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54 Titre: Synergistic herbicidal weed control from combinations of 2, 4-D-Choline and Glufosinate.

57 Abrégé:

Provided herein are herbicidal compositions comprising a mixture comprising (a) a choline salt of 2, 4-dichlorophenoxyacetic acid (2, 4-D-choline) and (2) a salt of 2-amino-4-(hydroxymethylphosphinyl) butanoic acid (glufosinate). The compositions provide synergistic weed control of undesirable vegetation and improved crop tolerance in 2, 4-d-and glufosinate-tolerant soybeans, corn, or cotton. The compositions also provide synergistic weed control of undesirable vegetation in areas including, but not limited to, non-crop, perennial crop, fruiting crop, and plantation crop areas.

SYNERGISTIC HERBICIDAL WEED CONTROL FROM COMBINATIONS OF 2,4-D-
CHOLINE AND GLUFOSINATE

Cross Reference to Related Applications

This application claims the benefit of U.S. Provisional Patent Application Serial Nos. 5 61/914,177 and 61/914,195 filed December 10, 2013, the disclosures of which are expressly incorporated herein by reference.

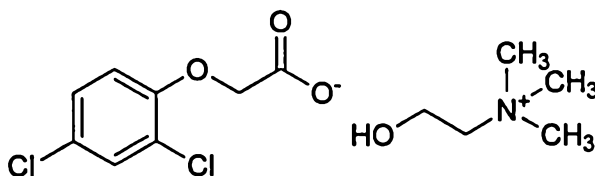
Background

The protection of crops from weeds and other vegetation which inhibit crop growth is a recurring problem in agriculture. To help combat this problem, a variety of chemicals and 10 chemical formulations effective in the control of such unwanted vegetation have been synthesized and evaluated. Different classes of chemical herbicides have been disclosed in the literature and a large number are in commercial use. However, there remains a need for improved compositions and methods of use thereof that are effective in controlling undesirable vegetation.

15 Summary

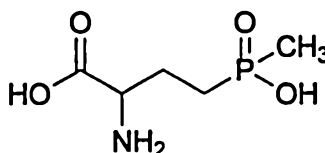
Compositions for controlling undesirable vegetation containing a mixture containing synergistic, herbicidally effective amounts of:

- (a) a choline salt of 2,4-dichlorophenoxyacetic acid (2,4-D-choline)



20 and

- (b) a salt of 2-amino-4-(hydroxymethylphosphinyl)butanoic acid (glufosinate)



are described herein. The compositions may also contain one or more agriculturally acceptable adjuvants and/or carriers.

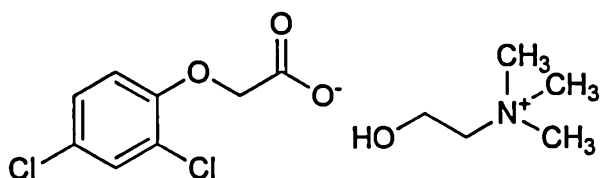
Additionally, methods of controlling undesirable vegetation and improving crop tolerance in 2,4-D- and glufosinate-tolerant soybeans, corn, or cotton including contacting the
 5 undesirable vegetation and the 2,4-D- and glufosinate-tolerant soybeans, corn, or cotton or the locus thereof, including but not limited to foliage, soil or water, with a composition containing a mixture containing synergistic, herbicidally effective amounts of 2,4-D-choline and glufosinate are described herein. The undesirable vegetation may include herbicide
 10 resistant or tolerant weeds and the undesirable vegetation may be located in non-crop, perennial crop, fruiting crop, or plantation crop areas.

In another embodiment, methods of controlling undesirable vegetation in non-crop, perennial crop, fruiting crop, or plantation crop areas including contacting the undesirable vegetation or the locus thereof, including but not limited to foliage, soil or water, with a composition containing a mixture containing synergistic, herbicidally effective amounts of
 15 2,4-D-choline and a salt of glufosinate are described herein.

Detailed Description

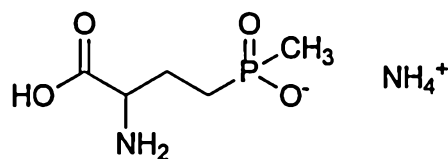
I. Definitions

As used herein, 2,4-D-choline is the choline salt of 2,4-dichlorophenoxyacetic acid or 2-hydroxy-*N,N,N*-trimethylethanaminium 2-(2,4-dichlorophenoxy)acetate, which has the
 20 following structure:



Exemplary uses of 2,4-D-choline include controlling annual and perennial broad-leaved weeds, including glyphosate-resistant broad-leaved weeds. 2,4-D-choline can be used in crops that have been made tolerant to 2,4-D, particularly in 2,4-D-tolerant soybeans, corn,
 25 and cotton. 2,4-D-choline is generally, but is not required to be, applied post-emergent. 2,4-D-choline can also be used for weed control in non-crop and perennial cropping systems.

As used herein, glufosinate is 2-amino-4-(hydroxymethylphosphinyl)butanoic acid. An exemplary salt of glufosinate is glufosinate-ammonium, which is also known as the ammonium salt of 2-amino-4-(hydroxymethylphosphinyl)butanoic acid or ammonium (3-amino-3-carboxypropyl)(methyl)phosphinate, and which has the following structure:



5

Glufosinate-ammonium is registered for controlling a wide variety of broad-leaved weeds and grasses particularly in glufosinate-tolerant crops like canola, corn, soybean, rice, cotton, and sugar beet. As used herein, glufosinate salt or salt of glufosinate generally refers to the reaction product of glufosinate with a moiety that can act as a base. Typically, the reaction is an acid-base reaction.

10

The term herbicide, as used herein, means an active ingredient that kills, controls or otherwise adversely modifies the growth of plants. As used herein, a herbicidally effective or vegetation controlling amount is an amount of active ingredient that causes a “herbicidal effect,” *i.e.*, an adversely modifying effect and includes deviations from natural development, killing, regulation, desiccation, retardation.

15

As used herein, “plants” and “vegetation” include, but are not limited to, germinant seeds, emerging seedlings, plants emerging from vegetative propagules, and established vegetation.

As used herein, immature vegetation refers to small vegetative plants prior to reproductive stage, and mature vegetation refers to vegetative plants during and after reproductive stage.

20

As used herein, 2,4-D-tolerant soybeans refer to soybeans that are genetically modified to be tolerant to 2,4-D. Examples of 2,4-D tolerant soybeans include soybeans containing the *aad-12* gene which confers tolerance to 2,4-D (U.S. Patent 8,283,522 B2). As used herein, 2,4-D-tolerant corn refers to corn that is genetically modified to be tolerant to 2,4-D. Examples of 2,4-D tolerant corn include corn containing the *aad-1* gene which confers tolerance to 2,4-D (U.S. Patent 7,838,733 B2). As used herein, 2,4-D-tolerant cotton refers to cotton that is genetically modified to be tolerant to 2,4-D. Examples of 2,4-D tolerant cotton include cotton containing the *aad-12* gene which confers tolerance to 2,4-D. However, tolerance in each of these crops by the *aad-1* or *aad-12* genes or with alternative

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genes providing additional or alternative tolerance to transgenic crops [e.g., *aad-13* (U.S. Patent 8,278,505 B2), *tfdA* (U.S. Patent 6,153,401 A), or *24dt02* (CN103060279)] is considered to be included within the scope of the 2,4-D- and glufosinate-tolerant soybeans, corn, or cotton described herein.

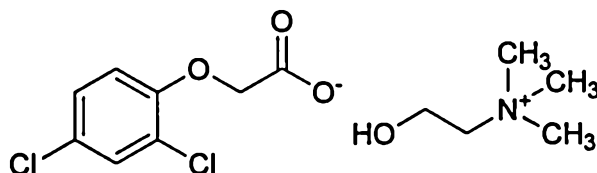
5 As used herein, glufosinate tolerance refers to soybeans, corn, or cotton that is genetically modified to be tolerant to glufosinate. Glufosinate tolerance can be provided, for example, by the *pat* gene (US 5,587,903 A) as shown herein; however, glufosinate tolerance could also be conferred within the scope of the 2,4-D- and glufosinate-tolerant soybeans, corn, or cotton described herein by other genes providing transgenic crop tolerance to
10 glufosinate [e.g., *bar* (U.S. Patent 5,561,236 A) and *dsm2* (WO2008070845)].

II. Compositions

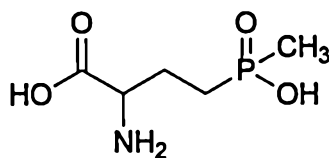
A. Synergistic combinations

Provided herein are herbicidal compositions containing a mixture containing synergistic, herbicidally effective amounts of:

15 (a) the choline salt of 2,4-dichlorophenoxyacetic acid (2,4-D-choline)



and (b) a salt of 2-amino-4-(hydroxymethylphosphinyl)butanoic acid (glufosinate)



20 Agriculturally acceptable salts of glufosinate are anticipated to control undesirable vegetation in combination with 2,4-D-choline and a salt of glyphosate. An example of such an agriculturally acceptable salt of glufosinate includes glufosinate-ammonium.

