

PATENT SPECIFICATION

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(54) A METHOD OF ENHANCING THE GROWTH REGULATING EFFECT IN A PLANT OF AN ETHYLENE-PROVIDING COMPOUND

(71) We, AMCHEM PRODUCTS, INC., a Corporation organized under the Laws of the Commonwealth of Pennsylvania, United States of America, of Brookside Avenue, Ambler, Pennsylvania, 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:—

This invention relates to a method of enhancing the growth regulating effect in a plant of an ethylene-providing compound. It concerns an improved method of regulating the growth of a plant in which the plant growth regulating activity of a compound capable of providing ethylene in the plant is enhanced by means of a chelating agent. The plant growth regulating effects with which this invention is concerned include, but are not necessarily limited to, ethylene responses and ethylene-type responses.

The induction of an ethylene response in plant growth has been known for some time in the art — for example, the method described in "Plant Biochemistry" by James Bonner and J. E. Varner (1965), pages 641 to 664. A fairly well known way of inducing ethylene response is the use of gaseous ethylene which has been utilized on a commercial scale in the ripening of bananas for many years. It is also known to employ ethylene in essentially gaseous form to stimulate flower initiation in pineapples, as is described in "Hormonal Control of Plant Growth" by N. S. Parihar (1964), pages 69 to 79. In the method described therein ethylene is applied on a commercial scale using cumbersome equipment to drench the pineapple plants with an ethylene-saturated liquid. Similar, but less powerful, effects on plant tissues have been brought about by unsaturated hydrocarbon gases other than ethylene using similar methods.

More recently, various other compounds

capable of providing ethylene in plants have been used as plant growth regulators, and foremost amongst these compounds are certain phosphonic acid derivatives and analogues thereof. These other compounds and their use as plant growth regulators are described in the literature. In particular, attention is directed to our own Patent Specifications Nos. 1,194,433 and 1,320,870.

Patent No. 1,194,433 concerns processes for producing a wide variety of growth regulator responses in a large number of plants employing phosphonic acid derivatives, and especially 2-chloroethyl phosphonic acid.

Specification Patent No. 1,320,870 describes the stimulation of latex from rubber trees using 2-chloroethyl phosphonic acid.

Furthermore, our U.S. Patent No. 3,928,406 describes growth regulating compositions comprising certain silane derivatives and the use of these compositions in regulating plant growth.

In addition, U.S. Patent No. 3,711,272 describes substituted diamides of 2-chloroethyl phosphonic acid and their use as plant growth regulators. U.S. Patent No. 3,713,805 describes the diamide of 2-chloroethyl phosphonic acid and its use as a plant growth regulator. U.S. Patent No. 3,837,834, describes certain alkyl phosphonic acid derivatives and their use as plant growth regulators. British Patent No. 1,371,804 describes certain β -haloethyl silanes and their use as plant growth regulators.

In one aspect this invention provides a method of regulating the growth of a plant by applying to the plant an ethylene-providing compound, which method incorporates the step of enhancing the growth regulating effect on the plant by also applying thereto an effective amount of a chelating agent.

The method of the invention may be used to treat entire plants so as to produce the desired growth regulating effect, but it is also applicable to the treatment of parts of the

17

plant, whether or not those parts have been detached from the plant provided that the plant tissue is still sufficiently fresh to be susceptible to treatment. In particular, the method of the invention may be applicable to the treatment of picked and unpicked fruits and leaves of plants.

By the terms "a compound capable of providing ethylene in a plant" and "ethylene-providing compound" as used herein there is meant any compound which when applied to a plant gives rise to ethylene in the plant tissue. The terms include ethylene itself, whether in gaseous form or in the form of an ethylene-saturated liquid or solid, and compounds which break down or are broken down in the plant ultimately to provide ethylene. Thus, amongst the ethylene-providing compounds are compounds which contain the basic ethylene skeleton a two carbon atom chain — although it must be understood that this 2 carbon moiety may bear an enormous variety of substituents and may be a small part of a very much more complicated molecule. Examples of ethylene-providing compounds which may be used in the method of this invention include:—

- a) phosphonic acid derivatives as defined hereinafter
- b) silanes and other silicon analogues of phosphonic acid;
- c) sulphonic acid derivatives;
- d) fatty acids and fatty alcohols;
- e) B-hydroxy-ethyl hydrazine;
- f) ethylhydrazine;
- g) sym-diethylhydrazine;
- h) unsym-bis(2-hydroxyethyl) hydrazine;
- i) aminomorpholine;
- j) 2 - hydroxyl - N - (2 - hydroxyethyl) carbazinate;
- k) 2 - (2 - hydroxyethyl) semicarbazone;
- l) monoethyl sulphate;
- m) methionine; and
- n) methional.

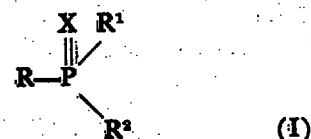
It should be emphasized that this list is by no means exhaustive, and other suitable compounds would be readily apparent to one skilled in the art.

The behaviour of these, and other, compounds in providing ethylene in plants is well known, and is described, for example, in "Ethylene in Plant Biology", Frederick B. Abeles, Academic Press, particularly in pages 73 to 83 thereof.

At the present time most interest is directed to derivatives of phosphonic acid, and particularly 2-chloroethyl phosphonic acid and its derivatives and analogues. Although the scope of the invention is in no way limited to these compounds, in a preferred aspect this invention provides a method of regulating the growth of a plant which comprises applying to the plant, a phosphonic acid derivative

and a chelating agent, in amounts which give the desired plant growth regulant effect. Included amongst the phosphonic acid derivatives which may be used in the process of the invention are haloalkyl and phosphonoalkyl phosphonic acids, and their esters, halides, amides, salts and anhydrides, as well as the corresponding sulphur analogues.

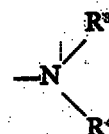
The preferred phosphonic acid derivatives are the compounds of the general formula:



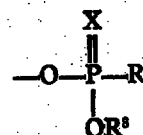
wherein X represents an oxygen or a sulphur atom;

R represents a haloethyl, halopropyl or phosphono-ethyl radical; and

R¹ and R², which may be the same or different, each represent a chlorine atom, a bromine atom, the group



(wherein R³ and R⁴, which may be the same or different, each represent a hydrogen atom, a substituted or unsubstituted alkyl radical, a substituted or unsubstituted aryl radical, a substituted or unsubstituted heterocyclyl radical, an alkenyl radical containing from 2 to 8 carbon atoms or an alkynyl radical containing from 2 to 8 carbon atoms), the group —XR³ (wherein R³ and X are as defined hereinbefore with the proviso that when R¹ and R² both represent OR³, R³ is not a substituted or unsubstituted alkyl radical) or the group:



(wherein X, R and R³ are as defined hereinbefore);

or a salt thereof formed with an agriculturally-acceptable cation.

The term "alkyl" as used herein is intended to include straight or branched chain alkyl radicals, preferably containing from 1 to 18 carbon atoms, and also includes cycloalkyl and cycloalkylalkyl groups, preferably containing from 3 to 18 carbon atoms.

When the phosphonic acid derivative contains an aryl substituent, the aryl group is preferably monocyclic, although bi- and polycyclic aryl substituents will be satisfactory.

The phosphonic acid derivative may also contain heterocyclyl substituents, and by the term "heterocyclyl" is meant a mono- or polycyclic group containing one or more atoms of oxygen, nitrogen or sulphur within the ring system. The heterocyclic substituent is also preferably monocyclic.

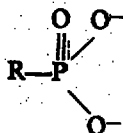
When a substituent group is itself stated to be substituted, this means that one or more hydrogen atoms on the group is replaced by a radical such as alkyl, aryl, hydroxy, alkoxy, amino (substituted or unsubstituted), halo, cyano, carboxy, nitro or sulphonamido.

The term "halo" is intended to include all the usual halogen groups, namely, the fluoro, chloro, bromo and iodo groups.

Salts of the compounds of general formula I may be employed, and these salts may be formed with a wide range of inorganic and organic salt-forming cations provided that they are agriculturally-acceptable.

The term "agriculturally-acceptable" is intended to exclude any possibility that the cation, considered of course in relation to a particular treatment, could be harmful to the plant under treatment, or have some deleterious or undesirable effect on the regulant effect of the phosphonic acid derivative. The cation may be a metal, and preferred metal cations include the ions of metals such as sodium, potassium, lithium, calcium, aluminium, zinc, copper, molybdenum, manganese, magnesium, cobalt, selenium and iron. The cation may also be an ammonium ion or a substituted ammonium ion, such as ammonium ions substituted by alkyl and aryl groups, and cyclic groups such as the morpholinium and piperidinium ions.

It is believed that the plant growth regulating activity of the phosphonic acid derivatives which may be used in the method of this invention, may result from the action of the



anion in the plant (assuming that the various acid derivatives readily hydrolyze to form such an anion). It is believed that any phosphonic acid derivative capable of releasing this anion in, on or around the plant under treatment will display plant growth regulating activities.

It should be noted that the phosphonic acid derivatives used in the method of this invention may include not only compounds which hydrolyze very readily but also compounds which hydrolyze only with difficulty, perhaps owing to steric hindrance. Moreover, there are compounds which in the laboratory can be hydrolyzed only with difficulty, yet which apparently can be metabolized by the plant

and hydrolyzed by its enzymatic systems quite readily.

The phosphonic acid derivatives which may be employed in the practice of the present invention are normally compounds known to be readily converted to the above anion, either in the laboratory or in the plant under treatment. The determination as to whether any phosphonic acid derivative may be used in the method of the present invention is believed to be within the competence of a person skilled in the art.

It has also been found that, in general, the phosphonic acid derivatives which display the most satisfactory results in the method of this invention are those in which R is either a phosphono-ethyl group, or more preferably, a halo-ethyl group.

