

- [54] Title: PROCESS FOR INCREASING RICE CROP YIELD CROSS-REFERENCES
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- [22] Filed: June 23, 1982
- [21] Application Serial No: 37107

FOREIGN APPLICATION PRIORITY DATA

- [31] Number (s) : 66958; 107,008
- [32] Date (s) : June 25, 1987; March 9, 1988
- [33] Country (ies) : U. S. A.
- [52] PH Class ..... 71/86
- [51] Int. Class ..... A01N 57/34
- [58] Field of Search ..... 71/86
- [56] Reference (s) Cited and/or Considered: None

[57] (see abstract next page)

BAD ORIGINAL



# 26822

## PROCESS FOR INCREASING RICE CROP YIELD

### CROSS-REFERENCES

This application is a continuation-in-part of U. S. Ser. No. 066,938, filed June 25, 1987, now abandoned.

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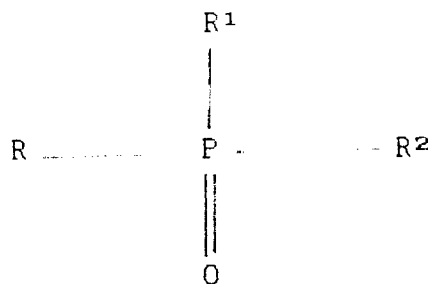
### FIELD OF THE INVENTION

The invention relates to a method of increasing rice crop yield which comprises applying to the plant a phosphonic acid plant growth regulator.

### BACKGROUND OF THE INVENTION

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Compounds having the formula



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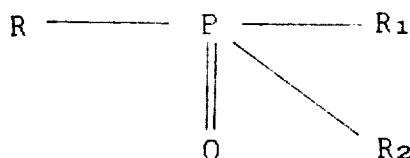
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wherein R, R<sup>1</sup> and R<sup>2</sup> are as hereinafter defined, are known to induce growth regulating responses in plants, which responses are exemplified but not necessarily limited to ethylene or ethylene-type responses. It is known that ethylene and other gases affect the growth cycle of plants,

although the mechanism of this effect is not fully understood. The phosphonic acid compounds generically represented by the formula shown above contain in their structures molecular configurations which are capable of forming ethylene or like compounds.

Plant growth regulators such as phosphonic acid are commonly used to regulate growth of small grain plants such as barley and wheat. Growth of such plants is regulated by applying the plant growth regulator during the growth stage between emergence of flag leaf and boot swelling. This stage is also described as early to late boot stage. Plant growth regulators are not commonly used to regulated growth of rice crops plants.

Fritz et al., U. S. Pat. Nos. 3,879,188, 4,374,661 and 4,401,454, all describe a growth regulation process involving application of certain phosphonic acid compounds having the general formula



where

R is selected from the group consisting of haloethyl and phosphono-ethyl; and

$R_1$  and  $R_2$  are selected from the group consisting of

(a) chlorine, hydroxy, and salts thereof;

(b) the group  $\text{---OR}_3$  and the group  $\text{---O---CH}_2\text{R}_3$   
where each  $R'$  is one member of the group of  
5 unsubstituted aryl, substituted aryl and  
heterocyclic groups;

(c) the group  $\text{---OR}_3$  and the group  $\text{---O---CH}_2\text{R}_3$   
where each  $R_3$  is a different member of the group  
of hydrogen, unsubstituted alkyl, substituted  
10 alkyl, unsubstituted aryl, substituted aryl,  
heterocycle, alkene and alkyne, provided that when  
one  $R_3$  is selected from the group of unsubstituted  
alkyl, substituted alkyl, alkene and alkyne, the  
other  $R_3$  is selected from the group of  
15 unsubstituted aryl, substituted aryl and  
heterocycle;

(d) together  $R_1$  and  $R_2$  represent the group



phosphonic derivative according to Fritz et al. is 2-chloroethyl phosphonic acid. This preferred derivative is claimed to be useful in hastening ripening in unpicked fruit.

