

HERBICIDAL COMPOSITIONS COMPRISING 4-AMINO-3-CHLORO-5-FLUORO-6-(4-CHLORO-2-FLUORO-3-METHOXYPHENYL)PYRIDINE-2-CARBOXYLIC ACID OR A DERIVATIVE THEREOF AND MICROTUBULE INHIBITING HERBICIDES

Priority Claim

5 This application claims the benefit of United States provisional patent application number 61/675,100 filed on July 24, 2012 and United States patent application number 13/840,303 filed March 15, 2013, the disclosure of each of which is incorporated herein by reference in its entirety.

Field

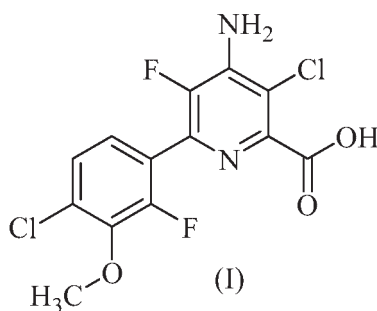
10 Provided herein are herbicidal compositions comprising (a) 4-amino-3-chloro-5-fluoro-6-(4-chloro-2-fluoro-3-methoxyphenyl)pyridine-2-carboxylic acid or an agriculturally acceptable ester or salt thereof and (b) a microtubule inhibiting herbicide. Provided herein are also methods of controlling undesirable vegetation comprising applying (a) 4-amino-3-chloro-5-fluoro-6-(4-chloro-2-fluoro-3-methoxyphenyl)pyridine-2-carboxylic acid or an
15 agriculturally acceptable ester or salt thereof and (b) a microtubule inhibiting herbicide.

Background

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
20 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.

Summary

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



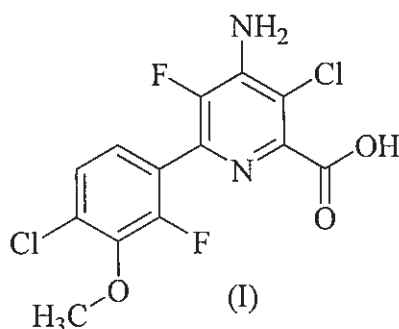
or an agriculturally acceptable salt or ester of thereof, and (b) a microtubule inhibiting herbicide. The compositions may also contain an agriculturally acceptable adjuvant or carrier.

Provided herein are also methods of controlling undesirable vegetation comprising applying (a) a compound of formula (I) or an agriculturally acceptable ester or salt thereof and (b) a microtubule inhibiting herbicide.

Several embodiments are recited below. In the embodiments, the ratio of compound (a) to compound (b) can be expressed in units of weight to weight (g to g), gae/ha to gae/ha or gae/ha to gai/ha.

A first embodiment of the invention provided herein includes a synergistic herbicidal

composition comprising a herbicidally effective amount of (a) a compound of the formula (I)



or an agriculturally acceptable salt or ester thereof and (b) a microtubule inhibiting herbicide.

A second embodiment includes the mixture of the first embodiment in which (a) is a C₁₋₄ alkyl or benzyl ester of compound (I).

A third embodiment includes the mixture of the second embodiment in which (a) is a benzyl ester of compound (I).

A fourth embodiment includes the mixture of the first embodiment in which (a) is the compound of formula (I), which is the carboxylic acid.

A fifth embodiment includes the mixture of any of the first through fourth embodiments in which the (b) is dimethenamid, S-dimethenamid, dithiopyr, oryzalin, pendimethalin, propyzamide, or thiazopyr.

A sixth embodiment includes the mixture of the first embodiment in which (a) is the compound of formula (I) or an agriculturally acceptable benzyl ester and (b) is dimethenamid or S-dimethenamid.

A seventh embodiment includes the mixture of the first embodiment in which (a) is the compound of formula (I) or an agriculturally acceptable benzyl ester and (b) is dithiopyr.

An eighth embodiment includes the mixture of the first embodiment in which (a) is the compound of formula (I) or an agriculturally acceptable benzyl ester and (b) is oryzalin.

A ninth embodiment includes the mixture of the first embodiment in which (a) is the compound of formula (I) or an agriculturally acceptable benzyl ester and (b) is pendimethalin.

A tenth embodiment includes the mixture of the first embodiment in which (a) is the compound of formula (I) or an agriculturally acceptable benzyl ester and (b) is propyzamide,

An eleventh embodiment includes the mixture of the first embodiment in which (a) is the compound of formula (I) or an agriculturally acceptable benzyl ester and (b) is thiazopyr.

5 A twelfth embodiment includes the mixture of any of the first through eleventh embodiments further comprising a herbicide safener.

A thirteenth embodiment includes the mixture of the fifth embodiment in which the weight ratio of the compound of formula (I) or agriculturally acceptable salt or ester thereof to dithiopyr or agriculturally acceptable salt or ester thereof is from about 1:3360 to about 1:1, or from about
10 1:400 to about 1:100, or from about 1:200 to about 1:50, or from about 1:100 to 1:35, or from about 1:1, or from about 1:2, or from about 1:4, or from about 1:8, or from about 1:16, or from about 1:32 to about 1:1, or from about 1:64 to 1:1.

A fourteenth embodiment includes the mixture of the fifth embodiment in which the weight ratio of the compound of formula (I) or agriculturally acceptable salt or ester thereof to dimethenamid
15 or S-dimethenamid or agriculturally acceptable salt or ester thereof is from about 1:820 to about 3:1, or from about 1:400 to about 2.5:1, from about 1:300 to about 2:1, from about 1:200 to about 1.5:1 and from about 1:100 to about 1:1.

A fifteenth embodiment includes the mixture of the fifth embodiment in which the weight ratio of the compound of formula (I) or agriculturally acceptable salt or ester thereof to oryzalin or
20 agriculturally acceptable salt or ester thereof is from about 1:1120 to about 9:1, or from about 1:600 to about 7:1, or from about 1:500 to about 6:1, or from about 1:400 to about 5:1, or from about 1:300 to about 4:1, or from about 1:200 to about 3:1, from about 1:9, from about 1:16, from about 1:35, from about 1:64 or from about 1:256 to about 1:9.

A sixteenth embodiment includes the mixture of the fifth embodiment in which the weight ratio
25 of compound of formula (I) or agriculturally acceptable salt or ester thereof to pendimethalin or agriculturally acceptable salt or ester thereof is from about 1:1120 to about 3:1, from about 1:1000 to 2:1, from about 1:750 to about 1.5:1, from about 1:500 to about 1:1, from about 1:4, from about 1:8, from about 1:16, from about 1:32, from about 1:64, from about 1:128 and from about 1:448 to 1:2.

A seventeenth embodiment includes the mixture of the fifth embodiment in which the weight
30 ratio of compound of formula (I) or agriculturally acceptable salt or ester thereof to propyzamide or agriculturally acceptable salt or ester thereof is from about 1:600 to about 4:1, from about 1:500 to about 3:1, from about 1:400 to about 2:1, from about 1:300 to about 1:1, from about 1:9, from about 1:18, from about 1:32, from about 1:64, from about 1:128 and from about 1:140 to about
35 1:2.2.

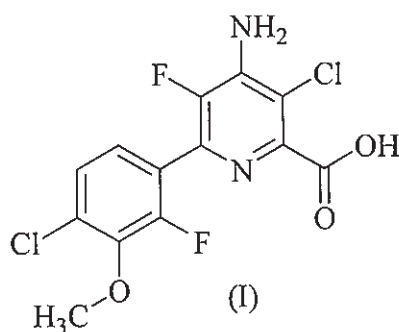
An eighteenth embodiment includes the mixture of the fifth embodiment in which the weight ratio of compound of formula (I) or agriculturally acceptable salt or ester thereof to thiazopyr or agriculturally acceptable salt or ester thereof is from about 1:1120 to about 6:1, or from about 1:1000 to about 5:1, from about 1:500 to about 4:1, from about 1:400 to 3:1, from about 1:400 to 2:1, from about 1:200 to about 1:1, from 1:9, from 1:18, from about 1:36, from about 1:72 and from about 1:10 to about 1:32.

A nineteenth embodiment includes the mixture of any of the first through eighteenth embodiments further comprising an agriculturally acceptable adjuvant or carrier.

A twentieth embodiment includes the mixture of any of the first through eighteenth embodiments which is synergistic as determined by the Colby equation.

A twenty-first embodiment includes a method of controlling undesirable vegetation which comprises contacting the vegetation or the locus thereof with or applying to the soil or water to prevent the emergence or growth of vegetation the composition of any of embodiments 1-20.

A twenty-second embodiment includes a method of controlling undesirable vegetation which comprises contacting the vegetation or the locus thereof with or applying to the soil or water to prevent the emergence or growth of vegetation a herbicidally effective amount of (a) a compound of the formula (I)



or an agriculturally acceptable salt or ester thereof and (b) a microtubule inhibiting herbicide.

A twenty-third embodiment includes the method of either of embodiments 21 or 22, wherein the method is practiced in at least one member of the group consisting of 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, aquatics, plantation crops, vegetables, industrial vegetation management (IVM) or rights-of-way (ROW).

A twenty-fourth embodiment includes the method of either of embodiments 21 or 22, wherein the undesirable vegetation is immature.

A twenty-fifth embodiment includes the method of either of embodiments 21 or 22, wherein the (a) and (b) are applied to water.

A twenty-sixth embodiment includes the method of embodiment 25, wherein the water is part of a flooded rice paddy.

A twenty-seventh embodiment includes the method of either of embodiments 21 or 22, wherein the (a) and (b) are applied pre-emergently to the weed or the crop.

- 5 A twenty-eighth embodiment includes the method of either of embodiments 21 or 22, wherein the (a) and (b) are applied post-emergently to the weed or the crop.

A twenty-ninth embodiment includes the method of either of embodiments 21 or 22, wherein the undesirable vegetation is controlled in glyphosate-, 5-enolpyruvylshikimate-3-phosphate (EPSP) synthase inhibitor-, glufosinate-, glutamine synthetase inhibitor-, dicamba-, phenoxy auxin-,

- 10 pyridyloxy auxin-, synthetic auxin-, auxin transport inhibitor-, aryloxyphenoxypionate-, cyclohexanedione-, phenylpyrazoline-, acetyl CoA carboxylase (ACCase) inhibitor-, imidazolinone-, sulfonyleurea-, pyrimidinylthiobenzoate-, triazolopyrimidine sulfonamide-, dimethoxy-pyrimidine, sulfonaminocarbonyltriazolinone-, acetolactate synthase (ALS) or acetohydroxy acid synthase (AHAS) inhibitor-, 4-hydroxyphenyl-pyruvate dioxygenase (HPPD)
15 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-, triazine-, or bromoxynil- tolerant crops.

- A thirtieth embodiment includes the method of embodiment twenty-nine, wherein the tolerant
20 crop possesses multiple or stacked traits conferring resistance and/or tolerance to multiple herbicides or multiple modes of action.

A thirty-first embodiment includes the method of either of embodiments 21 or 22, wherein the undesirable vegetation comprises a herbicide resistant or tolerant weed.

- A thirty-second embodiment includes the method of either of embodiments 21 or 22, wherein the
25 resistant or tolerant weed is a biotype with resistance or tolerance to multiple herbicides, multiple chemical classes, multiple herbicide modes-of-action or via multiple resistance mechanisms.

A thirty-third embodiment includes the method of the thirty-first embodiment in which the resistant or tolerant weed is a biotype resistant or tolerant to acetolactate synthase (ALS) or acetohydroxy acid synthase (AHAS) inhibitors, photosystem II inhibitors, acetyl CoA

- 30 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-
35 pyruvate-dioxygenase (HPPD) inhibitors, mitosis inhibitors, cellulose biosynthesis inhibitors,

herbicides with multiple modes-of-action, quinclorac, arylaminopropionic acids, difenzoquat, endothall, or organoarsenicals.