Furthermore, in some embodiments, the combination of 2,4-D-choline and a salt of glufosinate exhibit synergism, *i.e.*, the herbicidal active ingredients are more effective in combination than when applied individually. Synergism has been defined as “an interaction

of two or more factors such that the effect when combined is greater than the predicted effect based on the response of each factor applied separately.” Shaner, D. L., Ed. *Herbicide Handbook*, 10th ed. Lawrence: Weed Science Society of America, 2014. In certain embodiments, the compositions exhibit synergy as determined by Colby’s equation. Colby, S. R. Calculation of the synergistic and antagonistic response of herbicide combinations. *Weeds* 1967, 15, 20-22.

Additionally, in some embodiments, the combination of 2,4-D-choline and a salt of glufosinate improves crop tolerance in 2,4-D- and glufosinate-tolerant soybeans, corn and cotton.

Herbicidal activity is exhibited by the compounds when they are applied pre- and post-emergence directly to the plant or to the locus of the plant at any stage of growth. The effect observed depends upon the plant species to be controlled, the stage of growth of the plant, the application parameters of dilution and spray drop size, the particle size of solid components, the environmental conditions at the time of use, the specific compound employed, the specific adjuvants and carriers employed, the soil type, the amount of chemical applied, and the combinations thereof. These and other factors can be adjusted to promote non-selective or selective herbicidal action. In some embodiments, the compositions described herein are applied as a post-emergence application, to relatively immature and mature undesirable vegetation to achieve the maximum control of weeds.

In some embodiments, 2,4-D-choline and a salt of glufosinate are used in combination with other herbicides that are selective for the soybeans, corn or cotton being treated and which complement the spectrum of weeds controlled by these compounds at the application rate employed. In some embodiments, the compositions described herein and other complementary herbicides are applied at the same time, either as a combination formulation or as a tank mix, at the same time or as sequential applications.

The present compositions can be applied to weeds or their locus thereof, including but not limited to foliage, soil or water, by the use of conventional ground or aerial dusters, sprayers, and granule applicators and by other conventional means known to those skilled in the art.

In some embodiments, the concentration of the active ingredients in the compositions described herein is from about 0.0005 to 99 percent by weight. In some embodiments, the

concentration is from about 0.006 to 90 percent by weight. In compositions designed to be employed as concentrates, the active ingredients, in certain embodiments, are present in a concentration from about 0.01 to 98 weight percent, and in certain embodiments about 0.5 to 90 weight percent. Such compositions are, in certain embodiments, diluted with an inert carrier, such as water, before application. The diluted compositions usually applied to weeds or the locus of weeds contain, in certain embodiments, about 0.003 to 98 weight percent active ingredient and in certain embodiments contain about 0.007 to 25.0 weight percent active ingredient.

In certain embodiments of the compositions and methods described herein, 2,4-D-choline is used in combination with a salt of glufosinate. With regard to the compositions, in some embodiments, the weight ratio of the compound of 2,4-D-choline to a salt of glufosinate is within the range from about 1:48 to about 64:1, from about 1:32 to about 48:1, from about 1:16 to about 16:1, from about 1:10 to about 10:1, from about 1:8 to about 8:1, from about 1:7 to about 7:1, from about 1:6 to about 6:1, from about 1:5 to about 5:1, from about 1:4 to about 4:1, from about 1:3 to about 3:1, from about 2:1 to about 1:4, from about 1:1 to about 1:2, from about 1:16 to about 24:1, from about 1:8 to about 16:1, from about 4:1 to about 8:1, from about 2:1 to about 6:1, from about 1.5:1 to about 3:1, from about 1:1 to about 1.5:1, from about 1:1 to about 2.5:1, from about 2.5:1 to about 1:3, from about 3:1 to about 1:4, from about 1:2 to about 4:1 and from about 1:4 to about 7:1. In certain embodiments, the weight ratio of 2,4-D-choline to a salt of glufosinate is within the range from about 1:2 to about 2:1. In other embodiments, the weight ratio of 2,4-D-choline to a salt of glufosinate is within the range from about 3:1 to 2:3, from about 2:1 to about 8:1 and from about 1:1 to about 4:1.

With respect to the methods, in certain embodiments, the methods comprise contacting the undesirable vegetation with a composition described herein, *e.g.*, sequentially or simultaneously. In some embodiments, the composition is applied at an application rate from about 300 grams acid equivalent per hectare (g ae/ha) to about 11,200 g ae/ha based on the total amount of active ingredients in the composition. In certain embodiments, the composition is applied at an application rate from about 600 g ae/ha to about 7,810 g ae/ha based on the total amount of active ingredients in the composition. In certain embodiments, the composition is applied at an application rate from about 1,120 g ae/ha to about 2,800 g ae/ha based on the total amount of active ingredients in the composition. In certain

embodiments, the composition is applied at an application rate from about 1,300 g ae/ha to about 1,700 g ai/ha based on the total amount of active ingredients in the composition.

The components of the mixtures described herein can be applied either separately, sequentially, tankmixed or as part of a mixture or multipart herbicidal system. In some
 5 embodiments, both components may be formulated together (e.g., in the same formulation) or separately (e.g., in separate formulations) and applied simultaneously. In another embodiment, one or more components may be formulated separately and the formulations applied sequentially. The time period between applications can vary, for example 1, 2, 4, 6, 8, 10, or 12 hours or longer or 1, 2, 3, 4, 5, 6, or 7 days or longer.

10 In one embodiment, the compositions exhibit synergy against a variety of weed types. In one embodiment, the combination of 2,4-D-choline and a salt of glufosinate in a ratio of about 1:1 to about 4:1 exhibits greater than about 5, 6, 7, 8, 9, 10, 11, 13, 15, 18, 20, 21, 22, 23, 24, or 25% control compared to the Colby predicted value at 6–28 days after application (DAA).

15 In another embodiment, the compositions exhibit synergy in reducing crop injury. In one embodiment, the combination of 2,4-D-choline and a salt of glufosinate in a ratio of about 1:1 to about 4:1 exhibits reductions of 5, 6, 7, 8, 9, 10, 11, 13, 15, 18, 20, 21, 22, 23, 24, 25, 30 or 35% crop injury compared to the Colby predicted value at 2–15 days after application (DAA).

20 In another embodiment, the compositions exhibit synergy as defined by the efficacy values defined above against a variety of weed types or crops, including but not limited to, *Amaranthus palmeri* (Palmer pigweed, AMAPA), *Conyza canadensis* (horseweed, ERICA), *Salsola tragus* L. (Russian thistle, SASKR), and *Sesbania exaltata* (hemp sesbania, SEBEX).

25 In another embodiment, the compositions can be used to control glyphosate-tolerant soybeans (GLXMA) and other crops that have single site tolerance to, including but not limited to, glyphosate, acetolactate synthase (ALS) and other herbicide modes-of-action.

B. Other actives

The mixtures described herein can be applied in conjunction with one or more other herbicides to control a wider variety of undesirable vegetation. When used in conjunction

