

PATENT SPECIFICATION

(11) 1307489

1307489

NO DRAWINGS

- (21) Application No. 24692/71 (22) Filed 19 April 1971
 (31) Convention Application No. 21535 (32) Filed 20 March 1970
 (31) Convention Application No. 49519 (32) Filed 24 June 1970
 (31) Convention Application No. 100 410 (32) Filed 21 Dec. 1970 in
 (33) United States of America (US)
 (44) Complete Specification published 21 Feb. 1973
 (51) International Classification C07D 57/04; A01N 9/12, 9/22 // 9/02



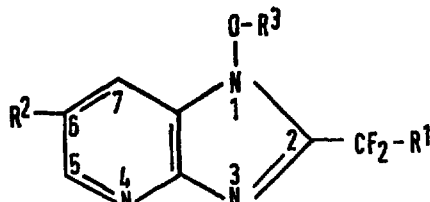
(52) Index at acceptance

C2C 173—197—288 17X—175—180 17X—27X—287
 1Q11G 1Q11H 1Q11J 1Q4 1Q6C 1Q7A
 1Q7B 1Q8A 1Q8B 1Q8C 1Q8D 1Q9D1
 1Q9F1 1Q9F2 200 20Y 214 215 220 221 225
 226 227 22Y 247 250 251 252 25Y 292 29X 29Y
 305 30Y 311 313 314 315 31Y 321 322 323
 32Y 332 337 338 339 340 342 34Y 351 352
 364 366 368 36X 36Y 373 37Y 380 395 396
 39Y 428 42Y 436 439 440 464 491 500 50Y
 560 577 601 60X 60Y 614 620 621 623 624
 627 628 62X 631 650 659 660 668 670 671
 672 679 67X 694 695 698 69Y 72Y 752 755
 75X 76Y 771 778 78X 791 79Y KA KT LS
 ML MM NC NN QF QL RC RM RV SL ZJ
 A5E 1A3B 1A3C 1A3G 1A5B3 1C14 1C15A3 1C15A7
 1C15A8 1C15B1 1C15B2 1C15B3 1C15C1
 1C15C2 1C15D1 1C15D2 1C15D3 1C15F3
 1C5G 1C5H 1C7C 1C7K 1C7M 1C7N

(54) 1-HYDROXY-2-(1,1-DIFLUOROALKYL)-1H-IMIDAZO(4,5-B)
 PYRIDINE COMPOUNDS AND ETHERS AND ESTERS
 AND SALTS THEREOF

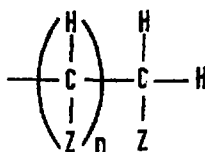
(71) We, ELI LILLY & COMPANY, a Corporation of the State of Indiana, United States of America, of 307 East McCarty Street, City of Indianapolis, State of Indiana, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The present invention is directed to 1-hydroxy-2-(1,1-difluoroalkyl)-1H-imidazo-(4,5-b)pyridine compounds and ethers and esters and salts thereof. These derivatives are of the following formula:



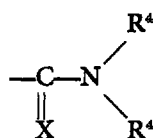
Formula I

In the above and succeeding formulae throughout the present specification and claims, R¹ represents hydrogen, chlorine, fluorine, perfluoroalkyl of C₁—C₆, or a radical of the formula



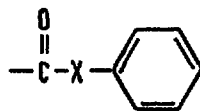
wherein each Z independently represents hydrogen or halogen and n represents 0 or 1; R² represents halogen, nitro, —CF₃, —CF₂Cl, —CF₂H, or lower alkyl sulfonyl of C₁—C₄; and R³ represents

- (1) hydrogen, or the alkali or alkaline earth metal salt thereof, or the salt thereof with an organic amine having a K_b of 10⁻⁵ or greater;
- (2) alkyl of C₁—C₈;
- (3) alkenyl of C₂—C₈;
- (4) cycloalkyl of C₅—C₆;
- (5) benzyl;
- (6) phenethyl;
- (7) alkanoyl of C₂—C₁₆;
- (8) alkenoyl of C₃—C₁₆;
- (9) a carbamoyl or thiocarbamoyl radical of the formula

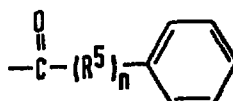


- wherein X represents oxygen or sulfur; and one R⁴ represents phenyl, lower alkyl of C₁—C₄, or lower alkenyl of C₂—C₄, and the other R⁴ represents hydrogen, lower alkyl of C₁—C₄, or lower alkenyl of C₂—C₄, subject to the limitation that both R⁴ moieties taken together do not contain more than six carbon atoms, or both R⁴ moieties taken together represent straight-chain alkylene of C₂—C₆, both inclusive;

- (10) a radical of the formula $\begin{array}{c} \text{O} \\ || \\ \text{---C---X---} \end{array}$ lower alkyl of C₁—C₄ or



- wherein X is oxygen or sulfur;
- (11) a radical of the formula



wherein R⁵ represents methylene, ethylene, or vinylene, and n represents 0 or 1;

- (12) a radical of the formulae $\begin{array}{c} \text{O} \\ || \\ \text{---C---} \end{array}$ substituted phenyl and $\begin{array}{c} \text{O} \\ || \\ \text{---C---R}^6\text{---O---} \end{array}$ substituted phenyl, wherein "substituted phenyl" is a phenyl radical bearing from 1—3 substituents, each of which is independently amino, nitro, chloro, methyl, or methoxy, and R⁶ represents lower alkylene of C₁—C₄, both inclusive;
- (13) —SO₂—R⁷ wherein R⁷ is lower alkyl of C₁—C₄, cycloalkyl of C₅—C₆, phenyl, "substituted phenyl" as defined in (12) above, or benzyl;
- (14) tetrahydro-2-pyranyl.

The compounds so defined are useful as herbicides. In addition, they can be used as starting materials for a process which results in rearrangement or reduction depending on the reaction conditions employed.

In the present specification and claims, the term "halogen" is employed to designate bromine, chlorine, fluorine, and iodine, only. In the case of the lower alkyl, lower alkenyl, alkyl, alkenyl, alkanoyl, alkenoyl, and lower alkylene radicals, such radicals can be branched or straight-chain.

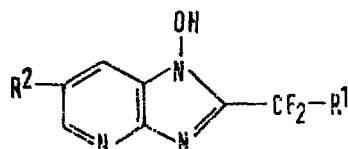
An essential and distinguishing structural feature of the compounds of Formula I is the substituent at the 2-position ($-\text{CF}_2-\text{R}^1$); representative such radicals including the following:

5	difluoromethyl	5
	trifluoromethyl	
	difluorochloromethyl	
	pentafluoroethyl	
	heptafluoro-n-propyl	
10	1,1-difluoroethyl	10
	1,1-difluoro-n-propyl	
	1,1-difluoro-2-bromoethyl	
	1,1-difluoro-2-chloroethyl	
	1,1-difluoro-2,3-dichloro-n-propyl	
	1,1-difluoro-3-bromo-n-propyl	
15	1,1,2-trifluoroethyl	15
	1,1,2-trifluoro-n-propyl	
	1,1,2,3-tetrafluoro-n-propyl	
	1,1-difluoro-2-bromo-3-chloro-n-propyl	
20	perfluoro-n-butyl	20
	perfluoro-n-pentyl	
	perfluoro-n-hexyl	

Preferred groups are trifluoromethyl, difluoromethyl, difluorochloromethyl, and pentafluoroethyl.

The compounds of Formula I are typically crystalline solids. They are prepared in standard procedures for the derivatization of hydroxy groups. Hence, those of the derivatives claimed herein which are ethers can be prepared by those procedures discussed in chapter 6 of *Synthetic Organic Chemistry*, by Wagner and Zook (John Wiley & Sons, Inc., New York, 1965). The same reference discusses various synthetic procedures which can be employed for the synthesis of those derivatives claimed herein which are carboxylic acid esters (chapter 14), carbamic acid esters (chapter 23), and sulfonic acid esters (chapter 37).

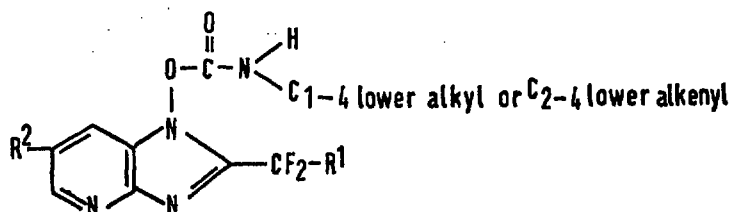
Generally, the ethers and esters of Formula I wherein R^3 is other than hydrogen are conveniently prepared by the reaction of the corresponding 1-hydroxy compounds:



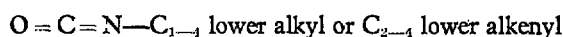
Formula II

with a halide of the formula R^3-X , where X is halo, in the presence of an alkali metal carbonate or other hydrogen halide acceptor. An inert liquid reaction medium can be used. The reaction proceeds under a wide range of temperatures, but is preferably conducted at temperatures of from -20°C . to the reflux temperature. Separation, and if desired, purification, are carried out in conventional procedures.

While the foregoing is the most general method for preparing compounds of Formula I, other methods are convenient and may be preferred for some of the compounds. Thus, those carbamates of the formula



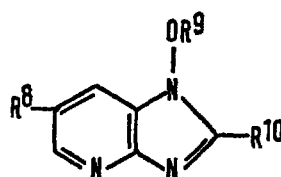
C_{1-4} lower alkyl or C_{2-4} lower alkenyl are more readily prepared by reacting the corresponding 1-hydroxy-1H-imidazo(4,5-b)pyridine with an isocyanate of the formula



The reaction is conducted in conventional procedures.

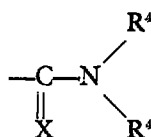
Likewise, the carboxylic ester compounds of Formula I other than the carbamate esters are often preferably prepared by reacting the desired carboxylic acid as its anhydride with the corresponding 1-hydroxy-1H-imidazo(4,5-b)pyridine starting compound. Furthermore, in the case of the compounds which are ethers, preparation is sometimes preferably carried out by reaction of the 1-hydroxy-1H-imidazo(4,5-b)-pyridine with an olefinic compound; this is particularly preferred in the case of the tetrahydro-2-pyranyl ether. The alkenyl ethers may also be preferably prepared by addition to an alkyne.

A preferred sub-genus of the compounds of Formula I wherein R³ is other than hydrogen is defined as follows:



Formula III

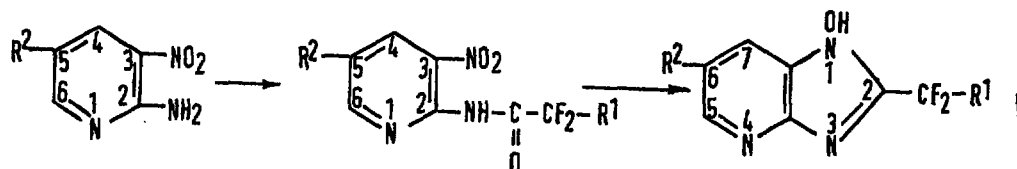
wherein R⁸ represents halo or —CF₃; R⁹ represents lower alkyl of C₁—C₄, lower alkenyl of C₂—C₄, benzyl, lower alkanoyl or C₂—C₄, lower alkenoyl of C₃—C₄, benzoyl, lower alkylsulfonyl of C₁—C₄, or a carbamoyl or thiocarbamoyl radical of the formula



wherein X represents oxygen or sulfur, and one R⁴ represents phenyl, lower alkyl of C₁—C₄, or lower alkenyl of C₂—C₄, and the other R⁴ represents hydrogen, lower alkyl of C₁—C₄, or lower alkenyl of C₂—C₄, subject to the limitation that both R⁴ moieties taken together do not contain more than six carbon atoms, or both R⁴ moieties taken together represent straight-chain alkylene of C₂—C₆, both inclusive; and R¹⁰ represents trifluoromethyl or pentafluoroethyl.

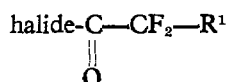
Yet other synthetic techniques can be used in the preparation of the compounds of Formula I wherein R³ is other than hydrogen; examples are the use of N,N'-carbonyldiimidazole or N,N'-dicyclohexyldicarbodiimide (See *Reagents for Organic Synthesis*, Fieser & Fieser (John Wiley & Sons, 1967), pages 114 *et seq.* and 231 *et seq.*, respectively).

The 1-hydroxy compounds of Formula II are prepared in accordance with the following reaction scheme:

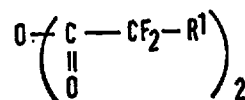


In accordance with the foregoing reaction scheme, the initial 5-substituted-2-amino-3-nitropyridine compound is acylated to yield the corresponding 5-substituted-2-(1,1-difluoroalkylamido)-3-nitropyridine, which is then reacted further to yield the final product in accordance with the present invention.

The acylation is carried out with an acylating agent, the identity of which is not critical; either the difluoroalkanoyl halide:

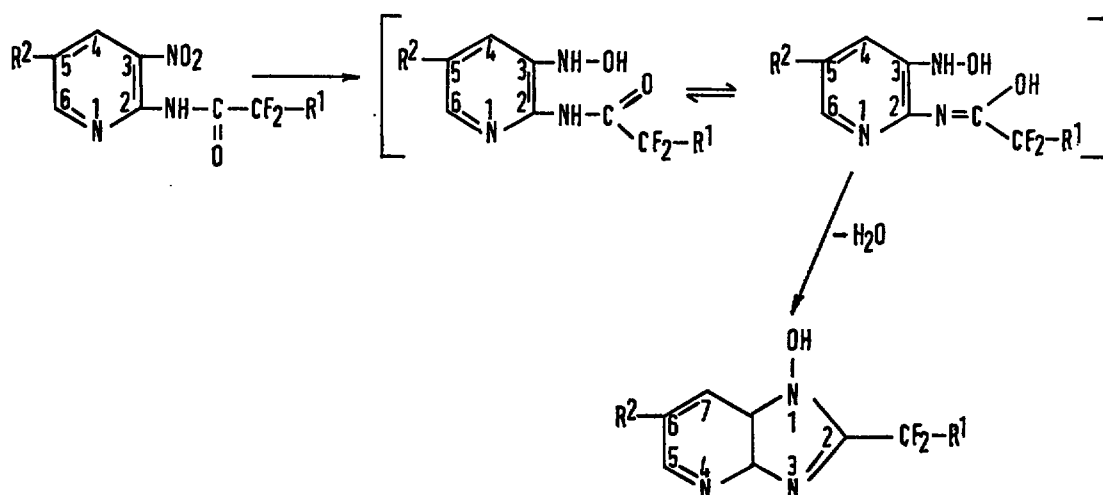


or the difluoroalkanoic anhydride:



is suitable, although the latter is often preferred. In general, the reaction is conducted by mixing the acylating agent and the 5-substituted-3-nitro-2-aminopyridine, preferably, and in the case of a difluoroalkanoyl halide, necessarily, in the presence of an organic tertiary amine, and heating the resulting mixture, such as to temperatures of 25—100° C. Particularly suited organic tertiary amines include triethylamine and pyridine. The reaction can be conducted in an inert liquid reaction medium, such as benzene, or an excess of the organic tertiary amine can be employed as reaction medium; in addition, the difluoroalkanoic anhydrides are generally liquid, and an excess amount can be used to assure fluidity. The reaction goes forward readily yielding the desired 5-substituted-3-nitro-2-(1,1-difluoroalkylamido)pyridine product. Separation of the product, and, if desired, purification, are carried out in conventional procedures.

In general, it has been found that subjecting the 5-substituted-3-nitro-2-(1,1-difluoroalkylamido)pyridine compounds, as well as other compounds, to any of a variety of reducing conditions results in the preparation of the ultimate 6-substituted-1-hydroxy-2-(1,1-difluoroalkyl)-1H-imidazo(4,5-b)pyridine compounds of the present invention. It is believed that the reaction proceeds through an intermediate:



To date, it has not been possible to isolate this intermediate. As will be obvious to those skilled in the art, however, the intermediate, if isolatable from any synthetic route, could itself be reacted to produce the compounds of the present invention.

While the reaction itself is unexpected, the reaction conditions are not critical. As reducing agent, there can be employed, for example, any of the substances and conditions ordinarily employed for the reduction of nitro compounds to amino compounds: hydrogen in the presence of a catalyst; zinc or iron in alkaline solution; sulfides in alkaline solution; and hydrosulfite in alkaline solution. The reactions are conducted in accordance with the conditions known for each of these agents (see *Kirk-Othmer Encyclopedia of Chemical Technology*, 2nd Ed., Vol. 2, pages 76—98 and references there cited [John Wiley & Sons, Inc., 1963, New York]); and in all instances, cyclodehydration of the intermediate occurs spontaneously under such reducing conditions.

