times 21\text{\AA}$ formed by the packing of β -sheet 1 and β -sheet 2. The eight total strands of the β -sandwich consist of four from each β -sheet. β -sheet 1 contains the N- and C-termini, β -strand 1 ($\beta 1$), β -strand 4 ($\beta 4$), β -strand 7 ($\beta 7$), and β -strand 8 ($\beta 8$). β -strand 1 and 4 as well as β -strands 7 and 8 are antiparallel whereas $\beta 1$ and $\beta 4$ are parallel to one another. β -sheet 2 contains β -strand 2 ($\beta 2$), β -strand 3 ($\beta 3$), β -strand 5 ($\beta 5$), and β -strand 6 ($\beta 6$) and are all antiparallel to each other. The C-terminal 8 residues fold back across the β -sandwich and close off one face of the sandwich interacting with both sheets 1 and 2. The core of the sandwich is almost completely hydrophobic. The

distance between β -sheet 1 and β -sheet 2 is approximately 12Å when measured C α to C α . The residues and amino acids, relative to SEQ ID NO: 2, comprising the β -strands and loops are shown in Table 31. Two views of a schematic ribbon representation of the PIP-72Aa NMR solution structure with β -strands of the β -sandwich identified are shown in
5 Figures 1 and 2.

PIP-72Aa exists as a homo dimer in the solution structure. Figure 5 shows a schematic ribbon representation of the dimer model based on the NMR solution structure. The PIP-72Aa structure also comprises a hydrophobic interface surface that is approximately 19Å x 20Å and consists of residues from β -sheet 2, loop 2, loop 4 and the
10 C-terminal final 2 residues. The hydrophobic interface surface is predominately hydrophobic with the majority of residue contacts involving either sidechains of hydrophobic residues or the aliphatic carbon sidechain atoms of the hydrophilic residues. The dimer interface is formed by burying hydrophobic sidechains from sheet 2 from each monomer. The C-terminus fold back a covers one face of the β -sandwich. The residues
15 comprising the hydrophobic interface surface are indicated in Table 31. Pi stacking between residues W20 is a significant feature of the loop 2-loop 2 interface region. Likewise, the main hydrophilic interaction across the hydrophobic interface surface is one of the terminal nitrogen atoms in the side chain of R45 and ϵ oxygen atom of the side chain of Q57. The C-terminal L85 makes hydrophobic contact with the corresponding L85
20 from the other monomer. Likewise, the C α and C β from S86 make hydrophobic contact with Y61 from the other monomer. This connects the two C-termini and effectively closes off one face of the sandwich.

Table 31

PIP-72Aa residue number relative to SEQ ID NO: 2	amino acids relative to SEQ ID NO: 2	feature	function	involved in interface
1 to 3	MGI	N-terminus		
4 to 9	TVTNNS	β strand 1		
10 to 14	SNPIE	loop 1		
15-18	<u>VAIN</u>	β strand 2		x
19-27	<u>HWGSDGDT</u> <u>S</u>	loop 2		x
28-33	FFSVGN	β strand 3		
34-35	GK	loop 3		
36-40	QETWD	β strand 4		

41-47	RSDS <u>R</u> GF	loop 4	hinge for hairpin	x
48-53	<u>V</u> L <u>S</u> LKK	β strand 5	beta hairpin	x
54-57	NGA <u>Q</u>	loop 5		x
58-62	H <u>P</u> <u>Y</u> <u>Y</u> V	β strand 6		x
63-67	QASSK	loop 6	hinge for hairpin	
68-72	IEVDN	β strand 7		
73-74	NA	loop 7		
75-78	VKDQ	β strand 8		
79-86	GRLEP <u>L</u> S	C-terminus		x

It should be understood that while the specific residue numbers referred to herein relate primarily to the exemplified PIP-72Aa polypeptide (SEQ ID NO: 2), one skilled in the art would know, with the benefit of this disclosure, corresponding residues and segments are now identifiable in the other PIP-72 polypeptides of the disclosure. The exact numbering of the residues might not strictly correspond to the PIP-72 polypeptide, but the corresponding residues are readily identifiable in light of the subject disclosure. See, e.g., Figures 1-5.

10 **Example 17 - 3-Dimensional Structure Based Protein Engineering of PIP-72Aa for Various Functional Enhancements.**

In silico modeling of the PIP-72Aa was done using Discovery Studio v3.5.0.12158, Copyright ©2005-12 Accelrys Software Inc. The “Calculate Mutation Energy” protocol was applied to selected residues using the CHARMM force field. The mutational energy was expressed as kcal/mol and indicates whether or not an amino acid change will stabilize, destabilize, or have a neutral effect on the model. The *in silico* calculation along with manual exploration of the PIP-72Aa solution structure were used to select candidate positions for mutagenesis.

The above description of various illustrated embodiments of the disclosure is not intended to be exhaustive or to limit the scope to the precise form disclosed. While specific embodiments of and examples are described herein for illustrative purposes, various equivalent modifications are possible within the scope of the disclosure, as those skilled in the relevant art will recognize. The teachings provided herein can be applied to other purposes, other than the examples described above. Numerous modifications and variations are possible in light of the above teachings and, therefore, are within the scope of the appended claims.

These and other changes may be made in light of the above detailed description. In general, in the following claims, the terms used should not be construed to limit the scope to the specific embodiments disclosed in the specification and the claims.

5 The entire disclosure of each document cited (including patents, patent applications, journal articles, abstracts, manuals, books or other disclosures) in the Background, Detailed Description, and Examples is herein incorporated by reference in their entireties.

10 Efforts have been made to ensure accuracy with respect to the numbers used (e.g. amounts, temperature, concentrations, etc.) but some experimental errors and deviations should be allowed for.