with other herbicides, the composition can be formulated with the other herbicide or herbicides, tank mixed with the other herbicide or herbicides or applied sequentially with the other herbicide or herbicides. Some of the herbicides that can be employed in conjunction with the compositions and methods described herein include, but are not limited to, acid, salt, and ester forms of the following herbicides: 4-CPA, 4-CPB, 4-CPP, 3,4-DA, 2,4-DB, 3,4-DB, 3,4-DP, 2,3,6-TBA, 2,4,5-T, 2,4,5-TB, acetochlor, acifluorfen, aclonifen, acrolein, alachlor, allidochlor, alloxydim, allyl alcohol, alorac, ametrifone, ametryn, amibuzin, amicarbazone, amidosulfuron, aminocyclopyrachlor, aminopyralid, amiprofos-methyl, amitrole, ammonium sulfamate, anilofos, anisuron, asulam, atraton, atrazine, azafenidin, azimsulfuron, aziprotryne, barban, BCPC, beflubutamid, benazolin, bencarbazine, benfluralin, benfuresate, bensulfuron-methyl, bensulide, bentazon, benthio carb, benzadox, benzfendizone, benzipram, benzobicyclon, benzofenap, benzofluor, benzoylprop, benzthiazuron, bicyclopyrone, bifenox, bilanafos, bispyribac-sodium, borax, bromacil, bromobonil, bromobutide, bromofenoxim, bromoxynil, brompyrazon, butachlor, butafenacil, butamifos, butenachlor, buthidazole, buthiuron, butralin, butroxydim, buturon, butylate, cacodylic acid, cafenstrole, calcium chlorate, calcium cyanamide, cambendichlor, carbasulam, carbetamide, carboxazole chlorprocarb, carfentrazone (*e.g.*, carfentrazone-ethyl), CDEA, CEPC, chlomethoxyfen, chloramben, chloranocryl, chlorazifop, chlorazine, chlorbromuron, chlorbufam, chloreturon, chlorfenac, chlorfenprop, chlorflurazole, chlorflurenol, chloridazon, chlorimuron, chlornitrofen, chloropon, chlorotoluron, chloroxuron, chloroxynil, chlorpropham, chlorsulfuron, chlorthal, chlorthiamid, cinidon (*e.g.*, cinidon-ethyl), cinmethylin, cinosulfuron, cisanilide, clethodim, cliodinate, clodinafop-propargyl, clofop, clomazone, clomeprop, cloprop, cloproxydim, clopyralid, cloransulam, CMA, copper sulfate, CPMF, CPPC, credazine, cresol, cumyluron, cyanatryn, cyanazine, cycloate, cyclopyrimorate, cyclosulfamuron, cycloxydim, cycluron, cyhalofop (*e.g.*, cyhalofop-butyl), cyperquat, cyprazine, cyprazole, cypromid, daimuron, dalapon, dazomet, delachlor, desmedipham, desmetryn, di-allate, dicamba, dichlobenil, dichloralurea, dichlormate, dichlorprop, dichlorprop-P, diclofop-methyl, diclosulam, diethamquat, diethatyl, difenopenten, difenoxuron, difenzoquat, diflufenican, diflufenzopyr, dimefuron, dimepiperate, dimethachlor, dimethametryn, dimethenamid, dimethenamid-P, dimexano, dimidazon, dinitramine, dinofenate, dinoprop, dinosam, dinoseb, dinoterb, diphenamid, dipropetryn, diquat, disul, dithiopyr, diuron, DMPA, DNOC, DSMA, EBEP, eglinazine, endothal, epronaz, EPTC, erbon, esprocarb, ethbenzamide, ethalfluralin, ethametsulfuron, ethidimuron,

ethiolate, ethobenzamid, etobenzamid, ethofumesate, ethoxyfen, ethoxysulfuron, etinofen, etnipromid, etobenzanid, EXD, fenasulam, fenoprop, fenoxaprop, fenoxaprop-P (*e.g.*, fenoxaprop-P-ethyl), fenoxaprop-P-ethyl + isoxadifen-ethyl, fenoxasulfone, fenquinotriene, fenteracol, fenthiaprop, fentrazamide, fenuron, ferrous sulfate, flamprop, flamprop-M, 5 flazasulfuron, florasulam, fluazifop, fluazifop-P (*e.g.*, fluazifop-P-butyl), fluazolate, flucarbazon, flucetosulfuron, fluchloralin, flufenacet, flufenican, flufenpyr (*e.g.*, flufenpyr-ethyl), flumetsulam, flumezin, flumiclorac (*e.g.*, flumiclorac-pentyl), flumioxazin, flumipropyn, fluometuron, fluorodifen, fluoroglycofen, fluoromidine, fluoronitrofen, fluothiuron, flupoxam, flupropacil, flupropanate, flupyrsulfuron, fluridone, flurochloridone, 10 fluroxypyr, flurtamone, fluthiacet, fomesafen, foramsulfuron, fosamine, fumiclorac, furyloxyfen, glyphosate, halauxifen, halosafen, halosulfuron (*e.g.*, halosulfuron-methyl), haloxydine, haloxyfop-methyl, haloxyfop-P (*e.g.*, haloxyfop-P-methyl), hexachloroacetone, hexaflurate, hexazinone, imazamox, imazapic, imazapyr, imazaquin, imazethapyr, imazosulfuron, indanofan, indaziflam, iodobonil, iodomethane, iodosulfuron, iodosulfuron-ethyl-sodium, iofensulfuron, ioxynil, ipazine, ipfencarbazon, iprymidam, isocarbamid, 15 isocil, isomethiozin, isonoruron, isopolinate, isopropalin, isoproturon, isouron, isoxaben, isoxachlortole, isoxaflutole, isoxapyrifop, karbutilate, ketospiradox, lactofen, lenacil, linuron, MAA, MAMA, MCPA esters and amines, MCPA-thioethyl, MCPB, mecoprop, mecoprop-P, medinoterb, mefenacet, mefluidide, mesoprazine, mesosulfuron, mesotriene, metam, 20 metamifop, metamitron, metazachlor, metazosulfuron, metflurazon, methabenzthiazuron, methalpropalin, methazole, methiobencarb, methiozolin, methiuron, methometon, methoprotryne, methyl bromide, methyl isothiocyanate, methyl dymron, metobenzuron, metobromuron, metolachlor, metosulam, metoxuron, metribuzin, metsulfuron, metsulfuron-methyl, molinate, monalide, monisouron, monochloroacetic acid, monolinuron, monuron, 25 morfamquat, MSMA, naproanilide, napropamide, napropamide-M, naptalam, neburon, nicosulfuron, nipyraclufen, nitralin, nitrofen, nitrofluorfen, norflurazon, noruron, OCH, orbencarb, *ortho*-dichlorobenzene, orthosulfamuron, oryzalin, oxadiargyl, oxadiazon, oxapyrazon, oxasulfuron, oxaziclomefone, oxyfluorfen, parafluron, paraquat, pebulate, pelargonic acid, pendimethalin, penoxsulam, pentachlorophenol, pentanochlor, pentoxazone, 30 perfluidone, pethoxamid, phenisopham, phenmedipham, phenmedipham (*e.g.*, phenmedipham-ethyl), phenobenzuron, phenylmercury acetate, picloram, picolinafen, pinoxaden, piperophos, potassium arsenite, potassium azide, potassium cyanate, pretilachlor, primisulfuron (*e.g.*, primisulfuron-methyl), procyazine, prodiamine, profluzol, profluralin,

profoxydim, proglinazine, prohexadione-calcium, prometon, prometryn, propachlor, propanil,
 propaquizafof, propazine, propham, propisochlor, propoxycarbazone, propyrisulfuron,
 propyzamide, prosulfalin, prosulfocarb, prosulfuron, proxan, prynachlor, pydanon,
 pyraclonil, pyraflufen (*e.g.*, pyraflufen-ethyl), pyrasulfotole, pyrazogyl, pyrazolynate,
 5 pyrazosulfuron-ethyl, pyrazoxyfen, pyribenzoxim, pyributicarb, pyriclor, pyridafof, pyridate,
 pyrifitalid, pyriminobac, pyrimisulfan, pyrithiobac-sodium, pyroxasulfone, pyroxulam,
 quinclorac, quinmerac, quinoclamine, quinonamid, quizalofop, quizalofop-P (*e.g.*,
 quizalofop-P-ethyl), rhodethanil, rimsulfuron, saflufenacil, S-metolachlor, sebuthylazine,
 secbumeton, sethoxydim, siduron, simazine, simeton, simetryn, SMA, sodium arsenite,
 10 sodium azide, sodium chlorate, sulcotrione, sulfallate, sulfentrazone, sulfometuron, sulfosate,
 sulfosulfuron, sulfuric acid, sulglycapin, swep, TCA, tebutam, tebuthiuron, tefuryltrione,
 tembotrione, tepraloxym, terbacil, terbucarb, terbuchlor, terbumeton, terbuthylazine,
 terbutryn, tetrafluron, thenylchlor, thiazafluron, thiazopyr, thidiazimin, thidiazuron,
 thiencarbazone-methyl, thifensulfuron, thifensulfuron-methyl, thiobencarb, tiocarbamil,
 15 tioclorim, topramezone, tralkoxydim, triafamone, tri-allate, triasulfuron, triaziflam,
 tribenuron, tribenuron (*e.g.*, tribenuron-methyl), tricamba, triclopyr (*e.g.*, triclopyr choline
 salt), triclopyr, tridiphane, trietazine, trifloxysulfuron, trifluralin, triflusulfuron, trifop,
 trifopsime, trihydroxytriazine, trimeturon, tripropindan, tritac, tritosulfuron, vernolate,
 xylachlor, benzyl 4-amino-3-chloro-5-fluoro-6-(4-chloro-2-fluoro-3-
 20 methoxyphenyl)pyridine-2-carboxylate and salts, choline salts, esters, optically active
 isomers and mixtures thereof.

C. Safeners

In some embodiments, the compositions described herein are employed in
 combination with one or more herbicide safeners, such as AD-67 (MON 4660), benoxacor,
 25 benthocarb, brassinolide, cloquintocet (mexyl), cyometrinil, daimuron, dichlormid,
 dicyclonon, dimepiperate, disulfoton, fenclorazole-ethyl, fenclorim, flurazole, fluxofenim,
 furilazole, harpin proteins, isoxadifen-ethyl, jiecaowan, jiecaoxi, mefenpyr-diethyl,
 mephenate, naphthalic anhydride (NA), oxabetrinil, R29148 and *N*-phenyl-sulfonylbenzoic
 acid amides, to enhance their selectivity. In some embodiments, the safeners are employed in
 30 rice, cereal, corn, or maize settings. In some embodiments, the safener is cloquintocet or an
 ester or salt thereof. In certain embodiments, cloquintocet is utilized to antagonize harmful

effects of the compositions on rice and cereals. In some embodiments, the safener is cloquintocet (mexyl).