5 A thirty-fourth embodiment includes the mixture of any of the first through fifth embodiments in which the weight ratio of the compound of formula (I) or agriculturally acceptable salt or ester thereof to dithiopyr or agriculturally acceptable salt or ester thereof is from about 1:3360 to about 1:1.

10 A thirty-fifth embodiment includes the mixture of any of the first through fifth embodiments in which the weight ratio of the compound of formula (I) or agriculturally acceptable salt or ester thereof to dimethenamid or S-dimethenamid or agriculturally acceptable salt or ester thereof is from about 1:820 to about 3:1.

A thirty-sixth embodiment includes the mixture of any of the first through fifth embodiments in which the weight ratio of the compound of formula (I) or agriculturally acceptable salt or ester thereof to oryzalin or agriculturally acceptable salt or ester thereof is from about 1:1120 to about 9:1.

15 A thirty-seventh embodiment includes the mixture of any of the first through fifth embodiments in which the weight ratio of compound of formula (I) or agriculturally acceptable salt or ester thereof to pendimethalin or agriculturally acceptable salt or ester thereof is from about 1:1120 to about 3:1.

20 A thirty-eighth embodiment includes the mixture of any of the first through fifth embodiments in which the weight ratio of compound of formula (I) or agriculturally acceptable salt or ester thereof to propyzamide or agriculturally acceptable salt or ester thereof is from about 1:600 to about 4:1.

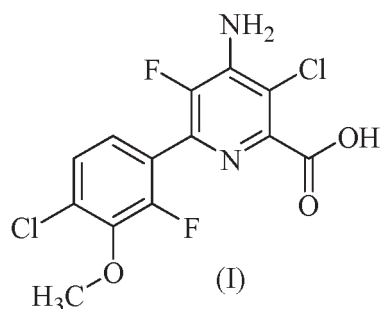
25 A thirty-ninth embodiment includes the mixture of any of the first through fifth embodiments in which the weight ratio of compound of formula (I) or agriculturally acceptable salt or ester thereof to thiazopyr or agriculturally acceptable salt or ester thereof is from about 1:1120 to about 6:1.

Detailed Description

DEFINITIONS

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

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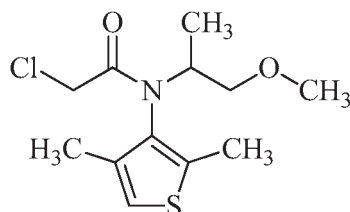


The compound of formula (I) can be identified by the name 4-amino-3-chloro-6-(4-chloro-2-fluoro-3-methoxyphenyl)-5-fluoropyridine-2-carboxylic acid and has been described in U.S. Patent 7,314,849 (B2), which is incorporated herein by reference in its entirety. Exemplary uses of the compound of the formula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

As used herein, microtubule inhibiting herbicides are herbicides that inhibit cell division by binding with tubulin and interfering with the formation of microtubules.

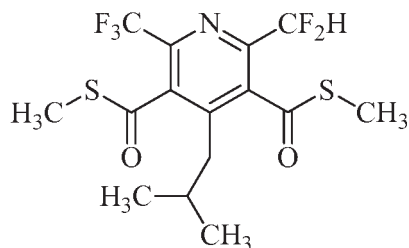
Exemplary microtubule inhibiting herbicides include, but are not limited to, dimethenamid, dithiopyr, oryzalin, pendimethalin, propyzamide, and thiazopyr or an agriculturally acceptable salt, carboxylic acid, carboxylate salt, or ester thereof.

As used herein, dimethenamid is (RS)-2-chloro-*N*-(2,4-dimethyl-3-thienyl)-*N*-(2-methoxy-1-methylethyl)acetamide and possesses the following structure:



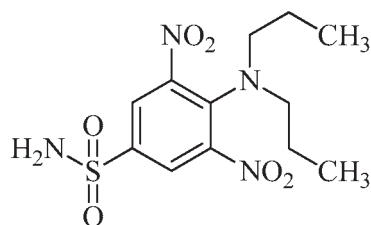
The S isomer, *i.e.*, (S) 2-chloro-*N*-(2,4-dimethyl-3-thienyl)-*N*-(2-methoxy-1-methylethyl)acetamide has also been used as a herbicide. Herbicidal activity for dimethenamid is exemplified in Tomlin, C., ed. A World Compendium The Pesticide Manual. 15th ed. Alton: BCPC Publications, 2009 (hereafter “*The Pesticide Manual*, Fifteenth Edition, 2009.”). Exemplary uses of dimethenamid include its use for pre- or early post-emergence control of annual grass and broadleaf weeds, *e.g.*, in maize, soybeans, sugar beet, potatoes, dry beans and other crops.

As used herein, dithiopyr is *S,S'*-dimethyl-2-(difluoromethyl)-4-(2-methylpropyl)-6-(trifluoromethyl)-3,5-pyridinedicarbothioate and possesses the following structure:



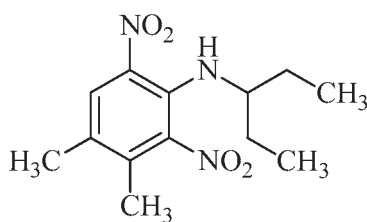
Its herbicidal activity is exemplified in *The Pesticide Manual*, Fifteenth Edition, 2009. Exemplary uses of dithiopyr include its use for pre-emergence and early post-emergence control of annual grass and broadleaf weeds, *e.g.*, in turf.

- 5 As used herein, oryzalin is 4-(dipropylamino)-3,5-dinitrobenzenesulfonamide and possesses the following structure:



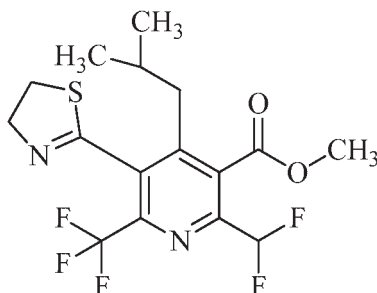
- Its herbicidal activity is exemplified in *The Pesticide Manual*, Fifteenth Edition, 2009. Exemplary uses of oryzalin include its use for pre-emergence control of annual grasses and
 10 small-seeded broadleaf weeds, *e.g.*, in fruit trees, nut trees, vines, ornamentals, soybeans, berries, amenity turf and non-crop areas.

As used herein, pendimethalin is *N*-(1-ethylpropyl)-3,4-dimethyl-2,6-dinitrobenzenamine and possesses the following structure:



- 15 Its herbicidal activity is exemplified in *The Pesticide Manual*, Fifteenth Edition, 2009. Exemplary uses of pendimethalin include its use for applied pre-plant, pre-emergence, pre-transplanting or early post-emergence control of annual grasses and annual broadleaf weeds, *e.g.*, in rice, soybeans and tree and vine orchards.
 propyzamide

As used herein, thiazopyr is methyl 2-(difluoromethyl)-5-(4,5-dihydro-2-thiazolyl)-4-(2-methylpropyl)-6-(trifluoromethyl)-3-pyridinecarboxylate and possesses the following structure:



5 Its herbicidal activity is exemplified in *The Pesticide Manual*, Fifteenth Edition, 2009. Exemplary uses of thiazopyr include its use for pre-emergence control of annual grass and some broadleaf weeds, *e.g.*, in tree fruit, vines, citrus, sugar cane, pineapples, alfalfa and forestry.

As used herein, herbicide means a compound, *e.g.*, active ingredient that kills,
10 controls or otherwise adversely modifies the growth of plants.

As used herein, a herbicidally effective or vegetation controlling amount is an amount of active ingredient 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.

15 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
20 to the vegetation, as well as preemergence, postemergence, 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.

25 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.

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.

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 aluminium cations of the formula:

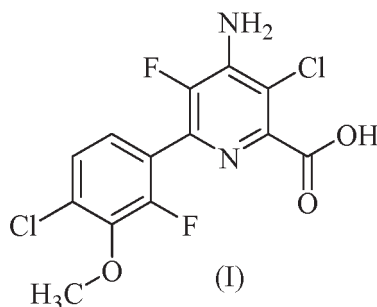


wherein R^1 , R^2 , R^3 and R^4 each, independently represents hydrogen or C_1 - C_{12} alkyl, C_3 - C_{12} alkenyl or C_3 - C_{12} alkynyl, each of which is optionally substituted by one or more hydroxy, C_1 - C_4 alkoxy, C_1 - C_4 alkylthio or phenyl groups, provided that R^1 , R^2 , R^3 and R^4 are 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.

Exemplary esters include those derived from C_1 - C_{12} alkyl, C_3 - C_{12} alkenyl, C_3 - C_{12} alkynyl or C_7 - C_{10} 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, C_1 - C_4 alkyl or C_1 - C_4 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

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



or an agriculturally acceptable salt or ester of thereof, and (b) a microtubule inhibiting herbicide. In some embodiments, the microtubule inhibiting herbicide is dimethenamid, dithiopyr, oryzalin, pendimethalin, propyzamide, and thiazopyr, or an agriculturally acceptable salt, carboxylic acid, carboxylate salt, or ester thereof.

Provided herein are also methods of controlling undesirable vegetation comprising contacting the vegetation or the locus thereof, or area adjacent to the vegetation, 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 agriculturally acceptable salt or ester thereof and (b) a microtubule inhibiting herbicide. In certain embodiments, the methods employ the compositions described herein.

Furthermore, in some embodiments, the combination of compound (I) or agriculturally acceptable salt or ester thereof and microtubule inhibiting herbicides, 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.

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.

In some embodiments, the compound of formula (I) or salt or ester thereof and
5 dimethenamid, dithiopyr, oryzalin, pendimethalin, propyzamide, and thiazopyr, or an agriculturally acceptable salt, carboxylic acid, carboxylate salt, or ester thereof are formulated in one composition, tank mixed, applied simultaneously, or applied sequentially.

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
10 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
15 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.

In some embodiments, the compositions and methods provided herein are utilized to
20 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, aquatics, plantation crops, vegetables, industrial vegetation management (IVM) and rights-of-way (ROW).

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

The compositions and methods described herein may be used to control undesirable vegetation in glyphosate-tolerant-, 5-enolpyruvylshikimate-3-phosphate (EPSP) synthase
30 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-, sulfonyleaminocarbonyltriazolinone-tolerant-, acetolactate
synthase (ALS) or acetohydroxy acid synthase (AHAS) inhibitor-tolerant-, 4-hydroxyphenyl-
5 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-
10 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, EPSP synthase inhibitors,
glufosinate, glutamine synthase inhibitors, dicamba, phenoxy auxins, pyridyloxy auxins,
synthetic auxins, auxin transport inhibitors, aryloxyphenoxypropionates, cyclohexanediones,
15 phenylpyrazolines, ACCase inhibitors, imidazolinones, sulfonyleureas,
pyrimidinylthiobenzoates, triazolopyrimidines, sulfonyleaminocarbonyltriazolinones, ALS or
AHAS inhibitors, HPPD inhibitors, phytoene desaturase inhibitors, carotenoid biosynthesis
inhibitors, PPO inhibitors, cellulose biosynthesis inhibitors, mitosis inhibitors, microtubule
inhibitors, very long chain fatty acid inhibitors, fatty acid and lipid biosynthesis inhibitors,
20 photosystem I inhibitors, photosystem II 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
25 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. The compositions and methods may be used in controlling
30 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).

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 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, ornamental species, aquatics, plantation crops, vegetables, or non-crop settings, (e.g., rights-of-way (ROW), industrial vegetation management (IVM)).

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, CYPPIR), *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 juncooides* 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 pennsylvanicum* 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).

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), *Brassica napus* (winter rapeseed, BRSNW), *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).

In some embodiments, the methods provided herein are utilized to control undesirable
 5 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.
 10 (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.
 15 (white clover, TRFRE), or *Urtica dioica* L. (common nettle, URTDI).