However, a preferred method for conducting the reduction reaction is the use of hydrogen in the presence of a catalyst. In general, in employing this preferred method, the 5-substituted-3-nitro-2-(1,1-difluoroalkylamido)pyridine, conveniently in an inert liquid as reaction medium, is subjected to hydrogenation in the presence of catalyst, typically a noble metal and preferably palladium or platinum. The catalyst can be employed alone, or — especially in the instance of palladium — can be supported on

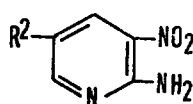
a carrier such as carbon or an alkali metal salt. Conveniently, a Parr or other pressure apparatus is used to contain the reaction mixture during hydrogenation, when conducted at superatmospheric pressures; however, the reaction also goes forward at atmospheric pressures. The reaction is further catalyzed by a small amount of an acid, such as, for example, a mineral acid such as hydrochloric acid or a compatible organic acid such as trifluoroacetic acid.

The amounts of reactants employed are not critical. In general, preferred amounts are 2 moles of hydrogen per mole of the starting 5-substituted-3-nitro-2-(1,1-difluoroalkylamido)pyridine and a catalytic amount of the noble metal, such as from 1 to 10 grams per kilogram of the starting compound. Temperatures of from 0° to 100° C. are operative, but better results are typically achieved at temperatures of from 10° to 25° C.

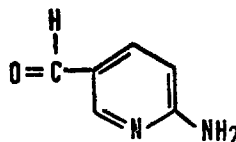
When hydrogen uptake is complete, the product is separated from the reaction mixture in conventional procedures. Most typically, the reaction mixture is filtered to remove remaining catalyst, and the filtrate evaporated to separate the product as a residue. This product residue can be purified, also in conventional procedures, typically recrystallization, or extraction into sodium bicarbonate solution followed by precipitation with mineral acid.

The foregoing synthetic method results in the preparation of the desired 6-substituted-1-hydroxy-2-(1,1-difluoroalkyl)-1H-imidazo(4,5-b)pyridine compounds of Formula I. However, the proton of the OH group being acidic, these compounds form salts with cations. Representative such salts include salts with alkali metals, such as sodium, potassium, lithium, caesium, and rubidium; alkaline earth metal salts, such as calcium, strontium, and barium salts; and salts with organic amines. While the identity of the organic amine is not critical, the organic amines are those which have relatively high base strength, that is, a dissociation constant (K_b) of 10^{-5} or greater. In general, the alkylamines, cycloalkylamines, alkylenepolyamines, and aralkylamines are classes of compounds exhibiting adequate base strengths. Thus, representative bases include methylamine, dimethylamine, trimethylamine, methyldiethylamine, ethylamine, diethylamine, triethylamine, n-propylamine, di-n-propylamine, tri-n-propylamine, n-amylamine, cyclohexylamine, piperidine, pyrrolidine, N-methylpyrrolidine, diisopropylamine, ethylenediamine, tetramethylenediamine, ethanolamine, benzylamine, isobutylamine, and di-n-butylamine. The foregoing salts are prepared in conventional procedures, by reaction of the 6-substituted-1-hydroxy-2-(1,1-difluoroalkyl)imidazo(4,5-b)pyridine and the particular amine or alkali metal or alkaline earth metal oxide, hydroxide, or salt. Such salt formation can be employed as a method of formulating the compounds.

The 5-substituted-3-nitro-2-aminopyridine starting materials to be employed in accordance with the process of the present invention:



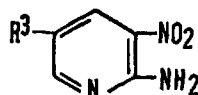
are in general prepared by nitration, in standard procedures, of suitably substituted 2,5-disubstituted pyridines. Certain 5-substituted-2-aminopyridine compounds, those wherein the 5-substituent is halo or nitro, are known. Others are prepared in procedures readily available to those skilled in the art. Thus, for example, in synthesizing those 5-substituted-2-aminopyridine compounds wherein the 5-substituent (R^2) is $-\text{CF}_2\text{Cl}$, a 2-amino-5-formylpyridine:



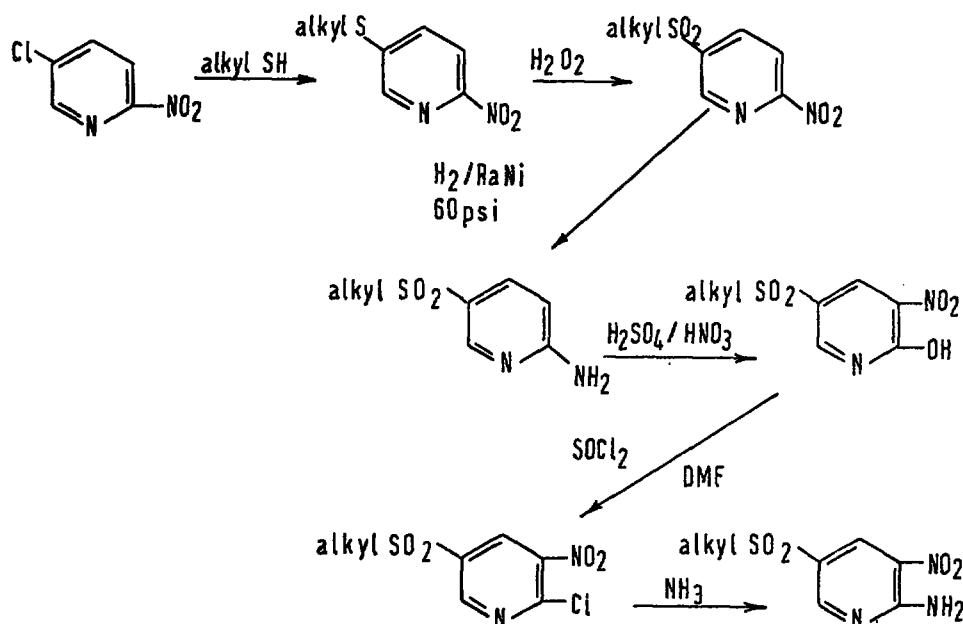
is reacted with SF_4 to obtain 5-(difluoromethyl)-2-aminopyridine; this compound, in turn, can be chlorinated to obtain the corresponding 5-(difluorochloromethyl)-2-aminopyridine. The 5-(trifluoromethyl)-2-aminopyridine is synthesized by treatment of 5-carboxy-2-hydroxypyridine with SF_4 in the presence of HF , to yield 5-(trifluoromethyl)-6-fluoro-5,6-dihydro-2-hydroxypyridine, which on treatment with sodium hydroxide, yields 5-(trifluoromethyl)-2-hydroxypyridine. The hydroxy moiety of this

compound can be converted in standard procedures to an amido group, thus yielding the desired 5-(trifluoromethyl)-2-aminopyridine compound. These various 5-substituted-2-aminopyridine compounds are then nitrated to obtain corresponding 5-substituted-3-nitro-2-aminopyridine compounds.

Those 5-substituted-3-nitro-2-aminopyridine compounds wherein the 5-substituent is alkylsulfonyl:



wherein R³ represents lower alkylsulfonyl of C₁—C₄, both inclusive, are prepared in accordance with the following reaction scheme:



Thus, in these various synthetic procedures are prepared all of the 5-substituted-3-nitro-2-aminopyridine compounds.

The compounds of Formula I are adapted to be employed as herbicides. The compounds can be utilized to achieve broad herbicidal action; hence, in its broadest sense, the present invention includes a method which comprises applying to a plant part, which can be a stem, leaf, flower, fruit, root, or seed or other similar reproductive unit of a plant, a growth-inhibiting amount of one of the compounds of the present invention. However, the compounds can also be utilized to take advantage of selective patterns of herbicidal activity.

It is not critical to the practice of the present invention that complete destruction of undesirable vegetation be obtained, it being adequate if the growth of the unwanted vegetation is merely inhibited. Especially where selective action is sought, inhibition falling short of actual killing is adequate, particularly when combined with naturally occurring conditions such as limited moisture and the like which more adversely affect the vegetation selectively inhibited than the crop plant.

The compounds of Formula I are suited to a wide variety of herbicidal applications. Thus, for example, at rates which evoke the selective action of the compounds, which rates are defined more completely hereinbelow, the compounds can be used as selective herbicides in crop plants, such as, for example, cotton, corn, sorghum, soybeans, and the like. In such use, application can be made preemergent to both crops and weeds, or, preferably by means of a directed spray application technique, postemergent to the crop plant but both preemergent and postemergent to the weeds. In another application, the compounds can be used to give broad herbicidal action on non-crop land, including intermittently non-crop strips of contour-farmed land. For such usage on so-called fallow land, application can be made in spring to suppress

vegetative growth until an autumn or following spring planting, or in the autumn to suppress vegetative growth until a spring or following autumn planting. Furthermore, in another application, the present compounds can be utilized to control weeds in tree crop plantings, such as plantings of the various citrus trees. In all of these various applications, and yet others for which the compounds of Formula I are suited, another advantage is that the compounds need not be disced into the soil being treated, it being adequate if one of the compounds, or a formulation containing one of the compounds, is merely spread onto the top surface. However, where desired or convenient, the compounds can be disced into, or otherwise mechanically mixed with the soil. In addition to the foregoing terrestrial embodiments, the present compounds can also be utilized as aquatic herbicides.

The practice of the present invention in any of its numerous embodiments can in some instances be carried out with unmodified compound; however, for good results, it is generally necessary that the compound be employed in modified form, that is, as one component of a composition formulated to implement the plant growth-inhibiting effects. Thus, for example, the active agent can be mixed with water or other liquid or liquids, preferably aided by the usage of a surface active agent. The active agent can also be incorporated on a finely divided solid, which can be a surface active substance, to yield a wettable powder, which can subsequently be dispersed in water or other liquid, or incorporated as part of a dust which can be applied directly. Other methods of formulations are known in the art and can be employed in implementing the present invention.

In carrying out the novel method of the present invention, the exact amount of the active agent employed is not critical and will vary, depending upon the type of growth-inhibiting effect desired, the identity of the plants concerned, the particular active agent used, weather conditions, and the like. In general, a broad growth-inhibiting effect is obtained with rates of from 3—5 to 20 pounds or more of active agent per acre, and such rates are suitable and effective for control of vegetative growth on fallow land. When it is desired to obtain a selective growth-inhibiting effect on weeds in areas containing crop plants such as corn, soybeans, and cotton, rates of from 0.25 or less to 5 pounds generally give good results. When in the typical mode of operation, the active agent is employed as a composition comprising the agent, the exact concentration of active agent in the composition is not critical, except that the concentration and total amount of formulation employed be adequate to supply the appropriate amount of active agent on a per acre basis. In general, good results are obtained when employing formulations containing the active agent in a concentration of from 0.5 to 10 percent or higher, in the instance of a liquid formulation; and in a concentration of from 1.0 to 5.0 percent or higher, in the instance of a dust, powder, granule, or the like. More concentrated formulations can be prepared and are often preferred in that they can serve, depending upon the particular application contemplated and the particular concentration, both as a concentrated formulation for purposes of shipment, storage, and the like, and as an ultimate treating composition. Thus, for example, formulations often preferably contain a surface active agent and the present active agent, the latter being present in an amount of from 0.5 to 99.5 percent, by weight; or an inert, finely divided solid and the present active agent, the latter being present in an amount of from 1.0 to 99.0 percent, by weight. Such formulations, as indicated, can be employed directly in certain applications, but can also be diluted and subsequently employed in many other applications.

Liquid compositions containing the desired amount of active agent are prepared by dissolving the substance in a liquid, with or without the aid of a surface active dispersing agent such as an ionic or non-ionic emulsifying agent. Most preferably, the subject compound is dissolved in water or in an organic liquid carrier, aided by the use of a surface active dispersing agent. Suitable such organic liquid carriers include agricultural spray oils and the petroleum distillates such as diesel fuel, kerosene, fuel oil naphthas and Stoddard solvent. The choice of dispersing and emulsifying agent and the amount thereof employed is dictated by the nature of the composition and by the ability of the agent to facilitate the dispersion of the active agent in the carrier to produce the desired composition. Dispersing and emulsifying agents which can be employed in the compositions include the condensation products of alkylene oxides with phenols and organic acids, alkyl aryl sulfonates, polyoxyalkylene derivatives or sorbitan esters, complex ether alcohols, and the like. Representative surface active agents which are suitably employed in implementing the present invention are identified in U.S. Patents 3,095,299, second column, lines 25—36, 2,655,447, column 5, and 2,412,510, columns 4 and 5.

In the preparation of dust compositions, the active ingredient is intimately dis-

persed in and on a finely divided solid such as clay, talc, chalk, gypsum, limestone, vermiculite fines, perlite, and the like. In one method of achieving such dispersion, the finely divided carrier is mechanically mixed or ground with the active agent.

5 Similarly, dust compositions containing the toxicant compounds can be prepared with various of the solid surface active dispersing agents such as bentonite, fuller's earth, attapulgite and other clays. Depending upon the proportions of ingredients, these dust compositions can be employed as concentrates and subsequently diluted with additional solid surface active dispersing agents or with chalk, talc, or gypsum and the like to obtain the desired amount of active ingredient in a composition adapted to be employed for the suppression of the growth of the plants. Also, such dust compositions can be dispersed in water, with or without the aid of a dispersing agent, to form spray mixtures. 10

Formulations containing the present active agent are often advantageously further modified by incorporation therein of an effective amount of a surfactant which facilitates the dispersion and spreading of the formulation of the plant leaf surfaces and the incorporation of the formulation by the plant. 15

In accordance with the present invention, the active agent can be dispersed in soil or other growth media in any convenient fashion. Applications can be carried out by simply mixing with the media, by applying to the surface of soil and thereafter dragging or disking into the soil to the desired depth, or by employing a liquid carrier to accomplish the penetration and impregnation. The application of spray and dust compositions to the surface of soil, or to plant parts or the above ground surfaces of plants can be carried out by conventional methods, e.g., power dusters, boom and hand sprayers and spray dusters, whether surface or air-borne. However, while such conventional modes of application can be used, they are not required. As above noted, it is an advantage of the present invention that the compounds serving as active agent are active and effective as herbicides when merely placed on the surface of the soil, without any additional step to assist incorporation. Thus, the compounds are of substantially the same efficacy regardless of whether they are applied to the surface only, or whether they are applied to the surface and subsequently disced into the soil. 20 25 30

In a further method, the distribution of the active agent in soil can be accomplished by introducing the agent into the water employed to irrigate the soil. In such procedures, the amount of water is varied with the porosity and water holding capacity of the soil to obtain a desired depth of distribution of the agent. 35

In addition, the present method also comprehends the employment of an aerosol composition containing one or more of the present active agents as an active compound. Such a composition is prepared according to conventional methods wherein the agent is dispersed in a solvent, and the resultant dispersion mixed with a propellant in liquid state. Such variables as the particular agent to be used and the nature of the vegetation which is to be treated will determine the desirability of the solvent and concentration of the agent therein. 40

Satisfactory results are obtained when the active agent of the present invention, or a composition comprising such active agent, is combined with other agricultural materials intended to be applied to plants, plant parts, or their habitats. Such materials include fertilizers, fungicides, nematocides, insecticides, other herbicides, soil conditioning agents, and the like. 45

Various of the compounds to be employed as active agent in accordance with the present invention were evaluated for preemergent application to various species of plants. In this evaluation, a soil was prepared consisting of one part masonry sand and one part shredded top soil blended together in a cement mixer. One gallon of this soil was placed in a 25×35 cm. galvanized flat and was patted down with a bench brush until level. A three-row marker was used to make 2½ cm. deep furrows in approximately two-fifths of the flat. Crop seeds consisting of four kernels of corn, five cotton seeds and five soybean seeds were placed in these furrows. A four-row template was then placed on the remaining soil and the indicated approximate numbers of each of the following seeds were planted, one species to each section: foxtail (millet), 80—100 seeds; velvetleaf (40—50 seeds); rough pigweed (150—250 seeds); and large crabgrass (100—150 seeds). 50 55

Sufficient soil was added to cover the entire flat. Thus, the weeds seeds were covered to a depth of about 6 mm, and the crop seeds were covered to a depth of about 3 cm. 60

In assaying the effect of the composition as preemergent herbicides, a flat prepared as above, taken either on the day of planting or on the next day, was placed in a chamber equipped with a turntable and an air exhaust. The herbicidal composition, either a spray-type emulsion or a wettable powder, was applied to the flat with a modi- 65

5 fied DeVilbiss (Registered Trade Mark) atomizer hooked to an air source. Twelve and one-half milliliters of the composition under test were applied to each flat either on the day of planting or the succeeding day. Injury ratings and observations as to type of injury were made eleven to twelve days after treatment. The injury rating scale used was as follows: 5

10 0—no injury
1—slight injury
2—moderate injury
3—severe injury
4—death 10

15 When more than one determination was carried out at a given rate, an average value was calculated for the injury rating. In the tests reported in Tables I and II, each compound evaluated was formulated as a spray by one of the following procedures. In one method the particular compound was wetted by grinding in a mortar with one part of polyoxyethylene sorbitan monolaurate. Five hundred parts of water were added slowly to the resultant creamy paste to give an aqueous dispersion with a surfactant concentration of 0.2 percent. This dispersion was entirely satisfactory for spray application. In a second procedure the compound was dissolved in one volume of acetone, and the acetone solution was diluted with nineteen volumes of water containing 0.1 percent of polyoxyethylene sorbitan monolaurate. 15

20 In all of the following tables setting forth the results of evaluation, column 1 gives the name of the compound under test; column 2, the rate in pounds per acre at which the compound was applied to the test flat; and the remaining columns, the injury to the particular plant seeds or seedlings as measured by the foregoing scale. 20

TABLE I

Injury Rating on Premergent Treatment

Compound	Pounds/ Acre	Corn	Cotton	Soybean	Crabgrass	Pigweed	Foxtail	Velvet Leaf
6-Chloro-1-hydroxy-2-(trifluoromethyl)-1H-imidazo(4,5-b)pyridine	8	1	2	1	4	4	3	3
	4	1	0	0	4	4	3	4
	2	0	0	0	3	4	3	4
	1	0	0	0	4	4	3	2
2,6-Bis (trifluoromethyl)-1-hydroxy-1H-imidazo-(4,5-b)pyridine	8	3	4	3	4	—	4	—
	2*	0	0	2	2	3	2	2

*Not tested at higher rates.