D. Adjuvants/Carriers

In some embodiments, compositions provided herein further comprise at least one agriculturally acceptable adjuvant or carrier. Suitable adjuvants or carriers should not be phytotoxic to valuable crops, particularly at the concentrations employed in applying the compositions for selective weed control in the presence of crops, and should not react chemically with herbicidal components or other composition ingredients. Such mixtures can be designed for application directly to weeds or their locus or can be concentrates or formulations that are normally diluted with additional carriers and adjuvants before application. They can be solids, such as, for example, dusts, granules, water-dispersible granules, microcapsules or wettable powders, or liquids, such as, for example, emulsifiable concentrates, solutions, emulsions or suspensions. They can also be provided as a pre-mix or tank mixed.

Suitable agricultural adjuvants and carriers include, but are not limited to, crop oil concentrate; nonylphenol ethoxylate; benzylcocoalkyldimethyl quaternary ammonium salt; blend of petroleum hydrocarbon, alkyl esters, organic acid, and anionic surfactant; C₉-C₁₁ alkylpolyglycoside; phosphated alcohol ethoxylate; natural primary alcohol (C₁₂-C₁₆) ethoxylate; di-*sec*-butylphenol EO-PO block copolymer; polysiloxane-methyl cap; nonylphenol ethoxylate + urea ammonium nitrate; emulsified methylated seed oil; tridecyl alcohol (synthetic) ethoxylate (8EO); tallow amine ethoxylate (15 EO); PEG(400) dioleate-99.

Liquid carriers that can be employed include water and organic solvents. The organic solvents include, but are not limited to, petroleum fractions or hydrocarbons such as mineral oil, aromatic solvents, paraffinic oils, and the like; vegetable oils such as soybean oil, rapeseed oil, olive oil, castor oil, sunflower seed oil, coconut oil, corn oil, cottonseed oil, linseed oil, palm oil, peanut oil, safflower oil, sesame oil, tung oil and the like; esters of the above vegetable oils; esters of monoalcohols or dihydric, trihydric, or other lower polyalcohols (4-6 hydroxy containing), such as 2-ethyl hexyl stearate, *n*-butyl oleate, isopropyl myristate, propylene glycol dioleate, di-octyl succinate, di-butyl adipate, di-octyl phthalate and the like; esters of mono, di and polycarboxylic acids and the like. Specific

organic solvents include, but are not limited to toluene, xylene, petroleum naphtha, crop oil, acetone, methyl ethyl ketone, cyclohexanone, trichloroethylene, perchloroethylene, ethyl acetate, amyl acetate, butyl acetate, propylene glycol monomethyl ether and diethylene glycol monomethyl ether, methyl alcohol, ethyl alcohol, isopropyl alcohol, amyl alcohol, ethylene glycol, propylene glycol, glycerine, *N*-methyl-2-pyrrolidinone, *N,N*-dimethyl alkylamides, dimethyl sulfoxide, liquid fertilizers and the like. In certain embodiments, water is the carrier for the dilution of concentrates.

Suitable solid carriers include but are not limited to talc, pyrophyllite clay, silica, attapulgus clay, kaolin clay, kieselguhr, chalk, diatomaceous earth, lime, calcium carbonate, bentonite clay, Fuller's earth, cottonseed hulls, wheat flour, soybean flour, pumice, wood flour, walnut shell flour, lignin, cellulose, and the like.

In some embodiments, the compositions described herein further comprise one or more surface-active agents. In some embodiments, such surface-active agents are employed in both solid and liquid compositions, and in certain embodiments those designed to be diluted with carrier before application. The surface-active agents can be anionic, cationic or nonionic in character and can be employed as emulsifying agents, wetting agents, suspending agents, or for other purposes. Surfactants which may also be used in the present formulations are described, *inter alia*, in *McCutcheon's Detergents and Emulsifiers Annual*, MC Publishing Corporation: Ridgewood, NJ, 1998 and in *Encyclopedia of Surfactants, Vol. I-III*, Chemical Publishing Company: New York, 1980-81. Surface-active agents include, but are not limited to salts of alkyl sulfates, such as diethanolammonium lauryl sulfate; alkylarylsulfonate salts, such as calcium dodecylbenzenesulfonate; alkylphenol-alkylene oxide addition products, such as nonylphenol-C₁₈ ethoxylate; alcohol-alkylene oxide addition products, such as tridecyl alcohol-C₁₆ ethoxylate; soaps, such as sodium stearate; alkyl-naphthalene-sulfonate salts, such as sodium dibutyl-naphthalenesulfonate; dialkyl esters of sulfosuccinate salts, such as sodium di(2-ethylhexyl) sulfosuccinate; sorbitol esters, such as sorbitol oleate; quaternary amines, such as lauryl trimethylammonium chloride; polyethylene glycol esters of fatty acids, such as polyethylene glycol stearate; block copolymers of ethylene oxide and propylene oxide; salts of mono and dialkyl phosphate esters; vegetable or seed oils such as soybean oil, rapeseed/canola oil, olive oil, castor oil, sunflower seed oil, coconut oil, corn oil, cottonseed oil, linseed oil, palm oil, peanut oil, safflower oil, sesame oil,

tung oil and the like; and esters of the above vegetable oils, and in certain embodiments, methyl esters.

In some embodiments, these materials, such as vegetable or seed oils and their esters, can be used interchangeably as an agricultural adjuvant, as a liquid carrier or as a surface
5 active agent.

Other exemplary additives for use in the compositions provided herein include but are not limited to compatibilizing agents, antifoam agents, sequestering agents, neutralizing agents and buffers, corrosion inhibitors, dyes, odorants, spreading agents, penetration aids, sticking agents, dispersing agents, thickening agents, freezing point depressants,
10 antimicrobial agents, and the like. The compositions may also contain other compatible components, for example, other herbicides, plant growth regulants, fungicides, insecticides, and the like and can be formulated with liquid fertilizers or solid, particulate fertilizer carriers such as ammonium nitrate, urea and the like.

III. Methods of use

15 Methods of controlling undesirable vegetation in 2,4-D- and glufosinate-tolerant soybeans, corn, or cotton, comprising contacting the vegetation or the locus thereof, including but not limited to foliage, soil or water, with a composition containing a mixture containing synergistic herbicidally effective amounts of (a) 2,4-D-choline and (b) a salt of glufosinate are described herein. In certain embodiments, the methods employ the compositions
20 described herein.

In another embodiment, methods of controlling undesirable vegetation in non-crop, perennial crop, fruiting crop, or plantation crop areas, comprising contacting undesirable
vegetation or the locus thereof, including but not limited to foliage, soil or water, with a composition containing a mixture containing synergistic herbicidally effective amounts of (a)
25 2,4-D-choline and (b) a salt of glufosinate are described herein. In certain embodiments, the methods employ the compositions described herein.

Agriculturally acceptable salts of glufosinate are anticipated to control undesirable vegetation in combination with 2,4-D-choline and a salt of glyphosate. An example of such an agriculturally acceptable salt of glufosinate includes glufosinate-ammonium.

The compositions and methods provided herein are utilized to control undesirable vegetation. Undesirable vegetation includes, but is not limited to, undesirable vegetation that occurs in 2,4-D- and glufosinate-tolerant soybeans, corn, or cotton; non-crop areas, including but not limited to pastures, grasslands, rangelands, fallowland, fencerows, parking areas, tank farms, storage areas, rights-of-way, utility areas, turf, forestry, aquatics, industrial vegetation management (IVM) and fallow-bed prior to planting crops; perennial crops where the application contacts the undesirable vegetation but does not contact the crop foliage, such as tree and vine orchards, including but not limited to citrus, grapes, almond, apple, apricot, avocado, beechnut, Brazil nut, butternut, cashew, cherry, chestnut, chinquapin, crab apple, date, feijoa, fig, filbert, hickory nut, kiwi, lemon, lime, loquat, macadamia nut, mandarins, mayhaws, nectarine, olives, oranges, peach, pear, pecan, persimmon, pistachio, plum, pomegranates, pome fruit, prune, stone fruit, tree nuts, quince and walnut; fruiting crops (including, but not limited to, blueberries, guava, papaya, strawberries, taro, blackberries and raspberries) and plantation crops (including, but not limited to, coffee, cacao, rubber and palm oil).

The compositions and methods provided herein are utilized to control undesirable vegetation. Undesirable vegetation includes, but is not limited to, undesirable vegetation that occurs in annual crops such as 2,4-D- and glufosinate-tolerant cereal crops, including but not limited to rice, wheat, barley, oats, rye and sorghum.