THAT WHICH IS CLAIMED:

1. A recombinant PIP-72 polypeptide comprising
 - a) at least 50% identity to the amino acid sequence of SEQ ID NO: 2; and
 - b) a structure comprising a hydrophobic interface surface.
- 5 2. The recombinant PIP-72 polypeptide of claim 1, wherein the structure further comprises a flat β -sandwich formed by the packing of a β -sheet 1 and a β -sheet 2.
3. The recombinant PIP-72 polypeptide of claim 2, wherein the flat β -sandwich is approximately 35Å x 28Å x 21Å.
4. The recombinant PIP-72 polypeptide of claim 2 or 3, wherein the β -sheet 1
 10 comprises the N-termini, C-termini, a β -strand 1 (β 1), a β -strand 4 (β 4), a β -strand 7 (β 7) and a β -strand 8 (β 8).
5. The recombinant PIP-72 polypeptide of claim 4, wherein β 1 and β 4 as well as β 7 and β 8 are antiparallel, whereas β 1 and β 4 are parallel to one another.
6. The recombinant PIP-72 polypeptide of claim 4 or 5, wherein β 1 comprises
 15 residues about 4 to about 9, β 4 comprises residues about 36 to about 40, β 7 comprises residues about 68 to about 72, and β 8 comprises residues about 75 to about 78 corresponding to SEQ ID NO: 2.
7. The recombinant PIP-72 polypeptide of claim 2, 3, 4, 5 or 6, wherein β -sheet 2 comprises a β -strand 2 (β 2), a β -strand 3 (β 3), a β -strand 5 (β 5) and a β -strand 6 (β 6).
- 20 8. The recombinant PIP-72 polypeptide of claim 7, wherein β 2, β 3, β 5 and β 6 and are all antiparallel to each other.
9. The recombinant PIP-72 polypeptide of claim 7 or 8, wherein β 2 comprises residues about 15 to about 18, β 3 comprises residues about 28 to about 33, β 5 comprises residues about 48 to about 53 and β 6 comprises residues about 58 to about 62.
- 25 10. The recombinant PIP-72 polypeptide of claim 4, 5, 6, 7, 8 or 9, wherein the structure further comprises a loop 1 between β 1 and β 2, a loop 2 between β 2 and β 3, a loop 3 between β 3 and β 4, a loop 4 between β 4 and β 5, a loop 5 between β 5 and β 6, a loop 6 between β 6 and β 7, a loop 7 between β 7 and β 8, and a C-terminal region after β 8.
11. The recombinant PIP-72 polypeptide of claim 10, wherein the hydrophobic
 30 interface surface comprises residues in β 2, loop 2, loop 4, β 5, loop 5, β 6, and the C-terminal region.
12. The recombinant PIP-72 polypeptide of any one of claims 1-11, wherein the hydrophobic interface surface comprises residues selected from positions 16, 18, 19, 20, 21, 22, 26, 27, 45, 46, 48, 50, 57, 59, 61, 85, and 86, corresponding to SEQ ID NO: 2.
- 35 13. The recombinant PIP-72 polypeptide of claim 12, wherein the amino acid at position 16 is Ala or Ser; the amino acid at position 18 is Asn, Gln, Thr or Ser; the amino

acid at position 19 is His, Lys, Ala, Arg, Glu, Leu, Pro, Ser or Tyr; the amino acid at position 20 is Trp, Ala or Thr; the amino acid at position 21 is Gly, Arg or Lys; the amino acid at position 22 is Ser, Ala, Asp, Phe, Gly, His, Ile, Lys, Leu, Met, Asn, Pro, Gln, Arg, Thr, Val or Tyr; the amino acid at position 26 is Thr, Glu, Asp, Ser or Pro; the amino acid at position 27 is Ser, Thr, Lys, Arg, Ala, Cys, Asp, Glu, Phe, Gly, His, Asn or Gln; the amino acid at position 45 is Arg, Lys or Ser; the amino acid at position 46 is Gly, Ala or Gln; the amino acid at position 48 is Leu, Met, Ile, Cys, Phe, Met, Arg, Tyr or Val; the amino acid at position 50 is Ser, Ala, Tyr, Cys, Asp, Ile, Met, Pro, Gln, Val or Thr; the amino acid at position 57 is Gln, Glu, Leu, Met, Ser, Val, Ala, Asn, Ile or Thr; the amino acid at position 59 is Pro, Thr or Ser; the amino acid at position 61 is Tyr; the amino acid at position 85 is Leu, Val, Cys, Gly or Ala; and the amino acid at position 86 is Ser, Ala, Tyr, Asn, Ile, Val or Thr.

14. The recombinant PIP-72 polypeptide of claim 12 or 13, wherein the amino acid at residue 20 is tryptophan.

15. The recombinant PIP-72 polypeptide of claim 12, wherein the amino acid at position 61 is tyrosine.

16. The recombinant PIP-72 polypeptide of claim 1, 2 or 3, further comprising 1 to 45 amino acid substitutions at position(s) 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 17, 18, 19, 20, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 42, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 56, 58, 60, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85 or 86 compared to the corresponding amino acid of SEQ ID NO: 2.

17. The recombinant PIP-72 polypeptide of claim 16, wherein

the amino acid at position 2 is Gly, Ala, Cys, Asp, Glu, Ile, Lys, Leu, Asn, Arg, Ser, Thr, Val, Trp or Tyr; the amino acid at position 3 is Ile, Leu, Val or Trp; the amino acid at position 4 is Thr, Ala, Asp, Glu, His, Ile, Lys, Leu, Arg, Ser, Val, Trp or Tyr; the amino acid at position 5 is Val, Ala, Cys, Gly, His, Ile, Leu or Tyr; the amino acid at position 6 is Thr; Ala, Cys, Phe, Gly, His, Ile, Lys, Met, Pro, Gln, Arg, Ser, Trp or Tyr; the amino acid at position 7 is Asn, Ala or Val; the amino acid at position 8 is Asn, Lys, Gly, Ser, Gln, Arg, Thr, Ala, Cys, Asp, Glu, His, Ile, Leu, Met or Val; the amino acid at position 9 is Ser, Ala, Cys, Gly or Thr; the amino acid at position 11 is Asn, Lys, Thr, Gln, Arg, Ser, Ala, Cys, Asp, Glu, Gly, His, Ile, Leu, Met, Val or Tyr; the amino acid at position 12 is Pro, Thr, Lys, Ser, Arg, Ala, Cys, Asp, Glu, Gly, His, Leu, Asn, Gln, Arg, Val, Trp or Tyr; the amino acid at position 13 is Ile, Asn, Gln, Leu or Val; the amino acid at position 14 is Glu, Ala, Cys, Phe, His, Lys, Asp or Gln; the amino acid at position 15 is Val, Ala, Ile, Leu, Cys, Met or Arg; the amino acid at position 16 is Ala or Ser; the amino acid at position 17 is Ile, Glu,

