

(19) **DANMARK**

(10) **DK/EP 2877006 T3**



(12) **Oversættelse af
europæisk patentskrift**

Patent- og
Varemærkestyrelsen

-
- (51) Int.Cl.: **A 01 N 43/40 (2006.01)** **A 01 N 41/10 (2006.01)** **A 01 N 43/56 (2006.01)**
A 01 N 43/80 (2006.01) **A 01 P 13/00 (2006.01)**
- (45) Oversættelsen bekendtgjort den: **2019-07-15**
- (80) Dato for Den Europæiske Patentmyndigheds bekendtgørelse om meddelelse af patentet: **2019-04-10**
- (86) Europæisk ansøgning nr.: **13822178.3**
- (86) Europæisk indleveringsdag: **2013-07-19**
- (87) Den europæiske ansøgnings publiceringsdag: **2015-06-03**
- (86) International ansøgning nr.: **US2013051312**
- (87) Internationalt publikationsnr.: **WO2014018402**
- (30) Prioritet: **2012-07-24 US 201261675063 P** **2013-03-15 US 201313833372**
- (84) Designerede stater: **AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR**
- (73) Patenthaver: **Dow AgroSciences LLC, 9330 Zionsville Road, Indianapolis IN 46268-1054, USA**
- (72) Opfinder: **YERKES, Carla N., 4571 South State Road 47, Crawfordsville, IN 47933, USA**
MANN, Richard K., 1828 South 550 East, Franklin, IN 46131, USA
- (74) Fuldmægtig i Danmark: **Chas. Hude A/S, H.C. Andersens Boulevard 33, 1780 København V, Danmark**
- (54) Benævnelse: **HERBICIDE SAMMENSÆTNINGER DER OMFATTER 4-AMINO-3-CHLOR-5-FLUOR-6-(4-CHLOR-2-FLUOR-3-METHOXYPHENYL)PYRIDIN-2-CARBOXYLSYRE**
- (56) Fremdragne publikationer:
WO-A2-2009/029518
US-A1- 2010 137 137
US-A1- 2012 115 727

DESCRIPTION

Field

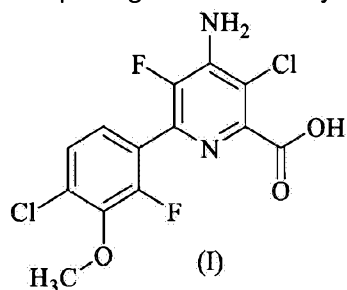
[0001] Provided herein are herbicidal compositions comprising (a) 4-amino-3-chloro-5-fluoro-6-(4-chloro-2-fluoro-3-methoxyphenyl)pyridine-2-carboxylic acid or a C₁₋₄ alkyl or benzyl ester or a sodium, potassium, magnesium, or ammonium salt thereof and (b) a 4-hydroxyphenyl-pyruvate dioxygenase (HPPD) inhibitor, wherein (b) is at least one compound, or an agriculturally acceptable salt, carboxylic acid, carboxylate salt, or ester thereof, selected from the group consisting of: benzobicyclon, isoxaflutole, mesotrione, pyrazolynate, and sulcotrione, as well as methods of controlling undesirable vegetation comprising applying (a) and (b).

Background

[0002] The protection of crops from weeds and other vegetation which inhibit crop growth is a constantly recurring problem in agriculture. To help combat this problem, researchers in the field of synthetic chemistry have produced an extensive variety of chemicals and chemical formulations effective in the control of such unwanted growth. Chemical herbicides of many types have been disclosed in the literature and a large number are in commercial use. However, there remains a need for compositions and methods that are effective in controlling undesirable vegetation. WO 2009/029518 discloses synergistic herbicidal mixtures of halauxifen with e.g. sulcotrione.

Summary

[0003] A first embodiment of the invention provided herein includes herbicidal compositions comprising an herbicidally effective amount of (a) a compound of the formula (I)



or a C₁₋₄ alkyl or benzyl ester or a sodium, potassium, magnesium, or ammonium salt thereof, and (b) at least one HPPD inhibitor, wherein (b) is at least one compound, or an agriculturally acceptable salt, carboxylic acid, carboxylate salt, or ester thereof, selected from the group consisting of: benzobicyclon, isoxaflutole, mesotrione, pyrazolynate, and sulcotrione.

[0004] A second embodiment includes the mixture of the first embodiment in which formula (I)

is present in at least one of the following forms: a carboxylic acid, an unsubstituted benzyl, a C₁₋₄ alkyl, and/or an n-butyl ester.

[0005] A third embodiment includes the mixtures according to either the first or second embodiments in which the HPPD inhibitor in the mixture is benzobicyclon wherein the weight ratio of the compound of formula (I) to benzobicyclon given in units of gae/ha to gai/ha or gae/ha to gae/ha is selected from the group of ranges of ratios and ratios consisting of about 1:150 to 6:1, 1:75 to 3:1, 1:46 to 2:1, 1:46 to 1:1, 1:9.4, 1:47, 1:18.9, 1:38, 1:19, 1:37.7 to 1:4.7, 1:11.4, 1:5.7, 1:23, 1:46, 1:23, 1:4.7 to 1:5.7, 1:46 to 1:11, 1:19, 1:19 to 1:4.7, 1:2.6, 1.18, and 1:23 to 1:6, or within any range defined between any pair of the foregoing values.

[0006] A fourth embodiment includes the mixtures according to either the first or second embodiments in which the HPPD inhibitor in the mixture is isoxaflutole wherein the weight ratio of the compound of formula (I) to isoxaflutole given in units of gae/ha to gai/ha or gae/ha to gae/ha is selected from the group of ranges of ratios and ratios consisting of about: 1:70 to 12:1, 1:70 to 2:1, 1:35 to 6:1, 1:9 to 3:1, 1:4.4, 1:2.2, 1:1, 1:4.4 to 1:1, 1:8, and 1:2, or within any range defined between any pair of the foregoing values.

[0007] A fifth embodiment includes the mixtures according to either the first or second embodiments in which the HPPD inhibitor in the mixture is mesotrione wherein the weight ratio of the compound of formula (I) to mesotrione given in units of gae/ha to gai/ha or gae/ha to gae/ha is selected from the group of ranges of ratios and ratios consisting of about: 1:115 to 17:1, 1:56 to 8:1, 1:32 to 2:1, 1:4, 1:2, 1:1, 1:1.7, 1:8, 1:3.3, 1:16, 1:8 to 1:1, 1:1 to 1:16, or within any range defined between any pair of the foregoing values.

[0008] A sixth embodiment includes the mixtures according to either the first or second embodiments in which the HPPD inhibitor in the mixture is pyrazolynate wherein the weight ratio of the compound of formula (I) to pyrazolynate given in units of gae/ha to gai/ha or gae/ha to gae/ha is selected from the group of ranges of ratios and ratios consisting of about: 1:229 to 8:1, 1:229 to 2:1, 1:115 to 4:1, 1:78 to 4:1, 1:34 to 3:1, 1:4.3, 1:3, 1:8, 1:9, 1:2 to 1:9, 1:4.3 to 1:1, 1:0.4, 1:0.8, 1:1.6, 1:0.4 to 1:1.6, 1:17, 1:4.3 to 1:17.1, 1:8.6 to 1:17, or within any range defined between any pair of the foregoing values.

[0009] A seventh embodiment includes the mixtures according to either the first or second embodiments in which the HPPD inhibitor in the mixture is sulcotrione wherein the weight ratio of the compound of formula (I) to sulcotrione given in units of gae/ha to gai/ha or gae/ha to gae/ha is selected from the group of ranges of ratios and ratios consisting of about: 1:300 to 13:1, 1:150 to 6.5:1, 1:75 to 3.3:1, 1:34 to 2:1, 1:9, 1:3, 1:4, 1:17, 1:34, 1:4.3 to 1:34.2, 1:2, 1:5, 1:8.6 to 1:35, or within any range defined between any pair of the foregoing values.

[0010] An eighth embodiment includes any composition according to any of the first through the seventh embodiments wherein the mixture further comprises at least one of an agriculturally acceptable agent selected from the group consisting of an adjuvant, a carrier, or a safener.

[0011] A ninth embodiment includes methods of controlling undesirable vegetation comprising the step of applying or otherwise contacting vegetation and/or soil, and/ or water with a herbicidally effective amount of at least one mixture according to any of the first through the eighth embodiments.

[0012] A tenth embodiment includes methods according to the ninth embodiment wherein the method is practiced in at least one member of the group consisting of: direct-seeded, water-seeded, and/or transplanted rice, cereals, wheat, barley, oats, rye, sorghum, corn/maize, sugarcane, sunflower, oilseed rape, canola, sugar beet, soybean, cotton, pineapple, pastures, grasslands, rangelands, fallowland, turf, tree and vine orchards, aquatics, plantation crops, vegetables, industrial vegetation management (IVM), or rights-of-way (ROW).

[0013] An eleventh embodiment includes methods according to either of the ninth and tenth embodiments wherein a herbicidally effective amount of the mixture is applied either pre- or post-emergently to at least one of the following: a crop, a field, a ROW, or a rice paddy.

[0014] A twelfth embodiment includes methods according to any of the ninth through the eleventh embodiments wherein the undesirable vegetation may be controlled in: glyphosate-, 5-enolpyruvylshikimate-3-phosphate (EPSP) synthase inhibitor-, glufosinate-, glutamine synthetase inhibitor-, dicamba-, phenoxy auxin-, pyridyloxy auxin-, synthetic auxin-, auxin transport inhibitor-, aryloxyphenoxypropionate-, cyclohexanedione-, phenylpyrazoline-, acetyl CoA carboxylase (ACCase) inhibitor-, imidazolinone-, sulfonyleurea-, pyrimidinylthiobenzoate-, triazolopyrimidine-, sulfonylaminocarbonyltriazolinone-, acetolactate synthase (ALS) or acetohydroxy acid synthase (AHAS) inhibitor-, 4-hydroxyphenyl-pyruvate dioxygenase (HPPD) inhibitor-, phytoene desaturase inhibitor-, carotenoid biosynthesis inhibitor-, protoporphyrinogen oxidase (PPO) inhibitor-, cellulose biosynthesis inhibitor-, mitosis inhibitor-, microtubule inhibitor-, very long chain fatty acid inhibitor-, fatty acid and lipid biosynthesis inhibitor-, photosystem I inhibitor-, photosystem II inhibitor-, protoporphyrinogen oxidase (PPO) inhibitor-, triazine-, or bromoxynil-tolerant crops.

[0015] A thirteenth embodiment includes at least one method according to any of the ninth through the twelfth embodiments wherein the resistant or tolerant crop possesses multiple or stacked traits conferring tolerance to multiple herbicides or inhibitors of multiple herbicide modes of action, in some embodiments the treated plant that expresses resistance or tolerant to a herbicide is a itself undesirable vegetation.

[0016] A fourteenth embodiment includes methods according to the twelfth embodiment, wherein the undesirable vegetation comprises a herbicide resistant or tolerant weed.

[0017] A fifteenth embodiment includes methods according to the fourteenth embodiment, wherein the resistant or tolerant weed is a biotype with resistance or tolerance to multiple herbicides, multiple chemical classes, inhibitors of multiple herbicide modes-of-action, or via multiple resistance mechanisms.

[0018] A sixteenth embodiment includes at least one of the methods according to either the fourteenth or fifteenth embodiments, wherein the resistant or tolerant undesirable plant is a biotype resistant or tolerant to at least one of the following herbicide groups: acetolactate synthase (ALS) inhibitors or acetohydroxy acid synthase (AHAS) inhibitors, photosystem II inhibitors, acetyl CoA carboxylase (ACCase) inhibitors, synthetic auxins, auxin transport inhibitors, photosystem I inhibitors, 5-enolpyruvylshikimate-3-phosphate (EPSP) synthase inhibitors, microtubule assembly inhibitors, fatty acid and 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-hydroxyphenyl-pyruvate-dioxygenase (HPPD) inhibitors, mitosis inhibitors, cellulose biosynthesis inhibitors, herbicides with multiple modes-of-action, quinclorac, arylaminopropionic acids, difenzoquat, endothall, or organoarsenicals.

[0019] A seventeenth embodiment includes methods of controlling undesirable vegetation comprising the step of applying a herbicidally effective amount of at least one mixture according to the third embodiment wherein the amount of the mixture is applied at a rate, expressed in gai/ha or gae/ha of benzobicyclon selected from the group of rates and ranges of rates consisting of, about: 25, 50, 100, 200, 300 or within any range defined between any pair of the foregoing values.

[0020] An eighteenth embodiment includes methods according to the seventeenth embodiment wherein the controlled plant is at least one plant selected from the group consisting of: SCPJU, ECHCO, CYPUR, CYPUR, ECHOR, ECHCG and SCPMA, still other embodiments include controlling plants from the genera consisting of: *Echinochloa*, *Schoenoplectus*, *Cyperus*, and *Bolboschoenus*.

[0021] A nineteenth embodiment includes methods of controlling undesirable vegetation comprising the step of applying a herbicidally effective amount of at least one a mixture according to the fourth embodiment wherein the amount of the mixture is applied at a rate, expressed in gai/ha or gae/ha of isoxaflutole selected from the group of rates and ranges of rates consisting of, about: 10, 25, 35, 70, 100, 140, or within any range defined between any pair of the foregoing values.

[0022] A twentieth embodiment includes methods according to the nineteenth embodiment wherein the controlled plant is at least one plant selected from the group consisting of: IPOHE, XANST and SETVI still other embodiments include controlling plants from the genera consisting of: *Ipomoea*, *Xanthium* and *Setaria*.

[0023] A twenty-first embodiment includes methods of controlling undesirable vegetation comprising the step of applying a herbicidally effective amount of at least one a mixture according to the fifth embodiment wherein the amount of the mixture is applied at a rate, expressed in gai/ha or gae/ha of mesotrione selected from the group of rates and ranges of rates consisting of, about: 5, 10, 17.5, 35, 70, 100, 140, 200, 225, 280, or within any range

defined between any pair of the foregoing values.

[0024] A twenty-second embodiment includes methods according to the twenty-first embodiment wherein the controlled plant is at least one plant selected from the group consisting of: BRAPP, ECHCO, CYPIR, IPOHE, SCPJU, DIGSA, ECHCG, ECHOR, FIMMI and SCPMA, still other embodiments include controlling plants from the genera consisting of: *Brachiaria*, *Echinochloa*, *Cyperus*, *Ipomoea*, *Schoenoplectus*, *Digitaria*, *Fimbristylis*, and *Bolboschoenus*.

[0025] A twenty-third embodiment includes methods of controlling undesirable vegetation comprising the step of applying a herbicidally effective amount of at least one a mixture according to the sixth embodiment wherein the amount of the mixture is applied at a rate, expressed in gai/ha or gae/ha of pyrazolynate selected from the group of rates and ranges of rates consisting of, about: 10, 25, 37.5, 70, 100, 150, 200, 250, 300, 350, 400, 450, 500, or within any range defined between any pair of the foregoing values.

[0026] A twenty-fourth embodiment includes methods according to the twenty-third embodiments wherein the controlled plant is at least one plant selected from the group consisting of: ECHCG, ECHCO, LEFCH, FIMMI, SCPMA, ECHOR, SCPJU, and CYPRO, still other embodiments include controlling plants from the genera consisting of: *Echinochloa*, *Leptochloa*, *Fimbristylis*, *Bolboschoenus*, *Schoenoplectus*, and *Cyperus*.

[0027] A twenty-fifth embodiment includes methods of controlling undesirable vegetation comprising the step of applying a herbicidally effective amount of at least one a mixture according to the seventh embodiment wherein the amount of the mixture is applied at a rate, expressed in gai/ha or gae/ha of sulcotrione selected from the group of rates and ranges of rates consisting of, about: 10, 20, 37.5, 75, 100, 150, 200, 250, 300, 400, 500, 600, or within any range defined between any pair of the foregoing values.

