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(54) **Title:** USE OF ETHYL HYDROGEN PHOSPHONATE AND ITS SALTS FOR CONTROLLING CERTAIN DISEASES IN PLANTS OF THE MUSACEAE FAMILY

(57) **Abstract:** The present invention relates to the use of ethyl hydrogen phosphonate (fosetyl) and/or its salts for controlling *Fusarium oxysporum* f.sp. *cubense* in plants or plant varieties of the Musaceae family, in particular bananas and plantains. The present invention further relates to corresponding methods of controlling *Fusarium oxysporum* f.sp. *cubense* in plants or plant varieties of the Musaceae family.



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Use of ethyl hydrogen phosphonate and its salts for controlling certain diseases in plants of the Musaceae family

The present invention relates to the use of ethyl hydrogen phosphonate (fosetyl) and/or its salts for controlling *Fusarium oxysporum* f.sp. *cubense* in plants or plant varieties of the Musaceae family, in particular bananas and plantains. The present invention further relates to corresponding methods of controlling *Fusarium oxysporum* f.sp. *cubense* in plants or plant varieties of the Musaceae family.

Fusarium oxysporum f.sp. *cubense* is a fungal plant pathogen that causes Panama disease of banana (*Musa* spp.), also known as fusarium wilt of banana.

Panama disease is a very destructive plant disease. It is believed to have originated in Southeast Asia and was first reported in Australia in 1876. By 1950 it had spread to virtually all the banana-producing regions of the world.

Panama disease affects a wide range of banana cultivars; however, it is best known for the damage it caused to a single cultivar in the early export plantations. Before 1960, a total reliance was put on the cultivar 'Gros Michel', and it supplied almost all the export trade. It proved susceptible to Panama disease and the use of infected rhizomes to establish new plantations caused widespread and severe losses. The cultivars 'Dwarf Cavendish' and 'Grand Nain' (Chiquita Banana) gained popularity after the previous mass-produced cultivar 'Gros Michel' had become commercially unviable due to Panama disease.

There are few effective options for managing Panama disease as fungicides are largely ineffective. Chemical sterilisation of the soil with methyl bromide significantly reduced incidence of the disease but was found to be effective for only three years after which the pathogen had recolonised the fumigated areas. Injecting the infested plants with the fungicide carbendazim appears to provide some control, but results have been reported to be not conclusive.

Several fungicides and fungicidal mixtures have been reported to control other fungal diseases in banana plants called Black Sigatoka and Yellow Sigatoka caused by the fungi *Mycosphaerella fijiensis* and *Mycosphaerella musicola*, respectively.

WO 2010/037482 discloses the use of certain compounds, such as isotianil, for controlling microbial and animal pathogens in plants of the Musaceae family, in particular in bananas and plantains.

EP 2 100 506 A2 suggests the use of fluopyram, optionally in combination with fosetyl or fosetyl-Al, for controlling *Mycosphaerella fijiensis* in banana.

AU 749429 B2 relates to a method of treating or preventing cercosporiosis in banana plants, said method comprising applying thereto an effective and non-phytotoxic dose of a monoalkyl hydrogen phosphonate salt with a mono-, di- or trivalent metal cation, such as fosetyl-Al. Specifically, treatment of *Mycosphaerella musicola* responsible for yellow cercosporiosis (also called Yellow Sigatoka) of banana plants is described.

FR 2 732 191 A1 discloses the use of fosetyl-Al, alone or in combination with further fungicides such as bromuconazole, against Black Sigatoka in banana plants.

EP 2 601 839 A1 discloses the use of certain synergistic mixtures comprising a phosphorous acid derivative and zoxamide, optionally further comprising cymoxanil. Said mixtures are described as being useful fungicides against numerous fungi, inter alia against *Fusarium oxysporum*.

Davis et al. investigated the effects of the phosphonate anion on *Fusarium oxysporum* f.sp. *cubense*, see Plant Pathology 1994, 43, 200-205 and in Australasian Plant Pathology 1996, 25, 31-35.

US 6,358,938 B teaches synergistic fungicidal compositions which may be applied on crops like arboricultural crops. Said synergistic fungicidal compositions comprise propamocarb, and at least one fungicide selected from the group consisting of fosetyl-Al, metal phosphites, phosphorous acid, alkali metal salts of phosphorous acid, and alkaline earth metal salts of phosphorous acid.

WO 2008/068308 A2 discloses the post-harvest treatment of bananas with a composition comprising a polyene antifungal agent (preferably natamycin) and a phosphite containing compound, such as for example aluminum ethyl phosphite.

WO 2009/077613 A2 relates to a process for the treatment of banana and plantain plants, the process comprising the step of applying a composition comprising a polyene antifungal agent, for example natamycin, and at least one phosphite containing compound to the plants, wherein the application of the composition preferably prevents or inhibits fungal growth on or in said plants, and wherein said fungus preferably is selected from the group consisting of *Mycosphaerella musicola*, *Mycosphaerella fijensis*, *Fusarium oxysporum*, *Alternaria solani* and *Alternaria alternata*.