Leu or Val; the amino acid at position 18 is Asn, Gln, Thr or Ser; the amino acid at position 19 is His, Lys, Ala, Arg, Glu, Leu, Pro, Ser or Tyr; the amino acid at position 20 is Trp, Ala or Thr; the amino acid at position 21 is Gly, Arg or Lys; the amino acid at position 22 is Ser, Ala, Asp, Phe, Gly, His, Ile, Lys, Leu, Met, Asn, Pro, Gln, Arg, Thr, Val or Tyr;

5 the amino acid at position 23 is Asp, Ala, Gly, His, Lys, Met, Asn, Gln, Ser, Thr or Val; the amino acid at position 24 is Gly, Asp or Phe; the amino acid at position 25 is Asp, Ala, Glu, Phe, Asn or Gln; the amino acid at position 26 is Thr, Glu, Asp, Ser or Pro; the amino acid at position 27 is Ser, Thr, Lys, Arg, Ala, Cys, Asp, Glu, Phe, Gly, His, Asn or Gln; the amino acid at position 28 is Phe, Tyr, Pro or Trp; the amino acid at position 29 is Phe, Ala,

10 Cys, Ile, Leu, Gln, Arg, Trp or Tyr; the amino acid at position 30 is Ser, Gly, Lys, Thr, Arg, Ala, Cys, Asp, Glu, Phe, His, Leu, Met, Asn, Pro, Gln, Val, Trp or Tyr; the amino acid at position 31 is Val, Ile, Met or Leu; the amino acid at position 32 is Gly, Ala, Asp, Glu, Phe, His, Lys, Leu, Met, Asn, Pro, Gln, Arg, Ser, Thr, Val, Trp or Tyr; the amino acid at position 33 is Asn, Ser, Gln, Pro, Thr, Ala, Cys, Asp, Glu, Phe, Gly, His, Ile, Lys, Leu, Arg, Val or

15 Tyr; the amino acid at position 34 is Gly, Glu, Phe, His, Lys, Leu, Met, Asn, Gln, Arg, Ser, Thr or Tyr; the amino acid at position 35 is Lys, Glu, Ala, Cys, Asp, Gly, His, Ile, Leu, Met, Asn, Gln, Arg, Ser, Thr or Val; the amino acid at position 36 is Gln, Ala, Cys, Glu, Gly, His, Ile, Lys, Leu, Asn, Pro, Arg, Ser, Thr or Val; the amino acid at position 37 is Glu, Asp, Ala, Cys, Phe, Gly, Ile, Lys, Leu, Met, Asn, Ser, Thr or Val; the amino acid at position 38 is

20 Thr, Ser, Ala, Cys, Asp, Glu, Phe, Gly, His, Ile, Leu, Met, Asn, Gln, Arg, Val, Trp or Tyr; the amino acid at position 39 is Trp or Phe; the amino acid at position 40 is Asp, Ala, Cys, Glu, Phe, Gly, His, Ile, Lys, Leu, Met, Asn, Gln, Arg, Ser, Thr, Val, Trp or Tyr; the amino acid at position 42 is Ser, Asn, Thr, Ala, Cys, Asp, Glu, Phe, Gly, Ile, Lys, Leu, Met, Arg, Val, Trp, Tyr or Gln; the amino acid at position 44 is Ser, Asp, Ala, Leu, Thr, Glu, Ile, Ala,

25 Gly, Leu, Met, Asn, Pro, Gln, Val, Tyr or Val; the amino acid at position 45 is Arg, Lys or Ser; the amino acid at position 46 is Gly, Ala or Gln; the amino acid at position 47 is Phe, Tyr Cys, Val or Trp; the amino acid at position 48 is Leu, Met, Ile, Cys, Phe, Met, Arg, Tyr or Val; the amino acid at position 49 is Leu, Met, Ile or Val; the amino acid at position 50 is Ser, Ala, Tyr, Cys, Asp, Ile, Met, Pro, Gln, Val or Thr; the amino acid at position 51 is

30 Leu, Val, Ala, Cys, Met or Ile; the amino acid at position 52 is Lys, Cys, Phe, His, Ile, Leu, Met, Asn, Arg, Ser, Thr, Gln, Trp or Tyr; the amino acid at position 53 is Lys, Arg, Met, Leu, Ile, Ala, Cys, Asp, Glu, Phe, His, Asn, Gln, Ser, Thr, Tyr or Val; the amino acid at position 54 is Asn, Cys, Asp, Glu, Phe, Gly, Lys, Met, Gln, Arg, Ser or Trp; the amino acid at position 55 is Gly, Ser or Thr; the amino acid at position 56 is Ala, Thr, Gln, Ser, Gly,

35 Leu, Pro, Arg or Asn; the amino acid at position 57 is Gln, Glu, Leu, Met, Ser, Val, Ala, Asn, Ile or Thr; the amino acid at position 58 is His, Ala, Lys, Asp, Phe, Leu, Met, Asn,