Representative compounds of the present invention were evaluated for postemergent application to plants including corn and several weed species. The evaluation was carried out in accordance with the procedures described above except that the test solutions were applied about 9—12 days after the preparation and seeding of the flats. The results are as set forth in the following table:

5

TABLE II

Injury Rating on Postemergent Treatment

Compound	Pounds/ Acre	Corn	Cotton	Soybean	Crabgrass	Pigweed	Foxtail	Velvet Leaf
2,6-Bis(trifluoromethyl)-1-hydroxy-1H-imidazo(4,5-b)pyridine	8	4	4	4	4	4	4	4
	4	4	4	4	4	4	4	4
	2	4	4	4	4	4	4	4
	1	1	4	4	4	4	4	4
6-Methylsulfonyl-1-hydroxy-2-trifluoromethyl-1H-imidazo(4,5-b)pyridine	2*	2	4	4	2	4	4	—
	1	1	3	3	2	3	4	—

*Not tested at higher rates.

Essentially the same results as those reported in foregoing Tables I and II are obtained when evaluating the following other representative compounds of the present invention.

5	6-Nitro-1-hydroxy-2-(difluoromethyl)-1H-imidazo(4,5-b)pyridine. 6-Bromo-1-hydroxy-2-(chlorodifluoromethyl)-1H-imidazo(4,5-b)pyridine. 6-Ethylsulfonyl-1-hydroxy-2-(trifluoromethyl)-1H-imidazo(4,5-b)pyridine. 6-Chloro-1-hydroxy-2-(pentafluoroethyl)-1H-imidazo(4,5-b)pyridine. 6 - (Chlorodifluoromethyl) - 1 - hydroxy - 2 - (heptafluoro - n - propyl) - 1H-imidazo(4,5 - b)pyridine.	5
10	6-(n-Butylsulfonyl)-1-hydroxy-2-(trifluoromethyl)-1H-imidazo(4,5-b)pyridine. 2,6-Bis(difluoromethyl)-1-hydroxy-1H-imidazo(4,5-b)pyridine 6-Chloro-1-hydroxy-2-(heptafluoro-n-propyl)-1H-imidazo(4,5-b)pyridine. 6-Chloro-1-hydroxy-2-(1,1-difluoroethyl)-1H-imidazo(4,5-b)pyridine.	10

In the tests reported in Table III, various compounds of the invention were evaluated for preemergent application to various crop and weed species. Each compound was formulated by dissolving it in a 1:1 mixture of acetone and ethanol containing a small amount of a blend of sulfonate nonionic emulsifying agents; the solution was then diluted first with deionized water, then serially with deionized water containing 1000 ppm. of the blend of emulsifiers. The resulting solutions contained the subject compound in various amounts, the emulsifiers blend in a concentration of 0.1 percent, and the acetone and ethanol each in a concentration of 4.0 percent.

5

5

TABLE III

Injury Rating on Preemergent Treatment

Compound	Pounds/ Acre	Corn	Cotton	Soybean	Crabgrass	Pigweed	Foxtail	Velvet Leaf
1-Methoxy-6-chloro-2-(trifluoromethyl)-1H-imidazo(4,5-b)pyridine	8	2	4	3	3	3	4	3
	4	2	2	1	4	4	4	4
	2	1	1	1	4	3	4	4
	1	0	1	0	3	3	3	4
1-Acetoxy-6-chloro-2-(trifluoromethyl)-1H-imidazo(4,5-b)pyridine	8	1	—	—	3	2	3	3
	4	1	0	0	2	2	3	3
	2	0	0	1	1	2	3	3
	8	3	—	—	3	4	4	—
1-Ethoxy-6-chloro-2-(trifluoromethyl)-1H-imidazo(4,5-b)pyridine	4	0	0	1	4	3	4	—
	2	0	0	0	3	2	2	—
	2	0	0	0	3	2	2	—

022

TABLE III (Continued)

Compound	Pounds/ Acre	Corn	Cotton	Soybean	Crabgrass	Pigweed	Foxtail	Velvet Leaf
1-Allyloxy-6-chloro-2-(trifluoromethyl)-1H-imidazo(4,5-b)pyridine	8	3	—	—	4	4	4	—
	4	1	0	0	4	3	4	—
	2	0	0	0	3	1	3	—
1-Isopropoxy-6-chloro-2-(trifluoromethyl)-1H-imidazo(4,5-b)pyridine	8	2	—	—	4	4	4	—
	4	1	0	1	4	2	4	—
	2	0	0	0	2	1	3	—
1-(Allylcarbamoxyloxy-6-chloro-2-(trifluoromethyl)-1H-imidazo(4,5-b)pyridine	8	2	—	—	3	3	4	—
	4	0	1	1	3	3	2	—
	2	1	2	1	2	0	2	—
1-Octanoyloxy-6-chloro-2-(trifluoromethyl)-1H-imidazo(4,5-b)pyridine	8	2	—	—	3	4	4	—
	4	1	4	1	2	2	4	—
1-(Methylcarbamoxyloxy)-6-chloro-2-(trifluoromethyl)-1H-imidazo(4,5-b)pyridine	8	1	—	—	3	3	4	—
	4	1	2	1	3	3	4	—
	2	0	1	1	1	3	4	—

NOTE: Dashes indicate species which were not tested.

Representative compounds of the present invention were evaluated for postemergent application to plants including corn and several weed species. The evaluation was carried out in accordance with the procedures described in respect of the tests reported in Table III except that the test solutions were applied about 9—12 days after the preparation and seeding of the flats. The results are as set forth in the following table:

5

5

TABLE IV
Injury Rating on Postemergent Treatment

Compound	Pounds/ Acre	Corn	Crabgrass	Pigweed	Foxtail	Velvetleaf
1-Acetoxy-6-chloro-2-(tri-fluoromethyl)-1H-imidazo-(4,5-b)pyridine	8	4	4	4	4	4
	4	4	4	4	4	4
	2	4	4	4	4	4
	1	2	4	4	4	4
1-Ethoxy-6-chloro-2-(tri-fluoromethyl)-1H-imidazo-(4,5-b)pyridine	3	4	4	4	4	4
	4	4	4	4	4	4
	2	2	4	4	4	4
	1	1	4	4	3	4
1-(3,6-Dichloro-2-methoxybenzoyloxy)-6-chloro-2-(tri-fluoromethyl)-1H-imidazo-(4,5-b)pyridine	8	1	4	4	3	3
	4	0	3	2	3	3

TABLE IV (Continued)

Compound	Pounds/ Acre	Corn	Crabgrass	Pigweed	Foxtail	Velvetleaf
1-(Methylcarbamoyloxy)-6-chloro-2-(trifluoromethyl)-1H-imidazo(4,5-b)pyridine	8	2	4	4	4	4
	4	2	4	4	4	3
	2	2	4	4	3	4
	1	1	3.5	4	4	2.5
	1/2	0	4	3	4	2
	1/4	0	4	3	3	2

Essentially the same results as those reported in foregoing Tables III and IV are obtained when evaluating the other representative compounds of Formula I.

Other studies were carried out, evaluating various compounds of the present invention for preemergent application. These studies were made with a greater variety of plant species, at lower rates of application. Formulation of the compounds, however, was carried out in the same manner as described in respect of the tests reported in Tables III and IV.

Rating of the herbicidal effect was on a scale of 0—10, with 0 indicating no herbicidal effect, and 10 indicating non-emergence or death. In addition, the kind of herbicidal effect was observed and recorded in accordance with the following notation system:

A = Abscission of leaves
 B = Burned
 C = Chlorosis
 D = Death
 E = Epinasty
 F = Formative effects other than epinasty
 G = Dark Green
 I = Increased plant growth
 L = Local necrosis
 N = No germination
 P = Purple pigmentation
 R = Reduced germination
 S = Stunting
 U = Unclassified injury

5

10

15

20

25

TABLE V

Compound	Pounds/ Acre	Corn	Cotton	Soybean	Rice	Peanut	Corn	Soybean	Morning- glory	Cocklebur	Velvet-leaf	Foxtail Millet	Ragweed	Barnyard Grass
1-Methoxy-6-chloro-2-(trifluoromethyl)-1H-imidazo(4,5-b)pyridine	0.5	2SC	0	0	0	0	0	0	10D	4BC	3BC	5BC	8BC	8BC
	1.0	4SC	3B	5BC	4BC	0	2SC	3CB	10D	10D	7BC	9BC	10D	9BC
	2.0	5SC	7BC	9BC	6BC	3C	4SC	8CB	10D	10D	10D	10D	10D	9.5BC
1-Acetoxy-6-chloro-2-(trifluoromethyl)-1H-imidazo(4,5-b)pyridine	0.5	0	0	0	0	0	0	0	10D	—	4BC	4BC	8BC	2BC
	1.0	4SC	6BC	5BC	4BC	0	3SC	6BC	10D	10D	8BC	5BC	10D	4BC
	2.0	5SC	10D	10D	7BC	3C	6SC	9BC	10D	10D	9BC	9.5BC	10D	8.5BC
1-Ethoxy-6-chloro-2-(trifluoromethyl)-1H-imidazo(4,5-b)pyridine	0.5	0	0	0	0	0	0	0	2BC	0	0	0	8BC	0
	1.0	0	0	0	0	0	0	0	10D	0	7BC	8BC	10D	8BC
	2.0	2SC	0	6BC	5BC	0	3SC	9BC	10D	10D	9BC	10D	10D	9BC
1-Benzoyloxy-6-chloro-2-(trifluoromethyl)-1H-imidazo(4,5-b)pyridine	0.5	0	0	0	0	0	0	0	0	0	0	0	4BC	0
	1.0	0	0	0	0	0	0	0	2SC	—	—	5SC	3BC	4BC
	2.0	0	0	0	0	0	0	0	5BC	0	3SC	3SB	3BC	4BC

TABLE V (Continued)

Compound	Pounds/ Acre	Corn	Cotton	Soybean	Rice	Peanut	Corn	Soybean	Morning- glory	Cocklebur	Velvetleaf	Foxtail Millet	Ragweed	Barnyard Grass
1-Allyloxy-6-chloro-2-(trifluoromethyl)-1H-imidazo(4,5-b)pyridine	0.5	0	0	0	0	0	0	0	9BC	0	4BC	0	6BC	3BC
	1.0	0	0	0	0	0	0	0	10D	0	8BC	7BC	9BC	8BC
	2.0	0	0	0	3BC	0	0	4BC	10D	5BC	8.5BC	9.5BC	9BC	9BC
1-Isopropoxy-6-chloro-2-(trifluoromethyl)-1H-imidazo(4,5-b)pyridine	0.5	0	0	0	0	0	0	0	8BC	2C	2BC	0	6BC	0
	1.0	0	0	0	0	0	0	0	10D	2C	2BC	2S	9BC	4BC
	2.0	2SC	0	0	0	0	0	0	10D	—	6BC	8.5BC	9.5BC	9BC
1-(Allylcarbamoxyloxy-6-chloro-2-(trifluoromethyl)-1H-imidazo(4,5-b)pyridine	0.5	0	0	0	0	0	0	0	8BC	4BC	0	2S	6BC	0
	1.0	0	0	0	2BC	0	0	0	10D	10D	2BC	4BC	8BC	6BC
	2.0	0	5BC	5BC	6BC	2C	2SC	5BC	10D	10D	5BC	8BC	10D	8BC
1-Octanoyloxy-6-chloro-2-(trifluoromethyl)-1H-imidazo(4,5-b)pyridine	0.5	0	0	0	0	0	0	0	7BC	—	0	0	5BC	0
	1.0	0	3C	5BC	3SB	0	0	2C	10D	—	4BC	4BS	9BC	6BC
	2.0	3SC	7BC	7BC	5BC	0	4SC	7BC	10D	10D	9BC	8BC	9.5BC	7BC

TABLE V (Continued)

Compound	Pounds/ Acre	Corn	Cotton	Soybean	Rice	Peanut	Corn	Soybean	Morning- glory	Cocklebur	Velvetleaf	Foxtail Millet	Ragweed	Barnyard Grass
1-(2-Methoxy-3,6-dichloro- benzoyloxy)-6-chloro-2- (trifluoromethyl)-1H- imidazo(4,5-b)pyridine	0.5	0	3F	7F	6F	6F	0	8F	7F	10D	2F	2S	8F	5FS
	1.0	2S	5F	10D	8F	10D	0	10D	8F	—	8F	3SF	10D	4FS
	2.0	4S	9F	10D	9F	9F	1S	10D	10D	10D	10D	4SF	10D	5FS
1-(Methylcarbamoyloxy)-6- chloro-2-(trifluoro- methyl)-1H-imidazo- (4,5-b)pyridine	0.5	0	0	0	0	0	0	0	10D	—	4BC	2BC	9BC	5BC
	1.0	2SC	3SC	4BC	4BC	0	1SC	3BC	10D	10D	7BC	8BC	10D	4BC
	2.0	4SC	8BC	10D	6BC	0	5SC	10D	10D	10D	10D	10D	10D	10D
1-Ethoxy-2,6-bis(trifluoro- methyl)-1H-imidazo(4,5-b)- pyridine	0.5	0	0	0	0	0	0	0	7BC	—	0	0	0	0
	1.0	0	0	0	0	0	0	0	10D	—	2BC	0	7BC	2S
	2.0	3SC	2SC	4BC	2BC	0	5SC	8BC	10D	10D	4BC	9BC	9BC	3S
Control		0	0	0	0	0	0	0	0	0	0	0	0	0
Control		0	0	0	0	0	0	0	0	0	0	0	0	0

1-Methoxy-6-chloro-2-(trifluoromethyl)-1H-imidazo(4,5-b)pyridine was also evaluated under field conditions. The compound was formulated in conventional procedures and applied as a soil surface spray to beds seeded with corn and selected weed species. The evaluations were carried out in a sub-tropical climate; there having been no rainfall in the first seven days following application, $\frac{1}{8}$ inch of sprinkler irrigation was applied. Observations were made periodically for emergence, corn injury, and weed control. The results were as expressed in the following table, with date of observation expressed as the number of days from the day of seeding and compound application.