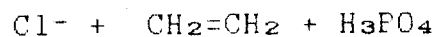
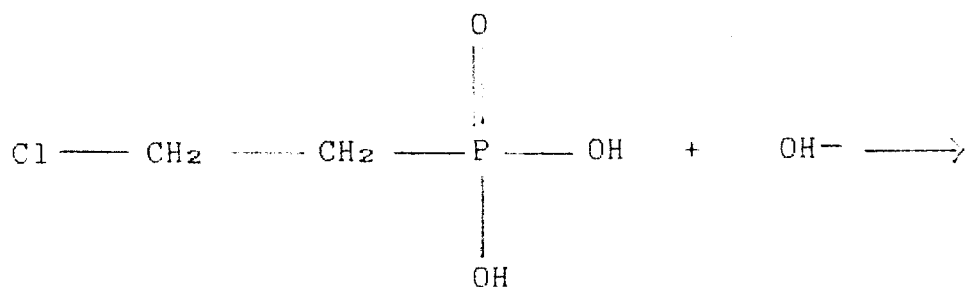
5 Jacques, U. S. Pat. No. 3,896,163, describes a purification process for separating an aliphatic phosphonic acid such as 2-chloroethyl phosphonic acid from its corresponding half-ester.

10 Hayakawa et al., U. S. Pat. No. 4,152,429, describe a method for controlling plant fungi and regulating plant growth comprising applying to the plant a composition comprising 2-chloroethyl phosphonic acid and a conventional agricultural fungicide.

15 Fritz et al., U. S. Pat. No. 4,240,819 describe a method for inhibiting plant growth which comprises applying thereto an effective amount of 2-chloroethyl phosphonic acid.

20 Fritz et al., U. S. Pat. No. 4,352,689, describe a method for controlling apical dominance which comprises applying to crops an effective amount of 2-chloroethyl phosphonic acid, ranging from about 0.2 lb to about 16 lbs per acre.

Ethephon is the generic name for 2-chloroethyl phosphonic acid marketed under ETHREL <sup>®</sup>, PREP <sup>™</sup>, CERONE <sup>®</sup>, AND FLOREL <sup>™</sup> trademarks Ethephon, upon decomposition by a simple base catalyzed reaction, releases ethylene gas. The release of ethylene increases with increasing solution pH. When ethephon is applied to higher plants, ethylene is released in plant cells by the following chemical reaction:



(2-chloroethyl phosphonic acid)

Ethylene is one of the 5 commonly recognized classes of naturally occurring plant hormones, i.e. Auxins, Gibberellins, Cytokinins, Abscisic acid, and Ethylene. Ethylene is known to play an important regulatory role in various physiological processes, from germination through senescence. Ethephon in liquid form provides a convenient means of ethylene application to plants and is widely used in research for studying ethylene-mediated processes.

Chaudhuri, D., et al., *Indian Agriculturist*, vol 24, pp. 169-175 (1980) describe rice yield increase with foliar application of ethephon or other plant growth regulators at tillering, booting or panicle initiation stages.

- 5 Fang, B. C. et al., *Shanghai Agricultural Science and Technology*, vol. 5, pp. 11-12 (1982) and Fang, B. C. et al., *Acta Botanica Sinica*, vol 25, pp. 344-351 (1983) described rice yield increase with application of ethephon to seedlings of double-cropping second season rice at the 5-leaf stage.
- 10 Chaudhuri, D. et al. and Fang et al. do not teach rates of application of ethephon and do not distinguish among the various growth stages of tillering, booting and panicle initiation. The present invention teaches a method for increasing rice crop yield by applying a phosphonic acid
- 15 plant growth regulator at specific application rates and at a specific Plant growth stage.

It is an object of this invention to increase rice grain yield by applying phosphonic acid growth regulators at specific rates and particular stages of plant growth. It is

20 a further object of the present invention to increase the number of seeds and seed producing tillers of a rice crop by applying phosphonic acid growth regulators at rates and plant growth stages which result in manipulation of certain plant physiological processes.