Arg, Trp, Tyr or Thr; the amino acid at position 59 is Pro, Thr or Ser; the amino acid at position 60 is Tyr, Glu or Phe; the amino acid at position 61 is Tyr; the amino acid at position 62 is Val, Ile or Leu; the amino acid at position 63 is Gln, Ser, Cys, Gly, Ile, Leu, Met, Asn, Thr, Val or Tyr; the amino acid at position 64 is Ala, Gln, Asn, Phe, Gly, His, Arg, Ser or Tyr; the amino acid at position 65 is Ser, Ala, Cys, Asp, Glu, Phe, Gly, His, Ile, Leu, Asn, Val or Thr; the amino acid at position 66 is Ser, Ala or Gly; the amino acid at position 67 is Lys, Gln, Asn or Arg; the amino acid at position 67 is Lys, Ala, Cys, Asp, Phe, His, Ile, Leu, Met, Asn, Gln, Arg, Ser, Thr, Val, Trp or Tyr; the amino acid at position 68 is Ile Asp, Leu or Val; the amino acid at position 69 is Glu, Ala, Cys, Asp, Phe, His, Ile, Leu, Met, Gln, Arg, Ser, Thr, Val or Tyr; the amino acid at position 70 is Val, Ile, Cys or Leu; the amino acid at position 71 is Asp, Glu, Tyr, Ala, Cys, Gly, His, Ile, Leu, Met, Asn, Ser, Thr, Val or Trp; the amino acid at position 72 is Asn, Ala, Cys, Asp, Glu, Gly, Lys, Met, Pro, Gln, Arg, Ser, Thr, Val, His or Trp; the amino acid at position 73 is Asn, Ser, Asp, Gln, Thr, Ala, Cys, Phe, Gly, His, Ile, Leu, Val, Tyr or Glu; the amino acid at position 74 is Ala, Thr, Met, Ile, Lys, Ser, Leu, Val, Cys, Asp, Phe, Gly, His, Asn, Gln, Tyr or Arg; the amino acid at position 75 is Val, Cys, Ile or Leu; the amino acid at position 76 is Lys, Ala, Cys, Phe, His, Ile, Leu, Gln, Arg, Ser, Thr, Val, Trp or Tyr; the amino acid at position 77 is Asp Tyr; the amino acid at position 78 is Gln, His, Ser, Asn, Ala, Cys, Asp, Phe, Gly, Ile, Leu, Met, Asn, Arg, Val, Tyr or Thr; the amino acid at position 79 is Gly, Arg, Ala, Cys, Asp, Glu, Phe, His, Lys, Leu, Asn, Gln, Arg, Ser, Thr, Trp or Tyr; the amino acid at position 80 is Arg, Glu, Gln, Lys, Asp, Ala, Cys, Phe, Gly, His, Ile, Leu, Ser, Thr, Val, Tyr or Asn; the amino acid at position 81 is Leu, Pro, Thr, Ile, Val, Ala, Cys, Asp, Phe, Gly, His or Ser; the amino acid at position 82 is Ile, Ala, Leu, Met, Arg and Val; the amino acid at position 83 is Glu, His, Asn, Leu, Gln, Ile, Ala, Cys, Asp, Phe, Gly, Lys, Pro, Arg, Ser, Thr, Tyr or Val; the amino acid at position 84 is Pro, Ala, Cys, Glu, Ile, Ser, Val, Trp or Tyr; the amino acid at position 85 is Leu, Val, Cys, Gly or Ala; and the amino acid at position 86 is Ser, Ala, Tyr, Asn, Ile, Val or Thr.

18. The recombinant PIP-72 polypeptide of any one of claims 1-17, wherein the PIP-72 polypeptide has insecticidal activity against at least western corn root worm.

19. A covalently linked homo-dimer of a PIP-72 polypeptide of any one of claims 1-18.

20. A covalently linked hetero-dimer comprising a first PIP-72 polypeptide and a second PIP-72 polypeptide, wherein the first and second PIP-72 polypeptide are independently selected from the PIP-72 polypeptide of any one of claims 1-18.

21. An isolated polynucleotide encoding the PIP-72 polypeptide of any one of claims 1-18.

22. An isolated polynucleotide encoding the PIP-72 polypeptide homo-dimer of claim 19.
23. An isolated polynucleotide encoding the PIP-72 polypeptide hetero-dimer of claim 20.
- 5 24. A DNA construct comprising the polynucleotide of claim 21 operably linked to a heterologous regulatory element.
25. A DNA construct comprising the polynucleotide of claim 22 operably linked to a heterologous regulatory element.
26. A DNA construct comprising the polynucleotide of claim 23 operably linked to a
10 heterologous regulatory element.
27. A transgenic plant comprising the DNA construct of claim 24.
28. A transgenic plant comprising the DNA construct of claim 25.
29. A transgenic plant comprising the DNA construct of claim 26.
30. The transgenic plant of claim 27, 28 or 29, wherein the plant is selected from the
15 group consisting of: maize, sorghum, wheat, sunflower, tomato, a cruciferous species, a capsicum species, potato, cotton, rice, soybean, sugar beet, sugarcane, tobacco, barley, sunflower, and oilseed rape.
31. Transformed seed of the transgenic plant of claim 27, 28, 29 or 30, wherein the seed comprise the DNA construct.
- 20 32. A composition comprising the PIP-72 polypeptide of any one of claims 1-18.
33. A composition comprising the PIP-72 polypeptide homo-dimer of claim 19.
34. A composition comprising the PIP-72 polypeptide hetero-dimer of claim 20.
35. A method for controlling a pest population comprising contacting said population with an insecticidally-effective amount of the PIP-72 polypeptide of any one of claims 1-
25 18.
36. A method for controlling a pest population comprising contacting said population with the transgenic plant of claim 27, 28, 29 or 30.
37. The method of claim 32 or 33, wherein the pest population is resistant to a Cry protein.
- 30 38. A method of engineering a PIP-72 polypeptide to have a modified physical property, the method comprising performing rational protein design with a secondary, tertiary or quaternary structure of the PIP-72 polypeptide.
39. The method of claim 38, further comprising identifying regions of the PIP-72 polypeptide to modify.
- 35 40. The method of claim 38 or 39, wherein the regions of the PIP-72 polypeptide to modify are loops.

41. The method of claim 39 or 40, further comprising making an amino acid substitute, delete or insert.
42. The method of claim 38, 39, 40 or 41, wherein the structure is the tertiary structure shown in Figures 1-5.
- 5 43. The method of claim 38, 39, 40, 41 or 42, wherein the tertiary structure is determined by NMR.
44. The method of claim 38, 39, 40, 41, 42 or 43, wherein the modified physical property is selected from protease stability, in-planta expression, phytotoxicity, solubility, potency, subunit affinity, channel activity, and receptor binding.
- 10 45. The recombinant PIP-72 polypeptide of any one of claims 1-18, wherein the PIP-72 polypeptide is labeled with a detectable label.
46. The PIP-72 polypeptide dimer of claim 19 or 20, wherein the PIP-72 polypeptide is labeled with a detectable label.
47. A method of identifying regions of PIP-72 polypeptides to modify, the method
15 comprising employing rational protein design with a secondary, tertiary or quaternary structure of the PIP-72 polypeptide.
48. The method of claim 47, wherein the region identified are loops.