5

5

TABLE VI

Compound	Rate Pounds/ Acre)	Emergence ^a			Crop Injury ^c			Percent weed control — All Observations Day 17						
		Day 5	Day 7	Day 11	Day 11	Day 17	Day 38	Prickly sida	Venice mallow	Common purslane	Morning- glory	Foxtail millet	Black nightshade	Pigweed
1-methoxy-6-chloro-2- (trifluoromethyl)-1H- imidazo(4,5-b)pyridine	1	97	90	89	0.0	0.0	0.0	98	90	100	89	98	100	100
	1.5	97	89	87	0.0	0.3	0.0	99	97	100	100	99	100	100
	2	72	94	95	0.0	0.7	0.0	99	96	100	91	99	100	100
	3	100+	100	98	0.3	2.3	1.7	100	100	100	96	100	100	100
Control	4	96	85	83	2.0	3.7	4.3	100	100	100	100	100	100	100
	0	100	100	100	0.0	0.0	0.0	0	0	0	0	0	0	0
		(72) ^b	(108)	(109)				(14.6) ^d	(5.6)	(3.8)	(5)	(24.5)	(2.6)	(4.1)

^aEmergence expressed as a percent of the control.^bNumber of emerged corn seedlings per 15 feet of row.^cCrop injury on a 0—10 scale where 0 = no injury, 1—3 = slight, 4—6 = moderate, 7—9 = severe, and 10 = death of all plants.^dWeeds/sq.ft. based on 5 one sq. ft. counts per plot.

As discussed hereinabove, the compounds of Formula I can be employed in a wide variety of embodiments. In all such embodiments, the compounds can be formulated and employed with known herbicides of other classes. The ratio of the individual components of such compositions to one another is not critical; all ratios provide compositions that have useful plant growth altering properties. However, generally preferred compositions are those wherein a substantial portion of each component is present — such as compositions wherein the ratio of the components ranges from 1:10 to 10:1, and especially from 1:5 to 5:1. Among the known plant growth altering substances which can be combined with the compounds described above to yield compositions useful for plant growth regulation are the following compounds. When a compound is here listed as an acid or comprehends any readily modified functional group, its salts, esters, and other derivatives are also comprehended.

	I. Substituted Ureas	
15	3-(3,4-dichlorophenyl)-1,1-dimethylurea 3-(4-chlorophenyl)-1,1-dimethylurea 1,1-dimethyl-3-phenylurea 1-n-butyl-3-(3,4-dichlorophenyl)-1-methylurea 3-(4-chlorophenyl)-1-methyl-1-(1-methyl-2-propynyl)urea 3-(3,4-dichlorophenyl)-1-methoxy-1-methylurea	15
20	1,1-dimethyl-3-(<i>m</i> -(trifluoromethyl)phenyl)urea 3-(3-chloro-4-methoxyphenyl)-1,1-dimethylurea 3-(hexahydro-4,7-methanoindan-5-yl)-1,1-dimethylurea 3-cyclooctyl-1,1-dimethylurea 3-(4-(4-chlorophenoxy)phenyl)-1,1-dimethylurea	20
25	3-(3-(<i>n</i> -isopropylcarbamoyloxy)phenyl)-1,1-dimethylurea 3-(4-chlorophenyl)-1-methoxy-1-methylurea 3-(4-bromophenyl)-1-methoxy-1-methylurea 3-(4-bromo-3-chlorophenyl)-1-methoxy-1-methylurea 1-(2-methylcyclohexyl)-3-phenylurea	25
30	1,3-bis(1-hydroxy-2,2,2-trichloroethyl)urea 1,1-dimethyl-3-phenylurea monotrichloroacetate 3-(4-chlorophenyl)-1,1-dimethylurea monotrichloroacetate 1-(4-chlorophenyl)-2,3,3-trimethylpseudourea 1-(3,4-dichlorophenyl)-2,3,3-trimethylpseudourea	30
35	1-benzoyl-1-(3,4-dichlorophenyl)-3,3-dimethylurea	35
	II. Substituted fully unsaturated triazines:	
	2-chloro-4,6-bis(ethylamino)- <i>s</i> -triazine 2-chloro-4-ethylamino-6-isopropylamino- <i>s</i> -triazine 2,4-bis(isopropylamino)-6-methoxy- <i>s</i> -triazine	
40	2-diethylamino-4-isopropylacetamido-6-methoxy- <i>s</i> -triazine 2,4-bis(isopropylamino)-6-methylthio- <i>s</i> -triazine 2-ethylamino-4-isopropylamino-6-methoxy- <i>s</i> -triazine 2,4-bis(ethylamino)-6-methylthio- <i>s</i> -triazine	40
45	2-isopropylamino-4-methylamino-6-methylthio- <i>s</i> -triazine 2-ethylamino-4-isopropylamino-6-methylthio- <i>s</i> -triazine 2,4-bis(ethylamino)-6-methoxy- <i>s</i> -triazine 2-chloro-4,6-bis(isopropylamino)- <i>s</i> -triazine 2- <i>tert</i> -butylamino-4-ethylamino-6-methylthio- <i>s</i> -triazine 2,4-bis(3-methoxypropyl)amino)-6-methylthio- <i>s</i> -triazine	45
50	2-chloro-4,6-bis(diethylamino)- <i>s</i> -triazine 2-chloro-4-diethylamino-6-ethylamino- <i>s</i> -triazine 2-chloro-4-diethylamino-6-isopropylamino- <i>s</i> -triazine 2-chloro-4-ethylamino-6-(1-cyano-1-methylethylamino)- <i>s</i> -triazine 2- <i>sec</i> -butylamino-4-ethylamino-6-methoxy- <i>s</i> -triazine	50
55	2- <i>tert</i> -butylamino-4-isopropylamino-6-methylthio- <i>s</i> -triazine 2-(1-cyano-1-methylethylamino)-4-ethylamino-6-methylthio- <i>s</i> -triazine 2-(1-cyano-1-methylethylamino)-4-isopropylamino-6-methylthio- <i>s</i> -triazine 2-azido-4-isopropylamino-6-methylthio- <i>s</i> -triazine 2- <i>sec</i> -butylamino-4-isopropylamino-6-methylthio- <i>s</i> -triazine	55
60	2,4-bis(isopropylamino)-6-ethylthio- <i>s</i> -thiazine 2-azido-4- <i>tert</i> -butylamino-6-ethylamino- <i>s</i> -triazine 2- <i>tert</i> -butylamino-4-chloro-6-ethylamino- <i>s</i> -triazine	60

	2- <i>tert</i> -butylamino-4-ethylamino-6-methoxy- <i>s</i> -triazine	
	2-ethylamino-4-ethylthio-6-isopropylamino- <i>s</i> -triazine	
	2-azido-4- <i>sec</i> -butylamino-6-methylthio- <i>s</i> -triazine	
5	2- <i>tert</i> -butylamino-4-methylamino-6-methylthio- <i>s</i> -triazine	5
	2-chloro-4-cyclopropylamino-6-isopropylamino- <i>s</i> -triazine	
	2-(4-chloro-6-ethylamino- <i>s</i> -triazin-2-ylamino)-2-methylbutyronitrile	
	III. Phenols	
	2- <i>sec</i> -butyl-4,6-dinitrophenol	
10	4,6-dinitro-2-(1-methylbutyl)phenol	10
	pentachlorophenol	
	4,6-dinitro- <i>o</i> -cresol	
	IV. Benzoic Acids	
	chlorinated benzoic acid	
15	2,3,6-trichlorobenzoic acid	15
	2,3,5,6-tetrachlorobenzoic acid	
	2-methoxy-3,5,6-trichlorobenzoic acid	
	3,6-dichloro-2-methoxybenzoic acid	
	3-amino-2,5-dichlorobenzoic acid	
	2,5-dichloro-3-nitrobenzoic acid	
20	V. Phenoxy compounds	20
	2-(2,4-dichlorophenoxy)acetic acid	
	2-(2,4-dichlorophenoxy)propionic acid	
	2-(2,4,5-trichlorophenoxy)acetic acid	
25	2-(4-chloro- <i>o</i> -tolylloxy)acetic acid	25
	2-(2,4,5-trichlorophenoxy)propionic acid	
	2-(2,4,5-trichlorophenoxy)ethyl 2,2-dichloropropionate	
	4-(2,4-dichlorophenoxy)butyric acid	
	4-(4-chloro- <i>o</i> -tolylloxy)butyric acid	
30	tris(2-(2,4-dichlorophenoxy)ethyl)phosphite	30
	3-(4-chloro- <i>o</i> -tolylloxy)propionic acid	
	2-(2,4-dichlorophenoxy)ethyl benzoate	
	2-(2,4,5-trichlorophenoxy)ethyl sodium sulfate	
	2-(2,4-dichlorophenoxy)ethyl sodium sulfate	
	2-(4-chloro- <i>o</i> -tolylloxy)ethyl sodium sulfate	
35	VI. Benzonitriles	35
	2,6-dichlorobenzonitrile	
	3,5-diiodo-4-hydroxybenzonitrile	
	3,5-dibromo-4-hydroxybenzonitrile	
	VII. Chlorinated Aliphatic Acids	
40	trichloroacetic acid	40
	2,2-dichloropropionic acid	
	VIII. Carbamates and Thiocarbamates	
	<i>S</i> -ethyl di- <i>n</i> -propylthiocarbamate	
	<i>S</i> - <i>n</i> -propyl di- <i>n</i> -propylthiocarbamate	
45	<i>S</i> - <i>n</i> -propyl <i>n</i> -butylethylthiocarbamate	45
	<i>S</i> -ethyl diisobutylthiocarbamate	
	<i>S</i> -ethyl cyclohexylethylthiocarbamate	
	<i>S</i> -ethyl hexahydro-1 <i>H</i> -azepine-1-carbothioate	
	<i>S</i> -isopropyl hexahydro-1 <i>H</i> -azepine-1-carbothioate	
50	2-chloroallyl diethyldithiocarbamate	50
	<i>S</i> -(2,3-dichloroallyl) diisopropylthiocarbamate	
	<i>S</i> -(2,3,3-trichloroallyl) diisopropylthiocarbamate	
	isopropyl carbanilate	
	isopropyl 3-chlorocarbanilate	
55	methyl 3,4-dichlorocarbanilate	55
	4-chloro-2-butyryl 3-chlorocarbanilate	
	methyl sulfanilylcarbamate	
	3,4-dichlorobenzyl methylcarbamate	

23	1,307,489	23
	2,3-dichlorobenzyl methylcarbamate	
	4-cyano-2,6-diiodophenyl methylcarbamate	
	2,6-di- <i>tert</i> -butyl- <i>p</i> -tolyl methylcarbamate	
	sodium methyldithiocarbamate	
5	2-(phenylcarbamoyl)ethyl <i>n</i> -butylcarbamate	5
	3-methoxycarboxamidophenyl 3-methylcarbanilate	
	<i>m</i> -propionamidophenyl isopropylcarbamate	
	1-(ethylcarbamoyl)ethyl carbanilate	
	1-(isopropylcarbamoyl) ethyl 3-chloro carbanilate	
10	IX. Phenylacetic acids	10
	2-(2,3,6-trichlorophenyl)acetic acid	
	X. Uracils	
	3-cyclohexyl-5,6-trimethylenuracil	
	5-bromo-3- <i>sec</i> -butyl-6-methyluracil	
15	5-bromo-3- <i>tert</i> -butyl-6-methyluracil	15
	5-bromo-3-isopropyl-6-methyluracil	
	3- <i>tert</i> -butyl-5-chloro-6-methyluracil	
	XI. Dinitroanilines	
	<i>N,N</i> -di- <i>n</i> -propyl-2,6-dinitro-4-(trifluoromethyl)aniline	
20	<i>N,N</i> -di- <i>n</i> -propyl-2,6-dinitro-4-methylaniline	20
	<i>N</i> -ethyl- <i>N</i> -butyl-2,6-dinitro-4-(trifluoromethyl)aniline	
	<i>N,N</i> -di- <i>n</i> -propyl-2,6-dinitro-4-(methylsulfonyl)aniline	
	<i>N,N</i> -di- <i>n</i> -propyl-2,6-dinitro-4-sulfamoylaniline	
	<i>N,N</i> -di- <i>n</i> -propyl-2,6-dinitro-4-isopropylaniline	
25	<i>N,N</i> -di- <i>n</i> -propyl-2,6-dinitro-4- <i>tert</i> -butylaniline	25
	XII. Diphenyl ethers	
	<i>m</i> -tolyl <i>p</i> -nitrophenyl ether	
	<i>p</i> -nitrophenyl 2,4-dichlorophenyl ether	
	<i>p</i> -nitrophenyl 2,4,6-trichlorophenyl ether	
30	<i>p</i> -nitrophenyl 4-(trifluoromethyl)-2-nitrophenyl ether	30
	XIII. Inorganics and Organometallics	
	phenylmercuric acetate	
	hydrated sodium tetraborate	
	sodium metaborate	
35	sodium pentaborate	35
	sodium chlorate	
	unrefined borate ore such as Borascu (Trade Mark for anhydrous Na ₂ B ₄ O ₇)	
	sodium chlorate	
	calcium propylarsonate	
40	disodium methanearsonate	40
	monosodium methanearsonate	
	calcium methanearsonate	
	monoammonium methanearsonate	
	octyl-dodecylammoniummethylarsonate	
45	sodium arsenite	45
	arsenic acid	
	cacodylic acid	
	arsenic trioxide	
	ammonium sulfamate	
50	potassium azide	50
	lead arsenate	
	calcium arsenate	
	potassium cyanate	
	calcium cyanamide	
55	methanearsonic acid	55
	magnesium chlorate	
	XIV. Amides	
	<i>N,N</i> -dimethyl-2,2-diphenylacetamide	
	<i>N</i> -isopropyl-2-chloroacetanilide	

	N,N-diethyl-2-chloroacetamide	
	N,N-diallyl-2-chloroacetamide	
	N-(isopropoxymethyl)-N-(2,6-xylyl)-2-chloroacetamide	
	N-(isobutoxymethyl)-N-(2,6-xylyl)-2-chloroacetamide	
5	N-(methoxymethyl)-N-(6- <i>tert</i> -butyl- <i>o</i> -tolyl)-2-chloroacetamide	5
	N-(methoxymethyl)-N-(2,6-diethylphenyl)-2-chloroacetamide	
	N-(<i>n</i> -butoxymethyl)-2-chloro-2',6'-diethylacetanilide	
	2-chloro-N-(2,6-diethyl-1-cyclohexen-1-yl)-N-(2- <i>n</i> -butoxyethyl)acetamide	
	6- <i>tert</i> -butyl-2-chloro- <i>o</i> -acetotoluidide	
10	4-chloro-N,N-di- <i>n</i> -propylcinnanamide	10
	N-(3,4-dichlorophenyl)propionamide	
	3',4'-dichloro-2-methylacrylanilide	
	3'-chloro-2-methyl- <i>p</i> -valerotoluidide	
	3',4'-dichlorocyclopropanecarboxanilide	
15	N-(5-chloro-2-thiazolyl)propionamide	15
	N-methoxy-2-(4-chloro- <i>o</i> -tolylloxy)acetamide	
	N,N-diethyl-2-methyl-2-(1-naphthylloxy)acetamide	
	N-(1,1-dimethylpropynyl)-3,5-dichlorobenzamide	
	N-(hydroxymethyl)-2,6-dichlorothiobenzamide	
20	2-(2,6-dinitro-4-toluidino)-N-methylpropionamide	20
	2-(4-chloro- <i>o</i> -tolylloxy)propionanilide	
	3'-4'-dichloropropionanilide	
	3'-chlorobenzanilide	
	XV. Phthalic Acids and their derivatives and this analogue	
25	N-(1-naphthyl)phthalamic acid	25
	dimethyl 2,3,5,6-tetrachloroterephthalate	
	methyl 2,3,5,6-tetrachloro-4-(methylthio)carbonylbenzoate	
	methyl 2,3,5,6-tetrachloro-N-methoxy-N-methylterephthalamate	
	XVI. Pyridazinones	
30	5-amino-4-chloro-2-phenyl-3(2H)-pyridazinone	30
	4-chloro-5-dimethylamino-2-(<i>m</i> -(trifluoromethyl)phenyl)-3(2H)-pyridazinone	
	XVII. Triazinones	
	3-methylthio-6-isopropyl-4-amino- <i>as</i> -triazin-5(4H)-one	
	3-methylthio-6-cyclohexyl-4-amino- <i>as</i> -triazin-5(4H)-one	
35	3-methylthio-6-phenyl-4-amino- <i>as</i> -triazin-5(4H)-one	35
	1-(3,4-dichlorophenyl)-3,5-dimethylhexahydro- <i>s</i> -triazin-2(4H)-one	
	1-phenyl-3-methyl-5-allylhexahydro- <i>s</i> -triazin-2(4H)-one	
	4-amino-3-methylthio-6- <i>tert</i> -butyl- <i>as</i> -triazin-5(4H)-one	
	XVIII. Miscellaneous	
40	acrolein	40
	3-amino-1,2,4-triazole	
	O,O-diisopropyl S-(2-(phenylsulfonamido)ethyl) phosphorodithioate	
	2-methyl-6-(trifluoromethyl)benzimidazole	
	2-isopropyl-6-(trifluoromethyl)benzimidazole	
45	2-isopropyl-6-chlorobenzimidazole	45
	5-methylsulfonyl-2-(trifluoromethyl)benzimidazole	
	2,6-bis(trifluoromethyl)-4-nitrobenzimidazole	
	3-(<i>p</i> - <i>tert</i> -butylphenylsulfonyl)acrylonitrile	
	2,3,5-trichloro-4-pyridinol	
50	6,7-dihydrodipyrido[1,2- <i>a</i> :2',1'- <i>c</i>]pyrazinedium salts	50
	α -(2,2,2-trichloroethyl)styrene	
	7-oxabicyclo(2.2.1)heptane-2,3-dicarboxylic acid	
	hexachlorocyclopentadiene	
	2-trifluoromethyl-6-chloro-1H-imidazo(4,5- <i>b</i>)pyridine	
55	3- <i>o</i> -tolylloxypyridazine	55
	1,1'-dimethyl-4,4'-bipyridinium salts	
	4-amino-3,5,6-trichloropicolinic acid	
	O-methyl O-(2,4-dichlorophenyl) isopropylphosphoramidothioate	
	2,3,6-trichlorobenzylloxypropanol	
60	2-amino-3-chloro-1,4-naphthoquinone	60
	hexachloroacetone	