Thus, the particularly preferred phosphonic acid derivatives for use in the method of the present invention are haloethyl- and phosphonoethyl-phosphonic acids and their functional derivatives: such as the mono- and di- (acid chlorides), mono- and diesters, mono- and diamides (substituted or unsubstituted), anhydrides and salts.

Of the esters of the phosphonic acid compound which may be used in the method of this invention, preferred mono- or half-esters include the 2-chloroethyl mono-ester and the 2-hydroxyphenyl mono-ester. Preferred diesters are the diphenyl and bis(2-oxo-1-pyrrolidinyl-methyl) esters, while preferred mixed diesters are the 2-hydroxyphenyl ester with an alkyl, alkenyl, alkynyl or aryl radical — for example, ethyl, isopropyl, propynyl, butyl, octyl, hexadecyl or phenyl — as the second ester group.

The phosphonic acid derivatives used in the method of this invention may also be cyclic esters, but these compounds are extremely readily converted to mono-ester in the conditions employed in the method of this invention and consequently the use of a cyclic ester amounts in practice to the use of the corresponding mono-ester. Cyclic esters which may be used include those formed with pyrocatechol or mono- or polyhalopyrocatechol derivatives — for example, 4-chloropyrocatechol or tetrachlorocatechol — and these compounds readily form the corresponding 2-hydroxyphenyl monoesters in the presence of water.

The particularly preferred phosphonic acid derivative for use with chelating agents in the method of this invention is 2-chloroethyl phosphonic acid.

Amongst the derivatives of 2-chloroethyl-phosphonic acid that may be used, the following compounds are at present preferred:

1. the bis (acid chloride) of 2-chloroethyl phosphonic acid;
2. the mixed ethyl and 2-hydroxyphenyl diester of 2-chloro-ethyl phosphonic acid;

3. the mixed butyl and 2-hydroxyphenyl diester of 2-chloroethyl phosphonic acid;
4. the mixed propynyl and 2-hydroxyphenyl diester of 2-chloroethyl phosphonic acid;
5. the 2-chloroethyl monoester of 2-chloroethyl phosphonic acid;
6. the bis(phenyl)-ester of 2-chloroethyl phosphonic acid;
7. the 3-hydroxyphenyl monoester of 2-chloroethyl phosphonic acid (which exists in polymeric form);
8. the bis(2-oxo-pyrrolidinylmethyl) ester of 2-chloroethyl phosphonic acid;
9. the o-hydroxyphenyl monoester of 2-chloroethyl phosphonic acid;
10. the mixed isopropyl and 2-hydroxyphenyl diester of 2-chloroethyl phosphonic acid;
11. the mixed octyl and 2-hydroxyphenyl diester of 2-chloroethyl phosphonic acid;
12. the mixed hexadecyl and 2-hydroxyphenyl diester of 2-chloroethyl phosphonic acid;
13. the mixed tridecyl and 2-hydroxyphenyl diester of 2-chloroethyl phosphonic acid;
14. the anhydride of 2-chloroethyl phosphonic acid;
15. the bis(2-chloroethyl) ester of 2-chloroethyl phosphonic acid;
16. the mixed phenyl and 2-hydroxyphenyl diester of 2-chloroethyl phosphonic acid;
17. 2-chloroethyl - dichloro - phosphine;
18. the bis(pentachlorophenyl) ester of 2-chloroethyl phosphonic acid;
19. 2-chloropropyl phosphonic acid; and
20. 2-chloroethyl phosphonic diamide.
- In addition, the method of this invention may advantageously employ a 2-chloroethyl phosphonic acid derivative selected from the following groups of derivatives:—
- a) the substituted diamides of 2-chloroethyl phosphonic acid, and in particular the N,N'-dimethyl, the N,N'-dicyclopropyl and the N,N'-dicyclohexyl diamides;
- b) the amide esters and amide thioesters of 2-chloroethyl compounds — for example, the 2-chloroethyl ester and the ethyl ester of N - (3,4 - dichlorophenyl) - 2 - chloroethyl phosphonamidic acid;
- c) 2 - chloroethyl - thionophosphonic acid and derivatives thereof, and in particular the dichloride, diesters (for example, the diphenyl ester), ester chlorides, amides, amide chlorides and amide esters;
- d) 2-chloroethyl dithiophosphonic acid and derivatives thereof, and in particular the diesters — for example, the diphenyl ester and the diethyl ester; and
- e) 2-chloroethyl trithiophosphonic acid and derivatives thereof, and in particular the

diesters — for example, the diphenyl ester.

Other phosphonic acid derivatives that may be employed are 2-fluoroethyl phosphonic acid, 2-bromoethyl phosphonic acid, 2-iodoethyl phosphonic acid, 2-phosphonoethyl phosphonic acid and functional derivatives of these acids. In general, it may be said that the functional derivatives corresponding to those listed above for 2-chloroethyl phosphonic acid will be preferred.

It is known that certain of the above-mentioned phosphonic compounds will polymerize, but such compounds may be used in this invention whether in monomeric or polymeric form so long as effective growth regulation is achieved.

As indicated hereinbefore, certain silane derivatives are known to behave as ethylene-providing compounds, and these compounds may, of course, be used in the method of this invention. The most important ethylene-providing silane derivatives are the 2-haloethyl silanes, and in particular the 2-chloroethyl - trialkoxysilanes and 2-chloroethyldialkoxysilanes. The preferred 2-chloroethyl - silanes for use in the method of this invention are 2-chloroethyl - tris(p-methoxybenzyl-oxy) - silane and 2-chloroethyl - tris(2-methoxy-ethoxy) - silane.

Another important group of ethylene-providing compounds are the 2-haloethyl sulphonic acid derivative, and in particular 2-chloroethyl sulphonic acid and its esters.

The chelating agent for use in the method of this invention may be any compound normally regarded by those skilled in the art as a chelating agent, provided of course that the compound will not have a harmful or undesirable effect upon the plant being treated. A chelating agent is usually defined by those skilled in the art as a bidentate or polydentate ligand capable of forming a coordination compound with a central atom, which central atom is usually a metal atom — the ligand forming with the coordinated central atom one or more heterocyclic rings. That is to say, a chelating agent is a complexing agent characterized in that more than one bond may be formed between the ion to be chelated and a molecule of the complexing agent, so that the resultant complex (the chelated ion) has a ring structure incorporating the ion.

Chelating agents may be classified according to structure type, and whilst the following list is by no means exhaustive, the most commonly employed chelating agents fall within the following structural types:

- 1) amino-carboxylic acids, nitrilo-carboxylic acids and their salts — for example, 1,3-propylenediamine - tetraacetic acid, ethylenediaminetetraacetic acid, ethylenediamine - di(o-hydroxyphenylacetic acid), 1,3-diamino - 2-propanol - tetraacetic acid, and nitriloacetic acid;

2) *hydroxy-carboxylic acids and their salts* — for example, gluconic, citric and tartaric acids;

3) *polycarboxylic acids and their salts* — for example, oxalic, aconitic and malonic acids;

4) *polyphosphates* — for example, pyrophosphates and tripolyphosphates;

5) *diketones* — for example, acetylacetone, furoylacetone and benzoylacetone — and derivative thereof, such as the oximes;

6) *polyamines and their salts* — for example, ethylenediamine, diethylenetriamine, tetraethylenepentamine, orthophenanthroline, α, α -dipyridyl, and the porphyrins;

7) *Schiff's bases* — for example, disalicylaldehyde ethylenediimide and acetylacetone phenylenediimide;

8) *amino alcohols and their salts* — for example, ethanolamines, diethanolamines, triethanolamines and 8-hydroxyquinoline;

9) *hydroxy-aldehydes and their salts* — for example, salicylaldehyde and analogues thereof, such as β - hydroxy - α - naphthyl aldehyde; and

10) *polyhydric alcohols and sugars* — for example, dextrose, glycerol and manitol.

It must be understood that not all members of the above groups of compounds are necessarily chelating agents, but it would be readily apparent to one skilled in the art which compounds falling within these structural types are likely to behave as chelating agents. It will also be appreciated that there is some overlap between these groups, and some compounds which fall in more than one group.

Although there are a very large number of chelating agents that could be used in the method of this invention, the following compounds are examples of the preferred chelating agents:—

1. citric acid;
2. tartaric acid;
3. gluconic acid;
4. aconitic acid;
5. L-sorbose;
6. glycine;
7. malic acid;
8. maleic acid;
9. malonic acid;
10. citraconic acid;
11. glutaric acid;
12. crotonic acid;
13. sorbitol;
14. glycerol;
15. diglycerol;
16. dextrose;
17. mannitol;
18. tannic acid;
19. kojic acid;
20. glutamic acid;
21. adipic acid;
22. maleuric acid;
23. mandelic acid;
24. succinic acid;

25. nitriloacetic acid;
 26. diethylenetriaminepentacetic acid;
 27. hydroxyethylethylenediamine triacetic acid;
 28. ethanol diglycine;
 29. diethanol glycine;
 30. ethylenediaminetetraacetic acid;
 31. itaconic acid;
 32. fumaric acid;
 33. ascorbic acid;
 34. chlorokojic acid;
 35. α, α -dipyridyl;
 36. 2-mercaptopyridine - N - oxide;
 37. sorbic acid; and
 38. saponin,
- and salts of these compounds, where appropriate.