Fig. 1

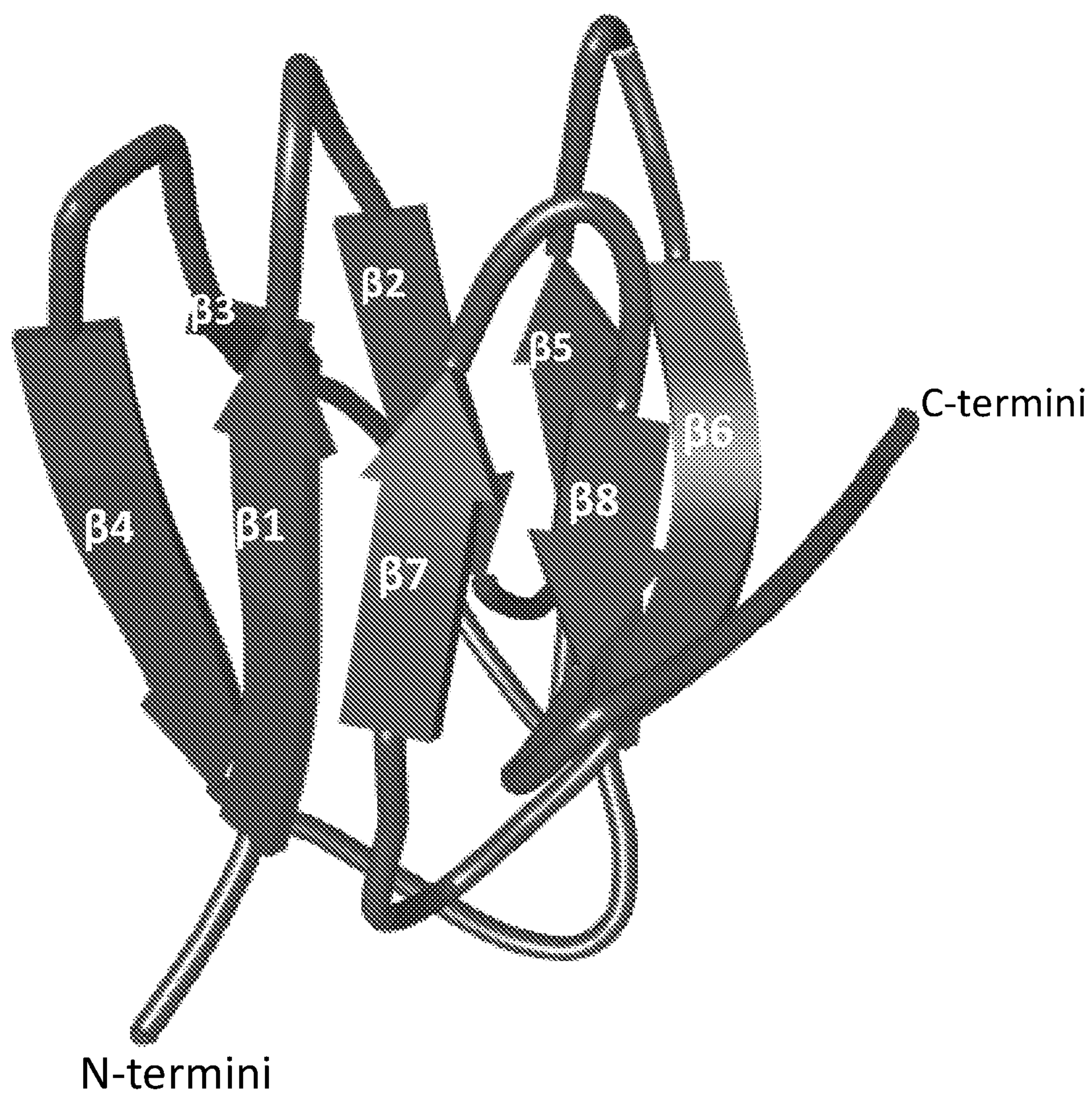


Fig. 2

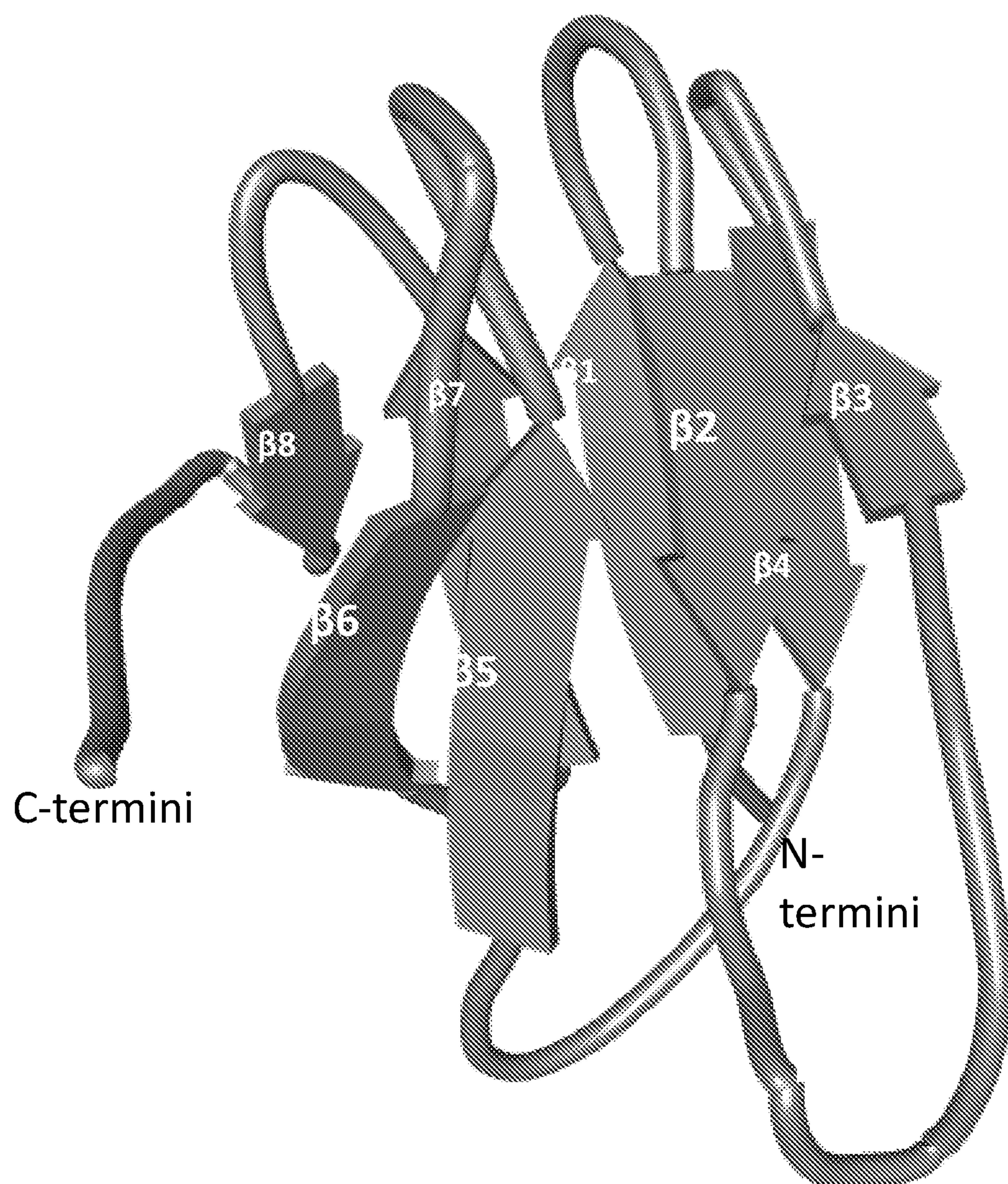