	trichlorobenzyl chloride	
	sodium <i>cis</i> -3-chloroacrylate	
	4,5,7-trichloro-2,1,3-benzothiadiazole	
5	1-(3,4-dichlorophenyl)-3-methyl-2-pyrrolidinone	5
	1-(3-chloro- <i>p</i> -tolyl)-3-methyl-2-pyrrolidinone	
	ethyleneglycol bis(trichloroacetate)	
	diphenylacetoneitrile	
	maleic hydrazide	
	allyl alcohol	
10	(1,1-dimethyl-2-chloroethyl)trimethylammonium chloride	10
	tri- <i>n</i> -butyl 2,4-dichlorobenzylphosphonium chloride	
	the ester of (4-hydroxycarvacryl)trimethylammonium chloride with 1-piperidinecarb- oxylic acid	
15	O,O-diethyl dithiobis(thioformate)	15
	tetrahydro-3,5-dimethyl-2H-1,3,5-thiadiazine-2-thione	
	(benzamidoxy)acetic acid	
	methyl 2-chloro-9-hydroxyfluorene-9-carboxylate	
	<i>n</i> -butyl 9-hydroxyfluorene-9-carboxylate	
	4-dimethylaminophenyl thiocyanate	
20	5- <i>tert</i> -butyl-3-(2,4-dichloro-6-isopropoxyphenyl)-1,3,4-oxadiazol-2(3H)-one	20
	5- <i>tert</i> -butyl-3-(2,4-dichloro-5-isopropoxyphenyl)-1,3,4-oxadiazol-2(3H)-one	
	2-(3,4-dichlorophenyl)-4-methyl-1,2,4-oxadiazolidine-3,5-dione	
	N-(3,5-dibromo-4-hydroxybenzylidene)-2,4-dinitroaniline	
	4-chlorobenzenesulfone- <i>o</i> -toluidide	
25	Representative combinations are those of the 6-substituted-1-hydroxy or alkoxy- 2-(1,1-difluoroalkanoyl)-1H-imidazo(4,5- <i>b</i>)pyridines and the substituted triazines of Class II hereinabove. Two such representative combinations are the combination of 6- chloro-1-hydroxy-2-(trifluoromethyl)-1H-imidazo(4,5- <i>b</i>)pyridine and 2-chloro-4-ethyl- amino-6-isopropylamino- <i>s</i> -triazine and the combination of 6-chloro-1-methoxy-2-(tri- fluoromethyl)-1H-imidazo(4,5- <i>b</i>)pyridine and 2-chloro-4-ethylamino-6-isopropylamino- <i>s</i> -triazine. These two combinations were evaluated for preemergent application to various species of plants. In this evaluation, a soil was prepared consisting of one part masonry sand and one part shredded top soil blended together in a cement mixer. One gallon of this soil was placed in a 21.5×31.5 cm. galvanized flat and was patted down with a bench brush until level. Rows were marked, and seeds planted, one species to a row. The species employed in the evaluation of the combination comprising the 1- hydroxy compound were corn, sorghum, ragweed, morning glory, cocklebur, purple nutsedge, and small crabgrass. The species employed in the evaluation of the combina- tion comprising the 1-methoxy compound were corn, jimson weed, barnyard grass, rice, pigweed, velvetleaf, sorghum, ragweed, morning glory, lambsquarter, large and small crabgrass, fantail millet, and johnson grass. Large seeded species were placed in trenches, and small seeded species were merely placed on the soil surface. Afterwards, a covering of the same soil was placed over the seeds to a depth of about one-fourth to three-eighths inch.	25
30		30
35		35
40		40
45	The compounds were separately formulated by suspending each in a 1:1 solution of acetone and ethanol containing a small amount of a blend of two sulfonate-non-ionic surfactants. Each suspension was then further diluted serially with an aqueous solution of the same blend of surfactants — to prepare a plurality of aqueous treating solutions containing the compound in various concentrations. In addition, each solution contain- ed the blend of surfactants in a total concentration of 0.55 percent and the acetone and ethanol each in a concentration of 4.15 percent. Two solutions were sprayed onto the surface of each flat in the tests reported in Table VII, one solution containing 6- chloro-1-hydroxy-2-(trifluoromethyl)-1H-imidazo(4,5- <i>b</i>)pyridine, the other containing 2-chloro-4-ethylamino-6-isopropylamino- <i>s</i> -triazine.	45
50		50
55	In the tests reported in Table VIII, two solutions were sprayed onto the surface of each flat also, one solution containing 6-chloro-1-methoxy-2-(trifluoromethyl)-1H- imidazo(4,5- <i>b</i>)pyridine, the other containing 2-chloro-4-ethylamino-6-isopropylamino- <i>s</i> -triazine. In each instance the solutions were supplied in the amount of 12.5 milli- liters each per flat, representing different amounts of the compounds per acre among the various flats. Another flat was left untreated to serve as a control.	55
60		60

All flats were held for an additional fourteen days under normal greenhouse conditions, at which time injury ratings and observations as to type of injury were made. The injury rating scale used was as follows:

5	0 — no injury	5
	1—3 — slight injury	
	4—6 — moderate injury	
	7—9 — severe injury	
	10 — death or no emergence	
10	B — burned	10
	D — death	
	R — reduced germination	
	S — stunting	

The following tables report the results of the evaluation of the treated flat, for each of two replications. In the control flat, there were healthy stands of each of the test species.

TABLE VII

Injury Rating

Compound	Rate Pounds/ Acre	Corn		Sorghum		Ragweed		Morning Glory		Cocklebur		Purple Nutsedge		Small Crabgrass	
		I	II	I	II	I	II	I	II	I	II	I	II	I	II
A	0.5	3SB	2S	4SB	8BS	9BS	10D	10D	10D	8BS	10D	0	0	6S	2S
A	1.0	2S	2S	10D	9.5BS	10D	10D	10D	10D	8RSB	9BSR	0	0	8BS	8BS
A	2.0	4S	4S	9BS	10D	10D	10D	10D	10D	10D	10D	0	0	9BS	10D
A + B	1/2 + 3.4	0	0	8BS	3BS	10D	9BS	10D	9BS	9BSR	10D	0	0	9.5BS	9BS
A + B	1 + 3/4	3BS	0	10D	10D	10D	10D	10D	10D	10D	9BS	0	0	10D	9BS
A + B	2 + 3/4	8BS	5SB	10D	10D	10D	10D	10D	10D	10D	10D	3B	0	10D	10D
B	0.75	0	2S	0	0	9BS	9BS	10D	9BSR	7BS	8BS	0	0	9BS	7BS
Control	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

A = 6-chloro-1-hydroxy-2-(trifluoromethyl)-1H-imidazo(4,5-b)pyridine.

B = 2-chloro-4-ethylamino-6-isopropylamino-s-triazine.

TABLE VIII

Injury Rating

Compound	Rate lb./A	Morn- ing glorys	Pigweed	Ragweed	Corn	Velvet leaf	Lambs- quarter	Jimson- weed	Barn- yard grass	Rice	Large Crab- grass	Corn	Foxtail Millet	Sor- ghum	Johnson- grass
C	$\frac{1}{4}$	1S	0	3S	0	0	6RS	2CS	2S	0	1S	0	0	0	0
C	$\frac{1}{2}$	6CS	5RS	7SD	0	4CS	7RS	8 $\frac{1}{2}$ SD	6BS	2BS	3S	0	3SD	0	2S
C	1	10D	9 $\frac{1}{2}$ RS	9SD	1S	7SD	7RSD	9 $\frac{1}{2}$ SD	9 $\frac{1}{2}$ SD	3BS	8SD	0	9SD	2S	3BS
C	2	10D	9 $\frac{1}{2}$ RS	9 $\frac{1}{2}$ SD	2S	9 $\frac{1}{2}$ SD	7S	9 $\frac{1}{2}$ SD	10D	4BS	9SD	2S	10D	7SD	7SD
B	$\frac{1}{4}$	3CS	9RS	4RS	0	1S	7RS	7S	2RS	1S	0	0	0	0	0
B	$\frac{1}{2}$	5SD	9RS	4RSB	0	3BS	9RS	8CS	5RS	1S	1S	0	0	0	0
B	1	7SD	9 $\frac{1}{2}$ RS	8RSB	0	6BS	8RS	9CS	7BSR	2S	2S	0	2S	0	2S
B	2	9 $\frac{1}{2}$ SD	9 $\frac{1}{2}$ RS	9RS	0	5BS	7RS	8CS	9 $\frac{1}{2}$ SD	4S	6S	0	3S	0	2S
C + B	$\frac{1}{4}$	8SD	9RS	8RS	0	3BS	7RS	8 $\frac{1}{2}$ SD	5BS	2BS	4S	0	3S	0	2S
C + B	$\frac{1}{2}$	10D	9 $\frac{1}{2}$ RS	8RSD	0	5BS	7RSD	9SD	8SD	3BS	4S	0	4BS	0	2S
C + B	$\frac{1}{4}$	9 $\frac{1}{2}$ SD	10N	8RSD	0	7SD	7RS	9SD	9 $\frac{1}{2}$ SD	3BS	6S	0	4BS	0	4BS
C + B	$\frac{1}{2}$	10D	9 $\frac{1}{2}$ RS	9 $\frac{1}{2}$ RSD	0	9 $\frac{1}{2}$ SD	7RS	9 $\frac{1}{2}$ SD	9 $\frac{1}{2}$ SD	3RS	8S	0	7SD	0	4BS
C + B	$\frac{1}{4}$	10D	9 $\frac{1}{2}$ RS	6 $\frac{1}{2}$ SD	0	7SD	7 $\frac{1}{2}$ RS	9SD	9SD	3BS	7RS	0	8SD	0	4BS

TABLE VIII (Continued)

Injury Rating

Compound	Rate lb./A	Morn- ing glorys	Pigweed	Ragweed	Corn	Velvet leaf	Lambs- quarter	Jimson weed	Barn- yard grass	Rice	Large Crab- grass	Corn	Foxtail Millet	Sor- ghum	Johnson- grass
C + B	$\frac{1}{2}$ $\frac{1}{2}$	10D	9RS	9SD	0	7SD	5RS	9 $\frac{1}{2}$ SD	9 $\frac{1}{2}$ SD	4BS	7RS	0	7SD	0	7SD
C + B	$\frac{1}{2}$ 1	10D	9 $\frac{1}{2}$ RS	9 $\frac{1}{2}$ RSD	1S	6SD	6 $\frac{1}{2}$ RS	9SD	9SD	3BS	8SD	0	8 $\frac{1}{2}$ SD	0	6 $\frac{1}{2}$ SD
C + B	$\frac{1}{2}$ 2	10D	9RS	9 $\frac{1}{2}$ RSD	0	9SD	7RS	8 $\frac{1}{2}$ SD	10D	3BS	9SD	0	9 $\frac{1}{2}$ SD	0	6 $\frac{1}{2}$ SD
C + B	1 $\frac{1}{4}$	10D	9RS	9SD	0	6 $\frac{1}{2}$ SD	7RS	9SD	9 $\frac{1}{2}$ SD	3BS	9 $\frac{1}{2}$ SD	0	10D	3BS	7SD
C + B	1 $\frac{1}{2}$	10D	9 $\frac{1}{2}$ RS	9 $\frac{1}{2}$ SD	0	9SD	7RS	9 $\frac{1}{2}$ SD	9 $\frac{1}{2}$ SD	2BS	9 $\frac{1}{2}$ SD	0	10D	4BS	8SD
C + B	1 1	10D	9 $\frac{1}{2}$ RS	10D	0	9SD	8RS	9 $\frac{1}{2}$ SD	10D	3BS	9 $\frac{1}{2}$ SD	0	10D	4BS	7SD
C + B	1 2	10D	9 $\frac{1}{2}$ RS	10D	0	9SD	7RSD	9 $\frac{1}{2}$ SD	10D	3BS	9 $\frac{1}{2}$ SD	0	10D	3BS	9SD
C + B	2 $\frac{1}{4}$	10D	9 $\frac{1}{2}$ RS	9SD	1S	9 $\frac{1}{2}$ SD	7RS	9 $\frac{1}{2}$ SD	10D	3BS	9 $\frac{1}{2}$ SD	0	10D	7SD	9 $\frac{1}{2}$ SD
C + B	2 $\frac{1}{2}$	10D	9 $\frac{1}{2}$ RS	10D	0	9 $\frac{1}{2}$ SD	7 $\frac{1}{2}$ RS	9 $\frac{1}{2}$ SD	9 $\frac{1}{2}$ SD	4BS	10D	0	8SD	8SD	9SD
C + B	2 1	10D	9 $\frac{1}{2}$ RS	10D	2S	10D	8RS	9 $\frac{1}{2}$ SD	9 $\frac{1}{2}$ SD	5BS	9 $\frac{1}{2}$ SD	1S	10D	8SD	9SD
C + B	2 2	10D	9 $\frac{1}{2}$ RS	10D	2S	10D	8RS	10D	10D	4BS	9 $\frac{1}{2}$ SD	0	10D	7SD	9SD
Control	—	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Control	—	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Control	—	0	0	0	0	0	0	0	0	0	0	0	0	0	0

C = 6-chloro-1-methoxy-2-(trifluoromethyl)-1H-imidazo(4,5-b)pyridine.

B = 2-chloro-4-ethylamino-6-isopropylamino-s-triazine.

Like results are achieved when combining 6-chloro-1-hydroxy-2-(trifluoromethyl)-1H-imidazo(4,5-b)pyridine, 6-chloro-1-methoxy-2-trifluoromethyl-1H-imidazo(4,5-b)pyridine, or other of the subject 1,6-di-substituted-2-(1,1-difluoroalkyl)-1H-imidazo(4,5-b)pyridine compounds with other of the substituted triazine compounds of Class II. In general, the combinations are employed to supply from 0.025 to 4.0 pounds of the 1,6-di-substituted-2-(1,1-difluoroalkyl)-1H-imidazo(4,5-b)pyridines per acre, and from 0.5 to 4.0 pounds of the substituted triazine per acre.

The following examples illustrate the present invention and the preparation of the starting materials and will enable those skilled in the art to practice the same.

Example 1:

5-Chloro-3-nitro-2-(trifluoroacetamido)pyridine

5-Chloro-3-nitro-2-aminopyridine (5.0 grams) and excess trifluoroacetic anhydride were refluxed together for 24 hours. Thin layer chromatography showed no reaction had taken place. Pyridine (2.0 ml.) was then added. After fifteen minutes the solution solidified. The product was dissolved in chloroform and washed twice with water, and the chloroform was then evaporated under vacuum. The resulting product residue was recrystallized from a mixture of benzene and aliphatic naphtha: m.p., 104—105° C., yield 6.0 g.