By the term "salt", as used in connection with the chelating agents, is meant any salt-like derivative of a chelating agent with an appropriate, agriculturally acceptable ion. As indicated hereinbefore, the term "agriculturally acceptable" is used to exclude any possibility that the ion has harmful effect on the plant under treatment, or a deleterious or undesirable effect on the regulant effect achieved by the method of the invention. There are a wide variety of ions that are agriculturally acceptable and which may be used to form salts with chelating agents for use in this invention; the choice of a suitable salt and salt-forming ion is believed to be within the competence of one skilled in the art. However, by way of illustration, it may be said that the most frequently employed salts of chelating agents are ammonium salts, amine salts, alkanolamine salts and alkali, alkaline earth and heavy metal salts. That is to say, commonly used salt-forming ions are the ammonium ion, substituted ammonium ions, and metal ions. The metal ions most frequently employed are lithium, sodium, potassium, calcium, magnesium, aluminum, molybdenum, manganese, cobalt, iron, copper, zinc and selenium ions.

Amongst the numerous chelating agents falling within the above structural types, a large number of compounds with a wide variety of structures have been found to give excellent results when used in the process of this invention. Amongst the preferred chelating agents for use in the method of this invention are those complexing agents capable of forming four or more bonds between the coordinated central atom and a molecule of the complexing agent.

It is also preferred that the chelating agent is an acid, or a salt thereof, and the particularly preferred acidic chelating agents are those of structural types 2) and 3) given above — namely, the hydroxy-carboxylic acids and the polycarboxylic acids.

The most preferred chelating agent for use in the method of this invention is a hydroxy-polycarboxylic acid — citric acid.

(21)

However, naturally the chelating agent is chosen having regard to the ethylene-providing compound with which it will be used in the method of this invention, as well as the plant being treated, the method of application and so on. The chelating agent and the ethylene-providing compound preferably do not react together in a manner which would detract from their combined effectiveness in the method of this invention, and the chelating agent may be chosen accordingly.

The addition of a chelating agent to an ethylene-providing compound greatly enhances the plant growth regulating activity of that ethylene-providing compound.

The terms "plant growth regulating activity", "growth regulation" and the like are used herein to mean a variety of plant responses which achieve promotion, inhibition or modification of any physiological process. Such plant responses include a direct herbicidal activity, and also use in a herbicidal context even though the growth response is not in itself herbicidal. For example, the compounds may be used to stimulate the growth of dormant rhizomes to make them more susceptible to the action of a separate herbicide.

By way of illustration, the following list is given to show some of the wide variety of plant responses which may be induced in a plant by the use of a compound capable of providing ethylene within the plant.

1. Apical dominance control.
2. Lateral or basal bud growth stimulation.
3. Vegetative growth inhibition or stimulation.
4. Leaf, flower, and fruit abscission.
5. Flowering inhibition, retardation, or abortion.
6. Fruiting inhibition or retardation.
7. Fruit ripening acceleration.
8. Leaf epinasty.
9. Cambium tissue proliferation.
10. Root formation induction.
11. Stiffness induction.
12. Geotropic response modification.
13. Chlorophyll decomposition induction.
14. Enzyme systems acceleration or inhibition.
15. Metabolism and respiration change.
16. Seed germination acceleration or inhibition.
17. Auxin transport influenced.
18. Cell shape, size, and permeability modification.
19. Dormant plant tissues stimulation.
20. Flower sex modification.
21. Leaf senescence acceleration.

By way of further illustration, the following list includes some of the principal responses that have been observed from plants treated with 2-chloroethylphosphonic acid alone. This list also gives examples of specific plants

in which the various responses have been observed.

1. Prevention of lodging — cereal crops, corn, soybeans.
2. Increased tillering — cereal crops, turf grasses. 70
3. Abscission of late immature cotton bolls.
4. Increased fiber yield — flax.
5. Termination of dormancy in seeds — peanuts, sunflower. 75
6. Gametocidal effects — cereals.
7. Vine dessicant — potatoes.
8. Hastening maturity — fruits, vegetables, including potatoes, coffeeberries, peppers, hot peppers, and tomatoes. 80
9. Defoliation — dry beans, ornamentals, cotton, mulberry bush leaves i.e. *Morus Spp.*, *Morus indicus*, *Morus alba*.
10. Concentration of maturity — fruits, vegetables including coffeeberries and tomatoes. 85
11. Promotion of daughter plants — strawberries.
12. Reduction of acid — grapes. 90
13. Delayed flowering.
14. Protection from frost and cold — cherries.
15. Turf inhibition.
16. Improved seedling vigor — turf. 95
17. Increased flow — sugar maples.
18. Abscission of coconuts.
19. Flower initiation — vegetables, tree crops, pineapples.
20. Yield increases — carrots. 100
21. Increased color — carrots, apples, peppers, cranberries and tomatoes.
22. Increased latex flow — rubber, papaya.
23. Improved tea quality.
24. Increased number of draws (plants) from sweet potatoes. 105
26. Earlier, concentrated maturity of fresh peas.
26. Vine inhibition — peas.
27. Increased tree stem diameter. 110
28. Termination of spore dormancy.
29. Increased activity of single cell and tissue cultures.
30. Increased sucrose content in sugar cane. 115
31. Increased leaf senescence — tobacco.
32. Abscission of fruits — olives, cherries, apples.

These lists are presented merely to exemplify the diversity of plant responses which may be obtained, and are in no way limiting on the plants which may be treated or the plant responses which may be obtained according to this invention. 120

By the use of terms such as "enhancement of plant growth regulating activity" is meant that the plant growth activity is in some way improved or accentuated having regard to the activity obtained from methods using the ethylene-providing compound alone, so that 125 130

a greater plant growth response may be obtained or the amount of the ethylene-providing compound necessary to produce a desired plant growth response is considerably reduced.

Since the cost of chelating agents used will normally be much lower than that of the ethylene-providing compound, the method of the invention has significant economic advantages over the prior art methods. In addition, some fields of treatment which hitherto have not been economically viable, because large amounts of ethylene-providing compounds were needed, may be practicable using the method of this invention.

The reduction in the amount of ethylene-providing compound made possible by the method of the invention may also, in some instances, lead to a decrease in, or even elimination of, undesirable side effects that the prior art methods have occasionally produced. A further advantage of being able to reduce the amount of ethylene-providing compound applied to a plant is that the residue remaining in the treated crop when it is harvested will be reduced. This could be of particular importance in the treatment of tobacco and food crops where the application of the active material is made shortly before harvesting.

Yet another benefit of the method of this invention is that it gives a more persistent (longer lasting) growth response. This may be of considerable use in, for example, the treatment of rubber trees, since promotion of the latex yield over a longer period of time will allow a lower intensity tapping system, with consequent economic advantages.

The enhancement of growth regulating activity obtained by the method of the invention would appear to result from some synergistic action between the chosen ethylene-providing compound and the chosen chelating agent. The exact mechanism of this synergy is not completely understood but it is thought that the chelating agent in some way potentiates the action of the ethylene-providing compounds. It should be pointed out that a chelating agent alone has not been found to have any significant growth regulating activity when applied to a plant.

Although it is not meant to be in any way limiting upon the invention, the following hypothesis is now given to seek to explain the mechanism by which the chelating agent operates to enhance the growth regulant activity of the ethylene-providing compound. It is believed that metal atoms may be important in determining the binding site of ethylene or an ethylene-type molecule in the plant. It is further believed that the addition of a chelating agent to the plant will lead to the formation of co-ordination compounds between the chelating agent and the metal atoms in the plant, and that the metal atoms in

complexed form (rather than as free atoms) will be more available to assist the action of ethylene or an ethylene-type molecule in the plant.

By the term "active materials" as used hereinafter is meant the ethylene-providing compound and chelating agents used in the method of this invention.

This invention extends, of course, to methods in which more than one ethylene-providing compound is applied to the plant, and also to methods in which more than one chelating agent is applied to the plant, always provided that at least one ethylene-providing compound and at least one chelating agent are applied to the plant.

The active materials used in the method of this invention may be applied to the plant to be treated either separately or in combination. There may be cases when it will be advantageous to apply the ethylene-providing compound and the chelating agent separately — for example, when the times taken for the two compounds to be assimilated by the plant tissue differ significantly.

Whether applied separately or in combination, the active materials used in the method of this invention may conveniently be applied to the plant to be treated in admixture with a suitable vehicle.

By the term "suitable vehicle" is meant any carrier or medium for containing the active materials in dissolved, dispersed, emulsified or suspended form, appropriate for transporting the active materials to the plant site being treated. The term "suitable" is intended to exclude any possibility that the vehicle, considered of course in relation to the means by which the compound in question is to be applied to the plant site, could be toxic to the plant being treated or have a deleterious effect on the method of this invention.

It is preferred that the ethylene-providing compound and the chelating agent are applied together, and it is thus preferable in these cases for the ethylene-providing compound and the chelating agent to be formed into a single composition. Accordingly, this invention extends to a composition for regulating the growth of plants, comprising an ethylene-providing compound and a chelating agent in a combined amount effective at regulating plant growth, in association with a suitable vehicle.

When such a composition is employed in the method of the invention it is preferred that the composition comprises one or more phosphonic acid derivatives, and most preferably these are selected from 2-chloroethylphosphonic acid, 2-chloroethylphosphonic diamide, 2-chloroethylphosphonic acid dichloride, 2-chloroethylphosphonic acid anhydride and 2-bromoethylphosphonic acid. One or more chelating agents are employed and these

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are preferably selected from hydroxy-carboxylic acids, polycarboxylic acids and salts thereof.

5 Depending upon how the active materials are to be applied in the method of this invention, the vehicle could be a solid (such as talc) or liquid (such as water or a common organic solvent), and it is believed to be within the competence of those skilled in the art to choose the appropriate vehicle for particular active materials and a particular application. It is often most advantageous if the carrier is water, and the active materials used in the method of this invention are most preferably applied in the form of an aqueous solution.

10 The active materials are, however, soluble in water to varying degrees, and, depending on their solubility, they can be applied to plants in aqueous solutions composed wholly or partially of water, or even as aqueous emulsions. Partial solutions which may be used include those formed of water and, for instance, an organic solvent such as acetone or methyl ethyl ketone. Where any particular material is of low solubility in water, it may be solubilized by the use of co-solvents.