[0028] A twenty-sixth embodiment includes methods according to the twenty-fifth embodiment wherein the controlled plant is at least one plant selected from the group consisting of: BRAPP, DIGSA, ECHCG, ECHCO, ECHOR, and IPOHE, still other embodiments include controlling plants from the genera consisting of: *Brachiaria* or *Urochloa*, *Digitaria*, *Echinochloa*, and *Ipomoea*.

[0029] A twenty-seventh embodiment includes methods according to any one of the ninth to twenty-sixth embodiments, wherein the undesirable vegetation is immature.

[0030] A twenty-eighth embodiment includes methods according to any one of the ninth to twenty- seventh embodiments, wherein in the (a) and (b) are applied to water.

[0031] A twenty-ninth embodiment includes compositions according to either the first or second embodiments, wherein the (b) is benzobicyclon or an agriculturally acceptable salt or ester thereof.

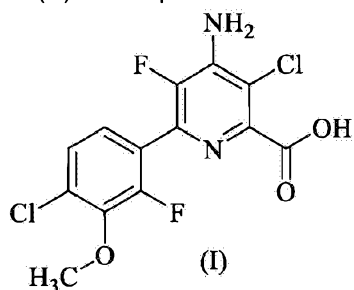
[0032] A thirtieth embodiment includes compositions according to either the first or second embodiments, wherein the (b) is isoxaflutole or an agriculturally acceptable salt or ester thereof.

[0033] A thirty-first embodiment includes compositions according to either the first or second embodiments, wherein the (b) is mesotrione or an agriculturally acceptable salt or ester thereof.

[0034] A thirty-second embodiment includes compositions according to either the first or second embodiments, wherein the (b) is pyrazolynate or an agriculturally acceptable salt or ester thereof.

[0035] A thirty-third embodiment includes compositions according to either the first or second embodiments, wherein the (b) is sulcotrione or an agriculturally acceptable salt or ester thereof.

[0036] Provided herein are herbicidal compositions comprising a herbicidally effective amount of (a) a compound of the formula (I)



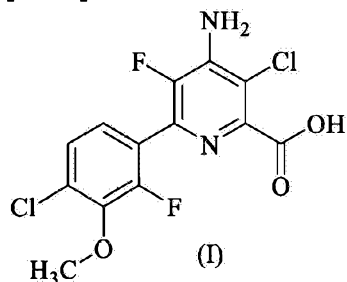
or a C₁₋₄ alkyl or benzyl ester of formula (I) or a sodium, potassium, magnesium, or ammonium salt of formula (I), and (b) a 4-hydroxyphenyl-pyruvate dioxygenase (HPPD) inhibitor. The compositions may also contain an agriculturally acceptable adjuvant or carrier, wherein (b) is at least one compound, or an agriculturally acceptable salt, carboxylic acid, carboxylate salt, or ester thereof, selected from the group consisting of: benzobicyclon, isoxaflutole, mesotrione, pyrazolynate, and sulcotrione.

[0037] Provided herein are also methods of controlling undesirable vegetation comprising applying (a) a compound of formula (I) or a C₁₋₄ alkyl or benzyl ester of formula (I) or a sodium, potassium, magnesium, or ammonium salt of formula (I) and (b) a 4-hydroxyphenyl-pyruvate dioxygenase (HPPD) inhibitor or an agriculturally acceptable salt or ester thereof, wherein (b) is at least one compound, or an agriculturally acceptable salt, carboxylic acid, carboxylate salt, or ester thereof, selected from the group consisting of: benzobicyclon, isoxaflutole, mesotrione, pyrazolynate, and sulcotrione.

Detailed Description

DEFINITIONS

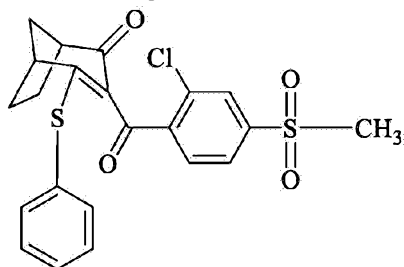
[0038] As used herein, the compound of formula (I) has the following structure:



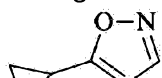
The compound of formula (I) can be identified by the name 4-amino-3-chloro-6-(4-chloro-2-fluoro-3-methoxyphenyl)-5-fluoropyridine-2-carboxylic acid and has been described in U.S. Patent 7,314,849 (B2). Exemplary uses of the compound of the formula (I) include controlling undesirable vegetation, including grass, broadleaf and sedge weeds, in multiple non-crop and cropping situations.

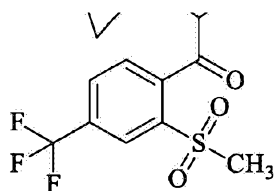
[0039] Without being limited to any theory, HPPD inhibitors are inhibitors of 4-hydroxyphenylpyruvate dioxygenase, an oxygenase involved in the creation of energy in plants and higher order eukaryotes. The HPPD inhibitors used herein include benzobicyclon, isoxaflutole, mesotrione, pyrazolynate, and sulcotrione,.

[0040] As used herein, benzobicyclon is 3-(2-chloro-4-mesylbenzoyl)-2-phenylthiobicyclo[3.2.1]oct-2-en-4-one. Exemplary uses of benzobicyclon are described in Tomlin, C., ed. *A World Compendium The Pesticide Manual*. 15th ed. Alton: BCPC Publications, 2009 (hereafter "The Pesticide Manual, Fifteenth Edition, 2009."). Exemplary uses of benzobicyclon include its use for pre-emergent and post-emergence control of annual and perennial paddy weeds in direct-seeded and transplanted rice. Benzobicyclon possesses the following structure:

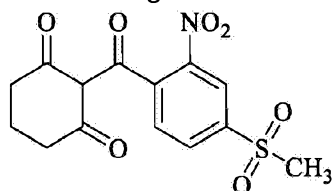


[0041] As used herein, isoxaflutole is (5-cyclopropyl-4-isoxazolyl)[2-(methylsulfonyl)-4-(trifluoromethyl)phenyl]methanone. Exemplary uses of isoxaflutole are described in *The Pesticide Manual, Fifteenth Edition, 2009*. Exemplary uses of isoxaflutole include its use for pre-emergence control of broadleaf weeds and grass weeds in maize. Isoxaflutole possesses the following structure:

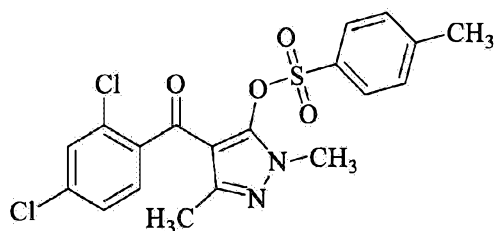




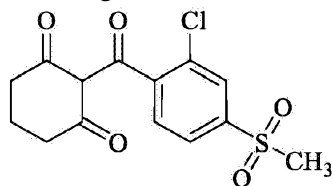
[0042] As used herein, mesotrione is 2-[4-(methylsulfonyl)-2-nitrobenzoyl]-1,3-cyclohexanedione. Exemplary uses of mesotrione are provided in The Pesticide Manual, Fifteenth Edition, 2009. Exemplary uses of mesotrione include its use for pre-emergence and post-emergence control of broadleaf weeds and grass weeds in maize. Mesotrione possesses the following structure:



[0043] As used herein, pyrazolynate is (2,4-dichlorophenyl)[1,3-dimethyl-5-[[4-(4-methylphenyl)sulfonyl]oxy]-1H-pyrazol-4-yl]methanone. Exemplary uses of pyrazolynate are described in The Pesticide Manual, Fifteenth Edition, 2009. Exemplary uses of pyrazolynate include its use for control of grasses, sedges, *Potamogeton distinctus*, *Sagittaria pygmaea*, *Sagittaria trifolia* and *Alisma canaliculatum* in paddy rice. Pyrazolynate possesses the following structure:



[0044] As used herein, sulcotrione is 2-[2-chloro-4-(methylsulfonyl)benzoyl]-1,3-cyclohexanedione. Exemplary uses of sulcotrione is described in The Pesticide Manual, Fifteenth Edition, 2009. Exemplary uses of sulcotrione include its use for control of broadleaf weeds and grasses post-emergence in maize and sugar cane. Sulcotrione possesses the following structure:



[0045] As used herein, herbicide means a compound, e.g., active ingredient that kills, controls

or otherwise adversely modifies the growth of plants.

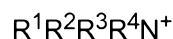
[0046] As used herein, a herbicidally effective or vegetation controlling amount is an amount of active ingredient which causes an adversely modifying effect to the vegetation *e.g.*, causing deviations from natural development, killing, effecting regulation, causing desiccation, causing retardation, and the like.

[0047] As used herein, controlling undesirable vegetation means preventing, reducing, killing, or otherwise adversely modifying the development of plants and vegetation. Described herein are methods of controlling undesirable vegetation through the application of certain herbicide combinations or compositions. Methods of application include, but are not limited to applications to the vegetation or locus thereof, *e.g.*, application to the area adjacent to the vegetation, as well as pre-emergence, post-emergence, foliar (broadcast, directed, banded, spot, mechanical, over-the-top, or rescue), and in-water applications (emerged and submerged vegetation, broadcast, spot, mechanical, water-injected, granular broadcast, granular spot, shaker bottle or stream spray) via hand, backpack, machine, tractor, or aerial (airplane and helicopter) application methods.

[0048] As used herein, plants and vegetation include, but are not limited to, germinant seeds, emerging seedlings, plants emerging from vegetative propagules, immature vegetation, and established vegetation.

[0049] As used herein, agriculturally acceptable salts and esters refer to salts and esters that exhibit herbicidal activity, or that are or can be converted in plants, water, or soil to the referenced herbicide. Exemplary agriculturally acceptable esters are those that are or can be hydrolyzed, oxidized, metabolized, or otherwise converted, *e.g.*, in plants, water, or soil, to the corresponding carboxylic acid which, depending on the pH, may be in the dissociated or undissociated form.

[0050] Exemplary salts include those derived from alkali or alkaline earth metals and those derived from ammonia and amines. Exemplary cations include sodium, potassium, magnesium, and aminium cations of the formula:



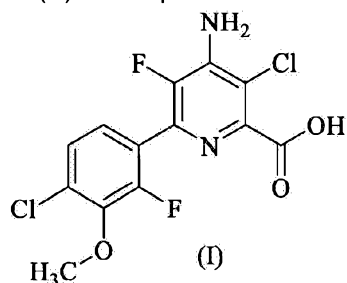
wherein R^1 , R^2 , R^3 and R^4 each, independently, represents hydrogen or C_1 - C_{12} alkyl, C_3 - C_{12} alkenyl or C_3 - C_{12} alkynyl, each of which is optionally substituted by one or more hydroxy, C_1 - C_4 alkoxy, C_1 - C_4 alkylthio or phenyl groups, provided that R^1 , R^2 , R^3 and R^4 are sterically compatible. Additionally, any two of R^1 , R^2 , R^3 and R^4 together may represent an aliphatic difunctional moiety containing one to twelve carbon atoms and up to two oxygen or sulfur atoms. Salts can be prepared by treatment with a metal hydroxide, such as sodium hydroxide, with an amine, such as ammonia, trimethylamine, diethanolamine, 2-methylthiopropylamine, bisallylamine, 2-butoxyethylamine, morpholine, cyclododecylamine, or benzylamine or with a

tetraalkylammonium hydroxide, such as tetramethylammonium hydroxide or choline hydroxide.

[0051] Exemplary esters include those derived from C₁-C₁₂ alkyl, C₃-C₁₂ alkenyl, C₃-C₁₂ alkynyl or C₇-C₁₀ aryl-substituted alkyl alcohols, such as methyl alcohol, isopropyl alcohol, 1-butanol, 2-ethylhexanol, butoxyethanol, methoxypropanol, allyl alcohol, propargyl alcohol, cyclohexanol or unsubstituted or substituted benzyl alcohols. Benzyl alcohols may be substituted with from 1-3 substituents independently selected from halogen, C₁-C₄ alkyl or C₁-C₄ alkoxy. Esters can be prepared by coupling of the acids with the alcohol using any number of suitable activating agents such as those used for peptide couplings such as dicyclohexylcarbodiimide (DCC) or carbonyl diimidazole (CDI); by reacting the acids with alkylating agents such as alkylhalides or alkylsulfonates in the presence of a base such as triethylamine or lithium carbonate; by reacting the corresponding acid chloride of an acid with an appropriate alcohol; by reacting the corresponding acid with an appropriate alcohol in the presence of an acid catalyst or by transesterification.

COMPOSITIONS AND METHODS

[0052] Provided herein are herbicidal compositions comprising a herbicidally effective amount of (a) a compound of the formula (I)



or an C₁₋₄ alkyl or benzyl ester or a sodium, potassium, magnesium, or ammonium salt thereof, and (b) an HPPD inhibitor, wherein (b) is at least one compound, or an agriculturally acceptable salt, carboxylic acid, carboxylate salt, or ester thereof, selected from the group consisting of: benzobicyclon, isoxaflutole, mesotrione, pyrazolynate, and sulcotrione.

[0053] Provided herein are also methods of controlling undesirable vegetation comprising contacting the vegetation or the locus thereof, *i.e.*, area adjacent to the plant, with or applying to the soil or water to prevent the emergence or growth of vegetation a herbicidally effective amount of the compound of formula (I) or C₁₋₄ alkyl or benzyl ester or sodium, potassium, magnesium, or ammonium salt thereof and (b) an HPPD inhibitor. In certain embodiments, the methods employ the compositions described herein, wherein (b) is at least one compound, or an agriculturally acceptable salt, carboxylic acid, carboxylate salt, or ester thereof, selected from the group consisting of: benzobicyclon, isoxaflutole, mesotrione, pyrazolynate, and sulcotrione.

[0054] The combination of compound (I) or C₁₋₄ alkyl or benzyl ester or sodium, potassium,

magnesium, or ammonium salt thereof and the HPPD inhibitor, or an agriculturally acceptable salt or ester thereof exhibits synergism, e.g., 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." Senseman, S., ed. *Herbicide Handbook*. 9th ed. Lawrence: Weed Science Society of America, 2007. In certain embodiments, the compositions exhibit synergy as determined by the Colby's equation. Colby, S.R. 1967. Calculation of the synergistic and antagonistic response of herbicide combinations. *Weeds* 15:20-22.

[0055] In certain embodiments of the compositions and methods described herein, the compound of formula (I), *i.e.*, the carboxylic acid, is employed. In certain embodiments, a carboxylate salt of the compound of formula (I) is employed. In certain embodiments, an aralkyl or alkyl ester is employed. In certain embodiments, a benzyl, substituted benzyl, or C₁₋₄ alkyl, e.g., n-butyl ester is employed. In certain embodiments, the benzyl ester is employed.

[0056] In the compositions and methods provided herein, the HPPD inhibitor is, benzobicyclon, isoxaflutole, mesotrione, pyrazolynate, or sulcotrione, including all salts and esters thereof.

[0057] In some embodiments, the compound of formula (I) or C₁₋₄ alkyl or benzyl ester or sodium, potassium, magnesium, or ammonium salt thereof and one of benzobicyclon, isoxaflutole, mesotrione, pyrazolynate, and sulcotrione, or an agriculturally acceptable salt or ester thereof, are formulated in one composition, tank mixed, applied simultaneously, or applied sequentially.

[0058] Herbicidal activity is exhibited by the compounds when they are applied 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, and the like, as well as the amount of chemical applied. 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, pre-emergence application, or in-water application to flooded paddy rice or water bodies (e.g., ponds, lakes and streams), to relatively immature undesirable vegetation to achieve the maximum control of weeds.