Analysis, Calc.: C, 31.20; H, 1.12; N, 15.59.

Found: C, 32.20; H, 1.44; N, 15.83.

Example 2:

5-Chloro-3-nitro-2-(trifluoroacetamido)pyridine

The compound of Example 1 was also synthesized by dissolving the 5-chloro-3-nitro-2-aminopyridine (5.0 grams) in a minimum amount of warm trifluoroacetic acid, and then adding 1.5 equivalents of trifluoroacetic anhydride and 0.5 milliliters of pyridine and refluxing for about an hour. The reaction mixture was then poured onto ice to precipitate the 5-chloro-3-nitro-2-(trifluoroacetamido)pyridine compound, which was separated, dissolved in chloroform, and washed twice with water. Thereafter, the solution was shaken with activated carbon and filtered, and chloroform removed under vacuum to obtain a purified product. It was further recrystallized from a low boiling (40—50° C.) petroleum ether, m.p., 104—105° C.

Example 3:

5-(Trifluoromethyl)-3-nitro-2-(trifluoroacetamido)pyridine

5-(Trifluoromethyl)-3-nitro-2-aminopyridine (2.0 grams) was mixed with 10 milliliters of pyridine and 1 milliliter of trifluoroacetic anhydride added with cooling. After 30 minutes, the reaction mixture was heated to 100° C. and maintained thereat for 10 minutes. The reaction mixture was then poured into ice and hydrochloric acid (of a concentration of 50 grams of ice per 10 milliliters of hydrochloric acid). The reaction mixture was then filtered and the resulting residue, the desired 5-(trifluoromethyl)-3-nitro-2-(trifluoroacetamido)pyridine, taken up in chloroform, dried, and solvent evaporated to obtain a purified product. It was further recrystallized from benzene, m.p. 68—70° C.

Example 4:

5-(Methylsulfonyl)-3-nitro-2-(trifluoroacetamido)pyridine

5-(Methylsulfonyl)-3-nitro-2-aminopyridine (2.0 grams) was mixed with 15 milliliters of trifluoroacetic anhydride and 4 milliliters of pyridine. The resulting mixture was stirred under reflux until the reaction mixture changed color, from gray to dark brown, and began solidifying. An additional 10 milliliters of the trifluoroacetic anhydride was then added and the reaction mixture refluxed for another hour. The excess anhydride was then removed by evaporation, yielding the desired 5-(methylsulfonyl)-3-nitro-2-(trifluoroacetamido)pyridine. It was dissolved in chloroform, washed once with water, and dried over magnesium sulfate; the chloroform was then removed by evaporation, and the resulting product was recrystallized from benzene/acetone, m.p., 159—61° C.

Analysis, Calc.: C, 30.67; H, 1.93; N, 13.42.

Found: C, 30.73; H, 2.00; N, 13.58.

Example 5:

1-Hydroxy-2,6-bis(trifluoromethyl)-1H-imidazo(4,5-b)pyridine

5-(Trifluoromethyl)-3-nitro-2-aminopyridine (10.0 grams) in trifluoroacetic anhydride (10 ml.) and pyridine (20 ml.) were heated in a steam bath for two hours. Solvents were then evaporated on a rotary evaporator at 100° C. for one hour, and the residue was taken up in ethyl acetate and hydrogenated over 2.0 g. of 5 percent palladium on carbon. The reaction mixture was then filtered, evaporated, and taken up in ethanol; subsequently, the mixture was washed with 10 percent hydrochloric acid, dried over magnesium sulfate, and evaporated. The resulting 1-hydroxy-2,6-bis(trifluoromethyl)-1H-imidazo(4,5-b)pyridine product was recrystallized from acetone, m.p., 239—40° C.

Analysis, Calc.: C, 35.44; H, 1.15; N, 15.50; F, 42.05.

Found: C, 35.40; H, 1.43; N, 15.28; F, 42.32.

Example 6:

6-Chloro-1-hydroxy-2-(trifluoromethyl)-1H-imidazo(4,5-b)pyridine

5-Chloro-3-nitro-2-(trifluoroacetamido)pyridine (2.0 grams) was hydrogenated with two moles of hydrogen in ethanol containing 0.5 gram of 5 percent palladium on carbon. The resulting reaction mixture was filtered and evaporated to separate the desired 6-chloro-1-hydroxy-2-(trifluoromethyl)-1H-imidazo(4,5-b)pyridine compound which, after recrystallization from benzene melted at 268—70° C.

Analysis, Calc.: C, 35.39; H, 1.27; N, 17.69.

Found: C, 35.59; H, 1.45; N, 17.77.

Example 7:

6-Chloro-1-hydroxy-2-(trifluoromethyl)-1H-imidazo(4,5-b)pyridine

5-Chloro-3-nitro-2-(trifluoroacetamido)pyridine (2.7 grams), anhydrous stannous chloride (3.8 grams), and 4.0 milliliters of concentrated hydrochloric acid were mixed in 20 milliliters of acetic acid. The mixture was cooled to temperatures of 0—10° C. and maintained thereat for 15 minutes. Water (50 milliliters) was then added to the reaction mixture, and the desired 6-chloro-1-hydroxy-2-(trifluoromethyl)imidazo-1H-(4,5-b)pyridine product precipitated. It was separated and dried. The yield was 1.3 grams, 55 percent. The product so obtained melted at 264—66° C.

Example 8:

6-Chloro-1-hydroxy-2-(trifluoromethyl)-1H-imidazo(4,5-b)pyridine triethylamine salt

6-Chloro-1-hydroxy-2-(trifluoromethyl)-1H-imidazo(4,5-b)pyridine (1 gram) was mixed with 15 milliliters of tetrahydrofuran, and 0.7 milliliter of triethylamine added. The reaction mixture was evaporated and then held in a vacuum desiccator overnight, resulting in the desired 6-chloro-1-hydroxy-2-(trifluoromethyl)-1H-imidazo(4,5-b)pyridine triethylamine salt. The compound was subjected to NMR analysis (in deuterium oxide); analysis showed a triplet centered at 82 cps. (9H); a quartet centered at 196 cps. (6H); a meta-coupled doublet at 400 cps. (1H); and a second meta-coupled doublet centered at 503 cps. (1H).

Example 9:

6-Chloro-1-hydroxy-2-(trifluoromethyl)-1H-imidazo(4,5-b)pyridine benzylamine salt

6-Chloro-1-hydroxy-2-(trifluoromethyl)-1H-imidazo(4,5-b)pyridine (1.4 grams) was mixed with 15 milliliters of ethyl acetate. The mixture was heated to reflux, and 0.6 milliliter of benzylamine was added dropwise. The mixture was then refluxed for another 30 minutes, cooled, and filtered, yielding the desired 6-chloro-1-hydroxy-2-(trifluoromethyl)-1H-imidazo(4,5-b)pyridine benzylamine salt, m.p., 200—02° C. NMR analysis in hexadeuteriodimethyl sulfoxide showed a peak at 236 cps. (2H); a peak at 437 cps. (5H); two meta-coupled doublets at the 462 cps. (1H), the other at 500 cps. (1H); and a broad peak at 474 cps. (3H).

Analysis, Calc.: C, 48.75; H, 3.51; N, 16.25.

Found: C, 48.52; H, 3.72; N, 16.07.

Examples 10—29:

Other products of the present invention are prepared in accordance with the procedures and teachings hereinabove. Representative such other products include the following:

- 5 3,5-Dinitro-2-aminopyridine is reacted with difluoroacetic anhydride to obtain 3,5-dinitro-2-(difluoroacetamido)pyridine, which in turn is hydrogenated in the presence of platinum to obtain 6-nitro-1-hydroxy-2-(difluoromethyl)-1H-imidazo(4,5-b)-pyridine. 5
 - 10 5-Bromo-3-nitro-2-aminopyridine is treated with chlorodifluoroacetic anhydride to yield 5-bromo-3-nitro-2-(chlorodifluoroacetamido)pyridine, which on hydrogenation in the presence of palladium on barium sulfate, yields 6-bromo-1-hydroxy-2-(chlorodifluoromethyl)-1H-imidazo(4,5-b)pyridine. 10
 - 15 5-Ethylsulfonyl-3-nitro-2-aminopyridine is reacted with trifluoroacetic anhydride to obtain 5-ethylsulfonyl-3-nitro-2-(trifluoroacetamido)pyridine, which on hydrogenation in the presence of palladium on carbon yields 6-ethylsulfonyl-1-hydroxy-2-(trifluoromethyl)-1H-imidazo(4,5-b)pyridine. 15
 - 20 5-Chloro-3-nitro-2-aminopyridine is treated with pentafluoropropionic anhydride to obtain 5-chloro-3-nitro-2-(pentafluoropropionamido)pyridine, which when hydrogenated in the presence of palladium on carbon yields 6-chloro-1-hydroxy-2-(pentafluoroethyl)-1H-imidazo(4,5-b)pyridine, m.p., 240—42° C. 20
 - 25 5-(Chlorodifluoromethyl)-3-nitro-2-aminopyridine is reacted with heptafluorobutyric anhydride to obtain 5-(chlorodifluoromethyl)-3-nitro-2-(heptafluorobutyramido)pyridine, which on hydrogenation in the presence of palladium on calcium sulfate yields 6-(chlorodifluoromethyl)-1-hydroxy-2-(heptafluoropropyl)-1H-imidazo(4,5-b)-pyridine. 25
 - 30 5-(n-Butylsulfonyl)-3-nitro-2-aminopyridine is reacted with trifluoroacetic anhydride to obtain 5-(n-butylsulfonyl)-3-nitro-2-(trifluoroacetamido)pyridine, which on hydrogenation in the presence of platinum yields 6-(n-butylsulfonyl)-1-hydroxy-2-(trifluoromethyl)-1H-imidazo(4,5-b)pyridine. 30
 - 35 5-(Difluoromethyl)-3-nitro-2-aminopyridine is reacted with difluoroacetic anhydride to obtain 5-(difluoromethyl)-3-nitro-2-(difluoroacetamido)pyridine, which when hydrogenated in the presence of palladium on barium sulfate yields 2,6-bis(difluoromethyl)-1-hydroxy-1H-imidazo(4,5-b)pyridine. 35
 - 5-(Methylsulfonyl)-3-nitro-2-aminopyridine is reacted with trifluoroacetic anhydride to obtain 5-(methylsulfonyl)-3-nitro-2-(trifluoroacetamido)pyridine which when hydrogenated yields 6-(methylsulfonyl)-1-hydroxy-2-(trifluoromethyl)-1H-imidazo(4,5-b)pyridine, m.p., 265—68° C. 35
- Analysis, Calc.: C, 34.17; H, 2.15; N, 14.94.
Found: C, 34.27; H, 2.37; N, 15.07.
- 40 5-Chloro-3-nitro-2-aminopyridine is reacted with heptafluorobutyric anhydride to obtain 5-chloro-3-nitro-2-(heptafluorobutyramido)pyridine which when hydrogenated yields 6-chloro-1-hydroxy-2-(heptafluoro-n-propyl)-1H-imidazo(4,5-b)pyridine. 40
 - 45 5-Chloro-3-nitro-2-aminopyridine is reacted with 2,2-difluoropropionic anhydride to obtain 5-chloro-3-nitro-2-(2,2-difluoropropionamido)pyridine, which on hydrogenation in the presence of palladium on calcium sulfate yields 6-chloro-1-hydroxy-2-(1,1-difluoroethyl)-1H-imidazo(4,5-b)pyridine. 45
 - 50 5-(Trifluoromethyl)-3-nitro-2-aminopyridine is reacted with 2,2-difluoro-3-bromopropionic anhydride to obtain 5-(trifluoromethyl)-3-nitro-2-(2,2-difluoro-3-bromopropionamido)pyridine, which on hydrogenation in the presence of platinum yields 6-(trifluoromethyl)-1-hydroxy-2-(1,1-difluoro-2-bromoethyl)-1H-imidazo(4,5-b)pyridine. 50
 - 55 5-Iodo-3-nitro-2-aminopyridine is reacted with 2,2-difluorobutyric anhydride to obtain 5-iodo-3-nitro-2-(2,2-difluorobutyramido)pyridine, which when hydrogenated in the presence of palladium on barium sulfate yields 6-iodo-1-hydroxy-2-(1,1-difluoro-n-propyl)-1H-imidazo(4,5-b)pyridine. 55
 - 60 5-(Methylsulfonyl)-3-nitro-2-aminopyridine is reacted with 2,2-difluoro-3,4-dichlorobutyric anhydride to obtain 5-(methylsulfonyl)-3-nitro-2-(2,2-difluoro-3,4-dichlorobutyramido)pyridine which when hydrogenated yields 6-(methylsulfonyl)-1-hydroxy-2-(1,1-difluoro-2,3-dichloro-n-propyl)-1H-imidazo(4,5-b)pyridine. 55
 - 60 5-Fluoro-3-nitro-2-aminopyridine is reacted with 2,2,3-trifluoropropionic anhydride to obtain 5-fluoro-3-nitro-2-(2,2,3-trifluoropropionamido)pyridine which on hydrogenation over palladium on carbon yields 6-fluoro-1-hydroxy-2-(1,1,2-trifluoroethyl)-1H-imidazo(4,5-b)pyridine. 60

5-(Trifluoromethyl)-3-nitro-2-aminopyridine is reacted with 2,2-difluoro-4-iodobutyric anhydride to obtain 5-(trifluoromethyl)-3-nitro-2-(2,2-difluoro-4-iodobutyramido)pyridine, which on hydrogenation yields 6-(trifluoromethyl)-1-hydroxy-2-(1,1-difluoro-3-iodo-n-propyl)-1H-imidazo(4,5-b)pyridine.

5-Chloro-3-nitro-2-aminopyridine is reacted with perfluorooctanoic anhydride to obtain 5-chloro-3-nitro-2-(2,2,3,3,4,4,5,5,6,6,7,7,8,8,8-pentafluorooctanamido)pyridine, which on hydrogenation yields 6-chloro-1-hydroxy-2-(perfluoro-n-heptyl)-1H-imidazo(4,5-b)pyridine. This compound is reacted with dimethylamine to obtain the dimethylamine salt thereof.

5-(Trifluoromethyl)-3-nitro-2-aminopyridine is reacted with perfluorobutyryl chloride to yield 5-(trifluoromethyl)-3-nitro-2-(2,2,3,3,4,4,4-heptafluorobutyramido)pyridine, which when hydrogenated yields 6-(trifluoromethyl)-1-hydroxy-2-(perfluoro-n-propyl)-1H-imidazo(4,5-b)pyridine.

6-(Chlorodifluoromethyl)-1-hydroxy-2-(trifluoromethyl)-1H-imidazo(4,5-b)pyridine is reacted with pyridine to obtain the pyridine salt thereof.

6-(Methylsulfonyl)-1-hydroxy-2-(trifluoromethyl)-1H-imidazo(4,5-b)pyridine, in a dilute aqueous solution of sodium hydroxide, forms the sodium salt thereof in solution.

6-Nitro-1-hydroxy-2-(trifluoromethyl)-1H-imidazo(4,5-b)pyridine is reacted with an aqueous solution of calcium carbonate, yielding the calcium salt thereof.

Example 30:

1-Methoxy-6-chloro-2-(trifluoromethyl)-1H-imidazo(4,5-b)pyridine

1-Hydroxy-6-chloro-2-(trifluoromethyl)-1H-imidazo(4,5-b)pyridine (5 grams), 80 milliliters of acetone, 5 milliliters of methyl iodide, and 10 grams of anhydrous potassium carbonate were mixed, heated and refluxed with stirring for twelve hours. The reaction mixture was then filtered, evaporated and eluted off of a silica column with diethyl ether, yielding the desired 1-methoxy-6-chloro-2-(trifluoromethyl)-1H-imidazo(4,5-b)pyridine product. It was recrystallized from petroleum ether (boiling at 60—80° C.). The product so obtained melted at 91—2° C.

Analysis, Calc.: C, 38.20; H, 1.99; N, 16.70.

Found: C, 37.92; H, 2.32; N, 16.75.