15 The amounts of chelating agent employed and the ratio between the amounts of ethylene-providing compound and chelating agent applied to the plant will be chosen having regard to the compounds employed, the particular response required, the particular plant being treated and the method of application used, but by way of indication it may be said that the ratio of ethylene-providing compound to chelating agent would typically be in the range of from about 1:10 to about 10:1. The ratio will usually lie within the narrower range of about 1:5 to about 5:1, and it has been found particularly advantageous for certain applications if the ratio is in the range of from about 1:2 to about 2:1.

20 When the preferred group of ethylene-providing compounds — the phosphonic acid derivatives — is employed, the preferred ratio of phosphonic acid derivative to chelating agent is from about 1:2 to about 2:1.

25 It will be well understood by any plant biologist that, as with any plant-growth regulator, the ethylene-providing compound and the chelating agent should be applied to any particular plant at certain optimum application rates (either of concentration in solution, or of weight per unit of ground area) and at certain stages in the growth cycle of the plant, if they are to achieve the desired growth regulating effect. While investigations have been made into the growth regulating properties both of ethylene-providing compounds alone and combinations of them with chelating agents, the almost limitless variety of plant species and the great diversity of desirable plant responses, coupled also with

the fairly wide range of climatic conditions which may be encountered, make it altogether impossible here to specify exact application rates of ethylene-providing compounds and appropriate amounts of chelating agents for all purposes. Such application rates and effective amounts of chelating agent for enhancing the growth regulating effect may be determined fairly readily for any particular case by standard procedures well known in themselves. For general guidance, experience indicates that the application rate will normally be chosen so as to apply from 0.1 to 30 pounds of the ethylene-providing compound per acre, or the equivalent thereof, and the amount of chelating agent that is employed will normally be chosen so that the ratio of ethylene-providing compound to chelating agent falls within the range of 1:10 to 10:1.

When the ethylene-providing compound is a phosphonic acid derivative, the application rate is usually in fact within the narrower range from 0.25 to 16 pounds per acre of phosphonic acid derivative, and most frequently within the still narrower range of from 0.5 to 4 pounds per acre. Obviously the amount of chelating agent applied at such rates will depend on the ratio of ethylene-providing compound to chelating agent in the composition being employed.

In some instances it may be desirable to apply the combination of active materials individually to each plant being treated for example, by painting the active materials onto each plant. A particular example of this is in the treatment of rubber trees to stimulate latex flow. When applied in this manner the active materials will normally be applied at a rate of from about 10 mg. to about 5 g. per plant.

By way of further example, when applied by drenching trees, by soaking seeds or tubers, or by immersing picked fruit therein, the combination of active materials will normally be applied in the form of a solution containing from 1 to 200,000 parts per million of the ethylene-providing compound (thus from 0.0001% to 20% by weight), and most often within the range of 10 to 10,000 parts per million, (thus from 0.0001% to 1% by weight).

When compositions are based on liquid media they will normally have a water-thin consistency, and can then be applied with any form of conventional agricultural spraying or like equipment. Compositions based on solid carriers may be applied in the form of powder or granules by the appropriate conventional distribution equipment. Although the preferred method of application is directly to the foliage and stems of the plants, the plant-growth regulating compositions used in this invention are efficacious when applied to the soil in which the plants are growing, since apparently they can be root-absorbed

to a sufficient extent to yield the desired effect.

While it is clear that, in applying the compositions to standing crops and other vegetation, the significant factor is the quantity of the ethylene-providing compound and chelating agent assimilated by the plants, it may be added that the indicated amounts of the active materials may in general be applied in liquid formulations with a carrier comprising sufficient aqueous or other liquid diluent so that the total volume sprayed is from about 1 to 100 gallons per acre.

The active materials are most conveniently handled and stored in the form of a liquid concentrate, which may be diluted with the chosen carrier to form the composition for use in the method of this invention. Again, the ethylene-providing compound and the chelating agent may be stored separately, but it is preferred for the concentrate to contain both active materials. Such concentrates may comprise solely the ethylene-providing compound and the chelating agent (that is, 100% active materials) or may additionally comprise a suitable liquid vehicle in an amount such that the concentrate contains between 10 and 100% (by weight) active materials.

Preferably the active materials will be handled in the form of aqueous liquid concentrates (for dilution before use) in which the concentrations of the active materials are each in the range of from 10% to 30% (by weight).

The compositions may sometimes with advantage incorporate surfactants and/or dispersing agents and/or emulsifiers and/or penetrants and/or stabilizers; they may also sometimes — for specific purposes — incor-

porate other plant growth regulators and/or herbicides.

The following Examples and Formulations are now given, though only by way of illustration, to show preferred materials, conditions and techniques which may be employed in relation to the method of this invention. The ethylene-providing compound used in the following is 2-chloroethylphosphonic acid which is the particularly preferred compound for use in the method of this invention. However, the formulations and treatment conditions given for compositions containing this one compound are believed to provide sufficient illustration to enable a person skilled in the art to perform similar treatments using any of the compositions which may be employed in this invention. Furthermore, it is acknowledged that the plants treated in the following Examples represent a small number of the virtually limitless range of plants which may be treated by the method of this invention, but regulation of plant growth by the promotion of an ethylene-type response is well known, and the techniques employed in the present invention will be similar (as would be appreciated by a person skilled in the art), although the results obtained thereby are much improved.

As described hereinbefore there appears to be a common mechanism to the plant growth regulation of ethylene-providing compounds, and thus the following illustrations of the improved response obtained by using a composition containing 2-chloroethylphosphonic acid and a chelating agent in accordance with this invention is clearly indicative of the improved response that may be obtained using other ethylene-providing compounds.

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EXAMPLES OF CONCENTRATE COMPOSITIONS FOR DILUTION
BEFORE USE IN THE METHOD OF THIS INVENTION

Formulation 1	% by weight
2-chloroethylphosphonic acid	20.06
Tartaric acid	19.90
Water q.s. for 100%	
Formulation 2	
2-chloroethylphosphonic acid	20.48
Maleic acid	20.30
Water q.s. for 100%	
Formulation 3	
2-chloroethylphosphonic acid	20.39
Malonic acid	20.23
Water q.s. for 100%	
Formulation 4	
2-chloroethylphosphonic acid	20.81
Diglycerol	20.64
Water q.s. for 100%	
Formulation 5	
2-chloroethylphosphonic acid	20.29
Tannic acid	20.12
Water q.s. for 100%	
Formulation 6	
2-chloroethylphosphonic acid	20.21
Citraconic acid	20.04
Water q.s. for 100%	
Formulation 7	
2-chloroethylphosphonic acid	20.39
Sorbitol	20.23
Water q.s. for 100%	



Formulation 8		% by weight
2-chloroethylphosphonic acid		20.90
Glycerol		20.72
Water	q.s. for 100%	
Formulation 9		
2-chloroethylphosphonic acid		20.19
Glycine		20.02
Water	q.s. for 100%	
Formulation 10		
2-chloroethylphosphonic acid		20.21
L-sorbose		20.04
Water	q.s. for 100%	
Formulation 11		
2-chloroethylphosphonic acid		5.79
Succinic acid		5.74
Water	q.s. for 100%	
Formulation 12		
2-chloroethylphosphonic acid		5.85
Crotonic acid		5.80
Water	q.s. for 100%	
Formulation 13		
2-chloroethylphosphonic acid		5.80
Itaconic acid		5.75
Water	q.s. for 100%	
Formulation 14		
2-chloroethylphosphonic acid		20.27
Saponin (refined)		20.11
Water	q.s. for 100%	
Formulation 15		
2-chloroethylphosphonic acid		20.78
Glutaric acid		20.61
Water	q.s. for 100%	

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		% by weight
Formulation 16		
2-chloroethylphosphonic acid		20.17
gluconic acid (50%)		39.97
Water	q.s. for 100%	
Formulation 17		
2-chloroethylphosphonic acid		20.80
Citric acid, anhydrous		10.40
Water	q.s. for 100%	
Formulation 18		
2-chloroethylphosphonic acid		20.02
Citric acid, anhydrous		20.02
Water	q.s. for 100%	
Formulation 19		
2-chloroethylphosphonic acid		18.60
Citric acid, anhydrous		37.21
Water	q.s. for 100%	

EXAMPLES OF THE TREATMENT OF PLANTS BY THE METHOD OF THIS INVENTION

Example 1.

Stimulation of Latex in Ficus Elastica

This example shows the improved stimulation of latex obtained by treating rubber plants (*Ficus elastica*) in accordance with this invention.

For the test, single-stemmed rubber plants were used approximately four feet tall. The effects of four different treatments were investigated, each treatment being carried out on four rubber plants. The treatments comprised painting a formulation onto the petioles of 10 leaves on each plant, at a rate of about 0.5 ml formulation per petiole. After three days this treatment was repeated.

The formulations used in the different treatments were:

1. a commercial paintable vehicle, containing 10% 2-chloroethylphosphonic acid;
2. the commercial paintable vehicle of 1, containing 10% 2-chloroethylphosphonic acid and 10% disodium salt of ethylenediaminetetraacetic acid (EDTA);
3. the commercial paintable vehicle of 1, containing only 10% disodium salt of EDTA; and
4. the commercial paintable vehicle of 1, containing no active material.

After treatment the rubber plants were tested by tapping at intervals over a period of time. Each tapping consisted of cutting the blade from the petiole of one leaf on each plant, and collecting the latex that issued over a period of 30 minutes.

The results, expressed in terms of ml. of latex, are given in the following table. The tapping time is the time elapsed from the initial treatment.