Fig. 3

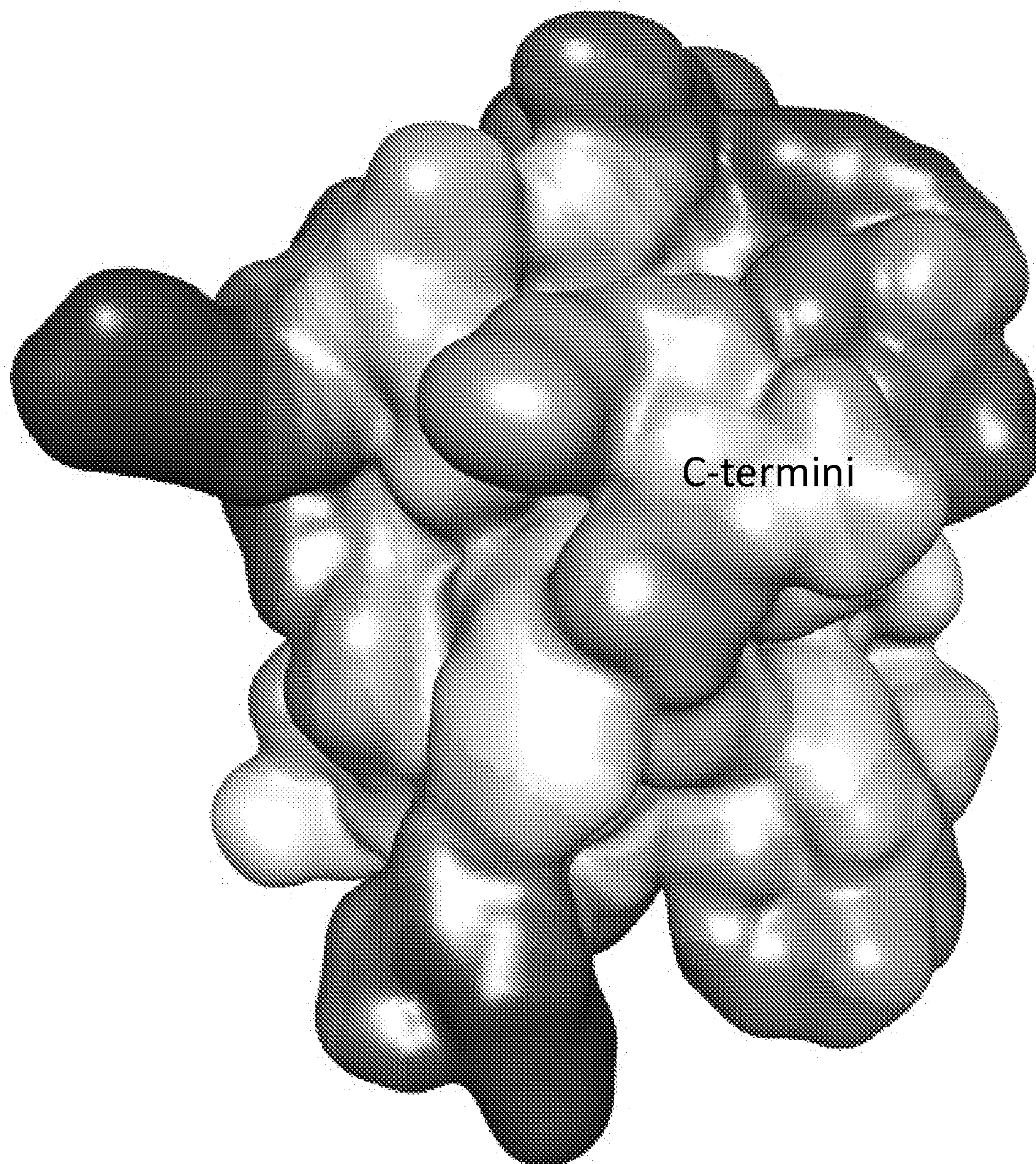
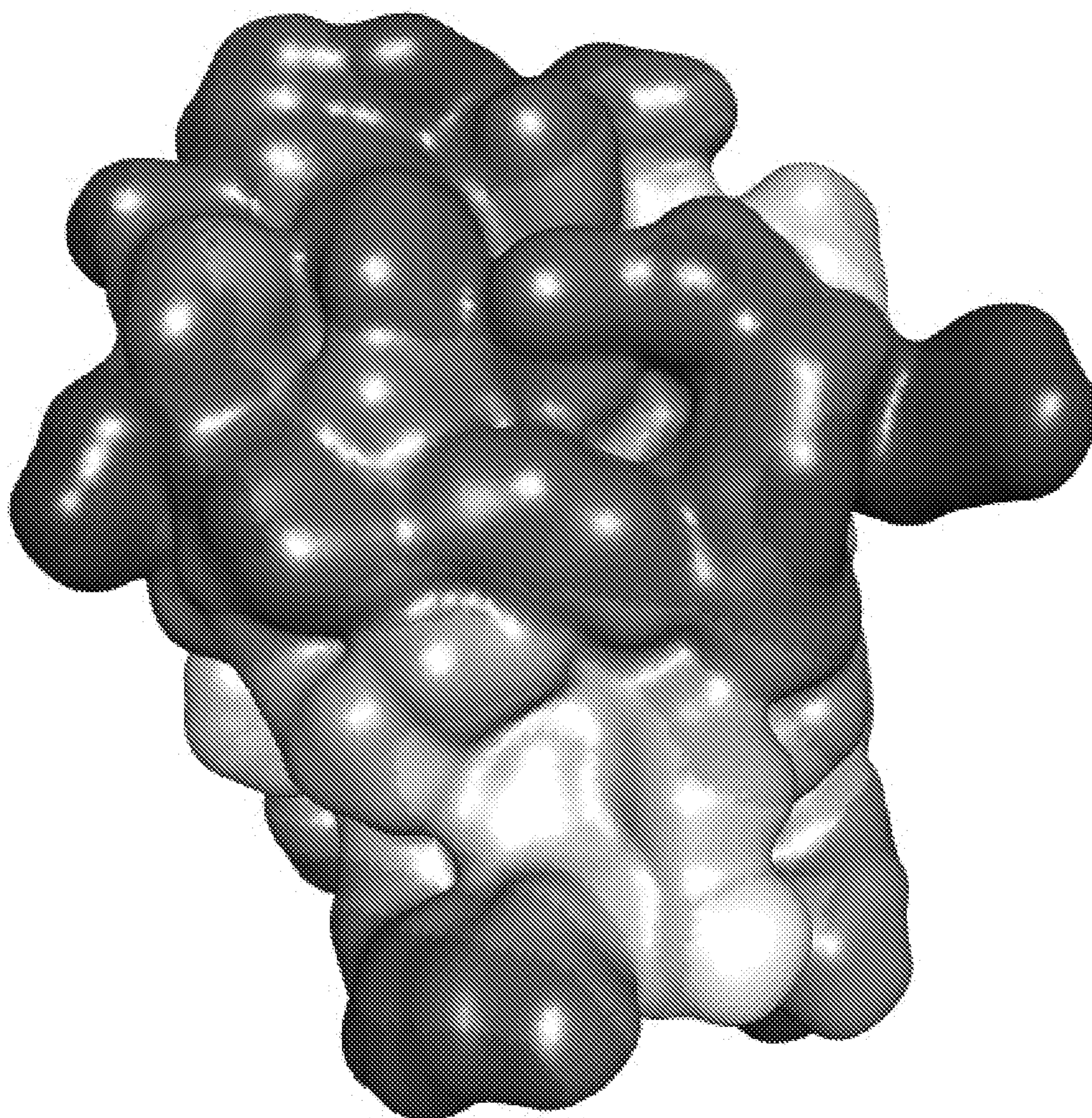