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
 20 A. Rich.) Stapf. or *Urochloa brizantha* (Hochst. ex A. Rich.) R.D. (beard grass, BRABR),
Brachiaria platyphylla (Groseb.) Nash or *Urochloa platyphylla* (Nash) R.D. Webster
 (broadleaf signalgrass, BRAPP), *Brachiaria plantaginea* (Link) Hitchc. or *Urochloa
 plantaginea* (Link) R.D. Webster (alexandergrass, BRAPL), *Cenchrus echinatus* L. (southern
 25 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
 30 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.
- 5 (western ragweed, AMBPS), *Ambrosia trifida* L. (giant ragweed, AMBTR), *Anoda cristata* (L.) Schlecht. (spurred anoda, ANVCR), *Asclepias syriaca* L. (common milkweed, ASCSY), *Bidens pilosa* L. (hairy beggarticks, BIDPI), *Borreria* species (BOISS), *Borreria alata* (Aubl.) DC. or *Spermacoce alata* Aubl. (broadleaf buttonweed, BOILF), *Spermacoce latifolia* (broadleaved button weed, BOILF), *Chenopodium album* L. (common lambsquarters,
- 10 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*
- 15 (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. (ivy leaf 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).
- 25 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.
- 30 (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, STAFL), *Stellaria media* (L.) Vill. (common chickweed, STEME), *Taraxacum officinale* G.H. Weber ex Wiggers
 5 (dandelion, TAROF), *Trifolium repens* L. (white clover, TRFRE), or *Viola* species (wild violet, VIOSS).

In some embodiments, the compositions and methods provided herein are utilized to control undesirable vegetation consisting of grass, broadleaf and sedge weeds. In certain
 10 embodiments, the compositions and methods provided herein are utilized to control

undesirable vegetation including *Amaranthus*, *Brachiaria* or *Urochloa*, *Chenopodium*,
Cirsium, *Cyperus*, *Digitaria*, *Echinochloa*, *Ipomoea*, *Kochia*, *Lamium*, *Leptochloa*, *Papaver*,
Schoenoplectus, *Sesbania*, *Setaria*, *Sinapis*, *Stellaria*, and *Xanthium*

In some embodiments, the combination of compound (I) or agriculturally acceptable ester or
 15 salt thereof and microtubule inhibiting herbicides or agriculturally acceptable salt or ester

thereof is used to control *Amaranthus retroflexus* L. (redroot pigweed, AMARE), *Brachiaria
 platyphylla* (Griseb.) Nash or *Urochloa platyphylla* (Nash) R.D. Webster (broadleaf
 signalgrass, BRAPP), *Brassica napus* (winter rapeseed, BRSNW), *Chenopodium album* L.
 (common lambsquarters, CHEAL), *Cirsium arvense* (L.) Scop. (Canada thistle, CIRAR),
Cyperus esculentus L. (yellow nutsedge, CYPES), *Cyperus difformis* L. (smallflower
 20 umbrella sedge, CYPDI), *Cyperus rotundus* L. (purple nutsedge, CYPRO), *Digitaria
 sanguinalis* (L.) Scop. (large crabgrass, DIGSA), *Echinochloa crus-galli* (L.) Beauv.
 (barnyardgrass, ECHCG), *Echinochloa colona* (L.) Link (junglerice, ECHCO), *Echinochloa
 oryzoides* (Ard.) Fritsch (early watergrass, ECHOR), *Ipomoea hederacea* Jacq. (ivy leaf
 morningglory, IPOHE), *Kochia scoparia* (L.) Schrad. (kochia, KCHSC), *Lamium purpureum*
 25 L. (purple deadnettle, LAMPU), *Leptochloa chinensis* (L.) Nees (Chinese sprangletop,
 LEFCH), *Papaver rhoeas* L. (common poppy, PAPRH), *choenoplectus juncooides* (Roxb.)
 Palla (Japanese bulrush, SCPJU), *Sesbania exaltata* (Raf.) Cory/Rydb. Ex Hill (hemp
 sesbania, SEBEX), *Setaria faberi* Herrm. (giant foxtail, SETFA), *Sinapis arvensis* L. (wild
 mustard, SINAR), *Stellaria media* (L.) Vill. (common chickweed, STEME), and *Xanthium
 30 strumarium* L. (common cocklebur, XANST).

The compounds of formula I or agriculturally acceptable salt or ester thereof may be
 used to control herbicide resistant or tolerant weeds. The methods employing the

combination of a compound of formula I or agriculturally acceptable salt or ester 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)

- 5 inhibitors (*e.g.*, imidazolinones, sulfonylureas, pyrimidinylthiobenzoates, dimethoxy-pyrimidiens, triazolopyrimidine sulfonamides, sulfonylaminocarbonyl triazolinones), photosystem II inhibitors (*e.g.*, phenylcarbamates, pyridazinones, triazines, triazinones, uracils, amides, ureas, benzothiadiazinones, nitriles, phenylpyridazines), acetyl CoA carboxylase (ACCase) inhibitors (*e.g.*, aryloxyphenoxypropionates, cyclohexanediones,
- 10 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,
- 15 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, protoporphyrinogen oxidase (PPO) inhibitors (*e.g.*, diphenylethers, N-phenylphthalimides, oxadiazoles, oxazolidinediones, phenylpyrazoles, pyrimidindiones, thiadiazoles, triazolinones), carotenoid biosynthesis
- 20 inhibitors (*e.g.*, clomazone, amitrole, acifluorfen), = phytoene desaturase (PDS) inhibitors (*e.g.*, amides, anilidex, furanones, phenoxybutan-amides, pyridiazinones, pyridines), 4-hydroxyphenyl-pyruvate-dioxygenase (HPPD) inhibitors (*e.g.*, callistemonones, isoxazoles, pyrazoles, triketones), cellulose biosynthesis inhibitors (*e.g.*, nitriles, benzamides, quinclorac, triazolocarbonyl amides), herbicides with multiple modes-of-action such as quinclorac, and
- 25 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
- 30 (*e.g.*, target site resistance or metabolic resistance).

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 dimethenamid or

a resolved isomer, *e.g.*, S-isomer thereof. With regard to the compositions, in some embodiments, the weight ratio of the compound of formula (I) or salt or ester thereof to dimethenamid or a resolved isomer thereof is within the range of from about 1:820 to about 3:1. In certain embodiments, the weight ratio of the compound of formula (I) or salt or ester thereof to dimethenamid or a resolved isomer thereof is within the range of from about 1:545 to about 1:2. In certain embodiments, the compositions comprise the compound of formula (I) or its benzyl or n-butyl ester and dimethenamid or a resolved isomer. 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 by a composition described herein. In some embodiments, the composition is applied at an application rate of from about 102 grams active ingredient per hectare (g ai/ha) to about 1940 g ai/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 105 grams active ingredient per hectare (g ai/ha) to about 1250 g ai/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 dimethenamid or a resolved isomer thereof, *e.g.*, sequentially or simultaneously. In some embodiments, the dimethenamid or a resolved isomer thereof is applied at a rate from about 100 g ai/ha to about 1640 g ai/ha and the compound of formula (I) or salt or ester thereof is applied at a rate from about 2 g ae/ha to about 300 g ae/ha. In certain embodiments, the methods utilize the compound of formula (I) or its benzyl or n-butyl ester and dimethenamid or a resolved isomer.

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 dithiopyr or agriculturally acceptable salt thereof. With regard to the compositions, in some embodiments, the weight ratio of the compound of formula (I) or salt or ester thereof to dithiopyr is within the range of from about 1:1120 to about 9:1. In certain embodiments, the weight ratio of the compound of formula (I) or salt or ester thereof to dithiopyr is within the range of from about 1:32 to about 1:1. In certain embodiments, the weight ratio of the compound of formula (I) or salt or ester thereof to dithiopyr is within the range of from about 1:1 to about 1:64. In certain embodiments, the weight ratio of the compound of formula (I)

or salt or ester thereof dithiopyr is within the range of from about 1:2 to about 1:32. In certain embodiments, the compositions provided herein comprise the compound of formula (I) or its benzyl ester and dithiopyr. In one embodiment, the composition comprises the compound of formula (I) and dithiopyr, wherein the weight ratio of the compound of formula (I) to

5 dithiopyr is about 1:4 to about 1:32. In one embodiment, the composition comprises the benzyl ester of the compound of formula (I) and dithiopyr, wherein the weight ratio of the benzyl ester of the compound of formula (I) to dithiopyr is about 1:2 to about 1:32. 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

10 emergence or growth of vegetation by a composition described herein. In some embodiments, the composition is applied at an application rate of from about 37 grams active ingredient per hectare (g ai/ha) to about 2540 g ai/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 40 grams active ingredient per hectare (g ai/ha) to about 200 g

15 ai/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 dithiopyr or salt or ester thereof, *e.g.*,

sequentially or simultaneously. In some embodiments, the dithiopyr is applied at a rate from about 35 g ai/ha to about 2240 g ai/ha and the compound of formula (I) of salt or ester thereof is applied at a rate from about 2 g ae/ha to about 300 g ae/ha. In some embodiments, the dithiopyr is applied at a rate from about 17 g ai/ha to about 280 g ai/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 (g ae/ha) to about 70 g ae/ha. In some embodiments, the dithiopyr is applied at a rate

25 from about 35 g ai/ha to about 140 g ai/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 (g ae/ha) to about 35 g ae/ha. In certain embodiments, the methods utilize the compound of formula (I), or its benzyl ester and dithiopyr. In one embodiment, the methods utilize the compound of formula

(I) and dithiopyr, wherein the compound of formula (I) is applied at a rate of from about 4.38 g acid equivalent per hectare (g ae/ha) to about 35 g ae/ha, and dithiopyr is applied at a rate of about 35 g ai/ha to about 280 g ai/ha. In one embodiment, the methods utilize the benzyl ester of the compound of formula (I) and dithiopyr, 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 (g ae/ha) to about 17.5 g ae/ha, and dithiopyr is applied at a rate of about 35 g ai/ha to about 140 g ai/ha. In certain embodiments, the methods and compositions utilizing the compound of formula (I) or salt or ester thereof in combination with dithiopyr are used to control BRAPP, ECHCG,
5 ECHCO, ECHOR, IPOHE, rSCPMA, or XANST .