[0059] In some embodiments, the compositions and methods provided herein are utilized to control weeds in crops, including but not limited to direct-seeded, water-seeded and transplanted rice, cereals, wheat, barley, oats, rye, sorghum, corn/maize, sugarcane, sunflower, oilseed rape, canola, sugar beet, soybean, cotton, pineapple, pastures, grasslands, rangelands, fallowland, turf, tree and vine orchards, plantation crops, vegetables, aquatics, industrial vegetation management (IVM) and rights-of-way (ROW).

[0060] In certain embodiments, the compositions and methods provided herein are utilized to control weeds in rice. In certain embodiments, the rice is direct-seeded, water-seeded, or transplanted rice.

[0061] The compositions and methods described herein may be used to control undesirable vegetation in glyphosate-tolerant-, 5-enolpyruvylshikimate-3-phosphate (EPSP) synthase inhibitor-tolerant-, glufosinate-tolerant-, glutamine synthetase inhibitor-tolerant-, dicamba-tolerant-, phenoxy auxin-tolerant-, pyridyloxy auxin-tolerant-, auxin-tolerant-, auxin transport inhibitor-tolerant-, aryloxyphenoxypropionate-tolerant-, cyclohexanedione-tolerant-, phenylpyrazoline-tolerant-, acetyl CoA carboxylase (ACCase) inhibitor-tolerant-, imidazolinone-tolerant-, sulfonyleurea-tolerant-, pyrimidinylthiobenzoate-tolerant-, triazolopyrimidine-tolerant-, sulfonyleaminocarbonyl triazolinone-tolerant-, acetolactate synthase (ALS) or acetohydroxy acid synthase (AHAS) inhibitor-tolerant-, 4-hydroxyphenyl-pyruvate dioxygenase (HPPD) inhibitor-tolerant-, phytoene desaturase inhibitor-tolerant-, carotenoid biosynthesis inhibitor-tolerant-, protoporphyrinogen oxidase (PPO) inhibitor-tolerant-, cellulose biosynthesis inhibitor-tolerant-, mitosis inhibitor-tolerant-, microtubule inhibitor-tolerant-, very long chain fatty acid inhibitor-tolerant-, fatty acid and lipid biosynthesis inhibitor-tolerant-, photosystem I inhibitor-tolerant-, photosystem II inhibitor-tolerant-, triazine-tolerant-, and bromoxynil-tolerant- crops (such as, but not limited to, soybean, cotton, canola/oilseed rape, rice, cereals, corn, sorghum, sunflower, sugar beet, sugarcane, turf, etc.), for example, in conjunction with glyphosate, glufosinate, dicamba, phenoxy auxins, pyridyloxy auxins, aryloxyphenoxypropionates, ACCase inhibitors, imidazolinones, ALS inhibitors, HPPD inhibitors, PPO inhibitors, triazines, and bromoxynil. The compositions and methods may be used in controlling undesirable vegetation in crops possessing multiple or stacked traits conferring tolerance to multiple chemistries and/or inhibitors of multiple modes of action. In some embodiments, the compound of formula (I) or salt or ester thereof and complementary herbicide or salt or ester thereof are used in combination with herbicides that are selective for the crop 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, as a tank mix, or sequentially.

[0062] The compositions and methods may be used in controlling undesirable vegetation in crops possessing agronomic stress tolerance (including but not limited to drought, cold, heat, salt, water, nutrient, fertility, pH), pest tolerance (including but not limited to insects, fungi and pathogens) and crop improvement traits (including but not limited to yield; protein, carbohydrate, or oil content; protein, carbohydrate, or oil composition; plant stature and plant architecture).

[0063] 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 direct-seeded, water-seeded and transplanted rice, cereals, wheat, barley, oats, rye, sorghum, corn/maize, sugarcane, sunflower, oilseed rape, canola, sugar beet, soybean, cotton, pineapple, pastures, grasslands, rangelands, fallowland, turf, tree and vine orchards,

plantation crops, vegetables, aquatics, industrial vegetation management (IVM) and rights of way ROW).

[0064] In some embodiments, the methods provided herein are utilized to control undesirable vegetation in rice. In certain embodiments, the undesirable vegetation is *Brachiaria platyphylla* (Groseb.) Nash or *Urochloa platyphylla* (Nash) R.D. Webster (broadleaf signalgrass, BRAPP), *Digitaria sanguinalis* (L.) Scop. (large crabgrass, DIGSA), *Echinochloa* species (ECHSS), *Echinochloa crus-galli* (L.) P. Beauv. (barnyardgrass, ECHCG), *Echinochloa crus-pavonis* (Kunth) Schult. (gulf cockspur, ECHCV), *Echinochloa colonum* (L.) LINK (junglerice, ECHCO), *Echinochloa oryzoides* (Ard.) Fritsch (early watergrass, ECHOR), *Echinochloa oryzicola* (Vasinger) Vasinger (late watergrass, ECHPH), *Echinochloa phyllopogon* (Stapf) Koso-Pol. (rice barnyardgrass, ECHPH), *Echinochloa polystachya* (Kunth) Hitchc. (creeping river grass, ECHPO), *Ischaemum rugosum* Salisb. (saramollagrass, ISCRU), *Leptochloa chinensis* (L.) Nees (Chinese sprangletop, LEFCH), *Leptochloa fascicularis* (Lam.) Gray (bearded sprangletop, LEFFA), *Leptochloa panicoides* (Presl.) Hitchc. (Amazon sprangletop, LEFPA), *Oryza* species (red and weedy rice, ORYSS), *Panicum dichotomiflorum* (L.) Michx. (fall panicum, PANDI), *Paspalum dilatatum* Poir. (dallisgrass, PASDI), *Rottboellia cochinchinensis* (Lour.) W.D. Clayton (itchgrass, ROOEX), *Cyperus* species (CYPSS), *Cyperus difformis* L. (smallflower flatsedge, CYPDI), *Cyperus dubius* Rottb. (MAPDU), *Cyperus esculentus* L. (yellow nutsedge, CYPES), *Cyperus iria* L. (rice flatsedge, CYPIR), *Cyperus rotundus* L. (purple nutsedge, CYPRO), *Cyperus serotinus* Rottb./C.B.Clarke (tidalmarsh flatsedge, CYPSE), *Eleocharis* species (ELOSS), *Fimbristylis miliacea* (L.) Vahl (globe fringerush, FIMMI), *Schoenoplectus* species (SCPSS), *Schoenoplectus juncoides* Roxb. (Japanese bulrush, SCPJU), *Bolboschoenus maritimus* (L.) Palla or *Schoenoplectus maritimus* L. Lye (sea clubrush, SCPMA), *Schoenoplectus mucronatus* L. (ricefield bulrush, SCPMU), *Aeschynomene* species, (jointvetch, AESSS), *Alternanthera philoxeroides* (Mart.) Griseb. (alligatorweed, ALRPH), *Alisma plantago-aquatica* L. (common waterplantain, ALSPA), *Amaranthus* species, (pigweeds and amaranths, AMASS), *Ammannia coccinea* Rottb. (redstem, AMMCO), *Commelina benghalensis* L. (Benghal dayflower, COMBE), *Eclipta alba* (L.) Hassk. (American false daisy, ECLAL), *Heteranthera limosa* (SW.) Willd./Vahl (ducksalad, HETLI), *Heteranthera reniformis* R. & P. (roundleaf mudplantain, HETRE), *Ipomoea* species (morningglories, IPOSS), *Ipomoea hederacea* (L.) Jacq. (ivyleaf morningglory, IPOHE), *Lindernia dubia* (L.) Pennell (low false pimpernel, LIDDU), *Ludwigia* species (LUDSS), *Ludwigia linifolia* POIR. (southeastern primrose-willow, LUDLI), *Ludwigia octovalvis* (Jacq.) Raven (longfruited primrose-willow, LUDOC), *Monochoria korsakowii* Regel & Maack (monochoria, MOOKA), *Monochoria vaginalis* (Burm. F.) C. Presl ex Kuhth, (monochoria, MOOVA), *Murdannia nudiflora* (L.) Brenan (doveweed, MUDNU), *Polygonum pensylvanicum* L., (Pennsylvania smartweed, POLPY), *Polygonum persicaria* L. (ladythumb, POLPE), *Polygonum hydropiperoides* Michx. (POLHP, mild smartweed), *Rotala indica* (Willd.) Koehne (Indian toothcup, ROTIN), *Sagittaria* species, (arrowhead, SAGSS), *Sesbania exaltata* (Raf.) Cory/Rydb. Ex Hill (hemp sesbania, SEBEX), or *Sphenoclea zeylanica* Gaertn. (gooseweed, SPDZE).

[0065] In some embodiments, the methods provided herein are utilized to control undesirable vegetation in cereals. In certain embodiments, the undesirable vegetation is *Alopecurus*

myosuroides Huds. (blackgrass, ALOMY), *Apera spica-venti* (L.) Beauv. (windgrass, APESV), *Avena fatua* L. (wild oat, AVEFA), *Bromus tectorum* L. (downy brome, BROTE), *Lolium multiflorum* Lam. (Italian ryegrass, LOLMU), *Phalaris minor* Retz. (littleseed canarygrass, PHAMI), *Poa annua* L. (annual bluegrass, POANN), *Setaria pumila* (Poir.) Roemer & J.A. Schultes (yellow foxtail, SETLU), *Setaria viridis* (L.) Beauv. (green foxtail, SETVI), *Amaranthus retroflexus* L. (redroot pigweed, AMARE), *Brassica* species (BRSSS), *Chenopodium album* L. (common lambsquarters, CHEAL), *Cirsium arvense* (L.) Scop. (Canada thistle, CIRAR), *Galium aparine* L. (catchweed bedstraw, GALAP), *Kochia scoparia* (L.) Schrad. (kochia, KCHSC), *Lamium purpureum* L. (purple deadnettle, LAMPU), *Matricaria recutita* L. (wild chamomile, MATCH), *Matricaria matricarioides* (Less.) Porter (pineappleweed, MATMT), *Papaver rhoeas* L. (common poppy, PAPRH), *Polygonum convolvulus* L. (wild buckwheat, POLCO), *Salsola tragus* L. (Russian thistle, SASKR), *Sinapis* species (SINSS), *Sinapis arvensis* L. (wild mustard, SINAR), *Stellaria media* (L.) Vill. (common chickweed, STEME), *Veronica persica* Poir. (Persian speedwell, VERPE), *Viola arvensis* Murr. (field violet, VIOAR), or *Viola tricolor* L. (wild violet, VIOTR).

[0066] In some embodiments, the methods provided herein are utilized to control undesirable vegetation in range and pasture, fallowland, IVM and ROW. In certain embodiments, the undesirable vegetation is *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), *Daucus carota* L. (wild carrot, DAUCA), *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), *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).

[0067] In some embodiments, the methods provided herein are utilized to control undesirable vegetation found in row crops, tree and vine crops, and perennial crops. In certain embodiments, the undesirable vegetation is *Alopecurus myosuroides* Huds. (blackgrass, ALOMY), *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. Webster (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), *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, AMBEL), *Ambrosia psilostachya* DC. (western ragweed, AMBPS), *Ambrosia trifida* L. (giant ragweed, AMBTR), *Eleusine indica* (L.) Gaertn. (goosegrass, ELEIN), *Asclepias syriaca* L. (common milkweed, ASCSY), *Bidens pilosa* L. (hairy beggarticks, BIDPI), *Borreria* species (BOISS), *Borreria alata* (Aubl.) DC. or *Spermacoce alata* Aubl. (broadleaf buttonweed, BOILF), *Spermacose latifolia* (broadleaved button weed, BOILF), *Chenopodium album* L. (common 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 *Conyza bonariensis* (L.) Cronq. (hairy fleabane, ERIBO), *Erigeron canadensis* L. or *Conyza canadensis* (L.) Cronq. (Canadian fleabane, 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), *Lactuca serriola* L./Torn. (prickly lettuce, LACSE), *Portulaca oleracea* L. (common purslane, POROL), *Richardia* species (pusley, RCHSS), *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 cocklebur, XANST).

[0068] In some embodiments, the methods provided herein are utilized to control undesirable vegetation in turf. In certain embodiments, the undesirable vegetation is *Bellis perennis* L. (English daisy, BELPE), *Cyperus esculentus* L. (yellow nutsedge, CYPES), *Cyperus* species (CYPSS), *Digitaria sanguinalis* (L.) Scop. (large crabgrass, DIGSA), *Diodia virginiana* L. (Virginia buttonweed, DIQVI), *Euphorbia* species (spurge, EPHSS), *Glechoma hederacea* L. (ground ivy, GLEHE), *Hydrocotyle umbellata* L. (dollarweed, HYDUM), *Kyllinga* species (kyllinga, KYLSS), *Lamium amplexicaule* L. (henbit, LAMAM), *Murdannia nudiflora* (L.) Brenan (doveweed, MUDNU), *Oxalis* species (woodsorrel, OXASS), *Plantago major* L. (broadleaf plantain, PLAMA), *Plantago lanceolata* L. (buckhorn/narrowleaf plantain, PLALA), *Phyllanthus urinaria* L. (chamberbitter, PYLTE), *Rumex obtusifolius* L. (broadleaf dock, RUMOB), *Stachys floridana* Shuttlew. (Florida betony, STAF), *Stellaria media* (L.) Vill. (common chickweed, STEME), *Taraxacum officinale* G.H. Weber ex Wiggers (dandelion, TAROF), *Trifolium repens* L. (white clover, TRFRE), or *Viola* species (wild violet, VIOSS).

[0069] In some embodiments, the compositions and methods provided herein are utilized to control undesirable vegetation consisting of grass, broadleaf and sedge weeds. In certain embodiments, the compositions and methods provided herein are utilized to control undesirable vegetation including *Brachiaria* or *Urochloa*, *Cyperus*, *Digitaria*, *Echinochloa*, *Fimbristylis*, *Ipomoea*, *Leptochloa*, *Schoenoplectus*, *Bolboschoenus*, *Setaria*, and *Xanthium*.

[0070] In some embodiments, the combination of compound (I) or C₁₋₄ alkyl or benzyl ester or sodium, potassium, magnesium, or ammonium salt thereof and benzobicyclon, isoxaflutole, mesotrione, pyrazolynate, and sulcotrione, or agriculturally acceptable salt or ester thereof is used to control broadleaf signalgrass (*Brachiaria platyphylla* (Griseb.) Nash or *Urochloa platyphylla* (Nash) R.D. Webster, BRAPP), yellow nutsedge, (*Cyperus esculentus* L., CYPES), purple nutsedge (*Cyperus rotundus* L., CYPRO), rice flatsedge (*Cyperus iria* L., CYPIR), large crabgrass (*Digitaria sanguinalis* (L.) Scop., DIGSA), barnyardgrass (*Echinochloa crus-galli* (L.) Beauv., ECHCG), junglerice (*Echinochloa colona* (L.) Link, ECHCO), early watergrass (*Echinochloa oryzoides* (Ard.) Fritsch, ECHOR), globe fringerush (*Fimbristylis miliacea* (L.) Vahl, FIMMI), ivyleaf morningglory (*Ipomoea hederacea* Jacq., IPOHE), Chinese sprangletop (*Leptochloa chinensis* (L.) Nees, LEFCH), Japanese bulrush (*Schoenoplectus juncooides* (Roxb.) Palla, SCPJU), sea clubrush (*Bolboschoenus maritimus* (L.) Palla or *Schoenoplectus maritimus* (L.) Lye, SCPMA), green foxtail (*Setaria viridis* (L.) Beauv., SETVI), and common cocklebur (*Xanthium strumarium* L.).

[0071] The compound of formula I or C₁₋₄ alkyl or benzyl ester or sodium, potassium, magnesium, or ammonium salt thereof may be used to control herbicide resistant or tolerant weeds. The methods employing the combination of a compound of formula I or C₁₋₄ alkyl or benzyl ester or sodium, potassium, magnesium, or ammonium salt thereof 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, sulfonylureas, pyrimidinylthiobenzoates, triazolopyrimidines, sulfonylaminocarbonyltriazolinones), 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, phenoxy-carboxylic 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, pyrimidindiones, 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 multiple herbicides, biotypes with resistance or tolerance to multiple chemical classes, biotypes with resistance or tolerance to multiple herbicide modes-of-action, and biotypes with multiple resistance or tolerance mechanisms (e.g., target site resistance or metabolic resistance).