Formulation	Tapping time (days)						Total latex collected from 6 tappings (ml)
	1	3	6	8	10	15	
1	0.8	0.7	0.9	0.8	0.8	0.8	4.8
2	1.1	0.8	1.2	1.1	0.9	1.0	6.1
3	0.8	0.7	0.9	0.8	0.8	0.7	4.7
4	0.9	0.8	1.0	0.9	0.8	0.8	5.2

These results clearly show that formulation 2 gave a significantly greater yield of latex than any of the other formulations. In particular it should be noted that treatment with EDTA disodium salt alone gave a small decrease in yield as compared to that obtained using formulation 4, which contained no active material.

Thus, the method of this invention gave a greatly improved plant growth response in *Ficus elastica* as compared to conventional treatments.

Example 2.

Leaf Drop in Valencia oranges

This example demonstrates the activity of compositions containing a phosphonic acid derivative and a chelating agent in causing defoliation of trees and bushes, particularly Valencia orange trees.

Valencia orange trees were treated with four formulations containing:

- 2 - chloroethylphosphonic acid;
- 2 - chloroethylphosphonic acid and citric acid in a ratio of 2:1 (by weight) [Formulation 17];
- 2 - chloroethylphosphonic acid and citric acid in a ratio of 1:1 (by weight) [Formulation 18]; and
- 2 - chloroethylphosphonic acid and citric acid in a ratio of 1:2 (by weight) [Formulation 19].

The formulations were applied in the form of an aqueous foliar spray containing 100, 200, 300 and 400 ppm of 2 - chloroethylphosphonic acid, and the amount of defoliation observed after 7 days. The results obtained are given in the following table, expressed in terms of average % defoliation of the trees.

TABLE 2 — Percent defoliation of Valencia orange trees.

Formulation	Rate of application of 2-chloroethylphosphonic acid (ppm)			
	100	200	300	400
a	3	13	43	83
b	6	39	100	100
c	0	50	86	100
d	7	90	93	100

It can be seen that the formulations containing 2 - chloroethylphosphonic acid and a chelating agent have a much greater activity than the formulation containing 2 - chloroethylphosphonic acid alone. Thus, the addition of the chelating agent, citric acid, to the phosphonic acid derivative greatly improves the activity of the latter.

To provide a comparison, other trees were left untreated. The formulations were applied at a rate corresponding to 10,000 ppm of 2 - chloroethylphosphonic acid.

The average percent defoliation was observed after 20 days and the results are expressed in the table below.

Example 3.

Defoliation of Sycamore

This example demonstrates the activity of the compositions used in the method of this invention in the treatment of trees and bushes, particularly Sycamore, to causing defoliation.

In the test, formulations a, b, c and d — defined in Example 2 — were applied as a foliar spray to Sycamore trees.

Formulation	Percent Defoliation
a	10
b	30
c	40
d	50
Untreated	0

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These results demonstrate that, by employing a chelating agent in combination with a phosphonic acid derivative, a greater defoliation of Sycamore may be obtained than with the phosphonic acid derivative alone.

of formulations a, b, c and d (defined in Example 2) in water. The bean plants were sprayed at 4 lbs. of 2-chloroethylphosphonic acid in 100 gal. per acre (that is, using a concentration in the treatment solution corresponding to 5,000 ppm of 2-chloroethylphosphonic acid). A further set of bean plants were left untreated to provide a comparison.

Example 4.

A series of tests were performed to investigate the defoliation of black Valentine beans tested by the method of this invention.

After three days the defoliation of the plants was noted, and the results are given, in the form of the number of abscissions, in the table below.

i) 22-day old black Valentine bean plants were sprayed with aqueous treatment solution

TABLE 4

Defoliation of black Valentine beans (number of abscissions in five plants)

Formulation	Primary Leaf Abscission	Trifoliolate Leaf Abscission
Untreated	0	0
a	2	9
b	8	10
c	9	10
d	10	10
Max. possible	10	10

ii) Text (i) was repeated using 24-day old black Valentine bean plants.

The results, in the form of the number of abscissions, are given in the table below.

TABLE 5

Defoliation of black Valentine beans (number of abscissions in five plants)

Formulation	Primary Leaf Abscission	1st Trifoliolate Leaf Abscission	2nd Trifoliolate Leaf Abscission
Untreated	0	0	0
a	0	1	1
b	8	2	4
c	5	4	5
d	3	2	4
Max. possible	10	5	5

These tests on black Valentine beans demonstrate that the method of the invention produces greater defoliation than the known method using a phosphonic acid derivative alone. Thus, the method of the invention provides an improved method of plant growth regulation, by promoting the response from the phosphonic acid derivative with a chelating agent.

Examples 5 to 23.

Tobacco Ripening

A series of tests were performed to investigate the effect of a number of compositions of the invention on the ripening of tobacco.

Tobacco of the Penbel variety was treated according to the method of this invention approximately 3 months after having been transplanted into fields, and at a time when

the leaves were mature and green. A number of compositions were used, containing 2 - chloroethylphosphonic acid and a variety of chelating agents, with 5 replications for each treatment.

10 ml. of the composition being investigated were applied to one leaf per plant at rates of 50 mg. and 100 mg. of 2 - chloroethylphosphonic acid per leaf.

5 days after treatment the ripening of the treated leaves was evaluated and rated on the following scale:

- 0 = no effect
- 1 = slight yellow colour
- 2 = less than 50% yellow
- 3 = 50-75% yellow
- 4 = over 75% yellow
- 5 = 100% yellow.

To provide a comparison a set of five plants were left untreated as controls, and a further set of five plants were treated with 2 - chloroethylphosphonic acid alone at the same rates. The results, expressed as averages of the 5 replications, are given in Table 6 below.

TABLE 6 - RIPENING OF TOBACCO

Example No.	Chelating Agent	Ratio of 2-chloroethylphosphonic acid to chelating agent (by weight)	Ripening Rating	
			50 mg/leaf 2-chloroethylphosphonic acid	100 mg/leaf 2-chloroethylphosphonic acid
5	tartaric acid	1:1	1.8	2.0
6	maleic acid	1:1	2.0	2.2
7	citraconic acid	1:1	1.8	2.4
8	sorbitol	1:1	1.4	1.8
9	glycerol	1:1	2.2	2.2
10	glycine	1:1	1.8	3.0
11	L-sorbose	1:1	2.4	3.2
12	saponin	1:1	1.0	2.0
13	glutaric acid	1:1	1.6	2.8
14	gluconic acid	1:1	1.8	2.0
15	dextrose	1:1	1.4	2.4
16	malic acid	1:1	2.2	2.2
17	Mannitol	1:1	1.8	1.8
18	succinic acid	1:1	1.8	2.4
19	crotonic acid	1:1	1.6	2.4
20	itaconic acid	1:1	2.0	1.6
21	citric acid	2:1	1.8	1.8
22	citric acid	1:1	2.0	2.4
23	citric acid	1:2	2.2	1.8
	2-chloroethylphosphonic acid alone		1.0	1.8
	control		0	0

These results clearly show the enhanced ripening effect on tobacco produced by the compositions of this invention in comparison to the 2 - chloroethylphosphonic acid alone.

Examples 24 to 42.

Tomato Ripening

A series of tests were performed to investigate the effect of a number of compositions of the invention on the ripening of tomatoes.

The test was performed on Heinz 1327 [Heinz is a Registered Trade Mark]. Mature green fruit were picked and the following day treated by being placed in a 2 liter volume of the composition being tested for 30 minutes. 10 fruit were treated by each

composition and the results are averages of these ten replications. For each composition of the invention concentrations of 500 ppm. and 1,000 ppm. of 2 - chloroethylphosphonic acid were used.

Five days after treatment the ripeness of the fruit was assessed on the following scale:

- 0 = green
- 1 = breaker
- 2 = breaker-pink
- 3 = pink
- 4 = pink-red.

The results are given in Table 7 below.

To provide a comparison, sets of fruit were left untreated (controls), and treated with 2 - chloroethylenephosphonic acid alone.

TABLE 7 - TOMATO RIPENING

Example No.	Chelating Agent	Ratio 2-chloroethylphosphonic acid to chelating agent (by weight)	Ripening rating	
			500 ppm of 2-chloroethylphosphonic acid	1000 ppm of 2-chloroethylphosphonic acid
24	tartaric acid	1:1	2.8	2.7
25	maleic acid	1:1	2.7	3.1
26	malonic acid	1:1	2.8	3.1
27	diglycerol	1:1	2.7	2.5
28	citraconic acid	1:1	3.3	2.9
29	glycerol	1:1	2.5	2.5
30	glycine	1:1	2.2	2.9
31	L-sorbose	1:1	2.8	3.2
32	glutaric acid	1:1	2.8	2.8
33	gluconic acid	1:1	2.9	2.4
34	malic acid	1:1	2.9	2.6
35	mannitol	1:1	2.5	2.6
36	succinic acid	1:1	2.7	2.9
37	crotonic acid	1:1	2.8	2.7
38	itaconic acid	1:1	2.7	2.9
39	citric acid	2:1	3.0	2.9
40	citric acid	1:1	2.3	2.8
41	citric acid	1:2	2.6	2.4
42	EDTA	1:1	2.6	2.4
	2-chloroethylphosphonic acid control		2.3	2.4
			2.2	1.9

These results illustrate the enhanced ripening effect of the compositions of the invention as compared to 2-chloroethylphosphonic acid alone.

Example 43.

Defoliation of Black Valentine Beans

A similar test to those described in Example 4 was performed to investigate further the defoliation of Black Valentine Beans according to the method of the invention.

23-day old Black Valentine bean plants were treated by spraying with various formula-

tions of 2-chloroethylphosphonic acid, alone and with citric acid, at a rate of 2 lb 2-chloroethylphosphonic acid in 100 gallons per acre. At the time of spraying the 3rd trifoliolate was 1/4 expanded. There were 5 replications for each treatment. A further set of 5 plants was treated with citric acid alone at a rate of 8 lb/A.