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 oryzalin or salt thereof. With regard to the compositions, in some embodiments, the weight ratio of the compound of formula (I) or salt or ester thereof to oryzalin or salt thereof is within the range
10 of from about 1:3360 to about 1:1. In certain embodiments, the weight ratio of the compound of formula (I) or salt or ester thereof to oryzalin or salt thereof is within the range of about 1:256 to about 1:2. In certain embodiments, the weight ratio of the compound of formula (I) or salt or ester thereof to oryzalin or salt thereof is within the range of from about 1:13 to about 1:512. In certain embodiments, the weight ratio of the compound of formula (I)
15 or salt or ester thereof to oryzalin or salt thereof is within the range of from about 1:26 to about 1:256. In certain embodiments, the compositions provided herein comprise the compound of formula (I) or its benzyl ester and oryzalin or salt thereof. In one embodiment, the composition comprises the compound of formula (I) and oryzalin, wherein the weight ratio of the compound of formula (I) to oryzalin is about 1:26 to about 1:212. In one
20 embodiment, the composition comprises the benzyl ester of the compound of formula (I) and oryzalin, wherein the weight ratio of the benzyl ester of the compound of formula (I) to oryzalin is about 1:32 to about 1:256. 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 by a composition
25 described herein. In some embodiments, the composition is applied at an application rate of from about 282 grams active ingredient per hectare (g ai/ha) to about 7020 g ai/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 285 grams active ingredient per hectare (g ai/ha) to about 1150 g ae/ha based on the total amount of active ingredients in the
30 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 oryzalin or

salt thereof, *e.g.*, sequentially or simultaneously. In some embodiments, the oryzalin or salt or free base thereof is applied at a rate from about 280 g ai/ha to about 6720 g ai/ha and the compound of formula (I) or salt or ester thereof is applied at a rate from about 2 g ae/ha to about 300 g ae/ha. In some embodiments, the oryzalin or salt thereof is applied at a rate from about 140 g ai/ha to about 2240 g ai/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 (g ae/ha) to about 42 g ae/ha. In some embodiments, the oryzalin or salt thereof is applied at a rate from about 280 g ai/ha to about 1120 g ai/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 (g ae/ha) to about 32 g ae/ha. In certain embodiments, the methods utilize the compound of formula (I), or its benzyl ester and oryzalin. In one embodiment, the methods utilize the compound of formula (I) and oryzalin, wherein the compound of formula (I) is applied at a rate of from about 5.3 g acid equivalent per hectare (g ae/ha) to about 21.2 g ae/ha, and oryzalin is applied at a rate of about 280 g ai/ha to about 1120 g ai/ha. In one embodiment, the methods utilize the benzyl ester of the compound of formula (I) and oryzalin, 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 (g ae/ha) to about 17.5 g ae/ha, and oryzalin is applied at a rate of about 280 g ai/ha to about 1120 g ai/ha. In certain embodiments, the methods and compositions utilizing the compound of formula (I) or salt or ester thereof in combination with oryzalin are used to control CYPDI, CYPES, CYPRO, ECHCG, IPOHE or SCPJU.

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 pendimethalin or a salt thereof. With regard to the compositions, in some embodiments, the weight ratio of the compound of formula (I) or salt or ester thereof to pendimethalin or a salt thereof is within the range of from about 1:1120 to about 1:2. In certain embodiments, the weight ratio of the compound of formula (I) or salt or ester thereof to pendimethalin or a salt thereof is within the range of from about 1:128 to about 1:4. In certain embodiments, the weight ratio of the compound of formula (I) or salt or ester thereof to pendimethalin or a salt thereof is within the range of from about 1:448 to about 1:2. The application rate will depend upon the particular type of weed to be controlled, the degree of control required, and the timing and method of application. In certain embodiments, the weight ratio of the compound of formula (I) or salt or ester thereof to pendimethalin or a salt thereof is within the range of from about

1:4 to about 1:250. In certain embodiments, the weight ratio of the compound of formula (I) or salt or ester thereof to pendimethalin or a salt thereof is within the range of from about 1:8 to about 1:128. In certain embodiments, the compositions provided herein comprise the compound of formula (I) or its benzyl ester and pendimethalin. In one embodiment, the composition comprises the compound of formula (I) and pendimethalin, wherein the weight ratio of the compound of formula (I) to pendimethalin is about 1:16 to about 1:128. In one embodiment, the composition comprises the benzyl ester of the compound of formula (I) and pendimethalin, wherein the weight ratio of the benzyl ester of the compound of formula (I) to pendimethalin is about 1:8 to about 1:128. 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 by a composition described herein. In some embodiments, the composition is applied at an application rate of from about 40 grams active ingredient per hectare (g ai/ha) to about 1980g ai/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 150 grams active ingredient per hectare (g ai/ha) to about 600 g ai/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 150 grams active ingredient per hectare (g ai/ha) to about 1190 g ai/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 pendimethalin or a salt or freebase thereof, *e.g.*, sequentially or simultaneously. In some embodiments, the pendimethalin or a salt or freebase thereof is applied at a rate from about 140 g ai/ha to about 1680 g ai/ha and the compound of formula (I) of salt or ester thereof is applied at a rate from about 2 g ae/ha to about 300 g ae/ha. In some embodiments, the pendimethalin or a salt or freebase thereof is applied at a rate from about 70 g ai/ha to about 1120 g ai/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 (g ae/ha) to about 70 g ae/ha. In some embodiments, the pendimethalin or a salt or freebase thereof is applied at a rate from about 140 g ai/ha to about 560 g ai/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 (g ae/ha) to about 35 g ae/ha. In certain embodiments, the methods utilize the compound of

formula (I), or its benzyl ester and pendimethalin. In one embodiment, the methods utilize the compound of formula (I) and pendimethalin, wherein the compound of formula (I) is applied at a rate of from about 4.38 g acid equivalent per hectare (g ae/ha) to about 35 g ae/ha, and pendimethalin is applied at a rate of about 140 g ai/ha to about 560 g ai/ha. In one
5 embodiment, the methods utilize the compound of formula (I) and pendimethalin, wherein the compound of formula (I) is applied at a rate of from about 2.5 g acid equivalent per hectare (g ae/ha) to about 70 g ae/ha, and pendimethalin is applied at a rate of about 140 g ai/ha to about 1120 g ai/ha. In one embodiment, the methods utilize the benzyl ester of the compound of formula (I) and the pendimethalin, wherein the benzyl ester of the compound of
10 formula (I) is applied at a rate of from about 4.38 g acid equivalent per hectare (g ae/ha) to about 35 g ae/ha, and the pendimethalin is applied at a rate of about 140 g ai/ha to about 560 g ai/ha. In certain embodiments, the methods and compositions utilizing the compound of formula (I) or salt or ester thereof in combination with pendimethalin or a salt thereof are used to control AMARE, BRNSW, CHEAL, CIRAR, CYPRO, DIGSA, ECHCG, ECHCO,
15 IPOHE, KCHSC, LAMPU, LEFCH, PAPRH, SCPMA, SINAR, or STEME.

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 thiazopyr, salt, carboxylic acid, carboxylate 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
20 thiazopyr is within the range of from about 1:1120 to about 6:1. In certain embodiments, the weight ratio of the compound of formula (I) or salt or ester thereof to thiazopyr is within the range of from about 1:509 to about 1:1. In certain embodiments, the compositions comprise the compound of formula (I) or its benzyl ester and thiazopyr. With respect to the methods, in certain embodiments, the methods comprise contacting the undesirable
25 vegetation or locus thereof or applying to the soil or water to prevent the emergence or growth of vegetation by a composition described herein. In some embodiments, the composition is applied at an application rate of from about 52 grams active ingredient per hectare (g ai/ha) to about 2540 g ai/ha based on the total amount of active ingredients in the composition. In certain embodiments, the composition is applied at an application rate of
30 from about 55 grams active ingredient per hectare (g ai/ha) to about 1170 g ai/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 thiazopyr, *e.g.*, sequentially or simultaneously. In some embodiments, the thiazopyr is applied at a rate from about 50 g ai/ha to about 2540 g ai/ha and the compound of formula (I) or salt or ester thereof is applied at a rate from about 2 g
5 ae/ha to about 300 g ae/ha. In certain embodiments, the methods utilize the compound of formula (I) or its benzyl ester and thiazopyr. In certain embodiments, the methods and compositions utilizing the compound of formula (I) or salt or ester thereof in combination with thiazopyr or a salt thereof are used to control IPOHE or XANST.

In certain embodiments of the compositions and methods described herein, the
10 compound of formula (I) or salt or ester thereof is used in combination with propyzamide, salt, carboxylic acid, carboxylate 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 thiazopyr is within the range of from about 1:600 to about 4:1. In certain embodiments, the weight ratio of the compound of formula (I) or salt or ester thereof to propyzamide is within
15 the range of from about 1:35 to about 1:2. In certain embodiments, the compositions comprise the compound of formula (I) or its benzyl ester and propyzamide. 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 by a composition described herein. In some embodiments, the
20 composition is applied at an application rate of from about 72 grams active ingredient per hectare (g ai/ha) to about 2500 g ai/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 78 grams active ingredient per hectare (g ai/ha) to about 1152 g ai/ha based on the total amount of active ingredients in the composition. In some embodiments, the methods
25 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 thiazopyr, *e.g.*, sequentially or simultaneously. In some embodiments, the propyzamide is applied at a rate from about 70 g ai/ha to about 1200 g ai/ha and the compound of formula (I) or salt or ester thereof is applied at a rate from about 2
30 g ae/ha to about 300 g ae/ha. In some embodiments, the propyzamide is applied at a rate from about 70 g ai/ha to about 1120 g ai/ha and the compound of formula (I) or salt or ester thereof is applied at a rate from about 2.5 g ae/ha to about 70 g ae/ha. In certain

embodiments, the methods utilize the compound of formula (I) or its benzyl ester and propyzamide. In certain embodiments, the methods and compositions utilizing the compound of formula (I) or salt or ester thereof in combination with propyzamide or a salt thereof are used to control of BRAPP, ECHCG, ECHCO, IPOHE, SEBEX, or SETFA.