[0072] In some embodiments, a C₁₋₄ alkyl or benzyl ester of formula (I) or a sodium, potassium, magnesium, or ammonium salt of compound (I) is employed. In certain embodiments, the ester is a C₁₋₄ alkyl ester. In certain embodiments, the ester is an n-butyl ester. In certain embodiments, the ester is a benzyl ester. In certain embodiments, compound (I), which is a carboxylic acid, is employed.

[0073] In certain embodiments of the compositions and methods described herein, the compound of formula (I) or salt or ester thereof is used in combination with benzobicyclon. With regard to the compositions, in some embodiments, the weight ratio of the compound of formula (I) or salt or ester thereof to benzobicyclon is within the range of from about 1:150 to about 6:1. In certain embodiments, the weight ratio of the compound of formula (I) or salt or ester thereof to benzobicyclon is within the range of from 1:45 to about 2.5:1. In certain embodiments, the weight ratio of the compound of formula (I) or salt or ester thereof to benzobicyclon is within the range of from about 1:80 to about 1:2. In certain embodiments, the weight ratio of the compound of formula (I) or salt or ester thereof to benzobicyclon is within the range of from about 1:46 to about 2:1. In certain embodiments, the weight ratio of the compound of formula (I) or salt or ester thereof to benzobicyclon is within the range of from about 1:40 to about 1:5. In certain embodiments, the compositions provided herein comprise the compound of formula (I) or its benzyl ester and benzobicyclon. In one embodiment, the composition comprises the compound of formula (I) and benzobicyclon, wherein the weight ratio of the compound of formula (I) to benzobicyclon is about 1:40 to about 1:1. In one embodiment, the composition comprises the benzyl ester of the compound of formula (I) and benzobicyclon, wherein the weight ratio of the benzyl ester of the compound of formula (I) to benzobicyclon is about 1:40 to about 1:5.7. In one embodiment, the composition comprises the benzyl ester of the compound of formula (I) and benzobicyclon, wherein the weight ratio of the benzyl ester of the compound of formula (I) to benzobicyclon is about 1:46 to about 2:1. With respect to the methods, in certain embodiments, the methods comprise contacting the undesirable vegetation or locus thereof or applying to the soil or water to prevent the emergence or growth of vegetation a composition described herein. In some embodiments, the composition is applied at an application rate of from about 52 grams active ingredient per hectare (gai/ha) to about 600 gai/ha based on the total amount of active ingredients in the composition. In certain embodiments, the composition is applied at an application rate of from about 54 gai/ha to about 240 gai/ha based on the total amount of active ingredients in the composition. In certain embodiments, the composition is applied at an application rate of from about 54 gai/ha to about 296 gai/ha based on the total amount of active ingredients in the composition. In some embodiments, the methods comprise contacting the undesirable vegetation or locus thereof or applying to the soil or water to prevent the emergence or growth of vegetation with a compound of formula (I) or salt or ester thereof and benzobicyclon, e.g.,

sequentially or simultaneously. In some embodiments, the benzobicyclon is applied at a rate from about 50 gai/ha to about 300 gai/ha and the compound of formula (I) of salt or ester thereof is applied at a rate from about 2 gae/ha to about 300 gae/ha. In some embodiments, the benzobicyclon is applied at a rate from about 25 gai/ha to about 400 gai/ha and the compound of formula (I) of salt or ester thereof is applied at a rate from about 2 g acid equivalent per hectare (gae/ha) to about 45 gae/ha. In some embodiments, the benzobicyclon is applied at a rate from about 50 gai/ha to about 200 gai/ha and the compound of formula (I) of salt or ester thereof is applied at a rate from about 4.38 g acid equivalent per hectare (gae/ha) to about 21.2 gae/ha. In some embodiments, the benzobicyclon is applied at a rate from about 50 gai/ha to about 200 gai/ha and the compound of formula (I) of salt or ester thereof is applied at a rate from about 4.38 g acid equivalent per hectare (gae/ha) to about 96 gae/ha. In certain embodiments, the methods utilize the compound of formula (I), or its benzyl ester and benzobicyclon. In one embodiment, the methods utilize the compound of formula (I) and benzobicyclon, wherein the compound of formula (I) is applied at a rate of from about 5.3 g acid equivalent per hectare (gae/ha) to about 21.2 gae/ha, and benzobicyclon is applied at a rate of about 50 gai/ha to about 200 gai/ha. In one embodiment, the methods utilize the compound of formula (I) and benzobicyclon, wherein the compound of formula (I) is applied at a rate of from about 5.3 g acid equivalent per hectare (gae/ha) to about 96 gae/ha, and benzobicyclon is applied at a rate of about 50 gai/ha to about 200 gai/ha. In one embodiment, the methods utilize the benzyl ester of the compound of formula (I) and benzobicyclon, wherein the benzyl ester of the compound of formula (I) is applied at a rate of from about 4.38 g acid equivalent per hectare (gae/ha) to about 17.5 gae/ha, and benzobicyclon is applied at a rate of about 100 gai/ha to about 200 gai/ha. In one embodiment, the methods utilize the benzyl ester of the compound of formula (I) and benzobicyclon, wherein the benzyl ester of the compound of formula (I) is applied at a rate of from about 4.38 g acid equivalent per hectare (gae/ha) to about 96 gae/ha, and benzobicyclon is applied at a rate of about 50 gai/ha to about 200 gai/ha. In certain embodiments, the methods and compositions utilizing the compound of formula (I) or salt or ester thereof in combination with benzobicyclon are used to control ECHCG, ECHCO, ECHOR, SCPMA, SCPJU, CYPPIR, or CYPPO.

[0074] In certain embodiments of the compositions and methods described herein, the compound of formula (I) or salt or ester thereof is used in combination with isoxaflutole or salt or ester thereof. With regard to the compositions, in some embodiments, the weight ratio of the compound of formula (I) or salt or ester thereof to isoxaflutole or salt or ester thereof is within the range of from about 1:70 to about 12:1. In certain embodiments, the weight ratio of the compound of formula (I) or salt or ester thereof to isoxaflutole or salt or ester thereof is within the range of from 1:23 to about 2:1. In certain embodiments, the weight ratio of the compound of formula (I) or salt or ester thereof to isoxaflutole or salt or ester thereof is within the range of from 1:9 to about 1:1. In certain embodiments, the compositions comprise the compound of formula (I) or its benzyl or *n*-butyl ester and isoxaflutole. With respect to the methods, in certain embodiments, the methods comprise contacting the undesirable vegetation or locus thereof or applying to the soil or water to prevent the emergence or growth of vegetation a composition described herein. In some embodiments, the composition is applied at an application rate of from about 27 grams active ingredient per hectare (gai/ha) to about 440 gai/ha based on the

total amount of active ingredients in the composition. In certain embodiments, the composition is applied at an application rate of from about 29 gai/ha to about 150 gai/ha based on the total amount of active ingredients in the composition. In certain embodiments, the composition is applied at an application rate of from about 43 gai/ha to about 102 gai/ha based on the total amount of active ingredients in the composition. In some embodiments, the methods comprise contacting the undesirable vegetation or locus thereof or applying to the soil or water to prevent the emergence or growth of vegetation with a compound of formula (I) or salt or ester thereof and isoxaflutole, e.g., sequentially or simultaneously. In some embodiments, the isoxaflutole or salt or ester thereof is applied at a rate from about 25 gai/ha to about 140 gai/ha and the compound of formula (I) or salt or ester thereof is applied at a rate from about 2 gae/ha to about 300 gae/ha. In some embodiments, the isoxaflutole or salt or ester thereof is applied at a rate from about 35 gai/ha to about 70 gai/ha and the compound of formula (I) or salt or ester thereof is applied at a rate from about 8 gae/ha to about 32 gae/ha. In certain embodiments, the methods utilize the compound of formula (I) or its benzyl or *n*-butyl ester and isoxaflutole. In certain embodiments, the methods and compositions utilizing the compound of formula (I) or salt or ester thereof in combination with isoxaflutole are used to control IPOHE, SETVI, or XANST.

[0075] In certain embodiments of the compositions and methods described herein, the compound of formula (I) or salt or ester thereof is used in combination with mesotrione. With regard to the compositions, in some embodiments, the weight ratio of the compound of formula (I) or salt or ester thereof to mesotrione is within the range of from about 1:115 to about 17:1. In certain embodiments, the weight ratio of the compound of formula (I) or salt or ester thereof to mesotrione is within the range of from 1:32 to about 5:1. In certain embodiments, the weight ratio of the compound of formula (I) or salt or ester thereof to mesotrione is within the range of from about 1:32 to about 2:1. In certain embodiments, the weight ratio of the compound of formula (I) or salt or ester thereof to mesotrione is within the range of from about 1:16 to about 1:1. In certain embodiments, the compositions provided herein comprise the compound of formula (I) or its benzyl or *n*-butyl ester and mesotrione. In one embodiment, the composition comprises the compound of formula (I) and mesotrione, wherein the weight ratio of the compound of formula (I) to mesotrione is about 1:16 to about 1:1. In one embodiment, the composition comprises the benzyl ester of the compound of formula (I) and mesotrione, wherein the weight ratio of the benzyl ester of the compound of formula (I) to mesotrione is about 1:8 to about 1:2. In one embodiment, the composition comprises the *n*-butyl ester of the compound of formula (I) and mesotrione, wherein the weight ratio of the *n*-butyl ester of the compound of formula (I) to mesotrione is about 1:4 to about 1:2. With respect to the methods, in certain embodiments, the methods comprise contacting the undesirable vegetation or locus thereof or applying to the soil or water to prevent the emergence or growth of vegetation a composition described herein. In some embodiments, the composition is applied at an application rate of from about 22 grams active ingredient per hectare (gai/ha) to about 600 gai/ha based on the total amount of active ingredients in the composition. In certain embodiments, the composition is applied at an application rate of from about 54 gai/ha to about 525 gai/ha based on the total amount of active ingredients in the composition. In some embodiments, the methods comprise contacting the undesirable vegetation or locus thereof or

applying to the soil or water to prevent the emergence or growth of vegetation with a compound of formula (I) or salt or ester thereof and mesotrione, e.g., sequentially or simultaneously. In some embodiments, the mesotrione is applied at a rate from about 17.5 gai/ha to about 225 gai/ha and the compound of formula (I) or salt or ester thereof is applied at a rate from about 2 gae/ha to about 300 gae/ha. In some embodiments, the mesotrione is applied at a rate from about 8 gai/ha to about 300 gai/ha and the compound of formula (I) or salt or ester thereof is applied at a rate from about 2 g acid equivalent per hectare (gae/ha) to about 300 gae/ha. In some embodiments, the mesotrione is applied at a rate from about 17.5 gai/ha to about 140 gai/ha and the compound of formula (I) or salt or ester thereof is applied at a rate from about 4.38 g acid equivalent per hectare (gae/ha) to about 140 gae/ha. In certain embodiments, the methods utilize the compound of formula (I), or its benzyl or *n*-butyl ester and mesotrione. In one embodiment, the methods utilize the compound of formula (I) and mesotrione, wherein the compound of formula (I) is applied at a rate of from about 4.38 g acid equivalent per hectare (gae/ha) to about 84.8 gae/ha, and mesotrione is applied at a rate of about 17.5 gai/ha to about 140 gai/ha. In one embodiment, the methods utilize the benzyl ester of the compound of formula (I) and mesotrione, wherein the benzyl ester of the compound of formula (I) is applied at a rate of from about 4.38 g acid equivalent per hectare (gae/ha) to about 35 gae/ha, and mesotrione is applied at a rate of about 17.5 gai/ha to about 140 gai/ha. In one embodiment, the methods utilize the *n*-butyl ester of the compound of formula (I) and mesotrione, wherein the *n*-butyl ester of the compound of formula (I) is applied at a rate of about 35 g acid equivalent per hectare (gae/ha) to about 70 gae/ha, and mesotrione is applied at a rate of about 140 gai/ha. In certain embodiments, the methods and compositions utilizing the compound of formula (I) or salt or ester thereof in combination with mesotrione are used to control BRAPP, ECHCO, CYPIR, IPOHE, SCPJU, DIGSA, ECHCG, or ECHOR.

[0076] In certain embodiments of the compositions and methods described herein, the compound of formula (I) or salt or ester thereof is used in combination with pyrazolynate. With regard to the compositions, in some embodiments, the weight ratio of the compound of formula (I) or salt or ester thereof to pyrazolynate is within the range of from about 1:229 to about 2:1. In certain embodiments, the weight ratio of the compound of formula (I) or salt or ester thereof to pyrazolynate is within the range of from 1:9 to about 1:4. In certain embodiments, the weight ratio of the compound of formula (I) or salt or ester thereof to pyrazolynate is within the range of from about 1:35 to about 2:1. In certain embodiments, the weight ratio of the compound of formula (I) or salt or ester thereof to pyrazolynate is within the range of from about 1:17.1 to about 1:1. In certain embodiments, the weight ratio of the compound of formula (I) or salt or ester thereof to pyrazolynate is within the range of from about 1:19 to about 3:1. In certain embodiments, the compositions provided herein comprise the compound of formula (I) or its benzyl or *n*-butyl ester and pyrazolynate. In one embodiment, the composition comprises the compound of formula (I) and pyrazolynate, wherein the weight ratio of the compound of formula (I) to pyrazolynate is about 1:8.6 to about 1:1. In one embodiment, the composition comprises the benzyl ester of the compound of formula (I) and pyrazolynate, wherein the weight ratio of the benzyl ester of the compound of formula (I) to pyrazolynate is about 1:17.1 to about 1:2.6. In one embodiment, the composition comprises the benzyl ester of the compound of formula (I) and pyrazolynate, wherein the weight ratio of the benzyl ester of the

compound of formula (I) to pyrazolynate is about 1:19 to about 3:1. In one embodiment, the composition comprises the *n*-butyl ester of the compound of formula (I) and pyrazolynate, wherein the weight ratio of the *n*-butyl ester of the compound of formula (I) to pyrazolynate is about 1:34 to about 1:4.3. With respect to the methods, in certain embodiments, the methods comprise contacting the undesirable vegetation or locus thereof or applying to the soil or water to prevent the emergence or growth of vegetation a composition described herein. In some embodiments, the composition is applied at an application rate of from about 152 grams active ingredient per hectare (gai/ha) to about 758 gai/ha based on the total amount of active ingredients in the composition. In certain embodiments, the composition is applied at an application rate of from about 167 gai/ha to about 200 gai/ha based on the total amount of active ingredients in the composition. In certain embodiments, the composition is applied at an application rate of from about 45 gai/ha to about 250 gai/ha based on the total amount of active ingredients in the composition. In some embodiments, the methods comprise contacting the undesirable vegetation or locus thereof or applying to the soil or water to prevent the emergence or growth of vegetation with a compound of formula (I) or salt or ester thereof and pyrazolynate, *e.g.*, sequentially or simultaneously. In some embodiments, the pyrazolynate is applied at a rate from about 150 gai/ha to about 458 gai/ha and the compound of formula (I) of salt or ester thereof is applied at a rate from about 2 gae/ha to about 300 gae/ha. In some embodiments, the pyrazolynate is applied at a rate from about 18 gai/ha to about 300 gai/ha and the compound of formula (I) of salt or ester thereof is applied at a rate from about 2 g acid equivalent per hectare (gae/ha) to about 70 gae/ha. In some embodiments, the pyrazolynate is applied at a rate from about 37.5 gai/ha to about 150 gai/ha and the compound of formula (I) of salt or ester thereof is applied at a rate from about 4.38 g acid equivalent per hectare (gae/ha) to about 35 gae/ha. In some embodiments, the pyrazolynate is applied at a rate from about 37.5 gai/ha to about 150 gai/ha and the compound of formula (I) of salt or ester thereof is applied at a rate from about 4.38 g acid equivalent per hectare (gae/ha) to about 96 gae/ha. In certain embodiments, the methods utilize the compound of formula (I), or its benzyl or *n*-butyl ester and pyrazolynate. In one embodiment, the methods utilize the compound of formula (I) and pyrazolynate, wherein the compound of formula (I) is applied at a rate of from about 8.75 g acid equivalent per hectare (gae/ha) to about 35 gae/ha, and pyrazolynate is applied at a rate of about 37.5 gai/ha to about 150 gai/ha. In one embodiment, the methods utilize the benzyl ester of the compound of formula (I) and pyrazolynate, wherein the benzyl ester of the compound of formula (I) is applied at a rate of from about 4.38 g acid equivalent per hectare (gae/ha) to about 17.5 gae/ha, and pyrazolynate is applied at a rate of about 37.5 gai/ha to about 75 gai/ha. In one embodiment, the methods utilize the benzyl ester of the compound of formula (I) and pyrazolynate, wherein the benzyl ester of the compound of formula (I) is applied at a rate of from about 4.38 g acid equivalent per hectare (gae/ha) to about 96 gae/ha, and pyrazolynate is applied at a rate of about 37.5 gai/ha to about 150 gai/ha. In one embodiment, the methods utilize the *n*-butyl ester of the compound of formula (I) and pyrazolynate, wherein the *n*-butyl ester of the compound of formula (I) is applied at a rate of about 4.38 g acid equivalent per hectare (gae/ha) to about 35 gae/ha, and pyrazolynate is applied at a rate of about 150 gai/ha. In certain embodiments, the methods and compositions utilizing the compound of formula (I) or salt or ester thereof in combination with pyrazolynate are used to control LEFCH, IPOHE, ECHCG, ECHCO, ECHOR, FIMMI, SCPMA, CYPRO, or

SCPJU.