Example 31:

1-Benzyloxy-6-chloro-2-(trifluoromethyl)-1H-imidazo(4,5-b)pyridine

1-Hydroxy-6-chloro-2-(trifluoromethyl)-1H-imidazo(4,5-b)pyridine (5 grams), 10 milliliters of benzyl bromide, 20 grams of anhydrous potassium carbonate, and 100 milliliters of ethanol were mixed, heated to reflux and refluxed for one hour. The reaction mixture was then filtered, evaporated under vacuum, and extracted with diethyl ether. The extract was filtered and evaporated under vacuum yielding a dark oil which on standing crystallized as the desired 1-benzyloxy-6-chloro-2-(trifluoromethyl)-1H-imidazo(4,5-b)pyridine. It was recrystallized from a mixture of acetone and petroleum ether boiling at 60—80° C., m.p., 107—09° C.

Analysis, Calc.: C, 51.31; H, 2.77; N, 12.82.

Found: C, 51.54; H, 2.62; N, 13.12.

Example 32:

1-Acetoxy-6-chloro-2-(trifluoromethyl)-1H-imidazo(4,5-b)pyridine

1-Hydroxy-6-chloro-2-(trifluoromethyl)-1H-imidazo(4,5-b)pyridine (5 grams), 25 milliliters of acetic anhydride and 0.1 milliliter of sulfuric acid were mixed with stirring at 25° C. for fifteen minutes. The reaction mixture was then heated to reflux and refluxed for one-half hour, poured into ice with stirring, stirred for ten minutes and filtered. Filtration yielded the desired 1-acetoxy-6-chloro-2-(trifluoromethyl)-1H-imidazo(4,5-b)pyridine product as a solid. It was taken up in ether, dried over magnesium sulfate, and the ether evaporated. The product then melted at 103—04° C.

Analysis, Calc.: C, 38.65; H, 1.80; N, 15.02.

Found: C, 38.88; H, 1.92; N, 15.02.

Example 33:

1-Octanoyloxy-6-chloro-2-(trifluoromethyl)-1H-imidazo(4,5-b)pyridine

To 1-hydroxy-6-chloro-2-(trifluoromethyl)-1H-imidazo(4,5-b)pyridine (2.37 grams) in 5 milliliters of pyridine was added octanoyl chloride (1.63 grams). The addition was carried out portionwise with stirring and resulted in the precipitation of

a white solid. The reaction mixture was set on a steam bath for twenty minutes, then poured over ice cold aqueous HCl. An oil separated and subsequently crystallized on vigorous stirring. This precipitate was removed by filtration, dissolved in ether, dried over magnesium sulfate, filtered, and ether removed by evaporation under vacuum. The substance was purified by distillation, m.p., 33.5—35.5° C.

Analysis, Calc.: C, 49.52; H, 4.71; N, 11.55.
Found: C, 49.81; H, 4.93; N, 11.29.

Example 34:

1-(Allylcarbamoyloxy)-6-chloro-2-(trifluoromethyl)-1H-imidazo(4,5-b)pyridine
1-Hydroxy-6-chloro-2-(trifluoromethyl)-1H-imidazo(4,5-b)pyridine (4.6 grams) was dissolved in 10 milliliters of diethyl ether and 2.4 milliliters of allyl isocyanate added and the reaction mixture stirred at room temperature for thirty-six hours. The reaction mixture was then filtered yielding 4.75 grams of a white powder, the desired 1-(allylcarbamoyloxy)-6-chloro-2-(trifluoromethyl)-1H-imidazo(4,5-b)pyridine. An additional portion of the product was obtained by evaporating the filtrate. The combined products were recrystallized from a mixture of diethyl ether and petroleum ether boiling at 60—80° C., m.p., about 210° C.

Analysis, Calc.: C, 41.20; H, 2.51; N, 17.47.
Found: C, 41.42; H, 2.51; N, 17.25.

Example 35:

1-(Methylsulfonyloxy)-6-chloro-2-(trifluoromethyl)-1H-imidazo(4,5-b)pyridine
1-Hydroxy-6-chloro-2-(trifluoromethyl)-1H-imidazo(4,5-b)pyridine (5 grams) in 15 milliliters of pyridine was cooled to 5° C. with stirring and methylsulfonyl chloride (5 milliliters) was added in 1-milliliter portions, maintaining the temperature at about 5° C. After the addition was completed, the reaction mixture was stirred for two hours at 5—10° C., then poured into 30 grams of ice and 20 milliliters of concentrated hydrochloric acid. The desired 1-(methylsulfonyloxy)-6-chloro-2-(trifluoromethyl)-1H-imidazo(4,5-b)pyridine product precipitated and was separated by filtration and washed with water. The washed product was taken up in diethyl ether with a trace of acetone, dried over magnesium sulfate and the solvent evaporated under vacuum. The product so obtained melted at 136.7° C.

Analysis, Calc.: C, 30.44; H, 1.60; N, 13.31.
Found: C, 30.48; H, 1.83; N, 13.00.

Examples 36—70

Other representative compounds where R³ is other than hydrogen, prepared in accordance with the process of the invention, include the following:
1-allyloxy-6-chloro-2-(trifluoromethyl)-1H-imidazo(4,5-b)pyridine, n_D²⁵ 1.5204.
1-isopropoxy-6-chloro-2-(trifluoromethyl)-1H-imidazo(4,5-b)pyridine, m.p., 49—51° C.
1-ethoxy-6-chloro-2-(trifluoromethyl)-1H-imidazo(4,5-b)pyridine, n_D²⁵ 1.5082.
1-(methylcarbamoyloxy)-6-chloro-2-(trifluoromethyl)-1H-imidazo(4,5-b)pyridine, m.p., 267° C.
1 - (2 - methoxy - 3,6 - dichlorobenzoyloxy) - 6 - chloro - 2 - (trifluoromethyl) - 1H-imidazo(4,5 - b)pyridine, m.p., 148—9° C.
1-ethoxy-2,6-bis(trifluoromethyl)-1H-imidazo(4,5-b)pyridine, n_D²⁵ 1.5100.
1-methoxy-6-nitro-2-(trifluoromethyl)-1H-imidazo(4,5-b)pyridine.
1-n-octyloxy-6-(methylsulfonyl)-2-(heptafluoro-n-propyl)-1H-imidazo(4,5-b)pyridine.
1-n-butoxy-6-fluoro-2-(1,1-difluoroethyl)-1H-imidazo(4,5-b)pyridine.
1-phenethoxy-2,6-bis(chlorodifluoromethyl)-1H-imidazo(4,5-b)pyridine.
1-vinyloxy-2,6-bis(difluoromethyl)-1H-imidazo(4,5-b)-pyridine.
1-(dimethylcarbamoyloxy)-6-bromo-2-(perfluoro-n-hexyl)-1H-imidazo(4,5-b)pyridine.
1-methacryloyloxy-6-chloro-2-(trifluoromethyl)-1H-imidazo(4,5-b)pyridine.
1-lauroyloxy-2,6-bis(trifluoromethyl)-1H-imidazo(4,5-b)pyridine.
1 - (2,4 - dichlorophenoxyacetoxy) - 6 - chloro - 2 - (trifluoromethyl) - 1H - imidazo-(4,5-b)pyridine.
1-benzoyloxy-2,6-bis(trifluoromethyl)-1H-imidazo(4,5-b)pyridine.
1-(phenylacetoxyl)-6-chloro-2-(trifluoromethyl)-1H-imidazo(4,5-b)pyridine.
1-cinnamoyloxy-6-chloro-2-(trifluoromethyl)-1H-imidazo(4,5-b)pyridine.

- 1 - (3 - (2,4,5 - trichlorophenoxy)propionyloxy) - 6 - chloro - 2 - (trifluoromethyl) - 1H-imidazo(4,5 - b)pyridine.
- 1-cyclohexyloxy-6-chloro-2-(trifluoromethyl)-1H-imidazo(4,5-b)pyridine.
- 1-(phenylsulfonyloxy)-2,6-bis(difluoromethyl)-1H-imidazo(4,5-b)pyridine.
- 5 1-(benzylsulfonyloxy)-6-chloro-2-(difluoromethyl)-1H-imidazo(4,5-b)pyridine. 5
- 1-(cyclohexylsulfonyloxy)-6-nitro-2-(trifluoromethyl)-1H-imidazo(4,5-b)pyridine.
- 1 - ((p - chlorophenyl)sulfonyloxy) - 6 - chloro - 2 - (trifluoromethyl) - 1H - imidazo(4,5 - b)pyridine.
- 1 - (2 - butenyloxy) - 6 - (isopropylsulfonyl) - 2 - (1,1 - difluoro - 3 - chloropropyl)-1H - imidazo(4,5 - b)pyridine.
- 10 1-(6-octenyloxy)-6-chloro-2-(trifluoromethyl)-1H-imidazo(4,5-b)pyridine. 10
- 1-(9-hexadecenoyloxy)-6-chloro-2-(trifluoromethyl)-1H-imidazo(4,5-b)pyridine.
- 1 - (isopropylthiocarbamoyloxy) - 6 - chloro - 2 - (pentafluoroethyl) - 1H - imidazo(4,5 - b)pyridine.
- 15 1 - (3 - amino - 2,5 - dichlorobenzoyloxy) - 6 - chloro - 2 - (trifluoromethyl) - 1H-imidazo(4,5 - b)pyridine. 15
- 1 - (2,5 - dichloro - 3 - nitrobenzoyloxy) - 6 - chloro - 2 - (trifluoromethyl) - 1H-imidazo(4,5 - b)pyridine.
- 1 - (2 - (4 - chloro - o - tolyloxy)acetoxy) - 2,6 - bis(trifluoromethyl) - 1H - imidazo(4,5 - b)pyridine.
- 20 1 - (tetrahydro - 2 - pyraniloxy) - 6 - chloro - 2 - (trifluoromethyl) - 1H - imidazo(4,5 - b)pyridine. 20
- 1-methoxy-2,6-bis(trifluoromethyl)-1H-imidazo(4,5-b)pyridine.
- 1-(methylcarbamoyloxy)-2,6-bis(trifluoromethyl)-1H-imidazo(4,5-b)pyridine.
- 25 The following example illustrates the preparation of the 5-(alkylsulfonyl)-3-nitro-2-aminopyridine compounds. 25

Example 71:

5-(Methylsulfonyl)-3-nitro-2-aminopyridine

- 5-Chloro-2-nitropyridine (8.0 grams) was added to a solution of 2.5 grams of sodium methanethiolate in 100 milliliters of ethanol at a temperature of 0° C. to which solution excess sodium methanethiolate was added portionwise. The resulting reaction mixture was then heated to reflux and refluxed for 15 hours with constant stirring. At the end of the 15 hours, the reaction mixture was filtered and allowed to concentrate to 75 milliliters. The reaction mixture was then permitted to cool and filtered again, yielding the desired 5-(methylthio)-2-nitro-pyridine; it was recrystallized from ethanol, m.p., 100.5—102.5° C.
- 30 30
- 35 35

- To 3.4 grams of the 5-(methylthio)-2-nitropyridine in 50 milliliters of glacial acetic acid there was added 23.8 grams of 30 percent hydrogen peroxide. The resulting reaction mixture was stirred for 60 hours at 25° C., then poured over ice and filtered to separate the desired 5-(methylsulfonyl)-2-nitropyridine product, which after recrystallization from ethanol/acetone, melted at 165—167° C.
- 40 40

- The entire yield of 5-(methylsulfonyl)-2-nitropyridine (3.2 grams) was dissolved in about 100 milliliters of acetone and 1 teaspoon of Raney nickel slurry in ethanol added. The mixture was then shaken on a Parr hydrogenator for 15 hours at 60 p.s.i. Thereafter, the mixture was filtered and solvent evaporated, yielding the desired 5-(methylsulfonyl)-2-aminopyridine product. It was mixed with hot water containing some charcoal, filtered and the mixture then cooled to 25° C. The resulting solid was crystallized from benzene/acetone, m.p., 132—134° C.
- 45 45

- 5-(Methylsulfonyl)-2-aminopyridine (1.0 gram) was dissolved in 10 milliliters of concentrated sulfuric acid and 2.0 milliliters of fuming nitric acid added dropwise with stirring, and the resulting reaction mixture stirred an additional 10 minutes, warmed on a steam bath for 10 minutes, and allowed to stir at 25° C. for 15 hours. The reaction mixture was then poured over ice with stirring. Precipitation occurred, and the mixture was filtered to separate 5-(methylsulfonyl)-3-nitro-2-hydroxypyridine; it was washed with water and recrystallized from ethanol/acetone, m.p., 229—232° C.
- 50 50
- 55 55

- 5-(Methylsulfonyl)-3-nitro-2-hydroxypyridine (2.0 grams) was mixed with 25 milliliters of thionyl chloride and 1 milliliter of dimethylformamide and the mixture refluxed for 2 hours. The reaction mixture was then evaporated to separate 5-(methylsulfonyl)-3-nitro-2-chloropyridine. It was shaken with water to remove any traces of thionyl chloride, and then filtered and mixed with 50 milliliters of ammonium hydroxide. This mixture was stirred, at room temperature, for 15 hours, then poured
- 60 60

into ice water and filtered to separate 5-(methylsulfonyl)-3-nitro-2-aminopyridine. It was recrystallized from ethanol/acetone, m.p., 239—41° C.

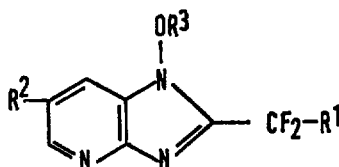
Analysis, Calc.: C, 33.19; H, 3.25; N, 19.35.

Found: C, 33.32; H, 3.31; N, 19.18.

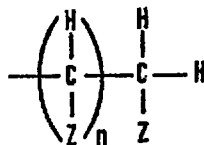
- 5 In like manner are prepared the other 5-(alkylsulfonyl)-3-nitro-2-aminopyridine compounds: 5
- 5-(ethylsulfonyl)-3-nitro-2-aminopyridine;
- 5-(isopropylsulfonyl)-3-nitro-2-aminopyridine;
- 5-(n-propylsulfonyl)-3-nitro-2-aminopyridine;
- 10 5-(n-butylsulfonyl)-3-nitro-2-aminopyridine; 10
- 5-(isobutylsulfonyl)-3-nitro-2-aminopyridine;
- 5-(sec-butylsulfonyl)-3-nitro-2-aminopyridine; and
- 5-(tert-butylsulfonyl)-3-nitro-2-aminopyridine.
- Intermediates in the preparation of these compounds include the following:
- 15 5-(ethylthio)-2-nitropyridine 15
- 5-(n-butylthio)-2-nitropyridine
- 5-(n-propylsulfonyl)-2-nitropyridine
- 5-(isobutylsulfonyl)-2-aminopyridine
- 5-(isopropylsulfonyl)-3-nitro-2-hydroxypyridine
- 20 5-(sec-butylsulfonyl)-3-nitro-2-chloropyridine 20
- 5-(ethylsulfonyl)-3-nitro-2-chloropyridine
- 5-(tert-butylsulfonyl)-3-nitro-2-aminopyridine
- 5-(ethylsulfonyl)-3-nitro-2-aminopyridine

WHAT WE CLAIM IS:—

- 25 1. 1-Substituted-2-(1,1-difluoroalkyl)-1H-imidazo(4,5-b)pyridine compounds of the formula 25



wherein R¹ represents hydrogen, chlorine, fluorine, perfluoroalkyl of C₁—C₆, or a radical of the formula:



30

30

wherein each Z independently represents hydrogen or halogen and n represents 0 or 1; R² represents halogen, nitro, —CF₃, —CF₂Cl, —CF₂H, or lower alkylsulfonyl of C₁—C₄; and R³ represents

- 35 (1) hydrogen, or the alkali or alkaline earth metal salt thereof, or the salt thereof with an organic amine having a K_a of 10⁻⁵ or greater; 35
- (2) alkyl of C₁—C₈;
- (3) alkenyl of C₂—C₈;
- (4) cycloalkyl of C₃—C₆;
- (5) benzyl;
- 40 (6) phenethyl; 40
- (7) alkanoyl of C₂—C₁₆;
- (8) alkenoyl of C₃—C₁₆;

into ice water and filtered to separate 5-(methylsulfonyl)-3-nitro-2-aminopyridine. It was recrystallized from ethanol/acetone, m.p., 239—41° C.

Analysis, Calc.: C, 33.19; H, 3.25; N, 19.35.

Found: C, 33.32; H, 3.31; N, 19.18.