In some embodiments, the methods provided herein are utilized to control undesirable vegetation found in row crops, tree and vine crops, perennial crops and non-crop areas. In certain embodiments, the undesirable vegetation is *Alopecurus myosuroides* Huds. (blackgrass, ALOMY), *Amaranthus palmeri* S. Wats. (Palmer amaranth, AMAPA), *Avena fatua* L. (wild oat, AVEFA), *Brachiaria decumbens* Stapf. or *Urochloa decumbens* (Stapf) R.D. Webster (Surinam grass, BRADC), *Brachiaria brizantha* (Hochst. ex A. Rich.) Stapf. or *Urochloa brizantha* (Hochst. ex A. Rich.) R.D. (beard grass, BRABR), *Brachiaria platyphylla* (Groseb.) Nash or *Urochloa platyphylla* (Nash) R.D. Webster (broadleaf signalgrass, BRAPP), *Brachiaria plantaginea* (Link) Hitchc. or *Urochloa plantaginea* (Link) R.D. Webster (alexandergrass, BRAPL), *Cenchrus echinatus* L. (southern sandbur, CENEC), *Digitaria horizontalis* Willd. (Jamaican crabgrass, DIGHO), *Digitaria insularis* (L.) Mez ex Ekman (sourgrass, TRCIN), *Digitaria sanguinalis* (L.) Scop. (large crabgrass, DIGSA), *Echinochloa crus-galli* (L.) P. Beauv. (barnyardgrass, ECHCG), *Echinochloa colonum* (L.)

- Link (junglerice, ECHCO), *Eleusine indica* (L.) Gaertn. (goosegrass, ELEIN), *Lolium multiflorum* Lam. (Italian ryegrass, LOLMU), *Panicum dichotomiflorum* Michx. (fall panicum, PANDI), *Panicum miliaceum* L. (wild-proso millet, PANMI), *Sesbania exaltata* (Raf.) Cory/Rydb. Ex Hill (hemp sesbania, SEBEX), *Setaria faberi* Herrm. (giant foxtail, SETFA), *Setaria viridis* (L.) Beauv. (green foxtail, SETVI), *Sorghum halepense* (L.) Pers. (Johnsongrass, SORHA), *Sorghum bicolor* (L.) Moench ssp. *Arundinaceum* (shattercane, SORVU), *Cyperus esculentus* L. (yellow nutsedge, CYPES), *Cyperus rotundus* L. (purple nutsedge, CYPRO), *Abutilon theophrasti* Medik. (velvetleaf, ABUTH), *Amaranthus* species (pigweeds and amaranths, AMASS), *Ambrosia artemisiifolia* L. (common ragweed, 10 AMBEL), *Ambrosia psilostachya* DC. (western ragweed, AMBPS), *Ambrosia trifida* L. (giant ragweed, AMBTR), *Anoda cristata* (L.) Schlecht. (spurred anoda, ANVCR), *Asclepias syriaca* L. (common milkweed, ASCSY), *Bidens pilosa* L. (hairy beggarticks, BIDPI), *Borreria* species (BOISS), *Borreria alata* (Aubl.) DC. or *Spermacoce alata* Aubl. or *Spermacoce latifolia* (broadleaf buttonweed, BOILF), *Chenopodium album* L. (common 15 lambsquarters, CHEAL), *Cirsium arvense* (L.) Scop. (Canada thistle, CIRAR), *Commelina benghalensis* L. (tropical spiderwort, COMBE), *Datura stramonium* L. (jimsonweed, DATST), *Daucus carota* L. (wild carrot, DAUCA), *Euphorbia heterophylla* L. (wild poinsettia, EPHHL), *Euphorbia hirta* L. or *Chamaesyce hirta* (L.) Millsp. (garden spurge, EPHHI), *Euphorbia dentata* Michx. (toothed spurge, EPHDE), *Erigeron bonariensis* L. or 20 *Conyza bonariensis* (L.) Cronq. (hairy fleabane, ERIBO), *Erigeron canadensis* L. or *Conyza canadensis* (L.) Cronq. (horseweed, ERICA), *Conyza sumatrensis* (Retz.) E. H. Walker (tall fleabane, ERIFL), *Helianthus annuus* L. (common sunflower, HELAN), *Jacquemontia tamnifolia* (L.) Griseb. (smallflower morningglory, IAQTA), *Ipomoea hederacea* (L.) Jacq. (ivyleaf morningglory, IPOHE), *Ipomoea lacunosa* L. (white morningglory, IPOLA), 25 *Lactuca serriola* L./Torn. (prickly lettuce, LACSE), *Portulaca oleracea* L. (common purslane, POROL), *Richardia* species (pusley, RCHSS), *Salsola tragus* L. (Russian thistle, SASKR), *Sida* species (sida, SIDSS), *Sida spinosa* L. (prickly sida, SIDSP), *Sinapis arvensis* L. (wild mustard, SINAR), *Solanum ptychanthum* Dunal (eastern black nightshade, SOLPT), *Tridax procumbens* L. (coat buttons, TRQPR), or *Xanthium strumarium* L. (common 30 cocklebur, XANST).

In some embodiments, the methods provided herein are utilized to control undesirable vegetation in range and pasture areas. In certain embodiments, the undesirable vegetation is *Amaranthus palmeri* S. Wats. (Palmer amaranth, AMAPA), *Ambrosia artemisiifolia* L.

(common ragweed, AMBEL), *Cassia obtusifolia* (sickle pod, CASOB), *Centaurea maculosa* auct. non Lam. (spotted knapweed, CENMA), *Cirsium arvense* (L.) Scop. (Canada thistle, CIRAR), *Convolvulus arvensis* L. (field bindweed, CONAR), *Conyza canadensis* (L.) Cronq. (horseweed, ERICA), *Euphorbia esula* L. (leafy spurge, EPHES), *Lactuca serriola* L./Torn. (prickly lettuce, LACSE), *Plantago lanceolata* L. (buckhorn plantain, PLALA), *Rumex obtusifolius* L. (broadleaf dock, RUMOB), *Salsola tragus* L. (Russian thistle, SASKR), *Sesbania exaltata* (Raf.) Cory/Rydb. Ex Hill (hemp sesbania, SEBEX), *Sida spinosa* L. (prickly sida, SIDSP), *Sinapis arvensis* L. (wild mustard, SINAR), *Sonchus arvensis* L. (perennial sowthistle, SONAR), *Solidago* species (goldenrod, SOOSS), *Taraxacum officinale* G.H. Weber ex Wiggers (dandelion, TAROF), *Trifolium repens* L. (white clover, TRFRE), or *Urtica dioica* L. (common nettle, URTDI).

In some embodiments, the combination of 2,4-D-choline and a salt of glufosinate is used to synergistically control *Amaranthus palmeri* S. Wats. (Palmer amaranth, AMAPA), *Conyza canadensis* (L.) Cronq. (horseweed, ERICA), *Salsola tragus* L. (Russian thistle, SASKR) and *Sesbania exaltata* (Raf.) Cory/Rydb. Ex Hill (hemp sesbania, SEBEX).

2,4-D-choline and a salt of glufosinate may be used to control herbicide resistant or tolerant weeds. The methods employing the combination of 2,4-D-choline and a salt of glufosinate and the compositions described herein may also be employed to control herbicide resistant or tolerant weeds. Exemplary resistant or tolerant weeds include, but are not limited to, biotypes resistant or tolerant to acetolactate synthase (ALS) or acetohydroxy acid synthase (AHAS) inhibitors (e.g., imidazolinones, sulfonyleureas, pyrimidinylthiobenzoates, dimethoxy-pyrimidines, triazolopyrimidine sulfonamides, sulfonylaminocarbonyl triazolinones), photosystem II inhibitors (e.g., phenylcarbamates, pyridazinones, triazines, triazinones, uracils, amides, ureas, benzothiadiazinones, nitriles, phenylpyridazines), acetyl CoA carboxylase (ACCase) inhibitors (e.g., aryloxyphenoxypropionates, cyclohexanediones, phenylpyrazolines), synthetic auxins (e.g., benzoic acids, phenoxycarboxylic acids, pyridine carboxylic acids, quinoline carboxylic acids), auxin transport inhibitors (e.g., phthalamates, semicarbazones), photosystem I inhibitors (e.g., bipyridyliums), 5-enolpyruvylshikimate-3-phosphate (EPSP) synthase inhibitors (e.g., glyphosate), glutamine synthetase inhibitors (e.g., glufosinate, bialafos), microtubule assembly inhibitors (e.g., benzamides, benzoic acids, dinitroanilines, phosphoramidates, pyridines), mitosis inhibitors (e.g., carbamates), very long chain fatty acid (VLCFA)

inhibitors (*e.g.*, acetamides, chloroacetamides, oxyacetamides, tetrazolinones), fatty acid and lipid synthesis inhibitors (*e.g.*, phosphorodithioates, thiocarbamates, benzofuranes, chlorocarbonic acids), protoporphyrinogen oxidase (PPO) inhibitors (*e.g.*, diphenylethers, *N*-phenylphthalimides, oxadiazoles, oxazolidinediones, phenylpyrazoles, pyrimidinediones, thiadiazoles, triazolinones), carotenoid biosynthesis inhibitors (*e.g.*, clomazone, amitrole, aclonifen), phytoene desaturase (PDS) inhibitors (*e.g.*, amides, anilidex, furanones, phenoxybutan-amides, pyridiazinones, pyridines), 4-hydroxyphenyl-pyruvate-dioxygenase (HPPD) inhibitors (*e.g.*, callistemones, isoxazoles, pyrazoles, triketones), cellulose biosynthesis inhibitors (*e.g.*, nitriles, benzamides, quinclorac, triazolocarboxamides), herbicides with multiple modes-of-action such as quinclorac, and unclassified herbicides such as arylaminopropionic acids, difenzoquat, endothall, and organoarsenicals. Exemplary resistant or tolerant weeds include, but are not limited to, biotypes with resistance or tolerance to single or multiple herbicides, biotypes with resistance or tolerance to single or multiple chemical classes, biotypes with resistance or tolerance to single or multiple herbicide modes-of-action, and biotypes with single or multiple resistance or tolerance mechanisms (*e.g.*, target site resistance or metabolic resistance).