[0077] In certain embodiments of the compositions and methods described herein, the compound of formula (I) or salt or ester thereof is used in combination with sulcotrione. With regard to the compositions, in some embodiments, the weight ratio of the compound of formula (I) or salt or ester thereof to sulcotrione is within the range of from about 1:300 to about 13:1. In certain embodiments, the weight ratio of the compound of formula (I) or salt or ester thereof to sulcotrione is within the range of from 1:34 to about 1:1. In certain embodiments, the weight ratio of the compound of formula (I) or salt or ester thereof to sulcotrione is within the range of from about 1:60 to about 2:1. In certain embodiments, the weight ratio of the compound of formula (I) or salt or ester thereof to sulcotrione is within the range of from about 1:30 to about 1:1.3. In certain embodiments, the compositions provided herein comprise the compound of formula (I) or its benzyl ester and sulcotrione. In one embodiment, the composition comprises the compound of formula (I) and sulcotrione, wherein the weight ratio of the compound of formula (I) to sulcotrione is about 1:30 to about 1:1.3. In one embodiment, the composition comprises the benzyl ester of the compound of formula (I) and sulcotrione, wherein the weight ratio of the benzyl ester of the compound of formula (I) to sulcotrione is about 1:30 to about 1:1.3. With respect to the methods, in certain embodiments, the methods comprise contacting the undesirable vegetation or locus thereof or applying to the soil or water to prevent the emergence or growth of vegetation a composition described herein. In some embodiments, the composition is applied at an application rate of from about 25 grams active ingredient per hectare (gai/ha) to about 900 gai/ha based on the total amount of active ingredients in the composition. In certain embodiments, the composition is applied at an application rate of from about 27 gai/ha to about 200 gai/ha based on the total amount of active ingredients in the composition. In some embodiments, the methods comprise contacting the undesirable vegetation or locus thereof or applying to the soil or water to prevent the emergence or growth of vegetation with a compound of formula (I) or salt or ester thereof and sulcotrione, *e.g.*, sequentially or simultaneously. In some embodiments, the sulcotrione is applied at a rate from about 23 gai/ha to about 600 gai/ha and the compound of formula (I) or salt or ester thereof is applied at a rate from about 2 gae/ha to about 300 gae/ha. In some embodiments, the sulcotrione is applied at a rate from about 10 gai/ha to about 300 gai/ha and the compound of formula (I) or salt or ester thereof is applied at a rate from about 2 g acid equivalent per hectare (gae/ha) to about 40 gae/ha. In some embodiments, the sulcotrione is applied at a rate from about 22.5 gai/ha to about 150 gai/ha and the compound of formula (I) or salt or ester thereof is applied at a rate from about 4.38 g acid equivalent per hectare (gae/ha) to about 17.5 gae/ha. In certain embodiments, the methods utilize the compound of formula (I), or its benzyl ester and sulcotrione. In one embodiment, the methods utilize the compound of formula (I) and sulcotrione, wherein the compound of formula (I) is applied at a rate of from about 4.38 g acid equivalent per hectare (gae/ha) to about 17.5 gae/ha, and sulcotrione is applied at a rate of about 22.5 gai/ha to about 150 gai/ha. In one embodiment, the methods utilize the benzyl ester of the compound of formula (I) and sulcotrione, wherein the benzyl ester of the compound of formula (I) is applied at a rate of from about 4.38 g acid equivalent per hectare (gae/ha) to about 17.5 gae/ha, and sulcotrione is applied at a rate of about 22.5 gai/ha to about 150 gai/ha. In certain embodiments, the methods and compositions utilizing the

compound of formula (I) or salt or ester thereof in combination with sulcotrione are used to control BRAPP, ECHCO, IPOHE, DIGSA, ECHCG, or ECHOR.

[0078] The components of the mixtures described herein can be applied either separately or as part of a multipart herbicidal system.

[0079] 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: 4-CPA; 4-CPB; 4-CPP; 2,4-D; 2,4-D choline salt, 2,4-D esters and amines, 2,4-DB; 3,4-DA; 3,4-DB; 2,4-DEB; 2,4-DEP; 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, ametrudione, ametryn, amibuzin, amicarbazone, amidosulfuron, aminocyclopyrachlor, aminopyralid, amiprofosmethyl, amitrole, ammonium sulfamate, anilofos, anisuron, asulam, atraton, atrazine, azafenidin, azimsulfuron, aziprotryne, barban, BCPC, beflubutamid, benazolin, bencarbazon, benfluralin, benfuresate, bensulfuron-methyl, bensulide, benthocarb, bentazon-sodium, benzadox, benzfendizone, benzipram, benzofenap, benzofluor, benzoylprop, benzthiazuron, bialaphos, bicyclopyrone, bifenox, bilanafos, bispyribacsodium, 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-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-ethyl, cinmethylin, cinosulfuron, cisanilide, clethodim, clodinate, clodinafop-propargyl, clofop, clomazone, clomeprop, cloprop, cloproxydim, clocypralid, cloransulam-methyl, CMA, copper sulfate, CPMF, CPPC, credazine, cresol, cumyluron, cyanatryn, cyanazine, cycloate, cyclopyrimorate, cyclosulfamuron, cycloxydim, cycluron, 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, ethalfuralin, ethbenzamide, ethametsulfuron, ethidimuron, ethiolate, ethobenzamid, etobenzamid, ethofumesate, ethoxyfen, ethoxysulfuron, etinofen, etnipromid, etobenzanid, EXD, fenasulam, fenoprop, fenoxaprop, fenoxaprop-P-ethyl, fenoxaprop-P-ethyl + isoxadifen-ethyl, fenoxasulfone, fenteracol, fenthiaprop, fentrazamide, fenuron, ferrous sulfate, flamprop, flamprop-M, flazasulfuron, florasulam, fluazifop, fluazifop-P-butyl, fluazolate, flucarbazone,

flucetosulfuron, fluchloralin, flufenacet, flufenican, flufenpyr-ethyl, flumetsulam, flumezin, flumicloracpenty, flumioxazin, flumipropyn, fluometuron, fluorodifen, fluoroglycofen, fluoromidine, fluoronitrofen, fluothiuron, flupoxam, fluproacil, flupropanate, flupyr-sulfuron, fluridone, flurochloridone, fluroxypyr, fluroxypyr-meptyl, flurtamone, fluthiacet, fomesafen, foramsulfuron, fosamine, fumiclorac, furyloxyfen, glufosinate, glufosinate-ammonium, glufosinate-P-ammonium, glyphosate, halauxifen, halauxifen-methyl, halosafen, halosulfuron-methyl, haloxydine, haloxyfop-methyl, haloxyfop-P-methyl, hexachloroacetone, hexaflurate, hexazinone, imazamethabenz, imazamox, imazapic, imazapyr, imazaquin, imazosulfuron, imazethapyr, indanofan, indaziflam, iodobonil, iodomethane, iodosulfuron, iodosulfuron-ethyl-sodium, iofensulfuron, ioxynil, ipazine, ipfencarbazone, iprymidam, isocarbamid, isocil, isomethiozin, isonoruron, isopolinate, isopropalin, isoproturon, isouron, isoxaben, isoxachlortole, isoxapyrifop, karbutilate, ketospiradox, lactofen, lenacil, linuron, MAA, MAMA, MCPA esters and amines, MCPA-thioethyl, MCPB, mecoprop, mecoprop-P, medinoterb, mefenacet, mefluidide, mesoprazine, mesosulfuron, metam, metamifop, metamidron, 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, morfamquat, MSMA, naproanilide, napropamide, naptalam, neburon, nicosulfuron, nipyraclufen, nitralin, nitrofen, nitrofluorfen, norflurazon, noruron, OCH, orbencarb, *ortho*-dichlorobenzene, orthosulfamuron, oryzalin, oxadiargyl, oxadiazon, oxapyrazon, oxasulfuron, oxaziclomefone, oxyfluorfen, paraflufen-ethyl, parafluron, paraquat, pebulate, pelargonic acid, pendimethalin, penoxsulam, pentachlorophenol, pentanochlor, pentoxazone, perfluidone, pethoxamid, phenisopham, phenmedipham, phenmedipham-ethyl, phenobenzuron, phenylmercury acetate, picloram, picolinafen, pinoxaden, piperophos, potassium arsenite, potassium azide, potassium cyanate, pretilachlor, primisulfuron-methyl, procyzazine, prodiamine, profluzol, profluralin, profoxydim, proglinazine, prohexadione-calcium, prometon, prometryn, pronamide, propachlor, propanil, propaquizafop, propazine, propham, propisochlor, propoxycarbazone, propyrisulfuron, propyzamide, prosulfalin, prosulfocarb, prosulfuron, proxan, prynachlor, pydanon, pyraclonil, pyraflufen-ethyl, pyrasulfotole, pyrazogyl, pyrazosulfuron-ethyl, pyrazoxyfen, pyribenzoxim, pyributicarb, pyriclor, pyridafol, pyridate, pyrifthalid, pyriminobac, pyrimisulfan, pyrithiobac-sodium, pyroxasulfone, pyroxsulam, quinclozac, quinmerac, quinclozamine, quinonamid, quizalofop, quizalofop-P-ethyl, rhodethanil, rimsulfuron, saflufenacil, S-metolachlor, sebutylazine, sebumeton, sethoxydim, siduron, simazine, simeton, simetryn, SMA, SYN-523, sodium arsenite, sodium azide, sodium chlorate, sulfallate, sulfentrazone, sulfometuron, sulfosate, sulfosulfuron, sulfuric acid, sulglycapin, swep, TCA, tebutam, tebuthiuron, tembotrione, tepraloxym, terbacil, terbucarb, terbuchlor, terbumeton, terbuthylazine, terbutryn, tetrafluron, thenylchlor, thiazafuron, thiazopyr, thidiazimin, thidiazuron, thiencarbazone-methyl, thifensulfuron, thifensulfuron-methyl, thiobencarb, tiocarbamil, tioclorim, topramezone, tralkoxydim, triafamone, tri-allate, triasulfuron, triaziflam, tribenuron, tribenuron-methyl, tricamba, triclopyr choline salt, triclopyr esters and salts, tridiphane, trietazine, trifloxysulfuron, trifluralin, triflusulfuron, trifop, trifopsime, trihydroxytriazine, trimeturon, tripropindan, tritac tritosulfuron, vernolate, xylachlor and salts, esters, optically active isomers

and mixtures thereof.

[0080] The compositions and methods described herein, can further be used in conjunction with glyphosate, 5-enolpyruvylshikimate-3-phosphate (EPSP) synthase inhibitors, glufosinate, glutamine synthetase inhibitors, dicamba, phenoxy auxins, pyridyloxy auxins, synthetic auxins, auxin transport inhibitors, aryloxyphenoxypropionates, cyclohexanediones, phenylpyrazolines, acetyl CoA carboxylase (ACCase) inhibitors, imidazolinones, sulfonylureas, pyrimidinylthiobenzoates, triazolopyrimidines, sulfonylaminocarbonyltriazolinones, acetolactate synthase (ALS) or acetohydroxy acid synthase (AHAS) inhibitors, 4-hydroxyphenyl-pyruvate dioxygenase (HPPD) inhibitors, phytoene desaturase inhibitors, carotenoid biosynthesis inhibitors, protoporphyrinogen oxidase (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 on glyphosate-tolerant, EPSP synthase inhibitor-tolerant, glufosinate-tolerant, glutamine synthetase inhibitor-tolerant, dicamba-tolerant, phenoxy auxin-tolerant, pyridyloxy auxin-tolerant, auxin-tolerant, auxin transport inhibitor-tolerant, aryloxyphenoxypropionate-tolerant, cyclohexanedione-tolerant, phenylpyrazoline-tolerant, ACCase-tolerant, imidazolinone-tolerant, sulfonylurea-tolerant, pyrimidinylthiobenzoate-tolerant, triazolopyrimidine-tolerant, sulfonylaminocarbonyltriazolinone-tolerant, ALS- or AHAS-tolerant, HPPD-tolerant, phytoene desaturase inhibitor-tolerant, carotenoid biosynthesis inhibitor tolerant, PPO-tolerant, cellulose biosynthesis inhibitor-tolerant, mitosis inhibitor-tolerant, microtubule inhibitor-tolerant, very long chain fatty acid inhibitor-tolerant, fatty acid and lipid biosynthesis inhibitor-tolerant, photosystem I inhibitor-tolerant, photosystem II inhibitor-tolerant, triazine-tolerant, and bromoxynil-tolerant crops, and crops possessing multiple or stacked traits conferring tolerance to multiple chemistries and/or multiple modes of action via single and/or multiple resistance mechanisms. In some embodiments, the compound of formula (I) or salt or ester thereof and complementary herbicide or salt or ester thereof are used in combination with herbicides that are selective for the crop 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.

[0081] In some embodiments, the compositions described herein are employed in combination with one or more herbicide safeners, such as AD-67 (MON 4660), benoxacor, benthocarb, brassinolide, cloquintocet (mexyl), cyometrinil, daimuron, dichlormid, dicyclonon, dimepiperate, disulfoton, fenchlorazole-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 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).

[0082] In some embodiments, the compositions described herein are employed in combination

with one or more plant growth regulators, such as 2,3,5-tri-iodobenzoic acid, IAA, IBA, naphthaleneacetamide, α -naphthaleneacetic acids, benzyladenine, 4-hydroxyphenethyl alcohol, kinetin, zeatin, endothal, ethephon, pentachlorophenol, thidiazuron, tribufos, aviglycine, ethephon, maleic hydrazide, gibberellins, gibberellic acid, abscisic acid, ancymidol, fosamine, glyphosine, isopyrimol, jasmonic acid, maleic hydrazide, mepiquat, 2,3,5-tri-iodobenzoic acid, morphactins, dichlorflurenol, flurprimidol, mefluidide, paclobutrazol, tetcyclacis, uniconazole, brassinolide, brassinolide-ethyl, cycloheximide, ethylene, methasulfocarb, prohexadione, triapenthenol and trinexapac.