A number of distinct groups of plants bearing edible fruit have been developed from species of *Musa*. In English, fruits which are sweet and used for dessert are usually called "bananas" whereas starchier varieties used for cooking are called "plantains", but these terms do not have any botanical significance. By far the largest and now the most widely distributed group of cultivated bananas is derived from *Musa*, particularly *Musa acuminata* and *Musa balbisiana*, either alone or in various hybrid combinations.

When the Linnaean binomial system was abandoned for cultivated bananas, an alternate genome-based system for the nomenclature of edible bananas was devised. The plant previously known by the name

Musa cavendishii became *Musa* (AAA Group) 'Dwarf Cavendish'. The "new" name shows clearly that 'Dwarf Cavendish' is a triploid, with three sets of chromosomes, all derived from *Musa acuminata* which is designated by the letter "A". When *Musa balbisiana* is involved the letter "B" is used to denote its genome. Thus the cultivar 'Rajapuri' may be called *Musa* (AAB Group) 'Rajapuri'. 'Rajapuri' is also a triploid having two sets of chromosomes from *Musa acuminata* and one from *Musa balbisiana*. In the genome of edible bananas, combinations such as AA, BB, ABB, BBB and even AAAB can be found.

The following races of *Fusarium oxysporum f.sp. cubense* have been described which, for example, infest different banana cultivars:

Race 1 may infest cultivars in the *Musa* (AAA group) 'Gros Michel' and caused the 20th century epidemic. It also may infest *Musa* (AAB group) 'Pome' and its subgroups, *Musa* (AAB group) 'Silk' and *Musa* (ABB group) 'Pisang Awak'.

Race 2 may infest *Musa* (ABB group) 'Bluggoe' and its close relatives.

Race 3 may infest *Heliconia* spp.

Race 4 (also known as tropical race 4 (TR4)) may infest *Musa* (AAA group) 'Dwarf Cavendish' as well as the hosts of race 1 and of race 2.

The authors of Plant Pathology 2010, 59, 348–357 analysed the genomic variation of the translation elongation factor 1a (TEF-1a) and the intergenic spacer region (IGS) of the nuclear ribosomal operon of *Fusarium oxysporum f. sp. cubense* isolates, from different banana production areas, representing strains within the known races, comprising 20 Vegetative Compatibility Groups (VCG). Based on two single nucleotide polymorphisms present in the IGS region, a PCR-based diagnostic tool was developed to specifically detect isolates from VCG 01213, also called tropical race 4 (TR4).

Journal of Agricultural and Biological Science Vol. 7, No. 4, 244-249 reports on the status VCGs of *Fusarium oxysporum f. sp. cubense* (Foc) in West Sumatera by identifying different isolates with Vegetative Compatibility Group test.

Fusarium oxysporum f.sp. cubense race 4, or tropical race 4 (TR4), is currently a major concern in global banana production becoming more and more problematic for banana cultivars and plantains.

Therefore, providing a – preferably improved – method for controlling *Fusarium oxysporum f.sp. cubense*, in particular for controlling *Fusarium oxysporum f.sp. cubense* race 4, is sought-after. Said method should preferably be curative, thereby providing a way to control and reduce *Fusarium oxysporum f.sp. cubense* in plants infested with said fungus.

The present invention primarily relates to the use of (i) ethyl hydrogen phosphonate and/or its salts or (ii) a formulation comprising ethyl hydrogen phosphonate and/or its salts for controlling *Fusarium oxysporum* f.sp. *cubense* in plants or plant varieties of the Musaceae family.

According to the present invention (i) ethyl hydrogen phosphonate and/or its salts or (ii) a formulation comprising ethyl hydrogen phosphonate and/or its salts are preferably applied on plants or plant varieties selected from the genus *Musa* spp., preferably plants or plant varieties selected from banana cultivars and plantains.

In comparison to the use of, for example, potassium phosphonate, the use of (i) ethyl hydrogen phosphonate and/or its salts or (ii) a formulation comprising ethyl hydrogen phosphonate according to the present invention shows higher efficacy for controlling *Fusarium oxysporum* f.sp. *cubense*, in particular for controlling tropical race 4 (TR4)), in plants or plant varieties of the Musaceae family and/or improved compatibility with respect to plants or plant varieties of the Musaceae family.

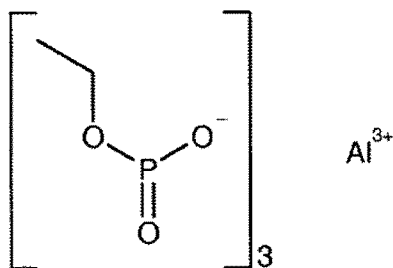
The present invention preferably relates to the use of (i) ethyl hydrogen phosphonate and/or its salts or (ii) a formulation comprising ethyl hydrogen phosphonate and/or its salts for controlling *Fusarium oxysporum* f.sp. *cubense* race 4, in particular tropical race 4 (TR4).

In the context of the present invention *Fusarium oxysporum* f.sp. *cubense* race 4, or tropical race 4 (TR4), preferably relates to Vegetative Compatibility Groups 01213, 01213/16, 01216, 0121 or 01219, most preferably to Vegetative Compatibility Groups 01213, 01213/16 or 01216.