Fig. 4



N-termini

Fig. 5

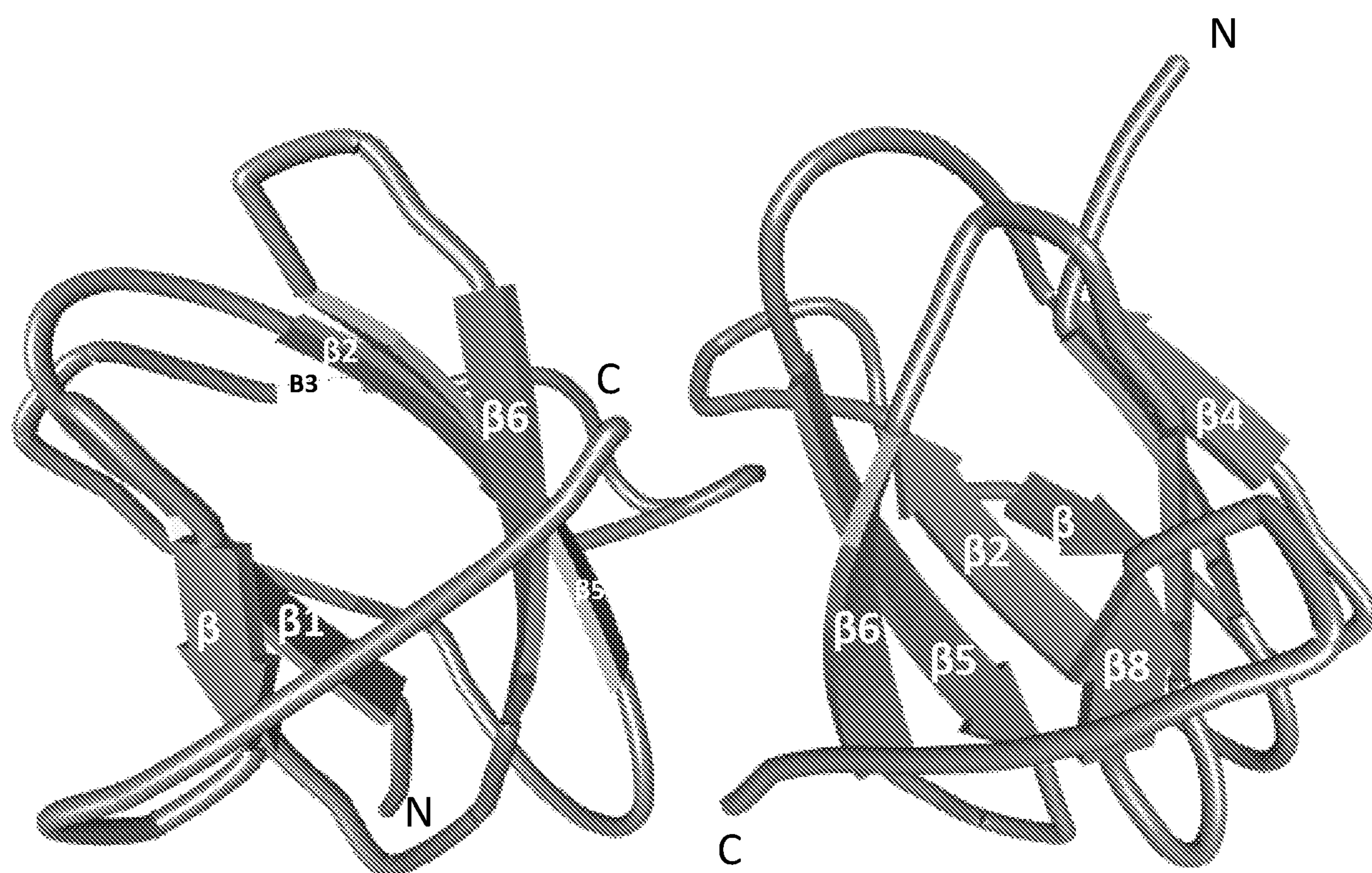


Fig. 6

	1	50
PIP-72Aa	(1)	--MGITVTNNSSNPIEVAINHWGSDG--DTSFFSVGNKGQETWDRSDSRG
PIP-72Ba	(1)	--MGITVKNNSSNTIEVAVNHWGKDG--DTSFFSIANGKQESWDRSDSRG
PIP-72Ca	(1)	--MGITVTNKSSKKIEVSINKWGS DG--DTTFFGVDSGKQESWDRSDDRG
PIP-72Cb	(1)	--MGITVTNKSSKKIEVSVNKWGS DG--DTTFFGIDSGKQESWDRSDDRG
PIP-72Da	(1)	--MGITVTNKSSKKIEASINKWGS DG--DTKFFGIDSGKQESWDRSDDRG
PIP-72Db	(1)	--MGITVTNKSSKKIEASINKWGS DG--DTKFFGIDSGKQESWDRSDDRG
PIP-72Dc	(1)	--MGITVTNKSSKKIEASINKWGS DG--DTKFFGIDSGKQESWDRSDDRG
PIP-72Ea	(1)	--MSITVKNNSTSNIEVAINQWDTDG--DTRYSPLAAGASDKWVRKDSRG
PIP-72Fa	(1)	--MKLTI TN GASTSIDIAVSAWRNDG--NDSYYSIAQGESDTWDRSDARG
GBP_A3175	(1)	--MAISVKNSASNTVEVSINHWGTDG--DTKPFKMAPGASDSWDRNDLRG
SRBS_294080	(1)	--MSITITNGASQTVQIAVSVWGRDG--SDDYYSLEPGKGD TWGRNDPRG
JG43047	(1)	MNMSITVTNGASTVNVVAISTWEKDG--SDAYWPLEQGKGD TWKRSDPRG
SwiRh_4910	(1)	--MSITITNGASRTVQIAVSVWGRDG--SDDYYSLEPGKGD TWGRNDPRG
PIP-72Ff	(1)	--MSITITNGASRTVQIAVSVWGRDG--SDDYYSLEPGKGD TWGRNDPRG
PIP-72Ga	(1)	--MSISITNAGSREIQVAVSTWSTDSDISDAYYSLAPDKGDKWKRNDPRG
PIP-72Gb	(1)	--MSITVTNGASTVNVVAISTWEKDG--SDAYYPLEQNGD TWKRSDPRG
XBJ1_1078	(1)	----MKIINNTQSNIIIVSVNKWGDDG--QTGRFTVSPGRSGSWNRTERG
plu2373	(1)	---MIIVKNSSNKVTKVSINKWGKDG--NTGYWDINPGDTASWNRTDGRG