[0083] In some embodiments, the plant growth regulators are employed in one or more crops or settings, such as rice, cereal crops, corn, maize, broadleaf crops, oilseed rape/canola, turf, pineapple, sugarcane, sunflower, pastures, grasslands, rangelands, fallowland, tree and vine orchards, plantation crops, vegetables, and non-crop (ornamentals) settings. In some embodiments, the plant growth regulator is mixed with the compound of formula (I), or mixed with the compound of formula (I) and an HPPD inhibitor to cause a preferentially advantageous effect on plants.

[0084] 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, 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.

[0085] 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.

[0086] 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.

[0087] 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.

[0088] 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 Corp., Ridgewood, New Jersey, 1998 and in "Encyclopedia of Surfactants," Vol. I-III, Chemical Publishing Co., 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-Cis 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.

[0089] 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 active agent.

[0090] 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, 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.

[0091] In some embodiments, the concentration of the active ingredients in the compositions described herein is from about 0.0005 to 98 percent by weight. In some embodiments, the concentration is from about 0.0006 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 0.1 to 98 weight percent, and in certain embodiment's 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 0.0006 to 3.0 weight percent active ingredient and in certain embodiments contain about 0.01 to 1.0 weight percent.

[0092] The present compositions can be applied to weeds or their locus by the use of conventional ground or aerial dusters, sprayers, and granule applicators, by addition to irrigation or paddy water, and by other conventional means known to those skilled in the art.

Examples

[0093] Results in Examples I, II, and III are greenhouse trial results.

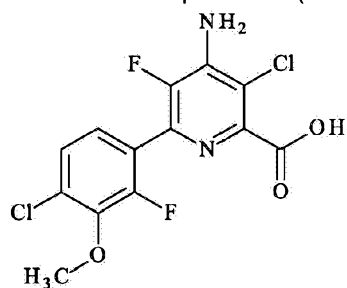
Example I. Evaluation of Post-emergence Foliar-Applied Herbicidal Mixtures for Weed Control in Direct Seeded Rice

[0094] Seeds or nutlets of the desired test plant species were planted in a soil matrix prepared by mixing a loam or sandy loam soil (*e.g.*, 28.6 percent silt, 18.8 percent clay, and 52.6 percent sand, with a pH of about 5.8 and an organic matter content of about 1.8 percent) and calcareous grit in an 80 to 20 ratio. The soil matrix was contained in plastic pots with a volume of 1 quart and a surface area of 83.6 square centimeters (cm²). When required to ensure good germination and healthy plants, a fungicide treatment and/or other chemical or physical treatment was applied. The plants were grown for 8-22 days in a greenhouse with an approximate 14 h photoperiod which was maintained at about 29°C during the day and 26°C during the night. Nutrients (Peters Excel® 15-5-15 5-Ca 2-Mg and iron chelate) were applied in the irrigation solution as needed and water was added on a regular basis. Supplemental lighting was provided with overhead metal halide 1000-Watt lamps as necessary. The plants were employed for testing when they reached the first through fourth true leaf stage.

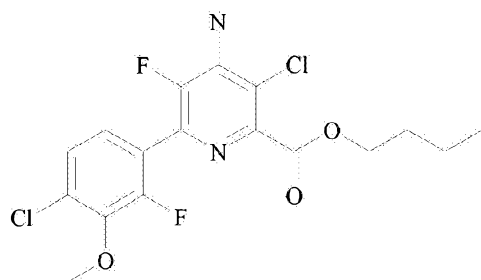
[0095] Treatments consisted of the acid or esters of 4-amino-3-chloro-5-fluoro-6-(4-chloro-2-fluoro-3-methoxy-phenyl)pyridine-2-carboxylic acid (Compound A), each formulated as an SC (suspension concentrate), and various herbicidal components alone and in combination.

Forms of Compound A were applied on an acid equivalent basis.

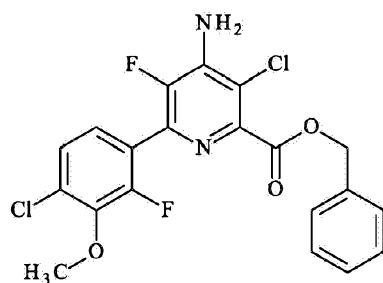
Forms of compound A (compound of formula I) tested include:



Compound A Acid



Compound A n-Butyl Ester



Compound A Benzyl Ester

[0096] Other herbicidal components were applied on an active ingredient basis and included 4-hydroxyphenyl pyruvate dioxygenase (HPPD)-inhibiting herbicides mesotrione formulated as Callisto®, sulcotrione formulated as Mikado®, pyrazolynate formulated as Sunbird® 10% GR, and benzobicyclon formulated as Benzobicyclon 3.5%.

[0097] Treatment requirements were calculated based upon the rates being tested, the concentration of active ingredient or acid equivalent in the formulation, and a 12 mL application volume at a rate of 187 L/ha.

[0098] For treatments comprised of formulated compounds, measured amounts of compounds were placed individually in 25 mL glass vials and diluted in a volume of 1.25% (v/v) Agri-Dex® crop oil concentrated to obtain 12X stock solutions. If a test compound did not dissolve readily, the mixture was warmed and/or sonicated. Application solutions were prepared by adding an appropriate amount of each stock solution (e.g., 1 mL) and diluted to the appropriate final

concentrations with the addition of 10 mL of an aqueous mixture of 1.25% (v/v) crop oil concentrate so that the final spray solutions contained 1.25±0.05% (v/v) crop oil concentrate.

[0099] For treatments comprised of technical compounds, weighed amounts can be placed individually in 25 mL glass vials and dissolved in a volume of 97:3 v/v acetone/DMSO to obtain 12X stock solutions. If a test compound does not dissolve readily, the mixture can be warmed and/or sonicated. Application solutions can be prepared by adding an appropriate amount of each stock solution (e.g., 1 mL) and diluted to the appropriate final concentrations with the addition of 10 mL of an aqueous mixture of 1.5% (v/v) crop oil concentrate so that the final spray solutions contain 1.25% (v/v) crop oil concentrate. When technical materials are used, the concentrated stock solutions can be added to the spray solutions so that the final acetone and DMSO concentrations of the application solutions are 16.2% and 0.5%, respectively.

[0100] For treatments comprised of formulated and technical compounds, weighed amounts of the technical materials were placed individually in 25 mL glass vials and dissolved in a volume of 97:3 v/v acetone/DMSO to obtain 12X stock solutions, and measured amounts of the formulated compounds were placed individually in 25 mL glass vials and diluted in a volume of 1.5% (v/v) crop oil concentrate or water to obtain 12X stock solutions. If a test compound did not dissolve readily, the mixture was warmed and/or sonicated. Application solutions were prepared by adding an appropriate amount of each stock solution (e.g., 1 mL) and diluted to the appropriate final concentrations with the addition of an appropriate amount of an aqueous mixture of 1.5% (v/v) crop oil concentrate so that the final spray solutions contained 1.25% (v/v) crop oil concentrate. As required, additional water and/or 97:3 v/v acetone/DMSO was added to individual application solutions so that the final acetone and DMSO concentrations of the application solutions being compared were 8.1% and 0.25%, respectively.

[0101] All stock solutions and applications solutions were visually inspected for compound compatibility prior to application. Spray solutions were applied to the plant material with an overhead Mandel track sprayer equipped with a 8002E nozzles calibrated to deliver 187 L/ha over an application area of 0.503 m² at a spray height of 18 to 20 inches (46 to 50 cm) above average plant canopy height. Control plants were sprayed in the same manner with the solvent blank.

[0102] The treated plants and control plants were placed in a greenhouse as described above and watered by sub-irrigation to prevent wash-off of the test compounds. After approximately 3 weeks, the condition of the test plants as compared with that of the untreated plants was determined visually and scored on a scale of 0 to 100 percent where 0 corresponds to no injury or growth inhibition and 100 corresponds to complete kill.

[0103] Colby's equation was used to determine the herbicidal effects expected from the mixtures (Colby, S.R. 1967. Calculation of the synergistic and antagonistic response of herbicide combinations. Weeds 15:20-22).

[0104] The following equation was used to calculate the expected activity of mixtures

containing two active ingredients, A and B:

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

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.

[0105] The compounds tested, application rates employed, plant species tested, and results are given in Tables 1-9.

Table 1. Synergistic Activity of Foliar-Applied Compound A Acid and Mesotrione Herbicidal Compositions on Weed Control in a Rice Cropping System.

Compound A Acid	Mesotrione	Visual Weed Control (%) - 20 DAA	
		BRAPP	
gae/ha	gai/ha	Obs	Exp
4.38	0	60	-
8.75	0	60	-
17.5	0	85	-
0	17.5	0	-
0	35	0	-
4.38	17.5	80	60
8.75	17.5	80	60
17.5	17.5	90	85
4.38	35	60	60
8.75	35	80	60
17.5	35	85	85
Compound A Acid	Mesotrione	Visual Weed Control (%) - 20 DAA	
		ECHCO	
gae/ha	gai/ha	Obs	Exp
4.38	0	40	-
8.75	0	60	-
17.5	0	85	-
0	17.5	0	-
0	35	0	-
0	70	0	-
4.38	17.5	65	40
8.75	17.5	85	60

Compound A Acid	Mesotrione	Visual Weed Control (%) - 20 DAA	
		ECHCO	
gae/ha	gai/ha	Obs	Exp
17.5	17.5	80	85
4.38	35	60	40
8.75	35	80	60
17.5	35	95	85
4.38	70	50	40
8.75	70	80	60
17.5	70	95	85
Compound A Acid	Mesotrione	Visual Weed Control (%) - 20 DAA	
		CYPIR	
gae/ha	gai/ha	Obs	Exp
4.38	0	75	-
8.75	0	90	-
17.5	0	90	-
0	17.5	0	-
0	35	50	-
4.38	17.5	100	75
8.75	17.5	100	90
17.5	17.5	100	90
4.38	35	100	88
8.75	35	100	95
17.5	35	100	95

Table 2. Synergistic Activity of Foliar-Applied Compound A Benzyl Ester and Mesotrione Herbicidal Compositions on Weed Control in a Rice Cropping System.

Compound A Benzyl Ester	Mesotrione	Visual Weed Control (%) - 20 DAA	
		IPOHE	
gae/ha	gai/ha	Obs	Exp
8.75	0	10	-
17.5	0	20	-
0	35	25	-
0	70	50	-
8.75	35	50	33

Compound A Benzyl Ester	Mesotrione	Visual Weed Control (%) - 20 DAA	
		IPOHE	
gae/ha	gai/ha	Obs	Exp
17.5	35	40	40
8.75	70	80	55
17.5	70	80	60
		SCPJU	
gae/ha	gai/ha	Obs	Exp
4.38	0	30	-
8.75	0	60	-
0	17.5	50	-
0	35	80	-
4.38	17.5	100	65
8.75	17.5	100	80
4.38	35	100	86
8.75	35	100	92
		DIGSA	
Compound A Benzyl Ester	Mesotrione	Visual Weed Control (%) - 20 DAA	
		DIGSA	
gae/ha	gai/ha	Obs	Exp
35	0	38	-
0	140	58	-
35	140	88	73

Table 3. Synergistic Activity of Foliar-Applied Compound A Acid and Sulcotrione Herbicidal Compositions on Control of Weeds Common to Rice Cropping Systems.

Compound A Acid	Sulcotrione	Visual Weed Control (%) - 20 DAA	
		BRAPP	
gae/ha	gai/ha	Obs	Exp
4.38	0	10	-
8.75	0	80	-
0	37.5	0	-
0	75	20	-
0	150	60	-
4.38	37.5	65	10

Compound A Acid	Sulcotrione	Visual Weed Control (%) - 20 DAA	
		BRAPP	
gae/ha	gai/ha	Obs	Exp
8.75	37.5	60	80
4.38	75	55	28
8.75	75	95	84
4.38	150	85	64
8.75	150	100	92
		DIGSA	
gae/ha	gai/ha	Obs	Exp
4.38	0	40	-
8.75	0	45	-
17.5	0	45	-
0	37.5	25	-
4.38	37.5	60	55
8.75	37.5	70	59
17.5	37.5	75	59
		ECHCG	
gae/ha	gai/ha	Obs	Exp
4.38	0	25	-
8.75	0	80	-
0	37.5	0	-
0	75	20	-
4.38	37.5	45	25
8.75	37.5	90	80
4.38	75	75	40
8.75	75	90	84
Compound A Acid	Sulcotrione	Visual Control (%) - 20 DAA	
		IPOHE	
gae/ha	gai/ha	Obs	Exp
4.38	0	10	-
8.75	0	35	-
17.5	0	40	-
0	37.5	20	-
4.38	37.5	50	28

Compound A Acid	Sulcotrione	Visual Control (%) - 20 DAA	
		IPOHE	
gae/ha	gai/ha	Obs	Exp
8.75	37.5	70	48
17.5	37.5	60	52

Table 4. Synergistic Activity of Foliar-Applied Compound A Benzyl Ester and Sulcotrione Herbicidal Compositions on Control of Weeds Common to Rice Cropping Systems.

Compound A Benzyl Ester	Sulcotrione	Visual Weed Control (%) - 20 DAA					
		BRAPP					
gae/ha	gai/ha	Obs	Exp				
4.38	0	50	-				
8.75	0	70	-				
0	37.5	0	-				
0	75	20	-				
0	150	60	-				
4.38	37.5	80	50				
8.75	37.5	80	70				
4.38	75	75	60				
8.75	75	85	76				
4.38	150	90	80				
8.75	150	90	88				
		DIGSA					
gae/ha	gai/ha	Obs	Exp				
4.38	0	25	-				
8.75	0	40	-				
17.5	0	50	-				
0	37.5	25	-				
4.38	37.5	70	44				
8.75	37.5	70	55				
17.5	37.5	70	63				
		ECHCG		ECHCO		IPOHE	
gae/ha	gai/ha	Obs	Exp	Obs	Exp	Obs	Exp
4.38	0	40	-	40	-	10	-
0	37.5	0	-	15	-	20	-
0	75	20	-	35	-	30	-

gae/ha	gai/ha	ECHCG		ECHCO		IPOHE	
		Obs	Exp	Obs	Exp	Obs	Exp
0	150	95	-	95	-	80	-
4.38	37.5	65	40	75	49	40	28
4.38	75	90	52	80	61	60	37
4.38	150	100	97	100	97	85	82

Table 5. Synergistic Activity of Foliar-Applied Compound A Acid and Pyrazolynate Herbicidal Compositions on Weed Control in a Rice Cropping System.

Compound A Acid gae/ha	Pyrazolynate gai/ha	Visual Weed Control (%) - 21 DAA			
		LEFCH		IPOHE	
		Obs	Exp	Obs	Exp
17.5	0	10	-	25	-
35	0	60	-	48	-
0	150	5	-	10	-
17.5	150	40	15	50	33
35	150	73	62	58	53

Table 6. Synergistic Activity of Foliar-Applied Compound A *n*-Butyl Ester and Pyrazolynate Herbicidal Compositions on Weed Control in a Rice Cropping System.

Compound A <i>n</i> -Butyl Ester gae/ha	Pyrazolynate gai/ha	Visual Weed Control (%) - 21 DAA	
		ECHCG	
		Obs	Exp
17.5	0	78	-
35	0	93	-
0	150	0	-
17.5	150	90	78
35	150	95	93

Table 7. Synergistic Activity of Foliar-Applied Compound A Benzyl Ester and Pyrazolynate Herbicidal Compositions on Weed Control in a Rice Cropping System.