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

 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
10 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,
15 acrolein, alachlor, allidochlor, alloxymid, allyl alcohol, alorac, ametrifone, ametryn, amibuzin, amicarbazone, amidosulfuron, aminocyclopyrachlor, aminopyralid, amiprofos-methyl, amitrole, ammonium sulfamate, anilofos, anisuron, asulam, atraton, atrazine, azafenidin, azimsulfuron, aziprotryne, barban, BCPC, beflubutamid, benazolin, bencarbazon, benfluralin, benfuresate, bensulfuron-methyl, bensulide, benthicarb,
20 bentazon-sodium, benzadox, benzfendazole, benzipram, benzobicyclon, benzofenap, benzoflur, benzoylprop, benzthiazuron, bialaphos, bicyclopyrone, bifenox, bilanafos, bispyribac-sodium, borax, bromacil, bromobonil, bromobutide, bromofenoxim, bromoxynil, brompyrazon, butachlor, butafenacil, butamifos, butenachlor, buthidazole, buthiuron, butralin, butoxydim, buturon, butylate, cacodylic acid, cafenstrole, calcium chlorate, calcium
25 cyanamide, cambendiclor, carbasulam, carbetamide, carboxazole chlorprocarb, carfentrazone-ethyl, CDEA, CEPC, chlormethoxyfen, chloramben, chloranocryl, chlorazifop, chlorazine, chlorbromuron, chlorbufam, chloreturon, chlorfenac, chlorfenprop, chlorflurazole, chlorflurenol, chloridazon, chlorimuron, chlornitrofen, chloropon, chlorotoluron, chloroxuron, chloroxynil, chlorpropham, chlorsulfuron, chlorthal,
30 chlorthiamid, cinidon-ethyl, cinmethylin, cinosulfuron, cisanilide, clethodim, clidinate, clodinafop-propargyl, clofop, clomazone, clomeprop, cloprop, cloproxydim, clopyralid, 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,
 5 difenopenten, difenoxuron, difenzoquat, diflufenican, diflufenzopyr, dimefuron,
 dimepiperate, dimethachlor, dimethametryn, dimexano, dimidazon, dinitramine, dinofenate,
 dinoprop, dinosam, dinoseb, dinoterb, diphenamid, dipropetryn, diquat, disuldiuron, DMPA,
 DNOC, DSMA, EBEP, eglinazine, endothal, epronaz, EPTC, erbon, esprocarb, ethalfluralin,
 ethbenzamide, ethametsulfuron, ethidimuron, ethiolate, ethobenzamid, etobenzamid,
 10 ethofumesate, ethoxyfen, ethoxysulfuron, etinofen, etnipromid, etobenzanid, EXD,
 fenasulam, fenoprop, fenoxaprop, fenoxaprop-P-ethyl, fenoxaprop-P-ethyl + isoxadifen-
 ethyl, fenoxasulfone, fenteracol, fenthiafop, fentrazamide, fenuron, ferrous sulfate,
 flamprop, flamprop-M, flazasulfuron, florasulam, fluazifop, fluazifop-P-butyl, fluazolate,
 flucarbazone, flucetosulfuron, fluchloralin, flufenacet, flufenican, flufenpyr-ethyl,
 15 flumetsulam, flumezin, flumiclorac-pentyl, flumioxazin, flumipropyn, fluometuron,
 fluorodifen, fluoroglycofen, fluoromidine, fluoronitrofen, fluothiuron, flupoxam, flupropacil,
 flupropanate, flupyrsulfuron, fluridone, flurochloridone, fluroxypyr, fluroxypyr-meptyl,
 flurtamone, fluthiacet, fomesafen, foramsulfuron, fosamine, fumiclorac, furyloxyfen,
 glufosinate, glufosinate salts and esters, glufosinate-ammonium, glufosinate-P-ammonium,
 20 glyphosate, glyphosate salts and esters, 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,
 25 isocarbamid, isocil, isomethiozin, isonoruron, isopolinate, isopropalin, isoproturon, isouron,
 isoxaben, isoxachlortole, isoxaflutole, isoxapyrifop, karbutilate, ketospiradox, lactofen,
 lenacil, linuron, MAA, MAMA, MCPA esters and amines, MCPA-thioethyl, MCPB,
 mecoprop, mecoprop-P, medinoterb, mefenacet, mefluidide, mesoprazine, mesosulfuron,
 mesotrione, metam, metamifop, metamitron, metazachlor, metazosulfuron, metflurazon,
 30 methabenzthiazuron, methalpropalin, methazole, methiobencarb, methiozolin, methiuron,
 methometon, methoprottryne, methyl bromide, methyl isothiocyanate, methyldymron,
 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, oxadiargyl, oxadiazon, oxapyrazon, oxasulfuron,
 5 oxaziclomefone, oxyfluorfen, paraflufen-ethyl, parafluron, paraquat, pebulate, pelargonic
 acidpenoxsulam, 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, procyazine, prodiamine, profluazol, profluralin,
 10 profoxydim, proglinazine, prohexadione-calcium, prometon, prometryn, pronamide,
 propachlor, propanil, propaquizafop, propazine, propham, propisochlor, propoxycarbazone,
 propyrisulfuron, prosulfalin, prosulfocarb, prosulfuron, proxan, prynachlor, pydanon,
 pyraclonil, pyraflufen-ethyl, pyrasulfotole, pyrazogyl, pyrazolynate, pyrazosulfuron-ethyl,
 pyrazoxyfen, pyribenzoxim, pyributicarb, pyriclor, pyridafof, pyridate, pyriftalid,
 15 pyriminobac, pyrimisulfan, pyrithiobac-sodium, pyroxasulfone, pyroxsulam, quinclorac,
 quinmerac, quinoclamine, quinonamid, quizalofop, quizalofop-P-ethyl, rhodethanil,
 rimsulfuron, saflufenacil, S-metolachlor, sebuthylazine, secbumeton, sethoxydim, siduron,
 simazine, simeton, simetryn, SMA, sodium arsenite, sodium azide, sodium chlorate,
 sulcotrione, sulfallate, sulfentrazone, sulfometuron, sulfosate, sulfosulfuron, sulfuric acid,
 20 sulglycapin, swep, SYN-523, TCA, tebutam, tebuthiuron, tefuryltrione, tembotrione,
 tepraloxydim, terbacil, terbucarb, terbuchlor, terbumeton, terbuthylazine, terbutryn,
 tetrafluron, thiazafluronthidiazimin, thidiazuron, thiencarbazone-methyl, thifensulfuron,
 thifensulfurn-methyl, thiobencarb, tiocarbamil, tioclorim, topramezone, tralkoxydim,
 triafamone, tri-allate, triasulfuron, triaziflam, tribenuron, tribenuron-methyl, tricamba,
 25 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.

The compositions and methods described herein, can further be used in conjunction
 30 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, sulfonylaminocarbonyltriaolinones, 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, sulfonylaminocarbonyltriaolinone-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, bromoxynil-tolerant, 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, as a tank mix, or as a sequential application.

In some embodiments, the compositions described herein are employed in combination with one or more herbicide safeners, such as AD-67 (MON 4660), benoxacor, benthicarb, 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).

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, 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.

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, turf, 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 microtubule inhibiting herbicides to cause a preferentially advantageous effect on plants.

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.

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

Liquid carriers that can be employed include water and organic solvents. The organic solvents include, but are not limited to, petroleum fractions or hydrocarbons such as mineral oil, aromatic solvents, paraffinic oils, and the like; vegetable oils such as soybean oil, rapeseed oil, olive oil, castor oil, sunflower seed oil, coconut oil, corn oil, cottonseed oil, linseed oil, palm oil, peanut oil, safflower oil, sesame oil, tung oil and the like; esters of the above vegetable oils; esters of monoalcohols or dihydric, trihydric, or other lower polyalcohols (4-6 hydroxy containing), such as 2-ethyl hexyl stearate, *n*-butyl oleate, isopropyl myristate, propylene glycol dioleate, di-octyl succinate, di-butyl adipate, di-octyl phthalate and the like; esters of mono, di and polycarboxylic acids and the like. Specific organic solvents include, but are not limited to toluene, xylene, petroleum naphtha, crop oil, acetone, methyl ethyl ketone, cyclohexanone, trichloroethylene, perchloroethylene, ethyl acetate, amyl acetate, butyl acetate, propylene glycol monomethyl ether and diethylene glycol monomethyl ether, methyl alcohol, ethyl alcohol, isopropyl alcohol, amyl alcohol, ethylene glycol, propylene glycol, glycerine, *N*-methyl-2-pyrrolidinone, *N,N*-dimethyl alkylamides, dimethyl sulfoxide, liquid fertilizers and the like. In certain embodiments, Water is the carrier for the dilution of concentrates.

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

In some embodiments, the compositions described herein further comprise one or more surface-active agents. In some embodiments, such surface-active agents are employed in both solid and liquid compositions, and in certain embodiments those designed to be diluted with carrier before application. The surface-active agents can be anionic, cationic or

nonionic in character and can be employed as emulsifying agents, wetting agents, suspending agents, or for other purposes. Surfactants which may also be used in the present formulations are described, *inter alia*, in "McCutcheon's Detergents and Emulsifiers Annual," MC Publishing Corp., Ridgewood, New Jersey, 1998 and in "Encyclopedia of Surfactants," Vol.

5 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-C₁₈ ethoxylate; alcohol-alkylene oxide addition products, such as tridecyl alcohol-C₁₆ ethoxylate; soaps, such as sodium stearate; alkyl-
10 naphthalene-sulfonate salts, such as sodium dibutylnaphthalenesulfonate; 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
15 seed oils such as soybean oil, rapeseed/canola oil, olive oil, castor oil, sunflower seed oil, coconut oil, corn oil, cottonseed oil, linseed oil, palm oil, peanut oil, safflower oil, sesame oil, tung oil and the like; and esters of the above vegetable oils, and in certain embodiments, methyl esters.

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

Other exemplary additives for use in the compositions provided herein include but are not limited to compatibilizing agents, antifoam agents, sequestering agents, neutralizing agents and buffers, corrosion inhibitors, dyes, odorants, spreading agents, penetration aids,
25 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.

30 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
5 or the locus of weeds contain, in certain embodiments, about 0.0006 to 10.0 weight percent active ingredient and in certain embodiments contain about 0.001 to 6.0 weight percent.

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.

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

Examples

15 Results in Examples I, II, III, and IV are greenhouse trial results.

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

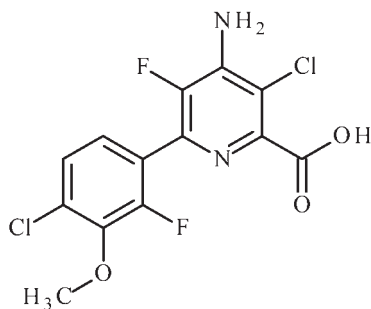
Seeds or nutlets of the desired test plant species were planted in a soil matrix prepared by mixing a loam or sandy loam soil (*e.g.*, 28.6 percent silt, 18.8 percent clay, and 52.6
20 percent sand, with a pH of about 5.8 and an organic matter content of about 1.8 percent) and calcareous grit in an 80 to 20 ratio. The soil matrix was contained in plastic pots with a volume of 1 quart and a surface area of 83.6 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
25 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.

30 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.

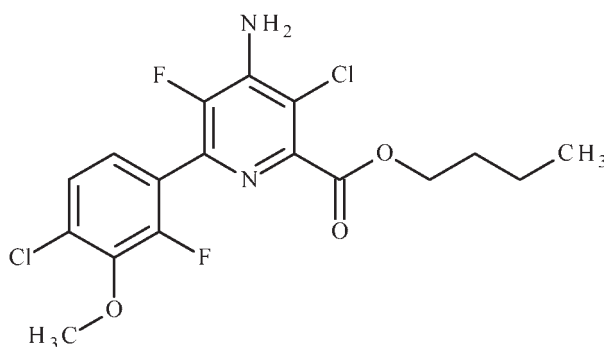
Forms of compound A were applied on an acid equivalent basis.

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

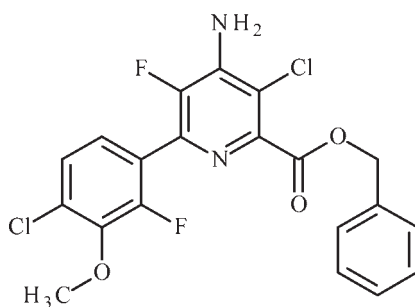


5

Compound A Acid



Compound A *n*-Butyl Ester



10

Compound A Benzyl Ester

Other herbicidal components were applied on an active ingredient basis and included microtubule inhibiting (MTI) herbicides pendimethalin applied as Prowl[®] 3.3EC, dithiopyr applied as Dithiopyr WP, oryzalin applied as Surflan[®] SC, propyzamide formulated as Kerb[®] 50WP, thiazopyr (technical grade material).

15

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.

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.

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.

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.

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.

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.

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.) .

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.

The compounds tested, application rates employed, plant species tested, and results are given in Tables 1-10.

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

Compound A Acid	Pendimethalin	Visual Weed Control (%) - 19 DAA	
		DIGSA	
g ae/ha	g ai/ha	Obs	Exp
4.38	0	30	-

0	140	0	-
0	280	0	-
4.38	140	50	30
4.38	280	45	30

Compound A Acid	Pendimethalin	Visual Weed Control (%) - 19 DAA	
		ECHCG	
g ae/ha	g ai/ha	Obs	Exp
4.38	0	60	-
0	140	0	-
0	280	0	-
0	560	10	-
4.38	140	80	60
4.38	280	85	60
4.38	560	95	64

Compound A Acid	Pendimethalin	Visual Weed Control (%) - 19 DAA	
		IPOHE	
g ae/ha	g ai/ha	Obs	Exp
4.38	0	0	-
8.75	0	10	-
0	140	0	-
0	280	0	-
0	560	0	-
4.38	140	15	0
8.75	140	15	10
4.38	280	20	0
8.75	280	25	10
4.38	560	15	0
8.75	560	20	10

Compound A Acid	Pendimethalin	Visual Weed Control (%) - 21 DAA	
		IPOHE	
g ae/ha	g ai/ha	Obs	Exp

35	0	45	-
0	1120	13	-
35	1120	70	52

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

Compound A Benzyl Ester	Pendimethalin	Visual Weed Control (%) - 19 DAA	
		DIGSA	
g ae/ha	g ai/ha	Obs	Exp
4.38	0	35	-
8.75	0	50	-
0	140	0	-
0	280	0	-
4.38	140	45	35
8.75	140	50	50
4.38	280	50	35
8.75	280	70	50

5

Compound A Benzyl Ester	Pendimethalin	Visual Weed Control (%) - 19 DAA					
		ECHCG		ECHCO		IPOHE	
g ae/ha	g ai/ha	Obs	Exp	Obs	Exp	Obs	Exp
4.38	0	55	-	65	-	0	-
8.75	0	85	-	90	-	0	-
0	140	0	-	0	-	0	-
0	280	0	-	0	-	0	-
0	560	10	-	0	-	0	-
4.38	140	75	55	85	65	25	0
8.75	140	90	85	95	90	10	0
4.38	280	85	55	90	65	15	0
8.75	280	95	85	95	90	25	0
4.38	560	90	60	90	65	10	0
8.75	560	95	87	95	90	15	0

Compound A Benzyl Ester	Pendimethalin	Visual Weed Control (%) - 19 DAA
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		LEFCH	
g ae/ha	g ai/ha	Obs	Exp
4.38	0	0	-
8.75	0	25	-
17.5	0	30	-
0	140	0	-
0	280	20	-
0	560	80	-
4.38	140	20	0
8.75	140	40	25
17.5	140	50	30
4.38	280	45	20
8.75	280	65	40
17.5	280	85	44
4.38	560	85	80
8.75	560	90	85
17.5	560	99	86

Table 3. Synergistic Activity of Foliar-Applied Compound A n-Butyl Ester and Pendimethalin Herbicidal Compositions on Weed Control in a Rice Cropping System.