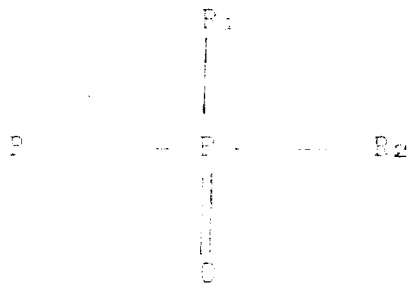
## SUMMARY OF THE INVENTION

It has been surprisingly discovered that application of phosphonic acid growth regulators at particular rates and plant growth stages promotes manipulation of certain physiological processes which reduces decline in tiller number and increases the number of seed producing tillers. The presence of high numbers of productive tillers bearing panicles results in high numbers of spikelets per unit land area.

Foliar application of a phosphonic acid plant growth regulator to rice crops at rates from about 50 to about 750 grams per hectare, and preferably from about 100 to about 500 grams per hectare, made between the start of tillering and initiation of panicle primordia, and preferably between the end of effective tillering and initiation of panicle primordia, promotes significantly greater dry grain yields of said crops.

## DETAILED DESCRIPTION OF THE INVENTION

The phosphonic acid compound useful in the present invention is



wherein:

R is selected from the group consisting of haloethyl and phosphonoethyl and

R<sup>1</sup> and R<sup>2</sup> are selected from

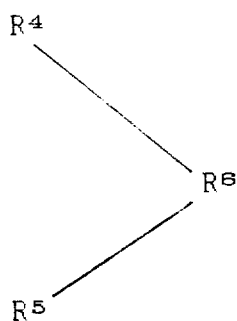
5 (a) chlorine, hydroxy, and salts thereof;

(b) the group  $\text{---OR}^3$  and the group  $\text{---O---CH}_2\text{R}^3$  wherein each R<sup>3</sup> is a member of the group of unsubstituted aryl, substituted aryl and heterocyclic groups;

10 (c) the group  $\text{---OR}^3$  and the group  $\text{---O---CH}_2\text{R}^3$  wherein each R<sup>3</sup> is a different member of the group of hydrogen, unsubstituted alkyl, substituted alkyl, unsubstituted aryl, substituted aryl, heterocyclic, alkenyl and alkynyl with the proviso that when one R<sup>3</sup> is selected  
 15 from the group of unsubstituted alkyl, substituted alkyl,

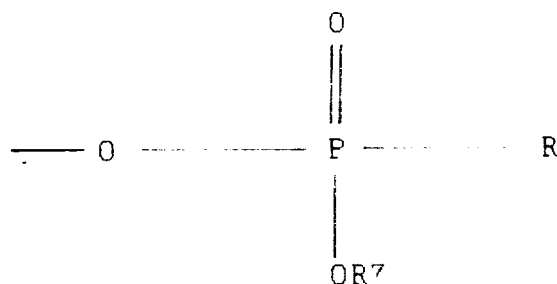
alkenyl and alkynyl, the other R<sup>3</sup> is selected from the group of unsubstituted aryl, substituted aryl and heterocycle;

(d) together R<sup>1</sup> and R<sup>2</sup> represent



(R<sup>4</sup> and R<sup>5</sup> are both each connected with the phosphorous atom by a separate single bond) where one R<sup>4</sup> and R<sup>5</sup> is —O— and the other is selected from the group of —O—, OCH<sub>2</sub>—, —CO—O and CONH, and R<sup>6</sup> represents a cyclic group selected from the group consisting of benzene, substituted benzene, heterocyclic rings and substituted heterocyclic rings; or

(e) one of R<sup>1</sup> and R<sup>2</sup>, is —OR<sup>7</sup> and the other is:



wherein each R<sup>7</sup> is the same or different and is selected from the group of hydrogen, unsubstituted alkyl, substituted alkyl, unsubstituted aryl, substituted aryl and a heterocyclic group, and wherein R is as defined  
5 hereinbefore.

Reference is hereby made to the following patents and patent applications, the disclosures of which are hereby incorporated by reference; application Ser. No. 617,860, filed Feb. 23, 1967, now abandoned, and applications Ser.  
10 No. 617,820, now U. S. Pat. No. 3,531,549 and Ser. No. 617,819 now U. S. Pat. No. 3,551,528, both filed Feb. 23, 1967.

The foregoing application specified hereinabove disclosure preparation techniques for the compounds utilized  
15 in the method of the present invention.