Preferably, the ethyl hydrogen phosphonate and/or its salts used according to the present invention are selected from the group consisting of fosetyl, fosetyl-Na, and fosetyl-Al.

Preferably, the ethyl hydrogen phosphonate salt used according to the present invention is fosetyl-Al.

Fosetyl-aluminum or fosetyl-Al is a known fungicidal compound. Its chemical name is aluminum tris-(O-ethyl phosphonate) or aluminum ethyl hydrogen phosphonate (CAS-number 39148-24-8), and its chemical structure is the following:



Fusarium oxysporum f.sp. cubense is a soil pathogen and saprophyte that feeds on dead and decaying organic matter. When *Fusarium oxysporum f.sp. cubense* infects a healthy plant, once in the xylem, the mycelium produces microconidia which are able to enter into the sap stream and are subsequently transported upward where the flow of the sap stops. Eventually, the plant transpires more than it can transport, the stomata close, the leaves wilt, and the plant dies. After the plant dies the fungus invades all tissues, sporulates, and infects neighboring plants.

An infection caused by *Fusarium oxysporum f.sp. cubense* triggers the self-defense mechanisms of the host plant. The signs of the disease are most noticeable as a dark stain where the stele joins the cortex. As the disease develops, large portions of the xylem turn a reddish-brown colour. Externally, the oldest leaves start turning yellow and there is often a longitudinal splitting of the lower part of the outer leaf sheaths on the pseudostem. The leaves begin to wilt and may buckle at the base of the petiole. As the disease progresses, younger leaves are affected, turn yellow and crumple and the whole canopy begins to consist of dead or dying leaves.

The plants of the Musaceae family have a large herbaceous growth habit with leaves with overlapping basal sheaths that form a pseudostem making some members appear to be woody trees. *Musa* is the agricultural important genera in the family Musaceae; it includes bananas and plantains. There are around 70 species of *Musa*. Though they grow as high as trees, banana and plantain plants are not woody and their apparent "stem" is the basis of the huge leaf stalks.

Although fruit of the wild banana, *Musa balbisiana* have large, hard seeds, these have been bred out of the modern culinary banana which is seedless. Banana plants are therefore propagated asexually from offshoots. Because these rhizomes are usually free of symptoms even when the plant is infected by *F. oxysporum f. sp. cubense*, they are a common means by which this pathogen is disseminated. It can also be spread in soil and running water, on farm implements or machinery.

"Banana" is the common name for an edible fruit produced by several kinds of large herbaceous flowering plants of the genus *Musa*. The fruit is variable in size, colour and firmness, but is usually elongated and curved, with soft flesh rich in starch covered with a rind which may be yellow, purple or red when ripe. The fruits grow in clusters hanging from the top of the plant. Almost all modern edible parthenocarpic (seedless) bananas come from two wild species – *Musa acuminata* and *Musa balbisiana*. The scientific names of most cultivated bananas are *Musa acuminata*, *Musa balbisiana*, and *Musa × paradisiaca* for the hybrid *Musa acuminata* × *Musa balbisiana*, depending on their genomic constitution.

Red bananas, also known as Red Dacca bananas in Australia, are a variety of banana with reddish-purple skin. Its official designation is *Musa acuminata* (AAA Group) 'Red Dacca'. It is known in English as Red dacca, Red banana, Claret banana, Cavendish banana "Cuban Red", Jamaican red banana, and Red cavendish banana. They are smaller and plumper than the common Cavendish banana.

In the context of the present invention "controlling" relates to

- preventing (preventive measures), i.e. protection of plants and plant varieties of the Musaceae family from *Fusarium oxysporum* f.sp. *cubense* infection,
- curing (curative measures), i.e. curing of plants and plant varieties of the Musaceae family already infected with *Fusarium oxysporum* f.sp. *cubense*, but not showing any symptoms of Panama disease,
- eradicating (eradicated measures), i.e. healing of plants and plant varieties of the Musaceae family already infected with *Fusarium oxysporum* f.sp. *cubense* showing the symptoms of Panama disease.

10 In conjunction with the present invention "controlling" denotes a reduction of *Fusarium oxysporum* f.sp. *cubense* infestation in plants and plant varieties of the Musaceae family, in particular of the genus *Musa* spp., in comparison to untreated plants, preferably infestation is reduced by 20% or more, more preferably by 25% or more, even more preferably by 30% or more, most preferably by 40% or more.

15 In conjunction with the present invention "curing" and "eradicating" denotes a reduction of *Fusarium oxysporum* f.sp. *cubense* infestation in plants and plant varieties of the Musaceae family, in particular of the genus *Musa* spp., in comparison to untreated plants, preferably infestation is reduced by 20% or more, more preferably by 25% or more, even more preferably by 30% or more, most preferably by 40% or more.

20 In conjunction with the present invention "preventing" denotes a significant reduction of *Fusarium oxysporum* f.sp. *cubense* infestation in plants and plant varieties of the Musaceae family, in particular of the genus *Musa* spp., in comparison to untreated plants, preferably infestation is reduced by 30% or more, more preferably by 60% or more, even more preferably by 75% or more, most preferably by 90% or more.