The compositions and methods described herein are used to control undesirable vegetation in 2,4-D- and glufosinate-tolerant soybeans, corn, or cotton which may also be combined with traits providing glyphosate tolerance (*e.g.*, resistant plant or bacterial *EPSPS*, *GOX*), dicamba-tolerance (*e.g.*, *DMO*), pyridyloxy auxin-tolerance (*e.g.*, *aad-12*, *aad-13*), auxin-tolerance, auxin transport inhibitor-tolerance, acetyl CoA carboxylase (*ACC*ase) inhibitor-herbicide tolerance [*e.g.*, aryloxyphenoxypropionate, cyclohexanedione, and phenylpyrazoline chemistries (*e.g.*, various *ACC*ase genes and *aad-1* gene)], acetolactate synthase (*ALS*)-inhibiting herbicide tolerance (*e.g.*, imidazolinone, sulfonylurea, triazolopyrimidine sulfonanilide, pyrimidinylthiobenzoates, and other chemistries = *AHAS*, *Csr1*, *SurA*), 4-hydroxyphenyl-pyruvate dioxygenase (HPPD) inhibitor-tolerance, phytoene desaturase (PDS) inhibitor-tolerance (*e.g.*, *pds*, *CYP1A1*, *CYP2B6*, *CYP2C19*), carotenoid biosynthesis inhibitor-tolerance, protoporphyrinogen oxidase (PPO) inhibitor-tolerance, cellulose biosynthesis inhibitor-tolerance (*e.g.*, *ixr2-1*, *CYP1A1*), mitosis inhibitor-tolerance, microtubule inhibitor-tolerance, very long chain fatty acid inhibitor-tolerance (*e.g.*, *CYP1A1*, *CYP2B6*, *CYP2C19*), fatty acid and lipid biosynthesis inhibitor-tolerance (*e.g.*, *CYP1A1*), photosystem I inhibitor-tolerance (*e.g.*, *SOD*), photosystem II inhibitor (triazine, nitrile, and phenylurea chemistries) tolerance (*e.g.*, *psbA*, *CYP1A1*, *CYP2B6*, *CYP2C19*, and *Bxn*), (such

as, but not limited to, soybean, corn, cotton, canola/oilseed rape, rice, cereals, sorghum, sunflower, sugar beet, sugarcane, and turf), for example, in conjunction with glyphosate, EPSP synthase inhibitors, glutamine synthase inhibitors, dicamba, phenoxy auxins, pyridyloxy auxins, synthetic auxins, auxin transport inhibitors, aryloxyphenoxypropionates, cyclohexanediones, phenylpyrazolines, ACCase inhibitors, imidazolinones, sulfonylureas, pyrimidinylthiobenzoates, dimethoxypyrimidines, triazolopyrimidine sulfonamides, sulfonylaminocarbonyltriazolinones, ALS or acetohydroxy acid synthase (AHAS) inhibitors, HPPD inhibitors, PDS inhibitors, carotenoid biosynthesis inhibitors, PPO inhibitors, cellulose biosynthesis inhibitors, mitosis inhibitors, microtubule inhibitors, very long chain fatty acid inhibitors, fatty acid and lipid biosynthesis inhibitors, photosystem I inhibitors, photosystem II inhibitors, triazines, and bromoxynil. The compositions and methods may be used in controlling undesirable vegetation in soybeans, corn, or cotton possessing single and multiple or stacked traits conferring tolerance to single or multiple chemistries and/or inhibitors of multiple modes of action.

The described embodiments and following examples are for illustrative purposes and are not intended to limit the scope of the claims. Other modifications, uses, or combinations with respect to the compositions described herein will be apparent to a person of ordinary skill in the art without departing from the spirit and scope of the claimed subject matter.

20

Examples

Example 1. Evaluation of Herbicidal Activity of Mixtures under Field Conditions

Methodology

These trials were conducted under field conditions in multiple states in the United States, including but not limited to Arkansas, Illinois, Indiana, Minnesota, Mississippi, Nebraska, Ohio, Oklahoma, Texas, South Carolina and South Dakota. Trials were

established as RCB (randomized complete block) design, with typically 3-4 replicates per treatment, and plot sizes varying from 6-15 feet (ft) wide by 10-25 ft long. Treatments were applied with small plot backpack sprayers, using pressurized air or carbon dioxide (CO₂) as propellant. Pressure varied from 22-50 pounds per square inch (psi), with spray tips typically of a Flat Fan type applying water diluent at 15 gallons per acre (GPA). Boom sizes varied from 6.3-10 ft in width. Treatments were applied to soybean, cotton, corn or fallow crop land. Weed sizes varied, but all treatments were applied as post-emergence treatments to weeds from 2 leaf to 2 tiller growth stages varying from 2 to 15 inches in height. The weed spectrum included, but was not limited to, *Amaranthus palmeri* S. Wats. (Palmer amaranth, AMAPA), *Conyza canadensis* (L.) Cronq. (horseweed, ERICA), *Salsola tragus* L. (Russian thistle, SASKR) and *Sesbania exaltata* (hemp sesbania, SEBEX).

2,4-D- and glufosinate-tolerant soybeans, corn and cotton and optionally a glyphosate trait in a breeding (*CP4 EPSPS*) or a molecular stack (*2mEPSPS*) were used in all tolerance trials.

15 Evaluation

Commercially available product of glufosinate-ammonium (Ignite[®] 280SL (Soluble Concentrate), containing 256 grams acid equivalent per liter (g ae/L)) was utilized in all trials, either applied alone or tank-mixed with ammonium sulfate liquid (2.5% volume per volume (vol/vol)). The 2,4-D-choline salt formulation was a 456 g ae/L SL. If ammonium sulfate was mixed with glufosinate-ammonium, then ammonium sulfate was also mixed with the 2,4-D-choline salt + glufosinate-ammonium mixture. All treatments were mixed in water at appropriate formulated product rates to achieve the desired rates as shown based on a unit area of application (hectare). Treatments were rated at 2 to 28 days after application (DAA) as compared to the untreated control plants. The trial sites had naturally occurring populations of weeds. The treated plots and control plots were rated blind at various intervals after application. Ratings were based on a Percent (%) Visual basis, where 0 corresponds to no visual effect as seen as exemplified by weed control or crop injury and 100 corresponds to complete kill of the target weeds or complete crop injury.

30 Data were collected for all trials and analyzed using various statistical methods.

Colby's equation was used to determine the herbicidal effects expected from the mixtures (Colby, S. R. Calculation of the synergistic and antagonistic response of herbicide combinations. *Weeds* 1967, 15, 20-22). A t-test ($\alpha=0.05$) between Colby predictions and observed combinations was used to test for significant differences indicating synergy or antagonism using replicate data. The results presented in Tables 1-5 were significant according to the described criteria.

The following equation was used to calculate the expected activity of mixtures containing two active ingredients, A and B:

$$\text{Expected} = A + B - (A \times B/100)$$

10 A = observed efficacy of active ingredient A at the same concentration as used in the mixture;

 B = observed efficacy of active ingredient B at the same concentration as used in the mixture.

The results are summarized in Tables 1-7.

15

Table 1. Synergistic Herbicidal Weed Control (%Visual Control) from Combinations of 2,4-D-Choline Salt + Glufosinate-ammonium in Multiple Field Trials at 7 to 28DAA.