PIP-72Ge	(1)	MNMSITVTNGASAVNVVAISTWEKDG--SDAYYPLEQSGD TWKRSDPRG
	51	100
PIP-72Aa	(47)	FVLSLKNG-AQHPYYVQASSKIEVDNNAVKDQGR LIEPLS-----
PIP-72Ba	(47)	FVLSLKRNG-AQHPYYVQASSQIEVDHNAVKDHGEPIHPLS-----
PIP-72Ca	(47)	FVLSLKRNG-TQAPYYVQATSKIEVDSSTVKDHGETIHPVA-----
PIP-72Cb	(47)	FVLSLKRNG-TQAPYYVQATSKIEVDSSTVKDHGETIHPVA-----
PIP-72Da	(47)	FVLSLKRNG-TQAPYYVQATSKIEIENSTVKDHGETIHPVA-----
PIP-72Db	(47)	FVLSLKRNG-TQAPYYVQATSKIEVENSMVKDHGETIHPVA-----
PIP-72Dc	(47)	FVLSLKRNG-TQAPYYVQATSKIEIENSAVKDHGETIHPVA-----
PIP-72Ea	(47)	YVLSLRQGG-TEKPYVVLVDSNIVVANTEVKDNDTVISPISR-----
PIP-72Fa	(47)	YLMAVKMKS-QVKTYIISQTSKIVVEDNIVKDHGQTLNPLYAVNNM----
GBP_A3175	(47)	FVMYVQLGG-SATPYVVLSTSNIVIYDDKVTD SGQTLLPANKRFG-----
SRBS_294080	(47)	YLMAIKAN--PAGVYYVAFDSQIVIEDNLVKDRGRTINPLASNNQ-----
JG43047	(49)	YLMAIQDKS-QTTEYYVTCNSVIVIEDNLVKDHGRTLNPVAAAGKKNVVNA
SwiRh_4910	(47)	YLMAIKGQT-QAGVYYVAFDSQIVIEDNLVKDRGRTINPLASNNQ-----
PIP-72Ff	(47)	YLMAIKGQT-QAGVYYVAFDSQIVIEDNLVKDRGRTINPLASNNQ-----
PFL_6283	(49)	YLMTVKGQS-QQGVYYVAFDSEIFIEDSLVKDRGKTITKLALLEVQ-----
PIP-72Gb	(47)	YLMAIQDKS-QTTEYYVTCNSVIVIEDNLVKDHGRTLNPVAAAGKRKVANA
XBJ1_1078	(45)	FVMAILKKG-VQDSFYIFSDSDIKVFDSYVTDNGRRIKPATDRYY-----
plu2373	(46)	FVMSIIRENEDQKSYFVLANSNIVIYDKDATGYGKNVQDNGRWIYPLN--
PIP-72Ge	(49)	YLMAIQDKS-QTTEYYVSCNSAIVIEDNLVKDHGRTLNPVAAAGKKKVANA

Fig. 1