25 In several cases almost full or full recovery of *Fusarium oxysporum* f.sp. *cubense* infested plants or plant varieties of the Musaceae family was observed after three or four applications of drenching, leaf axil application and pseudostem injection application. Applications preferably are carried out in 2 week intervals. Applications preferably are carried out starting at two to four (2-4) months old plants or at BBCH stage 1060 – 1090.

30 Preferably, (i) ethyl hydrogen phosphonate and/or its salts or (ii) a formulation comprising ethyl hydrogen phosphonate and/or its salts are applied to the plants or plant varieties of the Musaceae family once every two (2) weeks.

Alternatively, (i) ethyl hydrogen phosphonate and/or its salts or (ii) a formulation comprising ethyl hydrogen phosphonate and/or its salts are preferably applied to the plants or plant varieties of the Musaceae family once every four (4) weeks.

5 Preferably, (i) ethyl hydrogen phosphonate and/or its salts or (ii) a formulation comprising ethyl hydrogen phosphonate and/or its salts are applied two or more times per plant or plant variety per growing cycle, preferably two or more times per plant or plant variety before the plant or plant variety has reached its fruiting stage.

10 Preferably, (i) ethyl hydrogen phosphonate and/or its salts or (ii) a formulation comprising ethyl hydrogen phosphonate and/or its salts are applied three to ten times per plant or plant variety per growing cycle, preferably three to ten times per plant or plant variety before the plant or plant variety has reached its fruiting stage.

More preferably, applications preferably are carried out in 2 week intervals starting at two to four (2-4) months old plants or at BBCH stage 1060 - 1090. Applications are preferably continued until the fruiting stage of the plant is reached (mainly to maintain plant's health).

15 "BBCH stage" refers to the growth stages of plants or plant varieties of the Musaceae family as defined by the BBCH Codes in "Growth stages of mono- and dicotyledonous plants", 2nd edition 2001, edited by Uwe Meier from the Federal Biological Research Centre for Agriculture and Forestry. The BBCH codes are a well-established system for a uniform coding of growth stages of all mono- and dicotyledonous plant species.

20 It was found in our own investigations that a 100% reduction of *Fusarium oxysporum* f.sp. *cubense* infestation, i.e full control of Panama Disease, is achievable when ethyl hydrogen phosphonate and/or its salts are applied to the plant or plant variety through drenching, in particular soil drenching and leaf axil drenching (leaf axil pouring).

25 Preferably, (i) ethyl hydrogen phosphonate and/or its salts or (ii) a formulation comprising ethyl hydrogen phosphonate and/or its salts are applied by drenching, preferably soil drenching and/or leaf axil drenching.

30 Leaf axil drenching is preferably performed using a Phillips 20 mm automatic drencher (Code: PAD28, PAD69C), manufactured by NJ Phillips Pty. Limited, Australia an extended lance or a spot gun drencher mainly depending on the size of the plant or plant variety to be drenched. Preferably, ethyl hydrogen phosphonate (fosetyl) and/or its salts used in accordance with the present invention are applied to three or more different sites of the plant or plant variety to be treated, preferably to five or more different sites.

It was further observed that plants and plant varieties treated with early symptoms of *Fusarium oxysporum* f.sp. *cubense* infestation recovered faster than those applied during a later stages of the disease. Hence, early detection and early treatment of *Fusarium oxysporum* f.sp. *cubense* infestation is preferred.

- 5 Preferably, the total amount of ethyl hydrogen phosphonate and its salts per application is in the range from 250 to 6000 g/ha, preferably in the range from 500 to 4000 g/ha.

Preferably, the total amount of ethyl hydrogen phosphonate and its salts per application per plant is in the range from 0.8 g to 4 g/plant, preferably 1 to 3 g/plant.

- 10 In case a mixture of two or more fungicides is used in accordance with the present invention, said mixture of two or more fungicides preferably is free of zoxamide, free of cymoxanil, and free of isotianil.

In case a formulation comprising two or more fungicides is used in accordance with the present invention, said formulation of two or more fungicides preferably is free of zoxamide and free of cymoxanil, and free of isotianil.

- 15 In a preferred embodiment according to the present invention no further fungicide is used, i.e. the only fungicide used is ethyl hydrogen phosphonate (fosetyl) and/or its salts. In a more preferred embodiment according to the present invention fosetyl-Al is used as the sole fungicide.

- In a further preferred embodiment according to the present invention fosetyl-Al is used as the sole fungicide, wherein fosetyl-Al is applied three or more times, and wherein the total amount of fosetyl-A
20 in each application is in the range from 800 to 3500 g/ha.

The stages of external symptoms of a *Fusarium oxysporum* f.sp. *cubense* infestation are the following:

Early Infection – yellowing of the oldest leaves or a longitudinal splitting of the lower portion of the outer leaf sheaths on the pseudostem;

Moderate Infection - wilting and buckling of leaves at the petiole base;

- 25 Late Infection - younger leaves collapse until the entire canopy consists of dead or dying leaves.