Compound A n-Butyl Ester	Pendimethalin	Visual Weed Control (%) - 21 DAA	
		ECHCG	
g ae/ha	g ai/ha	Obs	Exp
17.5	0	45	-
35	0	70	-
0	1120	18	-
17.5	1120	90	55
35	1120	99	75

Compound A n-Butyl Ester	Pendimethalin	Visual Weed Control (%) - 21 DAA	
		IPOHE	
g ae/ha	g ai/ha	Obs	Exp
17.5	0	40	-
0	1120	13	-
17.5	1120	63	48

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

Compound A Acid	Dithiopyr	Visual Weed Control (%) -21 DAA	
		BRAPP	
g ae/ha	g ai/ha	Obs	Exp
8.75	0	60	-
0	35	0	-
0	70	0	-
0	140	0	-
8.75	35	90	60
8.75	70	75	60
8.75	140	90	60

Compound A Acid	Dithiopyr	Visual Weed Control (%) - 21 DAA	
		ECHCO	
g ae/ha	g ai/ha	Obs	Exp
4.38	0	60	-
8.75	0	90	-
0	35	0	-
0	70	0	-
0	140	0	-
4.38	35	90	60
8.75	35	95	90
4.38	70	95	60
8.75	70	95	90
4.38	140	95	60
8.75	140	95	90

5 Table 5. Synergistic Activity of Foliar-Applied Compound A Benzyl Ester and Dithiopyr Herbicidal Compositions on Control of Weeds Common to Rice Cropping Systems.

Compound A Benzyl Ester	Dithiopyr	Visual Weed Control (%) - 21 DAA	
		BRAPP	
g ae/ha	g ai/ha	Obs	Exp
4.38	0	70	-

0	35	0	-
0	70	0	-
0	140	0	-
4.38	35	75	70
4.38	70	85	70
4.38	140	85	70

Compound A Benzyl Ester	Dithiopyr	Visual Weed Control (%) - 21 DAA	
		IPOHE	
g ae/ha	g ai/ha	Obs	Exp
4.38	0	10	-
8.75	0	10	-
17.5	0	25	-
0	35	10	-
4.38	35	20	19
8.75	35	35	19
17.5	35	45	33

Table 6. Synergistic Activity of Foliar-Applied Compound A Acid and Oryzalin Herbicidal Compositions on Control of Weeds Common to Rice Cropping Systems.

5

Compound A Acid	Oryzalin	Visual Weed Control (%) - 20 DAA	
		CYPES	
g ae/ha	g ai/ha	Obs	Exp
5.3	0	0	-
10.6	0	90	-
0	280	0	-
0	560	0	-
0	1120	0	-
5.3	280	75	0
10.6	280	95	90
5.3	560	20	0
10.6	560	100	90
5.3	1120	50	0
10.6	1120	100	90

Compound A Acid	Oryzalin	Visual Weed Control (%) - 20 DAA
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		CYPDI		SCPJU	
g ae/ha	g ai/ha	Obs	Exp	Obs	Exp
5.3	0	80	-	25	-
0	280	0	-	0	-
0	560	0	-	0	-
0	1120	0	-	0	-
5.3	280	90	80	95	25
5.3	560	95	80	99	25
5.3	1120	95	80	99	25

Table 7. Synergistic Activity of Foliar-Applied Compound A Benzyl Ester and Oryzalin Herbicidal Compositions on Control of Weeds Common to Rice Cropping Systems.

Compound A Benzyl Ester	Oryzalin	Visual Weed Control (%) - 20 DAA	
		ECHCG	
g ae/ha	g ai/ha	Obs	Exp
4.38	0	40	-
8.75	0	70	-
0	280	0	-
0	560	10	-
0	1120	15	-
4.38	280	55	40
8.75	280	75	70
4.38	560	65	46
8.75	560	85	73
4.38	1120	65	49
8.75	1120	80	75

5

Compound A Benzyl Ester	Oryzalin	Visual Weed Control (%) - 20 DAA	
		IPOHE	
g ae/ha	g ai/ha	Obs	Exp
8.75	0	10	-
17.5	0	25	-
0	1120	15	-
8.75	1120	40	24
17.5	1120	50	36

Table 8. Synergistic Activity of Foliar-Applied Compound A Acid and Propyzamide Herbicidal Compositions on Control of Weeds Common to Rice Cropping Systems.

Compound A Acid	Propyzamide	Visual Weed Control (%) - 22 DAA	
		IPOHE	
g ae/ha	g ai/ha	Obs	Exp
8	0	25	-
16	0	35	-
32	0	40	-
0	70	0	-
0	140	0	-
0	280	0	-
8	70	NT	25
16	70	70	35
32	70	60	40
8	140	60	25
16	140	60	35
32	140	65	40
8	280	30	25
16	280	35	35
32	280	65	40

Table 9. Synergistic Activity of Foliar-Applied Compound A Benzyl Ester and Propyzamide Herbicidal Compositions on Control of Weeds Common to Rice Cropping Systems.

Compound A Benzyl Ester	Propyzamide	Visual Weed Control (%) - 22 DAA	
		IPOHE	
g ae/ha	g ai/ha	Obs	Exp
8	0	10	-
16	0	10	-
32	0	35	-
0	70	0	-
0	140	0	-
0	280	0	-
8	70	20	10
16	70	20	10
32	70	50	35
8	140	20	10
16	140	20	10

32	140	50	35
8	280	10	10
16	280	50	10
32	280	85	35

Table 10. Synergistic Activity of Foliar-Applied Compound A Benzyl Ester and Thiazopyr Herbicidal Compositions on Control of Weeds Common to Rice Cropping Systems.

Compound A Benzyl Ester	Thiazopyr	Visual Weed Control (%) - 20 DAA	
		IPOHE	
g ae/ha	g ai/ha	Obs	Exp
8	0	20	-
16	0	40	-
0	280	40	-
8	280	75	52
16	280	70	64

- 5 BRAPP *Brachiaria platyphylla* (Griseb.) Nash signalgrass, broadleaf
 CYPES *Cyperus esculentus* L. nutsedge, yellow
 CYPDI *Cyperus difformis* L. sedge, smallflower umbrella
 DIGSA *Digitaria sanguinalis* (L.) Scop. crabgrass, large
 ECHCG *Echinochloa crusgalli* (L.) Beauv. barnyardgrass
 10 ECHCO *Echinochloa colona* (L.) Link junglerice
 IPOHE *Ipomoea hederacea* Jacq. morningglory, ivyleaf
 LEFCH *Leptochloa chinensis* (L.) Nees sprangletop, Chinese
 SCPJU *Schoenoplectus juncooides* (Roxb.) Palla bulrush, Japanese

NT = not tested

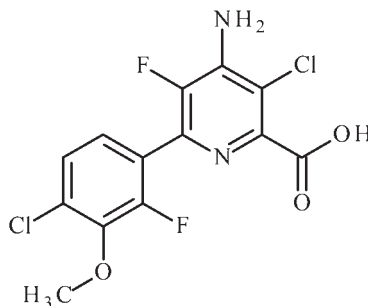
- 15 g ae/ha = grams acid equivalent per hectare
 g ai/ha = grams active ingredient per hectare
 Obs = observed value
 Exp = expected value as calculated by Colby's equation
 DAA = days after application

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

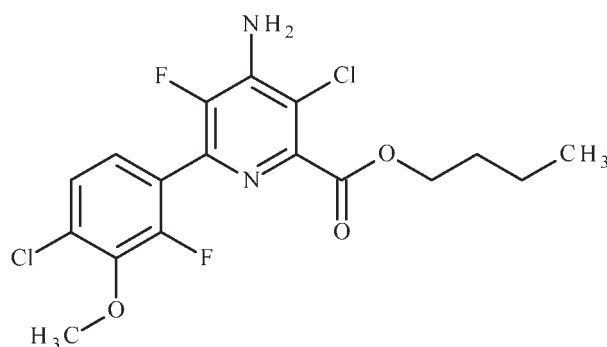
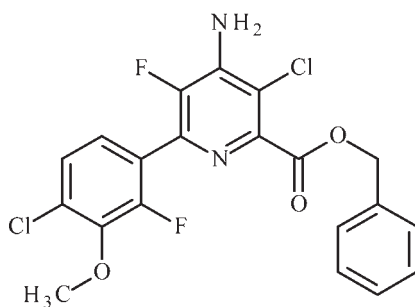
Weed seeds or nutlets of the desired test plant species were planted in puddled soil (mud) prepared by mixing a shredded, non-sterilized mineral soil (50.5 percent silt, 25.5 percent clay, and 24 percent sand, with a pH of about 7.6 and an organic matter content of about 2.9 percent) and water at a 1:1 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 860 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.

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 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

Other herbicidal components were applied on an active ingredient basis and included microtubule inhibiting (MTI) herbicides pendimethalin applied as Prowl[®] 3.3EC, dithiopyr
 10 applied as Dithiopyr WG, and oryzalin applied as Surflan[®] SC.

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.

15 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.

For technical grade compounds, a weighed amount was placed in an individual 100 to
 20 200 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.

5 Applications were made by injecting, with a pipetter, appropriate amounts of the application solutions 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.

10 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.

15 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.) .

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

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

20 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.

25 Some of the compounds tested, application rates employed, plant species tested, and results are given in Tables 11-17.

Table 11. Synergistic Activity of In-Water Applications of Compound A Acid and Pendimethalin Herbicidal Compositions on Weed Control in a Rice Cropping System.

Compound A Acid	Pendimethalin	Visual Weed Control (%) - 21 DAA	
		ECHCG	
g ae/ha	g ai/ha	Obs	Exp
8.75	0	0	-

17.5	0	0	-
35	0	20	-
0	280	20	-
0	560	0	-
8.75	280	10	20
17.5	280	60	20
35	280	60	36
8.75	560	55	0
17.5	560	100	0
35	560	40	20

Compound A Acid	Pendimethalin	Visual Weed Control (%) - 21 DAA	
		LEFCH	
g ae/ha	g ai/ha	Obs	Exp
8.75	0	0	-
17.5	0	0	-
35	0	30	-
0	280	40	-
8.75	280	50	40
17.5	280	100	40
35	280	100	58

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

Compound A Benzyl Ester	Pendimethalin	Visual Weed Control (%) - 21 DAA	
		ECHCG	
g ae/ha	g ai/ha	Obs	Exp
4.38	0	0	-
8.75	0	0	-
17.5	0	25	-
0	280	20	-
0	560	0	-
4.38	280	40	20
8.75	280	35	20
17.5	280	30	40
4.38	560	95	0
8.75	560	50	0
17.5	560	95	25

Compound A Benzyl Ester	Pendimethalin	Visual Weed Control (%) - 21 DAA	
		CYPRO	
g ae/ha	g ai/ha	Obs	Exp
8.75	0	0	-
17.5	0	0	-
0	280	0	-
0	560	0	-
8.75	280	20	0
17.5	280	20	0
8.75	560	40	0
17.5	560	50	0

Compound A Benzyl Ester	Pendimethalin	Visual Weed Control (%) - 21 DAA	
		SCPMA	
g ae/ha	g ai/ha	Obs	Exp
4.38	0	0	-
8.75	0	0	-
17.5	0	0	-
0	560	0	-
4.38	560	95	0
8.75	560	40	0
17.5	560	50	0

Compound A Benzyl Ester	Pendimethalin	Visual Weed Control (%) - 21 DAA	
		LEFCH	
g ae/ha	g ai/ha	Obs	Exp
35	0	50	-
70	0	50	-
0	1120	48	-
35	1120	78	74
70	1120	92	74

5 Table 13. Synergistic Activity of In-Water Applications of Compound A n-Butyl Ester and Pendimethalin Herbicidal Compositions on Weed Control in a Rice Cropping System.