Compound A Benzyl Ester gae/ha	Pyrazolynate gai/ha	Visual Weed Control (%) - 22 DAA	
		ECHCG	
		Obs	Exp
8	0	35	-
16	0	65	-
32	0	80	-

Compound A Benzyl Ester	Pyrazolynate	Visual Weed Control (%) - 22 DAA	
		ECHCG	
gae/ha	gai/ha	Obs	Exp
0	37.5	0	-
0	75	0	-
8	37.5	40	35
16	37.5	70	65
32	37.5	95	80
8	75	40	35
16	75	70	65
32	75	95	80

Table 8. Synergistic Activity of Foliar-Applied Compound A Acid and Benzobicyclon Herbicidal Compositions on Weed Control in a Rice Cropping System.

Compound A Acid	Benzo bicyclon	Visual Weed Control (%) - 22 DAA					
		ECHCG		ECHCO		SCPJU	
gae/ha	gai/ha	Obs	Exp	Obs	Exp	Obs	Exp
5.3	0	65	-	65	-	60	-
10.6	0	55	-	65	-	75	-
0	50	0	-	10	-	50	-
0	100	20	-	10	-	60	-
0	200	15	-	85	-	70	-
5.3	50	65	65	90	69	95	80
10.6	50	85	55	90	69	90	88
5.3	100	80	72	90	69	95	84
10.6	100	85	64	85	69	100	90
5.3	200	90	70	95	95	99	88
10.6	200	90	62	95	95	100	93

Table 9. Synergistic Activity of Foliar-Applied Compound A Benzyl Ester and Benzobicyclon Herbicidal Compositions on Weed Control in a Rice Cropping System.

Compound A Benzyl Ester	Benzo bicyclon	Visual Weed Control (%) - 22 DAA			
		ECHCG		ECHCO	
gae/ha	gai/ha	Obs	Exp	Obs	Exp
4.38	0	40	-	30	-
8.75	0	60	-	55	-

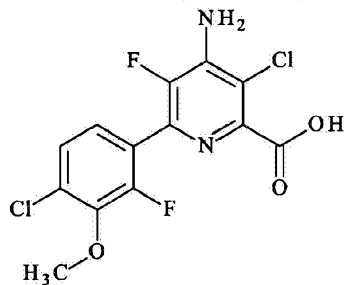
Compound A Benzyl Ester	Benzo bicyclon	Visual Weed Control (%) - 22 DAA			
		ECHCG		ECHCO	
gae/ha	gai/ha	Obs	Exp	Obs	Exp
0	50	0	-	10	-
0	100	20	-	10	-
0	200	15	-	85	-
4.38	50	45	40	80	37
8.75	50	75	60	80	60
4.38	100	85	52	85	37
8.75	100	85	68	90	60
4.38	200	90	49	90	90
8.75	200	90	66	95	93
Compound A Benzyl Ester	Benzobicyclon	Visual Weed Control (%) - 22 DAA			
		CYPIR			
gae/ha	gai/ha	Obs		Exp	
4.38	0	10		-	
8.75	0	65		-	
0	100	0		-	
0	200	0		-	
4.38	100	30		10	
8.75	100	95		65	
4.38	200	50		10	
8.75	200	100		65	
BRAPP <i>Brachiaria platyphylla</i> (Griseb.) Nash or <i>Urochloa platyphylla</i> (Nash) R.D. Webster signalgrass, broadleaf CYPES <i>Cyperus esculentus</i> L. nutsedge, yellow CYPIR <i>Cyperus iria</i> L. flatsedge, rice DIGSA <i>Digitaria sanguinalis</i> (L.) Scop. crabgrass, large ECHCG <i>Echinochloa crusgalli</i> (L.) Beauv. barnyardgrass ECHCO <i>Echinochloa colona</i> (L.) Link junglerice IPOHE <i>Ipomoea hederacea</i> Jacq. morningglory, ivyleaf LEFCH <i>Leptochloa chinensis</i> (L.) Nees sprangletop, Chinese SCPJU <i>Schoenoplectus juncooides</i> (Roxb.) Palla bulrush, Japanese gae/ha = grams acid equivalent per hectare gai/ha = grams active ingredient per hectare Obs = observed value Exp = expected value as calculated by Colby's equation DAA = days after application					

Example II. Evaluation of In-Water Applied Herbicidal Mixtures for Weed Control in Transplanted Paddy Rice

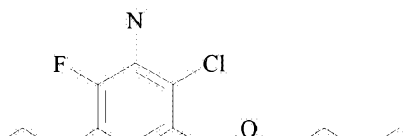
[0106] Weed seeds or nutlets of the desired test plant species were planted in puddled soil (mud) prepared by mixing a shredded, non-sterilized mineral soil (50.5 percent silt, 25.5 percent clay, and 24 percent sand, with a pH of about 7.6 and an organic matter content of about 2.9 percent) and water at a 1:1 volumetric ratio. The prepared mud was dispensed in 365 mL aliquots into 16-ounce (oz.) non-perforated plastic pots with a surface area of 86.59 square centimeters (cm²) leaving a headspace of 3 centimeters (cm) in each pot. Mud was allowed to dry overnight prior to planting or transplanting. Rice seeds were planted in Sun Gro MetroMix® 306 planting mixture, which typically has a pH of 6.0 to 6.8 and an organic matter content of about 30 percent, in plastic plug trays. Seedlings at the second or third leaf stage of growth were transplanted into 840 mL of mud contained in 32-oz. non-perforated plastic pots with a surface area of 86.59 cm² 4 days prior to herbicide application. The paddy was created by filling the headspace of the pots with 2.5 to 3 cm of water. When required to ensure good germination and healthy plants, a fungicide treatment and/or other chemical or physical treatment was applied. The plants were grown for 4-22 days in a greenhouse with an approximate 14 h photoperiod which was maintained at about 29°C during the day and 26°C during the night. Nutrients were added as Osmocote® (19:6:12, N:P:K + minor nutrients) at 2 g per 16-oz. pot and 4 g per 32-oz. pot. Water was added on a regular basis to maintain the paddy flood, and supplemental lighting was provided with overhead metal halide 1000-Watt lamps as necessary. The plants were employed for testing when they reached the first through fourth true leaf stage.

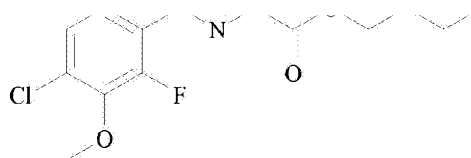
[0107] Treatments consisted of the acid or esters of 4-amino-3-chloro-5-fluoro-6-(4-chloro-2-fluoro-3-methoxy-phenyl)pyridine-2-carboxylic acid (compound A) each formulated as an SC (suspension concentrate) and various herbicidal components alone and in combination. Forms of compound A were applied on an acid equivalent basis.

Forms of compound A (compound of formula I) tested include:

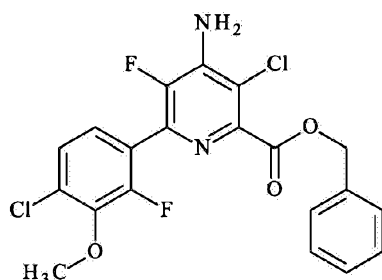


Compound A Acid





Compound A n-Butyl Ester



Compound A Benzyl Ester

[0108] Other herbicidal components were applied on an active ingredient basis and included 4-hydroxyphenyl pyruvate dioxygenase (HPPD)-inhibiting herbicides mesotrione formulated as Callisto®, sulcotrione formulated as Mikado®, pyrazolynate formulated as Sunbird® 10% GR, and benzobicyclon formulated as Benzobicyclon 3.5% or technical material.

[0109] Treatment requirements for each compound or herbicidal component were calculated based upon the rates being tested, the concentration of active ingredient or acid equivalent in the formulation, an application volume of 2 mL per component per pot, and an application area of 86.59 cm² per pot.

[0110] For formulated compounds, a measured amount was placed in an individual 100 or 200 mL glass vial and was dissolved in a volume of 1.25% (v/v) Agri-Dex® crop oil concentrate to obtain application solutions. If the test compound did not dissolve readily, the mixture was warmed and/or sonicated.

[0111] For technical grade compounds, a weighed amount was placed in an individual 100 to 200 mL glass vial and was dissolved in a volume of acetone to obtain concentrated stock solutions. If the test compound did not dissolve readily, the mixture was warmed and/or sonicated. The concentrated stock solutions obtained were diluted with an equivalent volume of an aqueous mixture containing 2.5% (v/v) crop oil concentrate so that the final application solutions contained 1.25% (v/v) crop oil concentrate.

[0112] Applications were made by injecting with a pipetter appropriate amounts of the application solutions, individually and sequentially, into the aqueous layer of the paddy. Control plants were treated in the same manner with the solvent blank. Applications were made so that all treated plant material received the same concentrations of acetone and crop oil concentrate.

[0113] The treated plants and control plants were placed in a greenhouse as described above and water was added as needed to maintain a paddy flood. After approximately 3 weeks the condition of the test plants as compared with that of the untreated plants was determined visually and scored on a scale of 0 to 100 percent where 0 corresponds to no injury or growth inhibition and 100 corresponds to complete kill.

[0114] Colby's equation was used to determine the herbicidal effects expected from the mixtures (Colby, S.R. 1967. Calculation of the synergistic and antagonistic response of herbicide combinations. Weeds 15:20-22.) .

[0115] The following equation was used to calculate the expected activity of mixtures containing two active ingredients, A and B:

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

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.

[0116] Some of the compounds tested, application rates employed, plant species tested, and results are given in Tables 10-20.

Table 10. Synergistic Activity of In-Water Applications of Compound A Acid and Mesotrione Herbicidal Compositions on Weed Control in a Rice Cropping System.

Compound A Acid	Mesotrione	Visual Weed Control (%) - 20 DAA	
		ECHCG	
gae/ha	gai/ha	Obs	Exp
8.75	0	0	-
17.5	0	35	-
35	0	55	-
0	35	10	-
0	70	25	-
8.75	35	30	10
17.5	35	50	42
35	35	99	60
8.75	70	40	25
17.5	70	45	51
35	70	75	66

Compound A Acid	Mesotrione	Visual Weed Control (%) - 20 DAA	
		ECHOR	
gae/ha	gai/ha	Obs	Exp
42.4	0	18	-
84.8	0	33	-
0	140	80	-
42.4	140	93	84
84.8	140	100	87

Table 11. Synergistic Activity of In-Water Applications of Compound A n-Butyl Ester and Mesotrione Herbicidal Compositions on Weed Control in a Rice Cropping System.

Compound A n-Butyl Ester	Mesotrione	Visual Weed Control (%) -20 DAA	
		ECHOR	
gae/ha	gai/ha	Obs	Exp
35	0	35	-
70	0	40	-
0	140	80	-
35	140	100	87
70	140	100	88

Table 12. Synergistic Activity of In-Water Applications of Compound A Benzyl Ester and Mesotrione Herbicidal Compositions on Weed Control in a Rice Cropping System.

Compound A Benzyl Ester	Mesotrione	Visual Weed Control (%) - 21 DAA	
		FIMMI	
gae/ha	gai/ha	Obs	Exp
8	0	15	-
16	0	65	-
0	35	78	-
8	35	100	81
16	35	100	92
		SCPMA	
gae/ha	gai/ha	Obs	Exp
8	0	0	-
16	0	0	-
32	0	0	-
0	35	80	-
8	35	100	80

		SCPMA	
gae/ha	gai/ha	Obs	Exp
16	35	100	80
32	35	100	80

Table 13. Synergistic Activity of In-Water Applications of Compound A Acid and Sulcotrione Herbicidal Compositions on Control of Weeds Common to Rice Cropping Systems.

Compound A Acid	Sulcotrione	Visual Weed Control (%) - 20 DAA	
		ECHCG	
gae/ha	gai/ha	Obs	Exp
8.75	0	40	-
17.5	0	30	-
0	22.5	0	-
8.75	22.5	90	40
17.5	22.5	100	30

Table 14. Synergistic Activity of In-Water Applications of Compound A Benzyl Ester and Sulcotrione Herbicidal Compositions on Control of Weeds Common to Rice Cropping Systems.

Compound A Benzyl Ester	Sulcotrione	Visual Weed Control (%) - 20 DAA	
		ECHOR	
gae/ha	gai/ha	Obs	Exp
4.38	0	10	-
8.75	0	20	-
17.5	0	30	-
0	22.5	10	-
4.38	22.5	30	19
8.75	22.5	45	28
17.5	22.5	55	37

Table 15. Synergistic Activity of In-Water Applications of Compound A Acid and Pyrazolynate Herbicidal Compositions on Weed Control in a Rice Cropping System.

Compound A Acid	Pyrazolynate	Visual Weed Control (%) - 21 DAA					
		ECHCG		ECHCO		LEFCH	
gae/ha	gai/ha	Obs	Exp	Obs	Exp	Obs	Exp
8.75	0	20	-	0	-	0	-
17.5	0	30	-	20	-	0	-
0	37.5	0	-	0	-	0	-
0	75	0	-	0	-	50	-

Compound A Acid	Pyrazolynate	Visual Weed Control (%) - 21 DAA					
		ECHCG		ECHCO		LEFCH	
gae/ha	gai/ha	Obs	Exp	Obs	Exp	Obs	Exp
8.75	37.5	50	20	0	0	20	0
17.5	37.5	95	30	35	20	100	0
8.75	75	25	20	25	0	100	50
17.5	75	45	30	40	20	100	50
		FIMMI					
gae/ha	gai/ha	Obs			Exp		
17.5	0	85			-		
35	0	85			-		
0	37.5	0			-		
0	75	0			-		
17.5	37.5	100			85		
35	37.5	100			85		
17.5	75	90			85		
35	75	100			85		
		SCPMA					
gae/ha	gai/ha	Obs			Exp		
8.75	0	0			-		
17.5	0	0			-		
35	0	0			-		
0	37.5	0			-		
8.75	37.5	30			0		
17.5	37.5	30			0		
35	37.5	100			0		

Table 16. Synergistic Activity of In-Water Applications of Compound A Benzyl Ester and Pyrazolynate Herbicidal Compositions on Weed Control in a Rice Cropping System.

Compound A Benzyl Ester	Pyrazolynate	Visual Weed Control (%) - 21 DAA	
		ECHOR	
gae/ha	gai/ha	Obs	Exp
96	0	80	-
0	37.5	0	-
0	75	8	-

Compound A Benzyl Ester	Pyrazolynate	Visual Weed Control (%) - 21 DAA	
		ECHOR	
gae/ha	gai/ha	Obs	Exp
0	150	13	-
96	37.5	95	80
96	75	95	81
96	150	100	82
		LEFCH	
gae/ha	gai/ha	Obs	Exp
4.38	0	15	-
8.75	0	15	-
0	37.5	0	-
0	75	50	-
4.38	37.5	100	15
8.75	37.5	100	15
4.38	75	100	58
8.75	75	100	58
		CYPRO	
gae/ha	gai/ha	Obs	Exp
17.5	0	10	-
0	37.5	0	-
0	75	0	-
17.5	37.5	60	10
17.5	75	50	10
		SCPJU	
gae/ha	gai/ha	Obs	Exp
4.38	0	70	-
0	37.5	0	-
0	75	0	-
4.38	37.5	99	70
4.38	75	99	70

Table 17. Synergistic Activity of In-Water Applications of Compound A Acid and Benzobicyclon (3.5%) Herbicidal Compositions on Weed Control in a Rice Cropping System.

Compound A Acid	Benzo bicyclon	Visual Weed Control (%) - 22 DAA	
		CYPRO	
gae/ha	gai/ha	Obs	Exp
10.6	0	0	-
21.2	0	40	-
0	100	30	-
0	200	45	-
10.6	100	30	30
21.2	100	95	58
10.6	200	30	45
21.2	200	99	67

Table 18. Synergistic Activity of In-Water Applications of Compound A Acid and Benzobicyclon (technical) Herbicidal Compositions on Weed Control in a Rice Cropping System.