After twelve days the defoliation of the plants was noted and the results are given, in the form of the number of abscissions for the five replications, in the table below.

TABLE 8 - DEFOLIATION OF BLACK VALENTINE BEANS
(No. of abscissions in Five Plants)

Rate of Application (lb/acre)		Primary Leaf Abscission	Trifoliolate Leaflet Abscission ¹⁾
2-chloroethylphosphonic acid	citric acid		
0	0	0	0
2	0	0	13
2	1	3	18
2	2	2	19
2	4	4	20
2	6	5	16
2	8	4	14
0	8	0	0
Max. Possible	—	10	30

¹⁾ This is a count of the number of individual leaflets abscised (3 leaflets to each trifoliolate leaf) from the 1st and 2nd trifoliolate leaves.

It may be seen from these results that the compositions of the invention containing 2 - chloroethylphosphonic acid and citric acid produce greater defoliation than either 2 - chloroethylphosphonic acid alone or citric acid alone. In particular, it should be noted that citric acid alone even at the high rate of 8 lb/A gave no defoliation of the beans.

Example 44.

10 Hastened Ripening and Color-Promotion of Coffee Berries

A series of tests were performed to investigate the effect of a number of the compositions of this invention on the hastening and concentration of maturity of coffee berries — a fruit.

The test was performed on coffee arabica, variety Mundo Novo.

Age at time of Application: 2 years after planting.

Height: The trees were about one (1) meter in height.

Date of Application: April 16.

Method of Application: Knapsack sprayer with No. 5 cone nozzle.

Plot Size: Twenty (20) trees per treatment separated by three (3) checks at each side of the plot. One complete row was left as an untreated check. The remainder of the plantation was treated with 2 - chloroethylphosphonic acid (control).

Treatments: In the test, formulations (a), (b), (c) and (d) — defined in Example 2 — were applied to the coffee trees when 5% of the berries were red ripe and the remainder were "green mature". Formulation (a) — the 2 - chloroethylphosphonic acid (control) was applied at 120 mg. active ingredient per tree (mg. a.i./tree) — a commercially preferred rate of application. Formulations (b), (c) and (d) — the formulations of this invention — were applied at two different rates.

The water volume was 5 liters per twenty (20) trees. A wetting agent was added at the rate of 1/2 cc per 5 liters.

An evaluation of the percent coffee berries which were red ripe was made on April 30, 14 days after application. The results of these observations are as follows:

TABLE 9

Hastened Ripening and Color-Promotion of Coffee Berries

Formulation	Actual Rate [mg.a.i./tree]	% Coffee Berries Red Ripe
(a) Control	120	85-90%
(b)	42 30	85-90% 75-80%
(c)	60 28.5	85-90% 70-75%
(d)	42 27	75-80% 45-50%
Untreated	0	7- 9%

These results clearly demonstrate the enhanced hastened ripening and color promotion of coffee berries produced by the compositions of this invention in comparison to the ethylene-providing compound 2 - chloroethylphosphonic acid alone.

Example 45.

Fruit Abscission — Olives

A series of tests were performed to investigate the effect of a number of the com-

positions of this invention on fruit abscission, particularly olives.

A

Tests were performed on olives for oil, variety Tsounati.

Formulations (a), (c) and (d) — defined in Example 2 — were applied when the oil content of the olives were at a maximum level, at a rate of ten (10) liters of solution

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per tree. The solutions were applied with a knapsack blower. Results of pull force measurements four (4) days after treatment were as follows:

TABLE 10
Fruit Abscission - Olives

Formulation	Concentration of Active Ingrid. (ppm)	Pull Force ^(b) (Grams - Avg.)
(a) control	360	212.96
(c)	360	168.30
(d)	360	145.46
Untreated	0	492.66

^(b) Measurement of one hundred (100) olives for each tree.

10 **B**
Tests were performed on olives, varieties Moraiolo and Frantoio.
Formulations (a), (b), (c) and (d) — defined in Example 2 — were applied at a

rate of 6 to 7 liters of solution per tree. Results of pull force measurements, as a percent reduction in pull force (compared to pull force just prior to treatment) seven (7) days after treatment were as follows:

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TABLE 11
Fruit Abscission - Olives

Formulation	% Reduction in Removal Force Avg. ^(b)		Concentration of Active Ingrid. (ppm)
	Moraiolo Var.	Frantoio Var.	
(a) control	23%	34%	960
(b)	25%	28%	960
(c)	32%	37%	960
(d)	49%	41%	960
Untreated	12%	6% GAIN in removal force	0

^(b) Measurement of eighty (80) olives for each tree.

20 The foregoing results demonstrate the enhanced fruit abscission produced by the compositions of this invention in comparison to the ethylene-providing compound 2 - chloroethylphosphonic acid alone.

Example 46.
Flower Initiation — Pineapple forcing

25 A series of tests were performed to investigate the effect of a composition of this

invention for flower initiation in pineapples i.e. pineapple forcing.

Smooth cayenne pineapple plants grown for two years were treated by drenching with solution containing I. 2 - chloroethylphosphonic acid; and II. 2 - chloroethylphosphonic acid and citric acid in a 1:2 weight ratio.

The plants were sprayed on July 11 and observations of all plants were made about one (1) month after treatment. The following is a summary of the observations:

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TABLE 12

Flower Initiation - Pineapple Forcing

Formulation	Concentration of Active Ingrid. (ppm)	Observations
I. 2-chloroethylphosphonic acid	1000	5 plants vegetative
	2000	4 plants vegetative, 1 forced
II. 2-chloroethylphosphonic acid plus citric acid in a 1:2 weight ratio	250	5 plants vegetative
	500	4 plants vegetative, 1 forced
	1000	3 plants vegetative, 1 forced

The foregoing results demonstrate the enhanced flower initiation i.e. pineapple forcing, produced by the compositions of this invention in comparison to the ethylene-providing compound 2 - chloroethylphosphonic acid alone.

Example 47.

Tomato Ripening

A series of tests were performed to investigate the effect of a number of the compositions of this invention on the ripening of tomatoes.

The tests were performed on Hines 1350 tomatoes in Northwest Ohio.

Ten (10) days after treatment two plants were selected at random from each plot, counted and the quality and amount of red fruit noted. All treatments were applied in 50 gallons per acre.

The formulations (b), (c) and (d) — as defined in Example 2 — were compared to the preferred commercial rate of 3/2 lbs./acre of 2 - chloroethylphosphonic acid [Formulation (a)]. The results of these treatments are as follows:

TABLE 13

Tomato Ripening

Formulation	Rate (lb./acre)	% Red Fruit
(a) control	3/2	56.5
(b)	3/8	57.9
(c)	3/8	57.9
(d)	3/8	49.4
Untreated check	0	21.6

The foregoing results clearly demonstrate the enhanced tomato ripening produced by the compositions of this invention in comparison to the ethylene-providing compound 2 - chloroethylphosphonic acid alone. A rate of 1/4 of the commercial rate of 2 - chloroethylphosphonic acid applied in combination with a chelating agent to the tomato plants

produces about the same ripening effect of the full commercial rate of 2 - chloroethylphosphonic acid alone.

Example 48.

Turf Inhibition

A series of tests were performed to investigate the effect of a number of the com-

positions of this invention on inhibition of turf grass.

Merion bluegrass, growing in 4" diameter pots, was clipped to a uniform height eight (8) days prior to the application of the formulations.

Formulations (a), (b), (c) and (d) — as defined in Example 2 — were applied to the

turf. An initial turf clipping was taken two (2) days after application. Clippings were taken and weighed ten (10), sixteen (16), thirty (30) and forty-one (41) days after application of the formulations.

The results of these treatments are as follows:

TABLE 14

Turf Inhibition

Formulation	Rate (lbs./acre)	Clipping weight in grams (10 reps)			
		days after treatment			
		10 days	16 days	30 days	41 days
(a) control	12	22.23	6.11	6.52	22.6
(b)	12	17.23	3.78	3.17	11.1
	6	17.87	4.00	4.77	14.8
(c)	12	16.46	3.47	4.05	13.8
	6	20.75	4.52	6.68	19.0
(d)	12	17.59	3.28	3.00	13.9
	6	19.58	7.05	9.14	23.1
Untreated Check	0	18.83	6.69	11.10	20.0

The foregoing results clearly demonstrate the enhanced turf grass inhibition achieved by the compositions of this invention when compared to 2 - chloroethylphosphonic acid alone.

Example 49.

Cotton Defoliation

A series of tests were performed to investigate the effect of a number of the compositions of this invention on cotton defoliation.

Delta Pine Cotton was seeded in vermiculite on April 8. During the week of June 16, seedlings were transplanted to four inch pots using a potting soil mixture.

Amex plus Cotoran (3/2+2 lb/A) was applied pre to the entire plot area on June 17. Transplants were set on June 17 with a starter solution of Chloradane+Rapid-Gro (1 pt.+3 lb/50 gal.). Row spacing was three feet and plant spacing thirty-one inches. On

June 18 one quarter inch irrigation was applied and one quarter additional on June 19 and June 23.

Spray applications of formulations (a), (b), (c) and (d) — as defined in Example 2 — were made on September 5. Temperature was 83°F with no wind. At this time the plants had mature green bolls in lower portions with flowering squares in upper portions. Spray volume was 100 gal/A. Applications were made with a hand held three nozzle boom. The boom was set up with one nozzle directly over the plant and the side nozzles directly and horizontally opposed to provide good spray coverage into the foliage. Plots consisted of two plants/treatment and three replications. The first recordable rainfall (0.08") and (0.02") occurred on the 6th and 7th of September respectively.