The present invention further relates to a method of controlling *Fusarium oxysporum* f.sp. *cubense* in plants of the Musaceae family, characterized in that said plants of the Musaceae family are treated with (i) ethyl hydrogen phosphonate and/or its salts or (ii) a formulation comprising ethyl hydrogen phosphonate and/or its salts.

In a preferred embodiment, the method according to the present invention is characterized in that the treatment with (i) ethyl hydrogen phosphonate and/or its salts or (ii) a formulation comprising ethyl hydrogen phosphonate and/or its salts is carried out on two to four months old plants or at BBCH stage 1060 – 1090.

- 5 In further preferred embodiments the method according to the present invention is characterized by the same features and aspects as described hereinbefore for the use of (i) ethyl hydrogen phosphonate and/or its salts or (ii) a formulation comprising ethyl hydrogen phosphonate and/or its salts according to the present invention.

10 In accordance with the present invention, all plants of the Musaceae family may be treated. Plants of the Musaceae family are, in the present context, understood as meaning all plant parts and plant populations, such as desired and undesired wild plants or crop plants (including naturally occurring crop plants). Crop plants may be plants of the Musaceae family which can be obtained by traditional breeding and optimization methods or else by biotechnological and recombinant methods, or combinations of these methods, including the transgenic plants of the Musaceae family and including the plant varieties
15 capable or not of being protected by Plant Breeders' Rights, such as, preferably, Gros Michel, Cavendish, Dwarf Cavendish, Dwarf Chinese, Enano, Caturra, Giant Cavendish, Gran Enano, Grand Nain, Williams Hybrid, Valery, Robusta, Poyo, Lacatan, Pisang masak hijau, Monte cristo, Bout rond.

The Musaceae family includes the following species: *Musa acuminata*, *Musa balbisiana*, *Musa acuminata* Colla with the varieties "Dwarf Cavendish", "Giant Cavendish" and "Gros Michel", *Musa*
20 *cavendishii* Lamb. ex Paxt., *Musa malaccensis* Ridl., *Musa angcorensis* Gagnep., *Musa aurantiaca*, *Musa balbisiana*, *Musa seminifera* Lour., *Musa banksii* F. Muell., *Musa basjoo* (Japanese Fiber banana, Hardy banana), *Musa cheesmanii*, *Musa flaviflora* Simmonds, *Musa griersonii*, *Musa itinerans*, *Musa laterita*, *Musa mannii*, *Musa nagensium*, *Musa ochracea*, *Musa ornata* Roxb., *Musa siamea*, *Musa sikkimensis*, *Musa thomsonii* Noltie, *Musa velutina* Wendl. & Drude (Pink banana), *Musa alinsanaya*, *Musa beccarii*,
25 *Musa boman*, *Musa borneënsis*, *Musa bukensis*, *Musa campestris*, *Musa coccinea* Andrews, *Musa uranoscopos* Lour., *Musa exotica* Valmayor, *Musa fitzalanii*, *Musa flavida*, *Musa gracilis*, *Musa hirta* Becc., *Musa insularimontana* Hayata, *Musa jackeyi*, *Musa johnsii*, *Musa lawitiensis*, *Musa lolodensis*, *Musa maclayi*, *Musa monticola*, *Musa muluensis*, *Musa paracoccinea*, *Musa peekelii*, *Musa pigmaea* Hotta, *Musa rubra*, *Musa salaccensis*, *Musa splendida* A. Chev., *Musa suratii*, *Musa textilis*: Abacá,
30 Japanese hardy or fibre banana, *Musa troglodytarum*, *Musa tuberculata*, *Musa violascens*, *Musa ingens*, *Musa paradisiaca* sapient, *Musa paradisiaca* normali, and crosses of these species.

Plant parts are intended to mean all aerial and subterranean parts and organs of the plants, such as herb, pseudostem, shoot, leaf, bract, leaf sheaths, petiole, lamina, flower and root, examples which may be mentioned being leaves, stalks, stems, flowers, fruiting bodies, fruits, banana hand, bunches and seeds,

and also roots, tubers, rhizomes, offshoots, suckers, and secondary growth. The plant parts also include crop material and vegetative and generative propagation material.

Plants and plant varieties of the Musaceae family which can also be treated in accordance with the invention are those plants which are characterized by improved yield characteristics.

- 5 Plants or plant varieties of the Musaceae family (obtained by plant biotechnology methods such as genetic engineering) which may be treated according to the invention can be herbicide-tolerant plants, i.e. plants made tolerant to one or more given herbicides. Such plants can be obtained either by genetic transformation, or by selection of plants containing a mutation imparting such herbicide tolerance.

- 10 Plants and plant varieties of the Musaceae family which are preferably treated in accordance with the invention include all plants which contain hereditary material which confers especially advantageous, useful traits to these plants (no matter whether this has been achieved by breeding and/or biotechnology).

- 15 Plants or plant varieties of the Musaceae family (obtained by plant biotechnology methods such as genetic engineering) which may also be treated according to the invention can be insect-resistant transgenic plants, i.e. plants made resistant to attack by certain target insects. Such plants can be obtained by genetic transformation, or by selection of plants containing a mutation imparting such insect resistance.