Compound A n-Butyl Ester	Pendimethalin	Visual Weed Control (%) - 21 DAA	
		LEFCH	
g ae/ha	g ai/ha	Obs	Exp
35	0	8	-
70	0	38	-
0	1120	48	-
35	1120	65	51
70	1120	78	67

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

Compound A Acid	Dithiopyr	Visual Weed Control (%) - 21 DAA			
		ECHOR		SCPMA	
g ae/ha	g ai/ha	Obs	Exp	Obs	Exp
8.75	0	10	-	0	-
17.5	0	40	-	0	-
35	0	40	-	0	-
0	70	30	-	0	-
8.75	70	40	37	50	0
17.5	70	100	58	100	0
35	70	100	58	100	0

- 5 Table 15. Synergistic Activity of In-Water Applications of Compound A Benzyl Ester and Dithiopyr Herbicidal Compositions on Control of Weeds Common to Rice Cropping Systems.

Compound A Benzyl Ester	Dithiopyr	Visual Weed Control (%) - 21 DAA	
		ECHOR	
g ae/ha	g ai/ha	Obs	Exp
4.38	0	40	-
8.75	0	60	-
17.5	0	75	-
0	70	30	-
4.38	70	90	58
8.75	70	70	72
17.5	70	99	83

Table 16. Synergistic Activity of In-Water Applications of Compound A Acid and Oryzalin Herbicidal Compositions on Control of Weeds Common to Rice Cropping Systems.

Compound A Acid	Oryzalin	Visual Weed Control (%) - 20 DAA	
		CYPRO	
g ae/ha	g ai/ha	Obs	Exp
10.6	0	10	-
21.2	0	20	-
0	560	0	-
0	1120	0	-
10.6	560	50	10
21.2	560	50	20
10.6	1120	50	10
21.2	1120	90	20

5 Table 17. Synergistic Activity of In-Water Applications of Compound A Benzyl Ester and Oryzalin Herbicidal Compositions on Control of Weeds Common to Rice Cropping Systems.

Compound A Benzyl Ester	Oryzalin	Visual Weed Control (%) - 20 DAA	
		CYPRO	
g ae/ha	g ai/ha	Obs	Exp
4.38	0	50	-
8.75	0	0	-
17.5	0	90	-
0	560	0	-
4.38	560	80	50
8.75	560	85	0
17.5	560	90	90

CYPRO *Cyperus rotundus* L.

ECHCG *Echinochloa crus-galli* (L.) Beauv.

10 ECHOR *Echinochloa oryzoides* (Ard.) Fritsch

LEFCH *Leptochloa chinensis* (L.) Nees

SCPMA *Schoenoplectus Maritimes* (L.) Lye

nutsedge, purple

barnyardgrass

watergrass, early

sprangletop, Chinese

club rush, sea

g ae/ha = grams acid equivalent per hectare

g ai/ha = grams active ingredient per hectare

Obs = observed value

Exp = expected value as calculated by Colby's equation

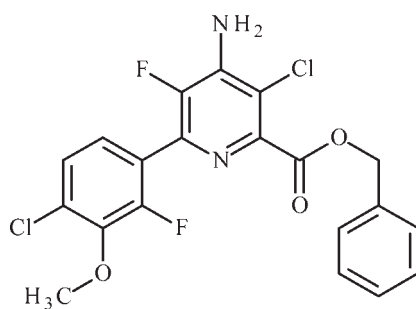
DAA = days after application

Example III. Evaluation of Postemergence Herbicidal Activity of Mixtures in Cereal Crops in the Greenhouse.

Seeds of the desired test plant species 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 pots with a surface area of 103.2 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 7-36 days in a greenhouse with an approximate 14 hour photoperiod which was maintained at about 18° C during the day and about 17° C during the night. Nutrients and water were added on a regular basis and supplemental lighting was provided with overhead metal halide 1000-Watt lamps as necessary. The plants were employed for testing when they reached the second or third true leaf stage.

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, a second cereal herbicide alone and then both in combination.

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



Compound A Benzyl Ester

Other herbicidal components were applied on an active ingredient basis and included microtubule-inhibiting herbicides.

Measured aliquots of benzyl ester of 4-amino-3-chloro-5-fluoro-6-(4-chloro-2-fluoro-3-methoxy-phenyl)pyridine-2-carboxylic acid (Compound A) were placed in 25 milliliter

(mL) glass vials and diluted in a volume of 1.25% (v/v) Agri-Dex[®] crop oil concentrate to obtain stock solutions. Compound requirements are based upon a 12 mL application volume at a rate of 187 liters per hectare (L/ha). Spray solutions of the second cereal herbicide and experimental compound mixtures were prepared by adding the stock solutions to the appropriate amount of dilution solution to form 12 mL spray solution with active ingredients in two- and three-way combinations. Formulated compounds were applied to the plant material with an overhead Mandel track sprayer equipped with an 8002E nozzle calibrated to deliver 187 L/ha over an application area of 0.503 square meters (m²) at a spray height of 18 inches (46 cm) above average plant canopy. Control plants were sprayed in the same manner with the solvent blank.

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 20-22 days, the condition of the test plants as compared with that of the control plants was determined visually and scored on a scale of 0 to 100 percent where 0 corresponds to no injury and 100 corresponds to complete kill.

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.) .

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.

The compounds tested, application rates employed, plant species tested, and results are given in Table 18.

Table 18. Synergistic Activity of Foliar-Applied Compound A Benzyl Ester and Pendimethalin Herbicidal Compositions on Weed Control in a Cereals Cropping System.

Compound A Benzyl Ester	Pendimethalin	Visual Weed Control (%) - 21 DAA		
		AMARE	CHEAL	SINAR

g ai/ha	g ai/ha	Obs	Exp	Obs	Exp	Obs	Exp
2.5	0	20	-	50	-	70	-
5	0	38	-	58	-	73	-
0	150	3	-	0	-	3	-
0	300	5	-	0	-	5	-
2.5	150	33	22	73	50	83	71
2.5	300	33	24	78	50	93	72
5	150	48	39	80	58	92	73
5	300	43	41	80	58	89	74

Compound A Benzyl Ester	Pendimethalin	Visual Weed Control (%) - 21 DAA					
		BRSNW		CIRAR		KCHSC	
g ai/ha	g ai/ha	Obs	Exp	Obs	Exp	Obs	Exp
2.5	0	18	-	48	-	20	-
5	0	13	-	39	-	41	-
10	0	13	-	60	-	62	-
0	150	3	-	10	-	10	-
0	300	5	-	10	-	10	-
0	600	18	-	10	-	57	-
2.5	150	30	20	48	53	63	28
2.5	300	48	22	60	53	78	28
5	150	38	15	68	45	55	47
5	300	50	17	65	45	73	47
5	600	72	29	70	45	80	74
10	600	85	29	85	64	85	83

Compound A Benzyl Ester	Pendimethalin	Visual Weed Control (%) - 21 DAA					
		LAMPU		PAPRH		STEME	
g ai/ha	g ai/ha	Obs	Exp	Obs	Exp	Obs	Exp
2.5	0	80	-	48	-	25	-
5	0	86	-	28	-	25	-
10	0	94	-	35	-	27	-
0	150	0	-	18	-	3	-
0	300	25	-	38	-	5	-
0	600	53	-	75	-	17	-
2.5	150	90	80	70	57	60	27
2.5	300	88	85	75	67	63	29
5	150	90	86	70	41	68	27

5	300	93	90	75	55	65	29
5	600	95	93	92	82	57	38
10	600	93	97	96	84	53	39

AMARE	<i>Amaranthus retroflexus</i> L.	pigweed, redroot
BRSNW	<i>Brassica napus</i>	rapeseed, winter
CHEAL	<i>Chenopodium album</i> L.	lambsquarters, common
5 CIRAR	<i>Cirsium arvense</i> (L.) Scop.	thistle, Canada
KCHSC	<i>Kochia scoparia</i> (L.) Schrad.	kochia
LAMPU	<i>Lamium purpureum</i> L.	deadnettle, purple
PAPRH	<i>Papaver rhoeas</i> L.	poppy, common
SINAR	<i>Sinapis arvensis</i> L.	mustard, wild
10 STEME	<i>Stellaria media</i> (L.) Vill.	chickweed, common

g ae/ha = grams acid equivalent per hectare

g ai/ha = grams active ingredient per hectare

Obs = observed value

Exp = expected value as calculated by Colby's equation

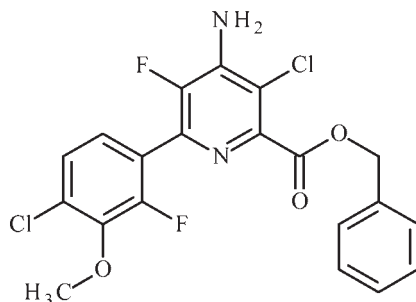
15 DAA = days after application

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

20 Seeds or nutlets of the desired test plant species were planted in a soil matrix prepared by mixing a loam soil (*e.g.*, 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).

25 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:

30



Compound A Benzyl Ester

Other herbicidal components were applied on an acid equivalent or active ingredient basis and included the microtubule inhibiting herbicides, dithiopyr formulated as Dithiopyr 40WP, oryzalin formulated as Surflan[®], pendimethalin formulated as Prowl[®] 3.3EC, propyzamide formulated as Kerb[®] 50WP, and thiazopyr (technical grade materials).

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.

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.

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.

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) COC 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) COC so that the final spray solutions contained 1.25% (v/v) COC. 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.

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.

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.

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.) .

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.

Some of the compounds tested, application rates employed, plant species tested, and results are given in Tables 18-22.

Table 18. Synergistic Activity of Soil-applied, Pre-emergence Applications of Compound A Benzyl Ester and Dithiopyr Herbicidal Compositions on Weed Control.

Compound A Benzyl Ester	Dithiopyr	Visual Weed Control (%) - 27 DAA			
		IPOHE		XANST	
g ae/ha	g ai/ha	Obs	Exp	Obs	Exp
16	0	20	-	27	-
32	0	40	-	52	-
0	140	3	-	0	-
0	280	20	-	17	-
16	140	43	23	43	27
32	140	55	42	55	52
16	280	48	36	47	39
32	280	50	52	60	60

Table 20. Synergistic Activity of Soil-applied, Pre-emergence Applications of Compound A Benzyl Ester and Oryzalin Herbicidal Compositions on Weed Control.