Compound A Acid	Benzobicyclon	Visual Weed Control (%) - 22 DAA			
		ECHOR		CYPRO	
gae/ha	gai/ha	Obs	Exp	Obs	Exp
21.2	0	20	-	60	-
42.4	0	40	-	90	-
0	50	50	-	10	-
21.2	50	50	60	90	64
42.4	50	100	70	95	91

Table 19. Synergistic Activity of In-Water Applications of Compound A Benzyl Ester and Benzobicyclon (3.5%) Herbicidal Compositions on Weed Control in a Rice Cropping System.

Compound A Benzyl Ester	Benzobicyclon	Visual Weed Control (%) - 22 DAA	
		ECHCG	
gae/ha	gai/ha	Obs	Exp
8.75	0	45	-
17.5	0	90	-
0	100	30	-
0	200	45	-
8.75	100	80	62
17.5	100	100	93
8.75	200	100	70
17.5	200	60	95
Compound A Benzyl Ester	Benzobicyclon	Visual Weed Control (%) - 21 DAA	
		SCPMA	

gae/ha	gai/ha	SCPMA	
		Obs	Exp
48	0	0	-
96	0	0	-
0	100	70	-
0	200	93	-

48	100	100	70
96	100	100	70
48	200	99	93
96	200	100	93

Table 20. Synergistic Activity of In-Water Applications of Compound A Benzyl Ester and Benzobicyclon (technical) Herbicidal Compositions on Weed Control in a Rice Cropping System.

Compound A Benzyl Ester	Benzyobicyclon	Visual Weed Control (%) - 21 DAA			
		ECHOR		SCPMA	
gae/ha	gae/ha	Obs	Exp	Obs	Exp
4.38	0	25	-	0	-
8.75	0	25	-	0	-
17.5	0	60	-	0	-
0	100	30	-	80	-
4.38	100	50	48	100	80
8.75	100	50	48	90	80
17.5	100	100	72	85	80

Compound A Benzyl Ester	Benzo bicyclon	Visual Weed Control (%) - 22 DAA	
		ECHOR	
gae/ha	gai/ha	Obs	Exp
8.75	0	40	-
17.5	0	95	-
0	50	50	-
8.75	50	100	70
17.5	50	100	98

CYPRO *Cyperus rotundus* L. nutsedge, purple

ECHCG *Echinochloa crusgalli* (L.) Beauv. barnyardgrass

ECHOR *Echinochloa oryzoides* (Ard.) Fritsch watergrass, early

FIMMI *Fimbristylis miliacea* (L.) Vahl fringerush, globe

LEFCH *Leptochloa chinensis* (L.) Nees sprangletop, Chinese

SCPJU *Schoenoplectus juncooides* (Roxb.) Palla bulrush, Japanese

SCPMA *Bolboschoenus maritimus* (L.) Palla or *Schoenoplectus maritimus* (L.) Lye clubrush, sea

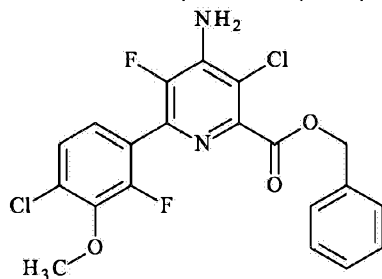
gae/ha = grams acid equivalent per hectare
 gai/ha = grams active ingredient per hectare
 Obs = observed value
 Exp = expected value as calculated by Colby's equation
 DAA = days after application

Example III. Evaluation of Pre-emergence Soil-Applied Herbicidal Mixtures for Weed Control

[0117] Seeds or nutlets of the desired test plant species were planted in a soil matrix prepared by mixing a loam soil (32 percent silt, 23 percent clay, and 45 percent sand, with a pH of about 6.5 and an organic matter content of about 1.9 percent) and calcareous grit in an 80 to 20 ratio. The soil matrix was contained in plastic pots with a volume of 1 quart and a surface area of 83.6 square centimeters (cm²).

[0118] Treatments consisted of the benzyl ester of 4-amino-3-chloro-5-fluoro-6-(4-chloro-2-fluoro-3-methoxy-phenyl)pyridine-2-carboxylic acid (compound A) formulated as an SC (suspension concentrate) and various herbicidal components alone and in combination. Forms of compound A were applied on an acid equivalent basis.

Forms of compound A (compound of formula I) tested include:



Compound A Benzyl Ester

[0119] Other herbicidal components were applied on an acid equivalent or active ingredient basis and included the 4-hydroxyphenyl pyruvate dioxygenase (HPPD)-inhibiting herbicide, isoxaflutole, formulated as Balance Pro®.

[0120] Treatment requirements were calculated based upon the rates being tested, the concentration of active ingredient or acid equivalent in the formulation, and a 12 mL application volume at a rate of 187 L/ha.

[0121] For treatments comprised of formulated compounds, measured amounts of compounds were placed individually in 25 mL glass vials and diluted in a volume of 1.25% (v/v) Agri-Dex® crop oil concentrate (COC) to obtain 12X stock solutions. If a test compound did not dissolve readily, the mixture was warmed and/or sonicated. Application solutions were prepared by

adding an appropriate amount of each stock solution (e.g., 1 mL) and diluted to the appropriate final concentrations with the addition of 10 mL of an aqueous mixture of 1.25% (v/v) COC so that the final spray solutions contained 1.25% (v/v) COC.

[0122] For treatments comprised of technical compounds, weighed amounts can be placed individually in 25 mL glass vials and dissolved in a volume of 97:3 (v/v) acetone/DMSO to obtain 12X stock solutions. If a test compound does not dissolve readily, the mixture can be warmed and/or sonicated. Application solutions can be prepared by adding an appropriate amount of each stock solution (e.g., 1 mL) and diluted to the appropriate final concentrations with the addition of 10 mL of an aqueous mixture of 1.5% (v/v) COC so that the final spray solutions contain 1.25% (v/v) COC. When technical materials are used, the concentrated stock solutions can be added to the spray solutions so that the final acetone and DMSO concentrations of the application solutions are 16.2% and 0.5%, respectively.

[0123] For treatments comprised of formulated and technical compounds, weighed amounts of the technical materials can be placed individually in 25 mL glass vials and dissolved in a volume of 97:3 (v/v) acetone/DMSO to obtain 12X stock solutions, and measured amounts of the formulated compounds can be placed individually in 25 mL glass vials and diluted in a volume of 1.5% (v/v) COC or water to obtain 12X stock solutions. If a test compound does not dissolve readily, the mixture can be warmed and/or sonicated. Application solutions can be prepared by adding an appropriate amount of each stock solution (e.g., 1 mL) and diluted to the appropriate final concentrations with the addition of an appropriate amount of an aqueous mixture of 1.5% (v/v) COC so that the final spray solutions contain 1.25% (v/v) COC. As required, additional water and/or 97:3 (v/v) acetone/DMSO can be added to individual application solutions so that the final acetone and DMSO concentrations of the application solutions being compared are 8.1% and 0.25%, respectively.

[0124] All stock solutions and applications solutions were visually inspected for compound compatibility prior to application. Spray solutions were applied to the soil with an overhead Mandel track sprayer equipped with a 8002E nozzles calibrated to deliver 187 L/ha over an application area of 0.503 m² at a spray height of 18 inches (46 cm) above average pot height. Control pots were sprayed in the same manner with the solvent blank.

[0125] The treated and control pots were placed in a greenhouse and top watered as needed. When required to ensure good germination and healthy plants, a fungicide treatment and/or other chemical or physical treatment was applied. The pots were maintained in a greenhouse with an approximate 14 hr photoperiod which was maintained at about 29° C during the day and 26° C during the night. Nutrients (Peters® Excel 15-5-15 5-Ca 2-Mg) were applied in the irrigation solution as needed and water was added on a regular basis. Supplemental lighting was provided with overhead metal halide 1000-Watt lamps as necessary. After approximately 4 weeks, the condition of the test plants as compared with that of the untreated plants was determined visually and scored on a scale of 0 to 100 percent where 0 corresponds to no injury or growth inhibition and 100 corresponds to complete kill.

[0126] Colby's equation was used to determine the herbicidal effects expected from the mixtures (Colby, S.R. 1967. Calculation of the synergistic and antagonistic response of herbicide combinations. Weeds 15:20-22.) .

[0127] The following equation was used to calculate the expected activity of mixtures containing two active ingredients, A and B:

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

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.

[0128] Some of the compounds tested, application rates employed, plant species tested, and results are given in Table 21.

Table 21. Synergistic Activity of Soil-applied, Pre-emergence Applications of Compound A Benzyl Ester and Isoxaflutole Herbicidal Compositions on Weed Control

Compound A Benzyl Ester	Isoxaflutole	Visual Weed Control (%) - 32 DAA			
		IPOHE		XANST	
		gae/ha	gai/ha	Obs	Exp
8	0	5	-	33	-
16	0	10	-	35	-
32	0	10	-	65	-
0	35	43	-	75	-
8	35	58	45	80	83
16	35	53	48	95	84
32	35	75	48	100	91
Compound A Benzyl Ester	Isoxaflutole	Visual Weed Control (%) - 32 DAA			
		SETVI			
		gae/ha	gai/ha	Obs	Exp
16	0	0	-		
32	0	13	-		
0	35	50	-		
0	70	93	-		
16	35	53	50		
32	35	70	56		
16	70	100	93		

Compound A Benzyl Ester	Isoxaflutole	Visual Weed Control (%) - 32 DAA	
		SETVI	
gae/ha	gai/ha	Obs	Exp
32	70	100	93

IPOHE *Ipomoea hederacea* (L.) Jacq. morningglory, ivyleaf
SETVI *Setaria viridis* (L.) Beauv. foxtail, green
XANST *Xanthium strumarium* L. cocklebur, common
gae/ha = grams acid equivalent per hectare
gai/ha = grams active ingredient per hectare
Obs = observed value
Exp = expected value as calculated by Colby's equation
DAA = days after application

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- [WO2009029518A](#) [0002]
- [US7314849B2](#) [0038]

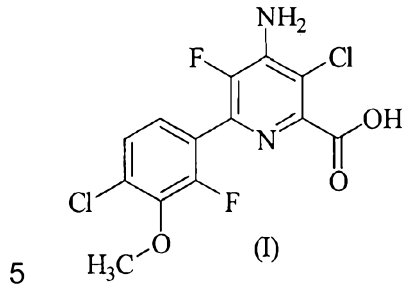
Non-patent literature cited in the description

- **ALTONA** World Compendium The Pesticide Manual BCPC Publications 20090000 [0040]
- The Pesticide Manual 20090000 [0040] [0042] [0043] [0044]
- Pesticide Manual 20090000 [0041]
- **LAWRENCE** Herbicide Handbook Weed Science Society of America 20070000 [0054]
- **COLBY, S.R.** Calculation of the synergistic and antagonistic response of herbicide combinations Weeds, 1967, vol. 15, 20-22 [0054] [0103] [0114] [0126]
- McCutcheon's Detergents and Emulsifiers Annual MC Publishing Corp. 19980000 [0088]
- Encyclopedia of Surfactants Chemical Publishing Co. vol. I-III, 1980-81 [0088]

Patentkrav

1. Synergistisk herbicid sammensætning der omfatter en herbicid effektiv mængde af

(a) en forbindelse med formlen (I):



eller en C₁₋₄-alkyl eller benzylester med formlen (I) eller et natrium-, kalium-, magnesium- eller ammoniums salt med formel (I), og

10 (b) HPPD-inhibitorer, hvor (b) er mindst en forbindelse, som er valgt fra gruppen der består af: benzobicyclon, isoxaflutol, mesotrion, pyrazolynat og sulcotrion, eller et landbrugsmæssigt acceptabelt salt, en carboxylsyre, et carboxylatsalt eller en ester deraf.

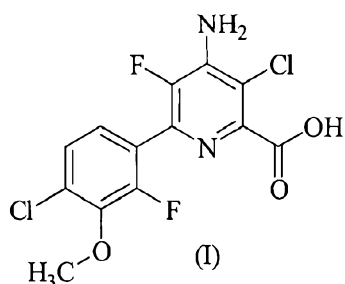
15 2. Sammensætningen ifølge krav 1, hvori (a) er forbindelsen med formel (I), en C₁₋₄-alkylester af forbindelsen med formel (I) eller en benzylester af forbindelsen med formel (I).

20 3. Sammensætning ifølge et hvilket som helst af kravene 1-2 der yderligere omfatter en landbrugsmæssig acceptabel adjuvans eller bærer.

4. Sammensætning ifølge et hvilket som helst af kravene 1-3 der yderligere omfatter en herbicid safener.

25 5. Fremgangsmåde til bekæmpelse af uønsket vegetation, hvilken fremgangsmåde omfatter at bringe en herbicid effektiv mængde af

(a) en forbindelse med formlen (I):



eller en C₁₋₄-alkyl eller benzylester med formlen (I), eller et natrium-, kalium-, magnesium- eller ammoniums salt med formlen (I), og

- 5 (b) en HPPD-inhibitor, hvori (b) er mindst en forbindelse, som er valgt fra gruppen, der består af: benzobicyclon, isoxaflutol, mesotrion, pyrazolynat og sulcotrion, eller et landbrugsmæssigt acceptabelt salt, en carboxylsyre, et carboxylatsalt eller en ester deraf, hvilken kombination af (a) og (b) udviser synergisme,
- 10 i kontakt med vegetationen eller lokuset derfor, eller anvende den på jorden eller i vandet, for at forhindre fremkomst eller vækst af vegetation.

6. Fremgangsmåden ifølge krav 5, hvori (a) er forbindelsen med formel (I), en C₁₋₄-alkylester af forbindelsen med formel (I) eller en benzylester af forbindelsen
- 15 med formel (I).

7. Fremgangsmåde ifølge et hvilket som helst af kravene 5-6, hvor den uønskede vegetation bekæmpes i direkte-sået, vand-sået og transplanteret ris, korn, hvede, byg, havre, rug, sorghum, corn/majs, sukkerrør, solsikkeolie, raps, canola,
- 20 la, sukkerroer, sojabønne, bomuld, ananas, græsgange, græsarealer, græsningsarealer, brakarealer, græstørv, træ- og vinmarker, akvatika, industriel vegetationsstyring (IVM) eller langs færdselsveje (ROW).

8. Fremgangsmåde ifølge et hvilket som helst af kravene 5-7, hvor (a) og (b)
- 25 påføres præ-emergent til ukrudtet eller afgrøden.

9. Fremgangsmåde ifølge et hvilket som helst af kravene 5-8, hvor den uønskede vegetation bekæmpes i afgrøder der er tolerante over for glyphosat, 5-

enolpyruvylshikimate-3-phosphat (EPSP)-syntaseinhibitor, glufosinat, glutaminsyntetaseinhibitor, dicamba, phenoxy-auxin, pyridyloxy-auxin, syntetisk auxin, auxintransportinhibitor, aryloxyphenoxypropionat, cyclohexandion, phenylpyrazolin, acetyl-CoA-carboxylase (ACCase)-inhibitor, imidazolinon, sulfonylurea, 5 pyrimidinylthiobenzoat, triazolopyrimidin, sulfonylaminocarbonyltriazolinon, acetolactat-syntase (ALS) eller acetohydroxysyre-syntase (AHAS)-inhibitorer, 4-hydroxyphenylpyruvat-dioxygenase (HPPD)-inhibitor, phytoen-desaturaseinhibitor, carotenoidbiosynteseinhibitor-, protoporphyrinogenoxidase (PPO)-inhibitor, cellulosebiosynteseinhibitor, mitoseinhibitor, mikrotubuli-inhibitorer, 10 meget langkædede fedtsyre-inhibitorer, fedtsyre- og lipidbiosynteseinhibitor, fotosystem I-inhibitor, fotosystem II-inhibitor, triazin- eller bromoxynil.

10. Fremgangsmåden ifølge krav 9, hvor den tolerante afgrøde har multiple eller stablede træk, der giver tolerance over for flere herbicider eller multiple virkningsmåder. 15

11. Fremgangsmåde ifølge et hvilket som helst af kravene 5-10, hvor den uønskede vegetation omfatter en herbicid resistent eller tolerant plante.