- 20 Plants or plant varieties of the Musaceae family (obtained by plant biotechnology methods such as genetic engineering) which may also be treated according to the invention can be tolerant to abiotic stress factors. Such plants are obtainable by genetic transformation, or by selection of plants containing a mutation imparting such stress resistance.

- 25 The abiotic stress conditions may include for example drought, low-temperature and high-temperature conditions, osmotic stress, water-logging, increased soil salinity, increased exposure to minerals, ozone conditions, intensive light conditions, limited availability of nitrogen nutrients, or limited availability of phosphorus nutrients.

The treatment according to the present invention of the plants or plant varieties of the Musaceae family and parts thereof is carried out directly or by acting on their environment, habitat or store by the customary treatment methods, for example by dipping, spraying, atomizing, nebulizing, scattering, painting on, injecting.

- 30 In an especially preferred embodiment of the present invention, ethyl hydrogen phosphonate (fosetyl) and/or its salts is used in accordance with the present invention in solid form, preferably in the form of a powder or in the form of granules, more preferably in the form of a wettable powder or of wettable granules.

The corresponding formulations for use in accordance with the present invention are aqueous formulations obtained from said powders or granules, particularly preferably from a wettable powder or from wettable granules.

5 Ethyl hydrogen phosphonate (fosetyl) and/or its salts used in accordance with the present invention can be converted into the formulations suitable for use in accordance with the present invention, such as solutions, emulsions, suspensions, powders, foams pastes, granules, sachets, aerosols, microencapsulations in polymeric substances, and ULV cold- and hot-fogging formulations.

10 These formulations are prepared in the known manner by mixing ethyl hydrogen phosphonate (fosetyl) and/or its salts with customary additives, such as, for example, customary extenders, solvents or diluents, colorants, wetters, dispersants, emulsifiers, antifoams, preservatives, secondary thickeners, adhesives, gibberellins, mineral oils, vegetable oils, and/or water.

If water is used as extender, it is possible for example also to use one or more organic solvents as cosolvents. Liquid solvents which are suitable in the main are: aromatics such as xylene, toluene or alkylnaphthalenes, chlorinated aromatics or chlorinated aliphatic hydrocarbons such as chlorobenzenes, 15 chloroethylenes or methylene chloride, aliphatic hydrocarbons, such as cyclohexane or paraffins, for example mineral oil fractions, alcohols such as butanol or glycol, and their ethers and esters, ketones such as acetone, methyl ethyl ketone, methyl isobutyl ketone or cyclohexanone, strongly polar solvents such as dimethylformamide and dimethyl sulphoxide, and water, and also mineral, animal and vegetable oils such as, for example, palm oil or other plant seed oils. Liquefied gaseous extenders or carriers are 20 understood as meaning those liquids which are gaseous at normal temperature and under normal pressure, for example aerosol propellants such as halohydrocarbons and butane, propane, nitrogen and carbon dioxide. Suitable solid carriers are: for example ground natural minerals such as kaolins, clays, talc, chalk, quartz, attapulgite, montmorillonite or diatomaceous earth, and ground synthetic minerals such as highly disperse silica, alumina and silicates. Suitable solid carriers for granules are: for example 25 crushed and fractionated natural rocks such as calcite, pumice, marble, sepiolite, dolomite, and synthetic granules of inorganic and organic meals, and granules of organic material such as sawdust, coconut shells, maize cobs and tobacco stalks. Emulsifiers and/or foam formers which are suitable are: for example nonionic, cationic and anionic emulsifiers, such as polyoxyethylene fatty acid esters, polyoxyethylene fatty alcohol ethers, for example alkylaryl polyglycol ethers, alkylsulphonates, alkyl 30 sulphates, arylsulphonates, and protein hydrolysates. Suitable dispersants are: for example, lagnosulphite waste liquors and methylcellulose.

Adhesives such as carboxymethylcellulose, natural and synthetic polymers in the form of powders, granules or latices, such as gum arabic, polyvinyl alcohol, polyvinyl acetate, and natural phospholipids such as cephalins and lecithins, and synthetic phospholipids, may be used in the formulations. Further 35 additives may be mineral and vegetable oils.

It is possible to use colorants such as inorganic pigments, for example iron oxide, titanium oxide, Prussian Blue, and organic dyestuffs, such as alizarin, azo and metal phthalocyanine dyestuffs, and trace nutrients, such as salts of iron, manganese, boron, copper, cobalt, molybdenum and zinc.

5 In general, the formulations contain a total amount of 0.1 to 95% by weight of ethyl hydrogen phosphonate (fosetyl) and/or its salts, preferably between 0.5 and 90% by weight.

Colorants which may be present in the formulations which can be used in accordance with the invention are all colorants which are customary for such purposes. In this context, both pigments, which are sparingly soluble in water, and dyes, which are soluble in water, may be used. Examples which may be mentioned are the colorants known by the names Rhodamin B, C.I. Pigment Red 112 and C.I. Solvent
10 Red 1.