Weed Bayer Code	Evaluation Interval	2,4-D-Choline salt		Glufosinate-ammonium		Combination	
		g ae/ha	Mean % weed control	g ae/ha	Mean % weed control	Measured mean % weed control	Colby predicted mean % weed control
AMAPA	7DAA	800	47.5	542	80.0	95.5	89.6
AMAPA	10DAA	1065	55.0	542	54.3	90.8	79.5
AMAPA	13DAA	1065	45.0	542	75.0	93.8	86.3
AMAPA	16DAA	800	62.5	542	65.0	95.3	86.9
AMAPA	21DAA	1065	38.8	542	51.3	92.5	70.3
AMAPA	22DAA	800	48.8	542	56.3	91.5	77.3
ERICA	7DAA	1065	40.0	542	75.0	90.0	85.0
ERICA	13DAA	1065	40.0	542	85.0	95.0	91.0
ERICA	22DAA	1065	40.0	542	80.0	98.0	88.0
ERICA	28DAA	1065	30.0	542	98.0	100.0	98.6
SASKR	14DAA	1065	67.5	542	12.5	91.3	71.4
SASKR	21DAA	1065	65.0	542	6.3	91.3	67.2
SEBEX	8DAA	800	32.5	542	73.8	97.0	81.4
SEBEX	16DAA	800	42.5	542	78.8	98.3	88.1
SEBEX	23DAA	800	38.8	542	65.0	96.5	79.1

Table 2. Improved AAD12 Soybean (GLXMA) Crop Tolerance Results (%Visual Injury) from Combinations of 2,4-D-Choline Salt + Glufosinate-ammonium in Multiple Field Trials at 2 to 7DAA.

		2,4-D-Choline salt		Glufosinate-ammonium		Combination	
Crop Bayer Code	Evaluation Interval	g ae/ha	Mean % crop injury	g ae/ha	Mean % crop injury	Measured mean % crop injury	Colby predicted mean % crop injury
GLXMA	2DAA	2130	5.0	1084	16.7	11.7	20.8
GLXMA	2DAA	2130	3.5	1084	1.5	1.5	4.9
GLXMA	3DAA	2130	0.3	1084	13.8	8.3	14.0
GLXMA	3DAA	1065	0.3	542	5.0	3.3	5.2
GLXMA	4DAA	2130	1.0	1084	23.3	16.7	24.1
GLXMA	4DAA	1065	0.0	542	16.7	6.0	16.7
GLXMA	4DAA	1065	0.0	542	9.3	3.0	9.3
GLXMA	6DAA	2130	4.0	1084	15.0	11.3	18.4
GLXMA	6DAA	1065	4.0	542	10.0	7.7	13.6
GLXMA	7DAA	2130	4.0	1084	28.3	16.0	31.2
GLXMA	7DAA	2130	13.3	822	15.0	20.0	26.3

5

Table 3. Improved AAD12 Soybean (GLXMA) Crop Tolerance Results (%Visual Injury) from Combinations of 2,4-D-Choline Salt + Glufosinate-ammonium in Multiple Field Trials at 9 to 15DAA.

		2,4-D-Choline salt		Glufosinate-ammonium		Combination	
Crop Bayer Code	Evaluation Interval	g ae/ha	Mean % crop injury	g ae/ha	Mean % crop injury	Measured mean % crop injury	Colby predicted mean % crop injury
GLXMA	9DAA	2130	0.0	1084	15.0	10.0	15.0
GLXMA	9DAA	1065	0.0	542	10.5	3.8	10.5
GLXMA	13DAA	2130	3.3	1084	10.7	6.3	13.6
GLXMA	13DAA	1065	2.0	542	6.3	3.3	8.2
GLXMA	14DAA	1065	3.0	542	3.5	4.5	6.4
GLXMA	14DAA	1065	0.0	542	2.5	1.3	2.5
GLXMA	14DAA	2130	2.3	1084	25.0	8.3	26.8
GLXMA	15DAA	2130	0.0	1084	8.3	1.5	8.3

10

Table 4. Improved AAD12 Soybean (GLXMA) Crop Tolerance Results (%Visual Chlorosis) from Combinations of 2,4-D-Choline Salt + Glufosinate-ammonium in Multiple Field Trials at 2 to 4DAA.

		2,4-D-Choline salt		Glufosinate-ammonium		Combination	
Crop Bayer Code	Evaluation Interval	g ae/ha	Mean % crop chlorosis	g ae/ha	Mean % crop chlorosis	Measured mean % crop chlorosis	Colby predicted mean % crop chlorosis
GLXMA	2DAA	2130	2.3	1084	12.8	9.3	14.7
GLXMA	2DAA	2130	0.0	1084	18.3	6.0	18.3
GLXMA	2DAA	2130	0.0	1084	9.3	4.5	9.3
GLXMA	3DAA	2130	0.0	1084	13.8	5.5	13.8
GLXMA	3DAA	2130	0.0	1084	15.0	3.8	15.0
GLXMA	3DAA	2130	1.3	1084	23.8	7.5	24.8
GLXMA	3DAA	2130	0.0	1084	12.8	7.3	12.8
GLXMA	3DAA	1065	0.0	542	6.8	3.5	6.8
GLXMA	3DAA	2130	0.8	1084	7.0	0.8	7.7
GLXMA	3DAA	2130	0.0	1084	10.5	6.3	10.5
GLXMA	3DAA	2130	0.5	1084	5.3	1.8	5.8
GLXMA	4DAA	2130	0.0	1084	25.0	6.0	25.0
GLXMA	4DAA	1065	0.0	542	10.7	3.0	10.7
GLXMA	4DAA	2130	0.0	1084	20.0	11.3	20.0
GLXMA	4DAA	1065	0.0	542	13.8	5.5	13.8
GLXMA	4DAA	2130	0.7	822	5.7	3.7	6.3
GLXMA	4DAA	2130	0.0	1084	15.3	9.0	15.3
GLXMA	4DAA	1065	0.0	542	7.0	5.0	7.0

Table 5. Improved AAD12 Soybean (GLXMA) Crop Tolerance Results (%Visual Chlorosis) from Combinations of 2,4-D-Choline Salt + Glufosinate-ammonium in Multiple Field Trials at 7 to 9DAA.

5

Crop Bayer Code	Evaluation Interval	2,4-D-Choline salt		Glufosinate-ammonium		Combination	
		g ae/ha	Mean % crop chlorosis	g ae/ha	Mean % crop chlorosis	Measured mean % crop chlorosis	Colby predicted mean % crop chlorosis
GLXMA	7DAA	2130	0.0	1084	10.0	0.0	10.0
GLXMA	7DAA	2130	0.0	822	4.3	0.0	4.3
GLXMA	7DAA	2130	0.0	1084	8.5	3.5	8.5
GLXMA	7DAA	1065	0.0	542	4.0	0.8	4.0
GLXMA	7DAA	2130	1.7	1084	28.3	7.7	29.6
GLXMA	7DAA	1065	0.0	542	11.7	3.7	11.7
GLXMA	7DAA	2130	0.0	822	8.3	0.0	8.3
GLXMA	7DAA	2130	1.3	822	18.3	11.7	19.4
GLXMA	7DAA	2130	3.0	822	18.3	11.7	20.8
GLXMA	8DAA	2130	0.0	1084	6.3	3.3	6.3
GLXMA	8DAA	2130	0.0	1084	11.0	5.0	11.0
GLXMA	8DAA	1065	0.0	542	4.5	2.5	4.5
GLXMA	8DAA	2130	0.0	1084	15.0	9.8	15.0
GLXMA	8DAA	1065	0.0	542	6.0	3.8	6.0
GLXMA	9DAA	2130	0.0	1084	20.0	11.3	20.0
GLXMA	9DAA	1065	0.0	542	15.0	5.8	15.0

Table 6. Improved AAD12 Soybean (GLXMA) Crop Tolerance Results (%Visual Chlorosis) from Combinations of 2,4-D-Choline Salt + Glufosinate-ammonium in Multiple Field Trials at 13 to 15DAA.

		2,4-D-Choline salt		Glufosinate-ammonium		Combination	
Crop Bayer Code	Evaluation Interval	g ae/ha	Mean % crop chlorosis	g ae/ha	Mean % crop chlorosis	Measured mean % crop chlorosis	Colby predicted mean % crop chlorosis
GLXMA	13DAA	2130	0.0	1084	1.3	0.3	1.3
GLXMA	13DAA	2130	0.0	1084	10.7	5.0	10.7
GLXMA	13DAA	1065	0.0	542	6.3	1.7	6.3
GLXMA	14DAA	2130	0.0	1084	1.5	0.0	1.5
GLXMA	14DAA	2130	0.0	822	1.7	0.0	1.7
GLXMA	14DAA	2130	0.0	1084	6.0	2.8	6.0
GLXMA	14DAA	2130	0.8	1084	9.0	4.5	9.7
GLXMA	14DAA	1065	0.0	542	1.8	0.8	1.8
GLXMA	14DAA	2130	1.3	1084	14.0	3.7	15.2
GLXMA	15DAA	2130	0.0	1084	7.0	0.0	7.0
GLXMA	15DAA	2130	0.0	1084	8.8	0.0	8.8

5 Table 7. Improved AAD12 Soybean (GLXMA) Crop Tolerance Results (%Growth Inhibition) from Combinations of 2,4-D-Choline Salt + Glufosinate-ammonium in Multiple Field Trials at 7 to 15DAA.