Evaluation of visual percent leaf abscission was recorded on September 17.

The following are the results of the foregoing treatments:

TABLE 15

Cotton Defoliation

Formulation	Rate (lbs./acre)	% Defoliation
(a) control	4	6.7%
(b)	4	30.0%
(c)	4	36.7%
(d)	4	23.3%
Untreated Check	0	0

The foregoing results clearly demonstrate the enhanced cotton defoliation achieved by the compositions of this invention when compared to the ethylene-providing compound to 2-chloroethylphosphonic acid alone.

Example 50.

Fruit Abscission — Cherries

A series of tests were performed to investigate the effect of a number of the compositions of this invention on fruit abscission, particularly cherries.

Ten (10) year old Montmorency tart cherries were sprayed on July 15 with formulations (a), (b), (c) and (d) — as defined in Example 2 — and evaluated on July 18 and July 27 for pull force. An equal volume of solution was applied to each tree. Formulation (a) was applied at the preferred commercial rate.

The following are the results of the foregoing treatment:

TABLE 16

Fruit Abscission — Cherries

Formulation	Rate (ppm)	Pull Force (*) (gms)		Decrease in Pull Force (gms)
		July 18	July 27	
(a) control	200	261.0	149.9	111.1
(b)	50	285	202	83.0
	100	346.6	180.3	166.3
(c)	50	294.0	196.2	97.8
	100	313.	207.7	105.3
(d)	50	321.3	198.7	122.6
	100	271.0	183.9	87.1
Untreated Control	0	250.	212.3	37.3

(*) Average of 15 samples.

B

Sweet cherries were sprayed with formulations (a) and (c) — as defined in Example 2 — and evaluated thirteen (13) days after

treatment for pull force. An equal volume of solution was applied to each tree.

The following are the results of the foregoing treatments:

TABLE 17

Fruit Abscission - Cherries

Formulation	Rate	Avg. (b) Fruit Removal Force (gms) 13 days after treatment
(a) Control	200	238
	250	182
	400	136
(c)	100	203
	200	141
Untreated check	0	456

(b) Avg. of 150 measurements.

5 The foregoing results clearly indicate the enhanced abscission of fruit, particularly cherries, achieved by the formulations of this invention when compared to 2 - chloroethylphosphonic acid alone.

Example 51.

Fruit Coloration — Apples

10 A series of tests were performed to investigate the effect of a number of the compositions

of this invention on fruit coloration, particularly apples.

Foliar applications of formulations (a), (b), (c) and (d) — as defined in Example 2 — were applied to apples (*pyrus malus nil*) var. "Double Red Delicious", three weeks before harvest, on equal volume of solution being applied to each tree.

The following table indicates percent color promotion per fruit at harvest to average ratings represent the color of ten (10) fruit.

TABLE 18

Formulation	Rate	% Red Color [avg. of ten (10) fruit]
(a) control	75	39.5
	150	55.
(b)	75	62.5
	150	86.5
(c)	75	76.
	150	67.6
(d)	75	55.
	150	59.5
Untreated check	0	33.

25 The foregoing results clearly indicate the enhanced coloration of fruit, particularly apples, achieved by the formulations of this invention when compared to the ethylene-providing compound 2 - chloroethylphosphonic acid alone.

Example 52.

Fruit Coloration — Cranberries

A series of tests were performed to investigate the effect of a number of the compositions of this invention on fruit coloration, particularly cranberries.

38

Foliar applications of formulations (a), (b), (c) and (d) — as defined in Example 2 — were applied to Early Black Cranberries thirteen (13) days prior to harvesting i.e. when 29.5% of the berries were pink to red, 45.7% green to pink and 24.7% green. The following are the results of those treatments:

5

TABLE 19

Formulation	Active Ingredient Rate (lbs./acre)	% Berries Red
(a) control	.25	38%
	.5	46%
(b)	.25	46%
	.5	56%
(c)	.25	53%
	.5	67%
(d)	.25	81%
	.5	67%
Untreated check	0	38%

10 The foregoing results clearly indicate the enhanced coloration of fruit, particularly cranberries, achieved by the formulations of this invention when compared to the ethylene-providing compound 2 - chloroethylphosphonic acid alone.

15

Example 53.

Tobacco Ripening

A series of tests were performed to investigate the effect of a number of composi-

tions of the invention on the ripening of tobacco.

20

Tobacco Coker 319, was planted April 14, treated August 15 and evaluated August 18. A volume of 70 gallons per acre was applied.

Formulations (a), (b), (c) and (d) — defined in Example 2 — were applied at various rates.

25

The following are the results of the foregoing treatments:

TABLE 20

Formulation	Rate	Avg. % of Yellowing
(a) control	2	83.3
	1	71.7
	.5	63.3
	.25	61.7
(b)	1.0	85.0
	.5	78.3
	.25	70.0
(c)	1.0	76.7
	.5	78.3
	.25	66.7
(d)	1.0	80.4
	.5	73.3
	.25	66.7
Untreated control	0	0

29

5 The foregoing results clearly indicate the enhanced tobacco ripening achieved by the formulations of this invention when compared to the ethylene-providing compound 2 - chloroethylphosphonic acid alone.

of the invention on the ripening i.e. increasing sucrose content, of sugarcane.

10

Example 54.

Ripening of Sugarcane

A series of tests were performed to investigate the effect of a number of compositions

Formulations (a) and (d) — as defined in Example 2 — were applied at various rates to sugarcane variety NCO 376. Samples were taken twelve (12) weeks after application. The crop treated was the first ratoon and eight (8) months of age at spraying.

The following are the results of the foregoing treatments:

20

TABLE 21

Sugarcane Ripening

Formulation	Rate (kg. a.i./ha)	Sucrose % Cane	Juice Purity (%)
(a) control	1.0	12.3	87.5
(d)	.5	12.5	88.1
	1.0	13.0	89.1
	1.5	13.4	89.8
Untreated check	0	11.2	83.8

B

25 Formulations (a) and (d) were applied at various rates to various sugarcane varieties. The sugarcane was harvested 4-1/2 months after treatment and data obtained on sugar

yield. The crop treated was first ratoon and seven (7) months of age at spraying.

The following are the results of the foregoing treatments:

30

TABLE 22

Sugarcane Ripening

Formulation	Rate (kg. a.i./ha)	Sugar Yield (tons/HA)			
		NCO376	NCO334	N55/805	L76
(a) control	1.	21.4	19.5	17.4	23.6
	2.	19.9	19.7	18.0	20.6
(d)	.25	19.5	18.4	19.2	23.3
	.5	22.5	19.5	17.6	21.8
Untreated check	0	17.4	15.9	17.8	19.7

35 The foregoing results clearly indicate the enhanced increase in sucrose content and enhanced ripening of sugarcane achieved by the formulations of this invention when compared to the ethylene-providing compound 2 - chloroethylphosphonic acid alone.

Example 55.

Bean Assay

Burpee Top Crop bean seeds were planted and treated with formulations of this invention at various rates in a volume of 100 gallons/acre. The plants are sprayed at the

40

emergence of the first trifoliate leaf. About two (2) weeks later, at the early flowering stage, observations were made of the height in centimeters from the primary leaf node.

In the foregoing test, the addition of citric acid enhanced the growth inhibition activity of the following ethylene-providing compounds:

- (a) 2 - chloroethylphosphonic acid;
- (b) 2 - chloroethyl tris - (2 - methoxyethoxy) silane;
- (c) 2 - chloroethylphosphonic acid, magnesium salt, dihydrate; and
- (d) 2 - chloroethylphosphonic acid - mono - 2 - chloroethyl ester.

Example 56.

Burpee Pickler cucumber seeds were planted and treated with formulations of this invention at various rates in a volume of 100 gallons/acre. The plants were sprayed at the emergence of the first leaf bud. About one (1) month later, observations were made of the height in centimeters from the cotyledonary node.

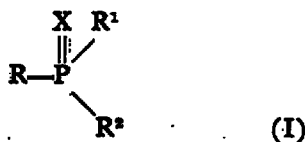
In the foregoing test, the addition of citric acid enhanced the growth inhibition activity of the following ethylene-providing compounds:

- (a) 2 - chloroethylphosphonic acid;
- (b) 2 - chloroethylphosphonic diamide; and
- (c) 2 - chloroethyl tris - (2 - methoxyethoxy) silane.

WHAT WE CLAIM IS:—

1. In a method of regulating the growth of a plant by applying to the plant an ethylene-providing compound the step of enhancing the growth regulating effect on the plant by applying thereto an effective amount of a chelating agent.

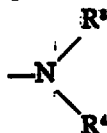
2. A method as claimed in claim 1, in which the ethylene-providing compound is a phosphonic acid derivative of the general formula:



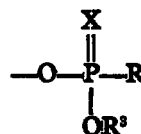
wherein X represents an oxygen or a sulphur atom;

R represents a haloethyl, halopropyl or phosphonoethyl radical; and

R¹ and R², which may be the same or different, each represent a chlorine atom, a bromine atom, the group



(wherein R³ and R⁴, which may be the same or different, each represent a hydrogen atom, a substituted or unsubstituted alkyl radical, a substituted or unsubstituted aryl radical, a substituted or unsubstituted heterocyclyl radical, an alkenyl radical containing from 2 to 8 carbon atoms, or an alkynyl radical containing from 2 to 8 carbon atoms) the group —XR³ (wherein X and R³ are as defined hereinbefore with the proviso that when R¹ and R² both represent OR³, R³ is not a substituted or unsubstituted alkyl radical) or the group:



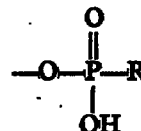
(wherein X, R and R³ are as defined hereinbefore),

or a salt thereof formed with an agriculturally-acceptable cation.