Wetters which may be present in the formulations which can be used in accordance with the invention are all substances which are customary for formulating agrochemical active substances and which promote wetting. Alkyl naphthalenesulphonates, such as diisopropyl- or diisobutyl naphthalenesulphonates, may preferably be used.

15 Suitable dispersants and/or emulsifiers which may be present in the formulations which can be used in accordance with the invention are all nonionic, anionic and cationic dispersants which are conventionally used for the formulation of agrochemical active substances. The following may be used by preference: nonionic or anionic dispersants or mixtures of nonionic or anionic dispersants. Suitable nonionic dispersants which may be mentioned are, in particular, ethylene oxide/propylene oxide block
20 polymers, alkylphenol polyglycol ethers and tristyrylphenol polyglycol ethers and their phosphated or sulphated derivatives. Suitable anionic dispersants are, in particular, lignosulphonates, salts of polyacrylic acid, and arylsulphonate/formaldehyde condensates.

Antifoams which may be present in the formulations which can be used in accordance with the invention are all foam-inhibitor substances which are conventionally used for the formulation of agrochemical
25 active substances. Silicone antifoams and magnesium stearate may be used by preference.

The following examples are intended to illustrate the present invention.

Examples:

The effects of applying fosetyl-Al to plants or plant varieties of the Musaceae family for controlling *Fusarium oxysporum* f.sp. *cubense* race 4 (“*Tropical Race IV*”) fosetyl-Al (used as commercially available product Aliette® 80 WP (WP = wettable powder), containing 80 wt.% of fosetyl-Al) was mixed with water and applied at the rate of 2 g product per mat or plant.

For comparison with the fosetyl-Al plots, in each case one plot was left untreated. The trials were designed in randomized complete block design.

Example 1:

The following experiments were carried out on 'Cavendish' banana plants in Compostela Valley in the Philippines.

When starting with these experiments, each plot consisted of 15 'Cavendish' banana plants, each at the BBCH growth stage 1060 – 1090.

For the soil drenching applications, fosetyl-Al was formulated with water such that 500 ml of resulting formulation comprised 2 g of fosetyl-Al.

For the leaf axil drenching applications, fosetyl-Al was formulated with water such that 50 ml of resulting formulation comprised 2 g of fosetyl-Al.

For the leaf axil drenching applications, initially a Phillips automatic drencher was used, and after the plants had grown taller (BBCH growth stage 1060 – 1090), an extended lance was used.

After the formulation procedure, the resulting formulation was applied to banana trees using either soil drenching (by pouring out of a calibrated container) or by axil leaf drenching using in the amounts and the timing indicated in Table 1.

Table 1:

Plot	Amount / plant	Application Type	Frequency of application
Untreated control*	-	-	-
Fosetyl-Al	2 grams formulated product	Soil drenching	Weekly
Fosetyl-Al	2 grams formulated product	Soil drenching	Every two weeks
Fosetyl-Al	2 grams formulated product	Soil drenching	Monthly

Fosetyl-Al	2 grams formulated product	Leaf axil drenching*	Weekly
Fosetyl-Al	2 grams formulated product	Leaf axil drenching*	Every two weeks
Fosetyl-Al	2 grams formulated product	Leaf axil drenching*	Monthly

*: Leaf axil drenching application was carried out by applying the fosetyl-Al formulation to the oldest five leaf axils per plant in an amount of 10 ml per leaf axil, starting from functional older to younger leaves

Results and conclusions:

- 5 Full visible recovery of infected plants was achieved 4 weeks after the first application of Fosetyl-Al. No significant difference of controlling *Fusarium oxysporum* f.sp. *cubense* could be observed between the weekly, biweekly and monthly application intervals. Thus, a monthly application interval is sufficient and a recommended application interval.

Example 2:

- 10 The following experiments were carried out on 'Grand Nain' banana plants in the Philippines.

'Grand Nain' seedlings were used as planting material. The seedlings were planted in areas infected with *Fusarium oxysporum* f.sp. *cubense* and then planted following standard planting procedures in standard distance.

Each plot consisted of ten banana plants, each plant at the BBCH growth stage 1060 - 1090.

- 15 Fosetyl-Al (used as Aliette® 80 WP) was diluted with water such that 250 ml of resulting solution comprised 2 g formulated product of fosetyl-Al. This amount of solution was applied to the plant/mat. Said formulation was applied during planting of all seedlings treated with treatments (excluding the untreated control plants) using soil drenching.

- Thereafter, further applications of the said fosetyl-Al formulation were carried out in four weeks intervals in all treatments, in each case using soil drenching.
- 20

The occurrence of symptoms of the Panama disease was monitored weekly.

The percentage of infection was calculated as

[number of infected plants in the respective plot]
 _____ * 100

- 25 [total number of plants in the said plot]

Table 2 shows the results observed after six months from planting.

Table 2:

Plot	Amount / plant	Time before PD symptoms	% Infection
Untreated control*	-	90 days	100
Fosetyl-Al	2 g	122 days	70

* no treatment on untreated control plots

“Time before PD symptoms” indicates the time in days from planting until the first symptoms of the

5 Panama disease were observed in the respective plot.

Example 3:

The following experiments were carried to investigate the recovery of banana plants from *Fusarium oxysporum* f.sp. *cubense* race 4, i.e. the curative effect of fosetyl-Al (used as Aliette® 80 WP) on infested banana plants.