5 In like manner are prepared the other 5-(alkylsulfonyl)-3-nitro-2-aminopyridine compounds: 5

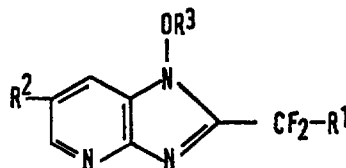
5-(ethylsulfonyl)-3-nitro-2-aminopyridine;
5-(isopropylsulfonyl)-3-nitro-2-aminopyridine;
5-(n-propylsulfonyl)-3-nitro-2-aminopyridine;
10 5-(n-butylsulfonyl)-3-nitro-2-aminopyridine;
5-(isobutylsulfonyl)-3-nitro-2-aminopyridine;
5-(sec-butylsulfonyl)-3-nitro-2-aminopyridine; and
5-(tert-butylsulfonyl)-3-nitro-2-aminopyridine.

Intermediates in the preparation of these compounds include the following:

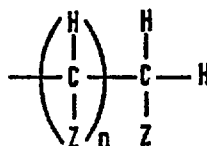
15 5-(ethylthio)-2-nitropyridine
5-(n-butylthio)-2-nitropyridine
5-(n-propylsulfonyl)-2-nitropyridine
5-(isobutylsulfonyl)-2-aminopyridine
5-(isopropylsulfonyl)-3-nitro-2-hydroxypyridine
20 5-(sec-butylsulfonyl)-3-nitro-2-chloropyridine
5-(ethylsulfonyl)-3-nitro-2-chloropyridine
5-(tert-butylsulfonyl)-3-nitro-2-aminopyridine
5-(ethylsulfonyl)-3-nitro-2-aminopyridine

WHAT WE CLAIM IS:—

25 1. 1-Substituted-2-(1,1-difluoroalkyl)-1H-imidazo(4,5-b)pyridine compounds of the formula 25



wherein R¹ represents hydrogen, chlorine, fluorine, perfluoroalkyl of C₁—C₆, or a radical of the formula:



wherein each Z independently represents hydrogen or halogen and n represents 0 or 1; R² represents halogen, nitro, —CF₃, —CF₂Cl, —CF₂H, or lower alkylsulfonyl of C₁—C₄; and R³ represents

(1) hydrogen, or the alkali or alkaline earth metal salt thereof, or the salt thereof with an organic amine having a K_b of 10⁻⁵ or greater;

(2) alkyl of C₁—C₆;

(3) alkenyl of C₂—C₆;

(4) cycloalkyl of C₃—C₆;

(5) benzyl;

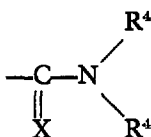
(6) phenethyl;

(7) alkanoyl of C₂—C₁₆;

(8) alkenoyl of C₃—C₁₆;



(9) a carbamoyl or thiocarbamoyl radical of the formula



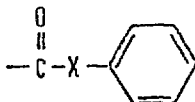
5

wherein X represents oxygen or sulfur; and one R⁴ represents phenyl, lower alkyl of C₁—C₄, or lower alkenyl of C₂—C₄, and the other R⁴ represents hydrogen, lower alkyl of C₁—C₄, or lower alkenyl of C₂—C₄, subject to the limitation that both R⁴ moieties taken together do not contain more than six carbon atoms, or both R⁴ moieties taken together represent straight-chain alkylene of C₂—C₆, both inclusive;

5

(10) a radical of the formulae $\begin{array}{c} \text{O} \\ || \\ -\text{C}-\text{X}-\text{lower alkyl of C}_1-\text{C}_4 \text{ or} \end{array}$

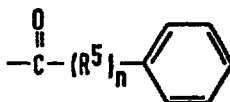
10



10

wherein X is, as above, oxygen or sulfur;

(11) a radical of the formula



15

wherein R⁵ represents methylene, ethylene, or vinylene, and n represents 0 or 1;

15

(12) a radical of the formulae $\begin{array}{c} \text{O} \\ || \\ -\text{C}-\text{substituted phenyl} \end{array}$ and $\begin{array}{c} \text{O} \\ || \\ -\text{C}-\text{R}^6-\text{O-substituted phenyl} \end{array}$ wherein "substituted phenyl" is a phenyl radical bearing from 1—3 substituents, each of which is independently amino, nitro, chloro, methyl, or methoxy, and R⁶ represents lower alkylene of C₁—C₄, both inclusive;

20

20

(13) —SO₂—R⁷ wherein R⁷ is lower alkyl of C₁—C₄, cycloalkyl of C₅—C₆, phenyl, substituted phenyl as defined in (12) above, or benzyl; or

(14) tetrahydro-2-pyranyl.

2. The compounds of claim 1 wherein R³ represents

25

25

(2) alkyl of C₁—C₆;

(3) alkenyl of C₂—C₆;

(4) cycloalkyl of C₅—C₆;

(5) benzyl;

(6) phenethyl;

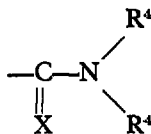
30

30

(7) alkanoyl of C₂—C₁₆;

(8) alkenoyl of C₃—C₁₆;

(9) a carbamoyl or thiocarbamoyl radical of the formula



35

wherein X represents oxygen or sulfur; and one R⁴ represents phenyl, lower alkyl of C₁—C₄, or lower alkenyl of C₂—C₄, and the other R⁴ represents hydrogen, lower alkyl of C₁—C₄, or lower alkenyl of C₂—C₄, subject to the

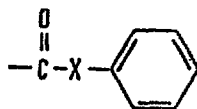
35



limitation that both R^4 moieties taken together do not contain more than six carbon atoms, or both R^4 moieties taken together represent straight-chain alkylene of C_2-C_6 , both inclusive;

(10) a radical of the formulae $\begin{array}{c} \text{O} \\ \parallel \\ -\text{C}-\text{X} \end{array}$ -lower alkyl of C_1-C_4 or

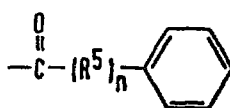
5



5

wherein X is, as above, oxygen or sulfur;

(11) a radical of the formula



wherein R^5 represents methylene, ethylene, or vinylene, and n represents 0 or 1;

10

10

(12) a radical of the formulae $\begin{array}{c} \text{O} \\ \parallel \\ -\text{C} \end{array}$ -substituted phenyl and $\begin{array}{c} \text{O} \\ \parallel \\ \text{C}-R^6 \end{array}$ -O-substituted phenyl, wherein "substituted phenyl" is a phenyl radical bearing from 1—3 substituents, each of which is independently amino, nitro, chloro, methyl, or methoxy, and R^6 represents lower alkylene of C_1-C_4 , both inclusive;

15

15

(13) $-\text{SO}_2-R^7$ wherein R^7 is lower alkyl of C_1-C_4 , cycloalkyl of C_3-C_6 , phenyl, substituted phenyl as defined in (12) above, or benzyl; or

(14) tetrahydro-2-pyranyl.

3. The compounds of claim 1 wherein R^3 is hydrogen, or the alkali or alkaline earth metal salt thereof, or the salt thereof with an organic amine having a K_b of 10^{-5} or greater.

20

20

4. The compound of claim 1 or 2 which is 1-methoxy-6-chloro-2-(trifluoromethyl)-1H-imidazo(4,5-b)pyridine; 1-ethoxy-2,6-bis(trifluoromethyl)-1H-imidazo(4,5-b)pyridine; 1-methylcarbamoyloxy-6-chloro-2-(trifluoromethyl)-1H-imidazo(4,5-b)pyridine; 1-allyloxy-6-chloro-2-(trifluoromethyl)-1H-imidazo(4,5-b)pyridine; 1-isopropoxy-6-chloro-2-trifluoromethyl-1H-imidazo(4,5-b)pyridine; or 1-methoxy-2,6-bis(trifluoromethyl)-1H-imidazo(4,5-b)pyridine.

25

30

5. The compounds of claim 1 or 3 which is 6-chloro-1-hydroxy-2-(trifluoromethyl)-1H-imidazo(4,5-b)pyridine; 2,6-bis(trifluoromethyl)-1-hydroxy-1H-imidazo(4,5-b)pyridine; 6-(methylsulfonyl)-1-hydroxy-2-(trifluoromethyl)-1H-imidazo(4,5-b)pyridine; 6-nitro-1-hydroxy-2-(trifluoromethyl)-1H-imidazo(4,5-b)pyridine; or 6-chloro-1-hydroxy-2-pentafluoroethyl-1H-imidazo(4,5-b)pyridine.

30

35

6. A herbicide which contains as an active agent an imidazo pyridine compound defined in claim 1.

7. The herbicide of claim 6 wherein the pyridine selected from 1-methoxy-6-chloro-2-(trifluoromethyl)-1H-imidazo(4,5-b)pyridine and 1-methoxy-2,6-bis(trifluoromethyl)-1H-imidazo(4,5-b)pyridine.

35

40

8. The herbicide of claim 6 wherein pyridine is selected from 6-chloro-1-hydroxy-2-(trifluoromethyl)-1H-imidazo(4,5-b)pyridine and 2,6-bis(trifluoromethyl)-1-hydroxy-1H-imidazo(4,5-b)pyridine.

40

25

9. The herbicide of claim 6, 7 or 8 which contains a surface active agent.

10. The herbicide of claim 6, 7, 8 or 9 which contains an inert carrier which is an inert finely divided solid.

11. Compounds as claimed in claim 1 wherein R^1 is hydrogen, fluorine, chlorine or trifluoromethyl.

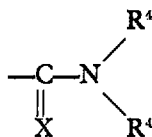
45

45

12. Compounds as claimed in claim 1 wherein R_1 is fluorine or trifluoromethyl; R^2 is halo or trifluoromethyl; and R^3 is lower alkyl of C_1-C_4 , lower alkenyl of C_2-C_4 ,

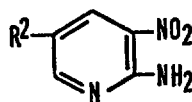


benzyl, lower alkanoyl of C_2-C_4 , lower alkenoyl of C_3-C_4 , benzoyl, lower alkylsulfonyl of C_1-C_4 , or a carbamoyl or thiocarbamoyl radical of the formula

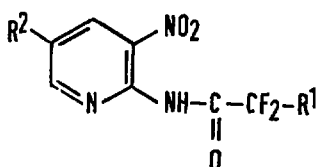


5 wherein X represents oxygen or sulfur, and one R^4 represents phenyl, lower alkyl of C_1-C_4 , or lower alkenyl of C_2-C_4 , and the other R^4 represents hydrogen, lower alkyl of C_1-C_4 , or lower alkenyl of C_2-C_4 , subject to the limitation that both R^4 moieties taken together do not contain more than six carbon atoms, or both R^4 moieties taken together represent straight-chain alkylene of C_2-C_6 , both inclusive.

10 13. A method of preparing compounds as claimed in claim 1 wherein R^3 is hydrogen comprising acylating a compound of the formula

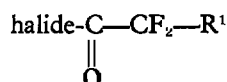


to give a compound of the formula

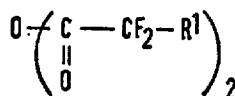


15 and then reducing this compound, R^1 and R^2 being as defined in claim 1.

15 14. A method as claimed in claim 13 wherein the acylating agent is: a difluoroalkanoyl halide:



or a difluoroalkanoic anhydride:



20 where R^1 is as defined in claim 1.

20 15. A method as claimed in claim 14 wherein the acylating agent is a difluoroalkanoic anhydride and the acylation is conducted in the presence of an organic tertiary amine.

25 16. A method as claimed in any one of claims 13 to 15 wherein the acylation is conducted in the presence of triethylamine or pyridine.

17. A method as claimed in any one of claims 13 to 16 wherein the reducing agent is hydrogen in the presence of a catalyst.

18. A method as claimed in claim 17 wherein the catalyst is palladium or platinum.

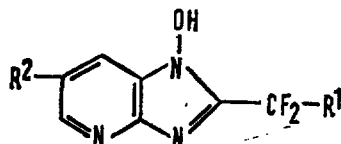
30 19. A method as claimed in claim 17 or claim 18 wherein 2 moles of hydrogen per mole of 5-substituted-3-nitro-2-(1,1-difluoroalkylamido)pyridine are used.

20. A method as claimed in any one of claims 17 to 19 wherein the catalyst is a noble metal used in an amount of between 1 and 10 grams per kilogram of 5-substituted-3-nitro-2-(1,1-difluoroalkylamido)pyridine.

35 21. A method as claimed in any one of claims 17 to 20 wherein the reduction is carried out at a temperature of from 10° to 25° C.



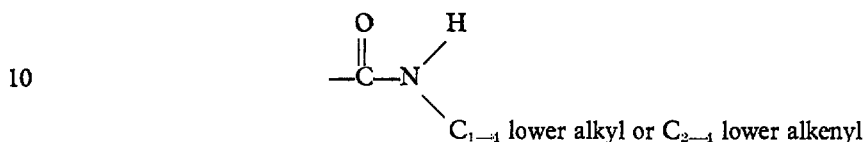
22. A method of preparing compounds as claimed in claim 1 wherein R^3 is other than hydrogen or a hydroxyl salt which comprises reacting a compound of the formula



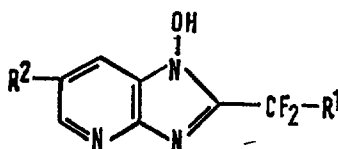
5 with a halide of the formula R^3-X , where X is halo, in the presence of a hydrogen halide acceptor, R^1 , R^2 and R^3 being as defined in claim 1 except in that R^3 is other than H or a hydroxyl salt. 5

23. A method as claimed in claim 22 wherein the reaction is conducted at a temperature of from -20°C . to the reflux temperature.

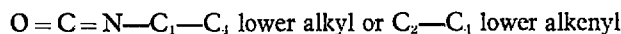
24. A method of preparing compounds as claimed in claim 1 wherein R^3 is



which comprises reacting a compound of the formula

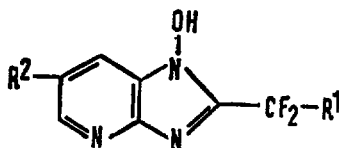


with an isocyanate of the formula



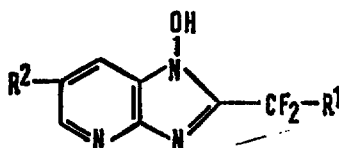
15 R^1 and R^2 being as defined in claim 1. 15

25. A method of preparing carboxylic esters as claimed in claim 1 wherein R^3 is a group defined under (10), (11) or (12) of claim 1 which comprises reacting the anhydride of a suitable carboxylic acid with a compound of the formula



20 R^1 and R^2 being as defined in claim 1. 20

26. A method of preparing compounds as claimed in claim 1 wherein $\text{O}-R^3$ is an ether linkage which comprises reacting a compound of the formula

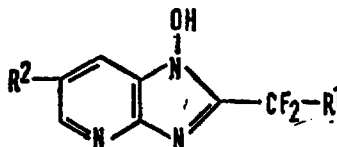


25 with a suitable olefinic compound. 25

27. A method as claimed in claim 26 wherein the olefinic compound is dehydropyran and R^3 is tetrahydro-2-pyranyl.



28. A method of preparing compounds as claimed in claim 1 wherein O—R³ is an alkenyl ether linkage which comprises reacting a compound of the formula



with a suitable alkyne.

- 5 29. A method of preparing a compound according to claim 1 substantially as described in any one of the Examples. 5
30. A compound according to claim 1 whenever prepared by a method as claimed in any one of claims 13 to 29.
- 10 31. A herbicidal composition which comprises a compound as claimed in any one of claims 11, 12 and 30 and one or more inert carriers. 10
32. A herbicidal composition as claimed in claim 31 additionally comprising a surface active agent.
- 15 33. A herbicidal composition as claimed in any one of claims 10, 31 and 32 which, either additionally or instead of the inert carrier, comprises an agricultural material which is a fertiliser, fungicide, nematocide, insecticide, further herbicide or soil conditioning agent. 15
- 20 34. A herbicidal composition as claimed in claim 33 wherein the agricultural material is a further herbicide which is present in a ratio of further herbicide: 1-substituted-2-(1,1-difluoroalkyl)-1H-imidazo(4,5-b)pyridine compound of from 1:5 to 5:1. 20
35. A herbicide as claimed in claim 6 substantially as described specifically herein.
36. A method of inhibiting the growth of a plant which comprises administering to the plant an effective amount of a compound as claimed in any one of claims 1 to 5, 11, 12 and 30 or a composition as claimed in any one of claims 6 to 10 and 31 to 35.

BOULT, WADE & TENNANT,
Chartered Patent Agents,
34 Cursitor Street, London EC4A 1PQ.

Printed for Her Majesty's Stationery Office by the Courier Press, Leamington Spa, 1973.
Published by the Patent Office, 25 Southampton Buildings, London, WC2A 1AY, from which copies may be obtained.