3. A method as claimed in claim 2, in which X represents an oxygen atom and R represents a haloethyl, or phosphonoethyl radical.

4. A method as claimed in claim 3, in which R¹ and R², which may be the same or different, each represent a chlorine atom, a hydroxy radical or an unsubstituted amino radical.

5. A method as claimed in claim 3, in which R¹ represents a hydroxy radical and R² represents the group:



wherein R is as defined in claim 3.

6. A method as claimed in claim 3, in which the phosphonic acid derivative is a haloethyl phosphonic acid.

7. A method as claimed in claim 6, in which the haloethylphosphonic acid is 2 - chloroethylphosphonic acid.

8. A method as claimed in claim 1, in which the ethylene-providing compound is a 2 - haloethyl silane.

9. A method as claimed in claim 8, in which the ethylene-providing compound is 2 - chloroethyl - tris(p - methoxybenzyloxy) - silane or 2 - chloroethyl - tris(2 - methoxyethoxy) - silane.

10. A method as claimed in any of the preceding claims, in which the chelating agent is:

citric acid, tartaric acid, gluconic acid; aconitic acid; L-sorbose, glycine, malic acid, maleic acid, malonic acid, citraconic acid, glutaric acid, crotonic acid, sorbitol, glycerol, diglycerol, dextrose, mannitol, tannic acid,

emergence of the first trifoliate leaf. About two (2) weeks later, at the early flowering stage, observations were made of the height in centimeters from the primary leaf node.

In the foregoing test, the addition of citric acid enhanced the growth inhibition activity of the following ethylene-providing compounds:

- (a) 2 - chloroethylphosphonic acid;
- (b) 2 - chloroethyl tris - (2 - methoxyethoxy) silane;
- (c) 2 - chloroethylphosphonic acid, magnesium salt, dihydrate; and
- (d) 2 - chloroethylphosphonic acid - mono - 2 - chloroethyl ester.

Example 56.

Burpee Pickler cucumber seeds were planted and treated with formulations of this invention at various rates in a volume of 100 gallons/acre. The plants were sprayed at the emergence of the first leaf bud. About one (1) month later, observations were made of the height in centimeters from the cotyledonary node.

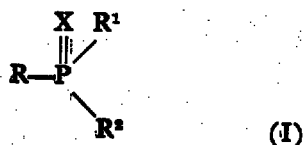
In the foregoing test, the addition of citric acid enhanced the growth inhibition activity of the following ethylene-providing compounds:

- (a) 2 - chloroethylphosphonic acid;
- (b) 2 - chloroethylphosphonic diamide; and
- (c) 2 - chloroethyl tris - (2 - methoxyethoxy) silane.

WHAT WE CLAIM IS:—

1. In a method of regulating the growth of a plant by applying to the plant an ethylene-providing compound the step of enhancing the growth regulating effect on the plant by applying thereto an effective amount of a chelating agent.

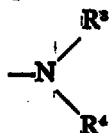
2. A method as claimed in claim 1, in which the ethylene-providing compound is a phosphonic acid derivative of the general formula:



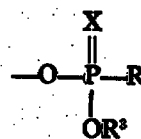
wherein X represents an oxygen or a sulphur atom;

R represents a haloethyl, halopropyl or phosphonoethyl radical; and

R¹ and R², which may be the same or different, each represent a chlorine atom, a bromine atom, the group



(wherein R³ and R⁴, which may be the same or different, each represent a hydrogen atom, a substituted or unsubstituted alkyl radical, a substituted or unsubstituted aryl radical, a substituted or unsubstituted heterocyclyl radical, an alkenyl radical containing from 2 to 8 carbon atoms, or an alkynyl radical containing from 2 to 8 carbon atoms) the group —XR³ (wherein X and R³ are as defined hereinbefore with the proviso that when R¹ and R² both represent OR³, R³ is not a substituted or unsubstituted alkyl radical) or the group:



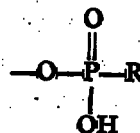
(wherein X, R and R³ are as defined hereinbefore),

or a salt thereof formed with an agriculturally-acceptable cation.

3. A method as claimed in claim 2, in which X represents an oxygen atom and R represents a haloethyl, or phosphonoethyl radical.

4. A method as claimed in claim 3, in which R¹ and R², which may be the same or different, each represent a chlorine atom, a hydroxy radical or an unsubstituted amino radical.

5. A method as claimed in claim 3, in which R¹ represents a hydroxy radical and R² represents the group:



wherein R is as defined in claim 3.

6. A method as claimed in claim 3, in which the phosphonic acid derivative is a haloethyl phosphonic acid.

7. A method as claimed in claim 6, in which the haloethylphosphonic acid is 2 - chloroethylphosphonic acid.

8. A method as claimed in claim 1, in which the ethylene-providing compound is a 2 - haloethyl silane.

9. A method as claimed in claim 8, in which the ethylene-providing compound is 2 - chloroethyl - tris(p - methoxybenzyloxy) - silane or 2 - chloroethyl - tris(2 - methoxyethoxy) - silane.

10. A method as claimed in any of the preceding claims, in which the chelating agent is:

citric acid, tartaric acid gluconic acid; aconitic acid; L-sorbose, glycine, malic acid, maleic acid, malonic acid, citraconic acid, glutaric acid, crotonic acid, sorbitol, glycerol, diglycerol, dextrose, mannitol, tannic acid,

(11)



26

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5 kojic acid, glutamic acid, adipic acid, maleuric acid, mandelic acid, succinic acid, nitriloacetic acid, diethylenetriaminepentacetic acid, hydroxyethylthylenediamine triacetic acid, ethanol diglycine, diethanol glycine, ethylenediaminetetraacetic acid, itaconic acid, fumaric acid, ascorbic acid, chlorokojic acid, α,α -dipyridyl, 2 - mercaptopyridine - N - oxide, sorbic acid, or saponin or a salt of one of these compounds.

10 11. A method as claimed in any of claims 1 to 9, in which the chelating agent is a hydroxy-carboxylic acid or a polycarboxylic acid, or a salt thereof.

15 12. A method as claimed in claim 11, in which the chelating agent is citric acid or ethylenediaminetetraacetic acid, or a salt thereof.

20 13. A method as claimed in claim 12, in which the ethylene-providing compound is 2 - chloroethylphosphonic acid and the chelating agent is citric acid.

25 14. A method as claimed in any of the preceding claims in which the ratio between the amount of ethylene-providing compound and the amount of chelating agent which are applied to the plant is in the range of from 1:10 to 10:1.

30 15. A method as claimed in claim 14, in which the ratio is in the range of from 1:2 to 2:1.

35 16. A method as claimed in any of claims 2 to 15, in which the phosphonic acid derivative is applied at a rate of from 0.1 pounds per acre to 30 pounds per acre.

40 17. A method as claimed in claim 16, in which the rate is from 0.5 pounds to 4 pounds of phosphonic acid derivative per acre.

45 18. A method as claimed in any of claims 2 to 15, in which the phosphonic acid derivative is applied at a concentration of from 10 to 10,000 parts per million.

50 19. A method as claimed in any of the preceding claims and substantially as described herein with reference to any one of the Examples.

55 20. A method of regulating the growth of a plant, which comprises applying to the plant an effective amount of composition comprising one or more chelating agents and one or more phosphonic acid derivatives of general formula I as defined in claim 2 and/or one or more salts thereof.

60 21. A method as claimed in claim 20, in which the phosphonic acid derivative is 2 - chloroethylphosphonic acid, 2 - chloroethylphosphonic diamide, 2 - chloroethylphosphonic acid dichloride, 2 - chloroethylphosphonic acid anhydride or 2 - bromo - ethyl - phosphonic acid and the chelating agent is a hydroxy-

carboxylic acid, a polycarboxylic acid or a salt thereof.

22. A method as claimed in claim 21, in which the phosphonic acid derivative is 2 - chloroethylphosphonic acid and the chelating agent is citric acid.

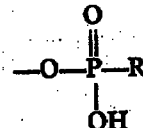
23. A composition for regulating the growth of plants, comprising an ethylene-providing compound and a chelating agent in a combined amount effective at regulating plant growth, in association with a suitable vehicle.

24. A composition as claimed in claim 23, in which the ethylene-providing compound is a phosphonic acid derivative of general formula I as defined in claim 2 or a salt thereof.

25. A composition as claimed in claim 24, in which the derivative of general formula I or a salt thereof is a compound wherein X represents an oxygen atom and R represents a haloethyl, phosphonoethyl radical.

26. A composition as claimed in claim 25, in which R^1 and R^2 , which may be the same or different, each represent a chlorine atom, a hydroxy radical or an unsubstituted amino radical.

27. A composition as claimed in claim 25, in which R^1 represents a hydroxy radical and R^2 represents the group:



wherein R is as defined in claim 25.

28. A composition as claimed in claim 26, in which the phosphonic acid derivative is a haloethylphosphonic acid.

29. A composition as claimed in claim 28, in which the haloethylphosphonic acid is 2 - chloroethylphosphonic acid.

30. A composition as claimed in any of claims 23 to 29, which comprises one or more of the chelating agents set out in claim 10.

31. A composition as claimed in any of claims 23 to 29, in which the chelating agent is citric acid, ethylenediamine-tetraacetic acid or a salt thereof.

32. A composition as claimed in claim 31, in which the phosphonic acid derivative is 2 - chloroethylphosphonic acid and the chelating agent is citric acid.

33. A composition as claimed in any of claims 23 to 32, in which the ratio between the amount of the ethylene-providing compound and the amount of chelating agent is in the range of 1:10 to 10:1.

34. A composition as claimed in claim 33, in which the ratio is in the range of from 1:2 to 2:1.



42

35. A composition for regulating the growth of plants as claimed in claim 23, and substantially as described herein with reference to any one of the Formulations.

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