10 The experiments were carried out on “Cavendish” banana plants in the Philippines, New Corella, Davao del Norte. At the beginning of the tests all plants in an early stage of infestation.

Table 3 shows the results observed for curative treatment with fosetyl-Al in an early stage of infestation.

Table 3:

Application Type	Number of infected plants in plot	Full Recovery
Leaf axil drenching*	30	90%
Soil drenching	30	86.7%
Pseudostem injection	15	100%
Leaf axil* + soil drenching	30	86.7

*: Leaf axil drenching was carried out as described in Example 1

15 The recovery of the plot of untreated plants was 0%.

In all cases two application were sufficient to observe full recovery

Claims:

1. Use of (i) ethyl hydrogen phosphonate and/or its salts or (ii) a formulation comprising ethyl hydrogen phosphonate and/or its salts for controlling *Fusarium oxysporum* f.sp. *cubense* in plants or plant varieties of the Musaceae family.
- 5 2. Use according to claim 1, wherein the plants or plant varieties are selected from the genus *Musa* spp., preferably plants or plant varieties are selected from banana cultivars and plantains.
3. Use according to claim 1 or 2 for controlling *Fusarium oxysporum* f.sp. *cubense* race 4.
4. Use according to any one of claims 1 to 3, wherein ethyl hydrogen phosphonate and/or its salts are selected from the group consisting of fosetyl, fosetyl-Na, and fosetyl-Al.
- 10 5. Use according to any one of claims 1 to 3, wherein the ethyl hydrogen phosphonate salt is fosetyl-Al.
6. Use according to any one of claims 1 to 5, wherein no further fungicide is used.
7. Use according to any one of claims 1 to 6, wherein (i) ethyl hydrogen phosphonate and/or its salts or (ii) a formulation comprising ethyl hydrogen phosphonate and/or its salts are applied by
15 drenching, preferably soil drenching and/or leaf axil drenching.
8. Use according to any one of claims 1 to 7, wherein (i) ethyl hydrogen phosphonate and/or its salts or (ii) a formulation comprising ethyl hydrogen phosphonate and/or its salts are applied two or more times per plant per growing cycle, preferably two or more times per plant before the plant has reached its fruiting stage.
- 20 9. Use according to any one of claims 1 to 8, wherein (i) ethyl hydrogen phosphonate and/or its salts or (ii) a formulation comprising ethyl hydrogen phosphonate and/or its salts are applied three to ten times per plant per growing cycle, preferably three to ten times per plant before the plant has reached its fruiting stage.
10. Use according to any one of claims 1 to 9, wherein the total amount of ethyl hydrogen
25 phosphonate and its salts per application is in the range from 250 to 6000 g/ha, preferably in the range from 500 to 4000 g/ha.
11. Use according to any one of claims 1 to 10, wherein the total amount of ethyl hydrogen phosphonate and its salts per application per plant is in the range from 0.8 g to 4 g/plant, preferably 1 to 3 g/plant.

12. Use according to any one of claims 1 to 11, wherein fosetyl-Al is the sole fungicide, and wherein fosetyl-Al is applied three or more times, and wherein the total amount of fosetyl-A in each application is in the range from 800 to 3500 g/ha.
- 5 13. Method of controlling *Fusarium oxysporum* f.sp. *cubense* in plants of the Musaceae family, characterized in that said plants of the Musaceae family are treated with (i) ethyl hydrogen phosphonate and/or its salts or (ii) a formulation comprising ethyl hydrogen phosphonate and/or its salts.
- 10 14. Method according to claim 13, characterized in that the treatment with (i) ethyl hydrogen phosphonate and/or its salts or (ii) a formulation comprising ethyl hydrogen phosphonate and/or its salts is carried out on two to four months old plants or at BBCH stage 1060 – 1090.

INTERNATIONAL SEARCH REPORT

International application No

PCT/EP2015/053765

A. CLASSIFICATION OF SUBJECT MATTER
 INV. A01N57/12 A01P3/00
 ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

A01N

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	A. J Davis ET AL: "Sensitivity of Fusarium oxysporum f. sp. cubense to phosphonate", Plant Pathology, 1 February 1994 (1994-02-01), pages 200-205, XP055137422, DOI: 10.1111/j.1365-3059.1994.tb00571.x Retrieved from the Internet: URL:http://onlinelibrary.wiley.com/store/10.1111/j.1365-3059.1994.tb00571.x/asset/j.1365-3059.1994.tb00571.x.pdf?v=1&t=hzi5hj f&s=32e939547bf7aa556e61ef1a6ef1d0fdc8c6bb38 the whole document	1-14
A	FR 2 732 191 A1 (RHONE POULENC AGROCHIMIE [FR]) 4 October 1996 (1996-10-04) cited in the application claims 1,4	1-14



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

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FR 2732191	A1	04-10-1996	
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		ID 20919 A	25-03-1999
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