Compound A Benzyl Ester	Oryzalin	Visual Weed Control (%) - 33 DAA	
		IPOHE	
g ae/ha	g ai/ha	Obs	Exp
16	0	0	-
32	0	5	-
0	1120	48	-
16	1120	80	48
32	1120	95	51

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

Compound A Benzyl Ester	Propyzamide	Visual Weed Control (%) - 33 DAA	
		IPOHE	
g ae/ha	g ai/ha	Obs	Exp
16	0	0	-
32	0	5	-
0	1120	35	-
16	1120	70	35
32	1120	68	38

Compound A Benzyl Ester	Propyzamide	Visual Weed Control (%) - 33 DAA	
		SEBEX	
g ae/ha	g ai/ha	Obs	Exp
16	0	40	-
0	280	20	-
0	560	13	-
0	1120	37	-
16	280	100	52
16	560	90	48
16	1120	95	62

Compound A Benzyl Ester	Propyzamide	Visual Weed Control (%) - 33 DAA	
		BRAPP	
g ae/ha	g ai/ha	Obs	Exp
16	0	23	-
32	0	50	-
0	280	20	-
0	560	37	-
16	280	28	39
32	280	73	60
16	560	80	51
32	560	60	68

Compound A Benzyl Ester	Propyzamide	Visual Weed Control (%) - 33 DAA	
		ECHCG	
g ae/ha	g ai/ha	Obs	Exp
16	0	20	-
32	0	33	-
0	560	35	-
0	1120	53	-
16	560	98	48
32	560	50	57
16	1120	100	62
32	1120	100	69

Compound A Benzyl Ester	Propyzamide	Visual Weed Control (%) - 33 DAA			
		ECHCO		SETFA	
g ae/ha	g ai/ha	Obs	Exp	Obs	Exp
16	0	12	-	13	-
32	0	3	-	13	-
0	280	0	-	0	-
0	560	23	-	68	-
0	1120	80	-	93	-
16	280	5	12	50	13
32	280	60	3	88	13
16	560	55	32	100	73
32	560	70	26	55	73
16	1120	75	82	100	94
32	1120	100	81	100	94

Table 22. Synergistic Activity of Soil-applied, Pre-emergence Applications of Compound A Benzyl Ester and Thiazopyr Herbicidal Compositions on Weed Control.

Compound A Benzyl Ester	Thiazopyr	Visual Weed Control (%) - 27 DAA	
		XANST	
g ae/ha	g ai/ha	Obs	Exp
16	0	10	-
32	0	25	-
0	280	15	-

0	560	10	-
16	280	40	24
16	560	35	19
16	1120	35	19

BRAPP	<i>Brachiaria platyphylla</i> (Groseb.) Nash or <i>Urochloa platyphylla</i> (Nash) R.D. Webster	signalgrass, broadleaf
ECHCG	<i>Echinochloa crus-galli</i> (L.) P. Beauv.	barnyardgrass
5 ECHCO	<i>Echinochloa colonum</i> (L.) Link	junglerice
IPOHE	<i>Ipomoea hederacea</i> (L.) Jacq.	morningglory, ivyleaf
SEBEX	<i>Sesbania exaltata</i> (Raf.) Cory/Rydb. Ex Hill	sesbania, hemp
SETFA	<i>Setaria faberi</i> Herrm.	foxtail, giant
XANST	<i>Xanthium strumarium</i> L.	cocklebur, common

10 g ae/ha = grams acid equivalent per hectare

g ai/ha = grams active ingredient per hectare

Obs = observed value

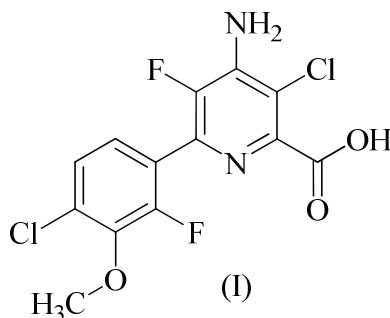
Exp = expected value as calculated by Colby's equation

DAA = days after application

15

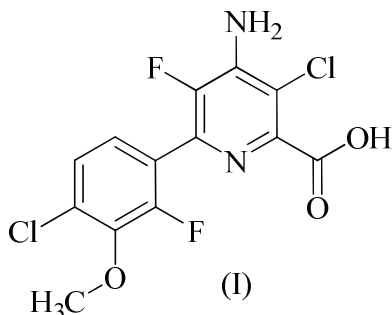
CLAIMS

1. A herbicidal composition comprising a herbicidally effective amount of (a) a compound of the formula (I):



or an alkyl or benzyl ester, or an agriculturally acceptable salt of formula (I) and (b) a microtubule inhibiting herbicide selected from the group consisting of: dithiopyr, oryzalin, pendimethalin, propyzamide, and thiazopyr, wherein (a) and (b) are present in the composition in a ratio such that the composition exhibits herbicidal synergy, and wherein the ratio of (a):(b) is from about 1:2 to about 1:255.7.

2. The composition of claim 1, wherein (a) is a C₁₋₄ alkyl or benzyl ester of the compound of formula (I).
3. The composition of claim 1, wherein (a) is a C₁₋₄ alkyl ester of the compound of formula (I).
4. The composition of claim 1, wherein (a) is a benzyl ester of the compound of formula (I).
5. The composition of claim 1, wherein (a) is the carboxylic acid of the compound of formula (I).
6. The composition of claim 1, further comprising at least one compound selected from the group consisting of agriculturally acceptable, herbicide safeners, adjuvants, and carriers.
7. A method of controlling undesirable vegetation, comprising the steps of:
- contacting a plant, wherein the plant is undesirable vegetation, or the locus thereof, soil or water, wherein the soil or the water supports the growth of the undesirable vegetation, with a herbicidally effective amount of a combination comprising (a) a compound of the formula (I):



or an alkyl or benzyl ester, or an agriculturally acceptable salt of formula (I) and (b) a microtubule inhibiting herbicide selected from the group consisting of: dithiopyr, oryzalin, pendimethalin, propyzamide, and thiazopyr, wherein (a) and (b) are present in the combination in a ratio such that the combination exhibits herbicidal synergy, and wherein the ratio of (a):(b) is from about 1:2 to about 1:255.7.

8. The method of claim 7, wherein the (a) and (b) are applied to water.
9. The method of claim 8, wherein the water is part of a flooded rice paddy.
10. The method of claim 7, wherein the (a) and (b) are applied pre-emergently to the undesirable vegetation in a crop.
11. The method of claim 7, wherein the (a) and (b) are applied post-emergently to the undesirable vegetation in a crop.
12. The method of claim 7, wherein the undesirable vegetation is controlled in glyphosate-, 5-enolpyruvylshikimate-3-phosphate synthase inhibitor-, glufosinate-, glutamine synthetase inhibitor-, dicamba-, phenoxy auxin-, pyridyloxy auxin-, synthetic auxin-, auxin transport inhibitor-, aryloxyphenoxypropionate-, cyclohexanedione-, phenylpyrazoline-, acetyl CoA carboxylase inhibitor-, imidazolinone-, sulfonyleurea-, pyrimidinylthiobenzoate-, triazolopyrimidine-, sulfonaminocarbonyltriazolinone-, acetolactate synthase or acetohydroxy acid synthase inhibitors-, 4-hydroxyphenyl-pyruvate dioxygenase inhibitor-, phytoene desaturase inhibitor-, carotenoid biosynthesis inhibitor-, protoporphyrinogen oxidase 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-, triazine-, or bromoxynil-tolerant crops.

13. The method of claim 12, wherein the tolerant crop possesses multiple or stacked traits conferring tolerance to multiple herbicides.
14. The method of claim 7, wherein the undesirable vegetation comprises a herbicide resistant or tolerant plant.
15. The method of claim 14, wherein the resistant or tolerant plant is resistant or tolerant to multiple herbicides.
16. The method of claim 14, wherein the resistant or tolerant plant is resistant or tolerant to acetolactate synthase or acetohydroxy acid synthase inhibitors, photosystem II inhibitors, acetyl CoA carboxylase inhibitors, synthetic auxins, auxin transport inhibitors, photosystem I inhibitors, 5-enolpyruvylshikimate-3-phosphate synthase inhibitors, microtubule assembly inhibitors, fatty acid and lipid synthesis inhibitors, protoporphyrinogen oxidase inhibitors, carotenoid biosynthesis inhibitors, very long chain fatty acid inhibitors, phytoene desaturase inhibitors, glutamine synthetase inhibitors, 4-hydroxyphenyl-pyruvate-dioxygenase inhibitors, mitosis inhibitors, cellulose biosynthesis inhibitors, herbicides with multiple modes-of-action, quinclorac, arylaminopropionic acids, difenzoquat, endothall, or organoarsenicals.
17. The method of claim 7, wherein the undesirable vegetation is controlled 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, aquatics, industrial vegetation management or rights of way.
18. The method of claim 7, wherein the (a) and (b) are applied pre-emergently to a weed or a crop.
19. The method of claim 7, wherein the (a) and (b) are applied post-emergently to a weed or a crop.
20. The method of claim 14, wherein the resistant or tolerant plant is a biotype with resistance or tolerance to multiple herbicides.
21. The method of claim 14, wherein the resistant or tolerant plant is a biotype resistant or tolerant to acetolactate synthase or acetohydroxy acid synthase inhibitors, photosystem II

inhibitors, acetyl CoA carboxylase inhibitors, synthetic auxins, auxin transport inhibitors, photosystem I inhibitors, 5-enolpyruvylshikimate-3-phosphate synthase inhibitors, microtubule assembly inhibitors, fatty acid and lipid synthesis inhibitors, protoporphyrinogen oxidase inhibitors, carotenoid biosynthesis inhibitors, very long chain fatty acid inhibitors, phytoene desaturase inhibitors, glutamine synthetase inhibitors, 4-hydroxyphenyl-pyruvate-dioxygenase inhibitors, mitosis inhibitors, cellulose biosynthesis inhibitors, herbicides with multiple modes-of-action, quinclorac, arylaminopropionic acids, difenzoquat, endothall, or organoarsenicals.

22. The composition according to claim 1, wherein the ratio of (a):(b) is selected from the group consisting of: from about 1:2 to about 1:32 when (b) is dithiopyr; from about 1:32 to about 1:255.7 when (b) is oryzalin; from about 1:8 to about 1:127.9 when (b) is pendimethalin; from about 1:2.2 to about 1:70 when (b) is propyzamide; and from about 1:17.5 to about 1:70 when (b) is thiazopyr.

23. The method according to claim 7, wherein the ratio of (a):(b) is selected from the group consisting of: from about 1:2 to about 1:32 when (b) is dithiopyr; from about 1:32 to about 1:255.7 when (b) is oryzalin; from about 1:8 to about 1:127.9 when (b) is pendimethalin; from about 1:2.2 to about 1:70 when (b) is propyzamide; and from about 1:17.5 to about 1:70 when (b) is thiazopyr.

24. The composition according to claim 1, wherein (b) is pendimethalin, wherein the ratio of (a):(b) is from 1:8 to 1:127.9.

25. The composition according to claim 1, wherein (b) is dithiopyr, wherein the ratio of (a):(b) is from 1:2 to 1:32.

26. The composition according to claim 1, wherein (b) is thiazopyr, wherein the ratio of (a):(b) is from 1:17.5 to 1:70.

27. The composition according to claim 1, wherein (b) is oryzalin, wherein the ratio (a):(b) is from 1:32 to 1:255.7.

28. The composition according to claim 1, wherein (b) is propyzamide, wherein the ratio of (a):(b) is from 1:2.2 to 1:70.

29. The method according to claim 7, wherein (b) is pendimethalin, wherein the ratio of (a):(b) is from 1:8 to 1:127.9.
30. The method according to claim 7, wherein (b) is dithiopyr, wherein the ratio of (a):(b) is from 1:2 to 1:32.
31. The method according to claim 7, wherein (b) is thiazopyr, wherein the ratio of (a):(b) is from 1:17.5 to 1:70.
32. The method according to claim 7, wherein (b) is oryzalin, wherein the ratio (a):(b) is from 1:32 to 1:255.7.
33. The method according to claim 7, wherein (b) is propyzamide, wherein the ratio of (a):(b) is from 1:2.2 to 1:70.