		2,4-D-Choline salt		Glufosinate-ammonium		Combination	
Crop Bayer Code	Evaluation Interval	g ae/ha	Mean % crop growth inhibition	g ae/ha	Mean % crop growth inhibition	Measured mean % crop chlorosis	Colby predicted mean % crop growth inhibition
GLXMA	7DAA	2130	1	1084	14.0	6.7	14.9
GLXMA	14DAA	2130	0	1084	23.3	0.0	23.3
GLXMA	14DAA	2130	0	1084	3.0	0.0	3.0
GLXMA	15DAA	2130	0	1084	9.8	0.0	9.8

The following abbreviations are used in the tables above:

10

2,4-D-choline = choline salt of 2,4-dichlorophenoxyacetic acid

glufosinate-ammonium = ammonium salt of 2-amino-4-(hydroxymethylphosphinyl)butanoic acid

15

AMAPA = *Amaranthus palmeri* S. Wats. (Palmer amaranth)

ERICA = *Conyza canadensis* (L.) Cronq. (horseweed)

SASKR = *Salsola tragus* L. (Russian thistle)

SEBEX = *Sesbania exaltata* (Raf.) Cory/Rydb. Ex Hill (hemp sesbania)

GLXMA = *Glycine max* L. (soybean)

5

g ae/ha = grams acid equivalent per hectare

DAA = Days After Application

10 The compositions and methods of the appended claims are not limited in scope by the specific compositions and methods described herein, which are intended as illustrations of a few aspects of the claims and any compositions and methods that are functionally equivalent are intended to fall within the scope of the claims. Various modifications of the compositions and methods in addition to those shown and described herein are intended to fall within the

15 scope of the appended claims. Further, while only certain representative composition materials and method steps disclosed herein are specifically described, other combinations of the composition materials and method steps also are intended to fall within the scope of the appended claims, even if not specifically recited. Thus, a combination of steps, elements, components, or constituents may be explicitly mentioned herein; however, other

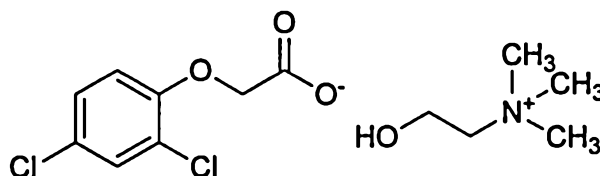
20 combinations of steps, elements, components, and constituents are included, even though not explicitly stated. The term “comprising” and variations thereof as used herein is used synonymously with the term “including” and variations thereof and are open, non-limiting terms. Although the terms “comprising” and “including” have been used herein to describe various embodiments, the terms “consisting essentially of” and “consisting of” can be used in

25 place of “comprising” and “including” to provide for more specific embodiments of the invention and are also disclosed.

WHAT IS CLAIMED IS:

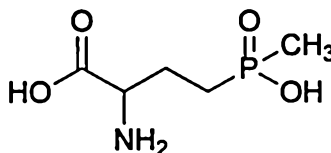
1. A composition for controlling undesirable vegetation, comprising a mixture comprising a synergistic, herbicidally effective amount of:

(a) a choline salt of 2,4-dichlorophenoxyacetic acid (2,4-D-choline)



and

(b) a salt of 2-amino-4-(hydroxymethylphosphinyl)butanoic acid (glufosinate)



2. The composition of claim 1, wherein the salt of glufosinate is the ammonium salt.

10 3. The composition of claim 1 or claim 2, wherein the weight ratio of (a) to (b) is from about 1:48 to about 64:1, from about 1:16 to about 24:1, from about 1:4 to about 4:1, or from about 1:2 to about 2:1.

4. The composition of any of claims 1-3, further comprising a herbicidally effective amount of an additional herbicide.

15 5. The composition of any of claims 1-4, further comprising an agriculturally acceptable adjuvant.

6. A method of controlling undesirable vegetation comprising contacting undesirable vegetation or the locus thereof, or foliage, water or soil, with the composition of any of claims 1-5.

20 7. The method of claim 6, wherein the composition is applied post-emergence to the undesirable vegetation.

8. The method of claim 6, wherein the composition is applied pre-emergence to the undesirable vegetation.
9. The method of claim 6, wherein the undesirable vegetation is contacted prior to planting a crop.
- 5 10. The method of claim 6, wherein the salt of glufosinate is the ammonium salt.
11. The method of any of claims 6-10, wherein the weight ratio of (a) to (b) is from about 1:48 to about 64:1, from about 1:16 to about 24:1, from about 1:4 to about 4:1, or from about 1:2 to about 2:1.
12. The method of any of claims 6-11, wherein (a) and (b) are applied simultaneously.
- 10 13. The method of any of claims 6-11, wherein (a) and (b) are applied sequentially.
14. The method of any of claims 6-13, wherein synergy is determined by the Colby equation.
15. The method of any of claims 6-14, wherein the undesirable vegetation comprises a herbicide resistant or tolerant weed.
- 15 16. The method of claim 15, wherein the resistant or tolerant weed is a biotype with resistance or tolerance to single or multiple herbicides or single or multiple chemical classes, or inhibitors of single or multiple herbicide modes-of-action.
17. The method of claim 15 or claim 16, wherein the resistant or tolerant weed is a biotype resistant or tolerant to acetolactate synthase (ALS) or acetohydroxy acid synthase
20 (AHAS) inhibitors, photosystem II inhibitors, acetyl CoA carboxylase (ACCase) inhibitors, photosystem I inhibitors, 5-enolpyruvyl-shikimate-3-phosphate (EPSP) synthase inhibitors, microtubule assembly inhibitors, lipid synthesis inhibitors, protoporphyrinogen oxidase (PPO) inhibitors, carotenoid biosynthesis inhibitors, very long chain fatty acid (VLCFA) inhibitors, phytoene desaturase (PDS) inhibitors, glutamine synthetase inhibitors, 4-
25 hydroxyphenyl-pyruvate-dioxygenase (HPPD) inhibitors, mitosis inhibitors, cellulose biosynthesis inhibitors, herbicides with multiple modes-of-action, quinclorac, arylaminopropionic acids, difenzoquat, endothall or organoarsenicals.

18. The method of any of claims 6-17, further comprising contacting the undesirable vegetation with a herbicidally effective amount of an additional herbicide.

19. The method of any of claims 6-18, wherein the undesirable vegetation is controlled in a non-crop, perennial crop, fruiting crop, or plantation crop area, comprising contacting
5 undesirable vegetation or the locus thereof, or foliage, water or soil, in a non-crop, perennial crop, fruiting crop, or plantation crop area.

20. The method of claim 19, wherein the undesirable vegetation is in a non-crop area and the non-crop area is a pasture, grassland, rangeland, fallowland, fencerow, parking area, tank farm, storage area, rights-of-way, utility area, turf, forestry, aquatics, industrial vegetation
10 management (IVM) or fallow-bed.

21. The method of claim 19, wherein the undesirable vegetation is in a perennial crop area and the foliage of the perennial crop is not contacted when the undesirable vegetation is contacted.

22. The method of claim 21, wherein the perennial crop is a tree and vine orchard.

15 23. The method of claim 22, wherein the tree and vine orchard is selected from citrus, grapes, almond, apple, apricot, avocado, beechnut, Brazil nut, butternut, cashew, cherry, chestnut, chinquapin, crab apple, date, feijoa, fig, filbert, hickory nut, kiwi, lemon, lime, loquat, macadamia nut, mandarin, mayhaws, nectarine, olives, orange, peach, pear, pecan, persimmon, pistachio, plum, pome fruit, pomegranates, prune, quince, stone fruit, tree nuts
20 and walnut.

24. The method of claim 19, wherein the undesirable vegetation is in a fruiting crop area and the foliage of the fruiting crop is not contacted when the undesirable vegetation is contacted.

25 25. The method of claim 24, wherein the fruiting crop is selected from blueberries, guava, papaya, strawberries, taro, blackberries and raspberries.

26. The method of claim 19, wherein the undesirable vegetation is in a plantation crop area and the foliage of the plantation crop is not contacted when the undesirable vegetation is contacted.

27. The method of claim 26, wherein the plantation crop is selected from coffee, cacao, rubber and palm oil.

ABSTRACT

Provided herein are herbicidal compositions comprising a mixture comprising (a) a choline salt of 2,4-dichlorophenoxyacetic acid (2,4-D-choline) and (b) a salt of 2-amino-4-(hydroxymethylphosphinyl) butanoic acid (glufosinate). The compositions provide synergistic weed control of undesirable vegetation and improved crop tolerance in 2,4-D- and glufosinate-tolerant soybeans, corn, or cotton. The compositions also provide synergistic weed control of undesirable vegetation in areas including, but not limited to, non-crop, perennial crop, fruiting crop, and plantation crop areas.