Where the term "halo" is used, it is to be understood that this term means the familiar halogens, i.e., fluorine, chlorine, bromine and iodine, so long as an operative growth regulation compound is obtained.

20 With reference to the general formula utilized in the method of the present invention, preferred groups for substituent R are haloethyl, for example, 2-chloroethyl, 2-bromoethyl and 2-iodoethyl. Preferred half-esters of the

phosphonic acid and moiety include the 2-chloroethyl mono-  
ester and the 2-hydroxyphenyl mono-ester. Preferred  
diesters include the diphenyl and the bis (2-oxo-1-  
pyrrolidinyl-methyl) esters and as mixed esters, the 2-  
5 hydroxyphenyl ester with an alkyl or alkenyl or aryl radical  
for example, ethyl, isopropyl, propynyl, butyl, octyl,  
hexadecyl or phenyl radicals. Aryl groups are preferably  
monocyclic, and bi- or polycyclic aryl groups may be used  
provided a group to render them soluble (e.g., a sulphonate  
10 group), is present thereon.

The term "alkyl" as used herein is intended to include  
the analogous compounds which have the same growth promotion  
properties and includes for example cycloalkyl groups, such  
as cyclohexyl. Preferred alkyl groups are those having up  
15 to preferably 18 carbon atoms because above this range, the  
derivatives are less soluble.

Preferred cyclic esters include those formed with  
pyrocatechol or mono- or polyhalopyrocatechol derivatives,  
for example 4-chloropyrocatechol or tetrachloropyrocatechol;  
20 with salicylic acid, with saligenin, and with 2,3-  
pyridinediol. Another preferred derivative is the acid  
chloride.

Specific phosphonic acids and derivatives thereof  
suitable for use in this invention include:

1. 2-chloroethyl phosphonic acid.
2. The bis(acid chloride) or 2-chloroethyl phosphonic acid.
3. The pyrocatechol cyclic ester of 2-chloroethyl  
5 phosphonic acid.
4. The 4-chloropyrocatechol cyclic ester of 2-chloroethyl phosphonic acid.
5. The mixed ethyl and 2-hydroxyphenyl diester of 2-chloroethyl phosphonic acid.
- 10 6. The mixed butyl and 2-hydroxyphenyl diester of 2-chloroethyl phosphonic acid.
7. The mixed propynyl and 2-hydroxyphenyl diester of 2-chloroethyl phosphonic acid.
8. The 2-chloroethyl monoester of 2-chloroethyl  
15 phosphonic acid.
9. 2-bromoethyl phosphonic acid.

10. The bis(phenyl)-ester of 2-chloroethyl phosphonic acid.

11. The tetrachloroprocatechol cyclic ester of 2-chloroethyl phosphonic acid.

5 12. 2-iodoethyl phosphonic acid.

13. The saligenin cyclic ester of 2-chloroethyl phosphonic acid.

14. Salicylic acid cyclic ester of 2-chloroethyl phosphonic acid.

10 15. Phosphonoethyl phosphonic acid.

16. Phosphonoethylthioethyl phosphonic acid.

17. The 3-hydroxyphenyl monoester of 2-chloroethyl phosphonic acid (which exists in polymeric form).

15 18. The bis(2-oxo-pyrrolidinylmethyl) ester of 2-chloroethyl phosphonic acid.

19. The 2-hydroxyphenyl monoester of 2-chloroethyl phosphonic acid.

20. The mixed isopropyl and 2-hydroxyphenyl diester of 2-chloroethyl phosphonic acid.

21. 2-fluoroethyl phosphonic acid.

22. The mixed octyl and 2-hydroxyphenyl diester of 2-chloroethyl phosphonic acid.

23. The mixed hexadecyl and 2-hydroxyphenyl diester of 2-chloroethyl phosphonic acid.

24. The mixed tridecyl and 2-hydroxyphenyl diester of 2-chloroethyl phosphonic acid.

25. The anhydride of 2-chloroethyl phosphonic acid.

26. The mixed butyl and 2-hydroxyphenyl diester of 2-chloroethyl phosphonic acid.

27. The 2-chloroethylester of 2-chloroethyl phosphonic acid.

2-chloroethyl phosphonic acid is preferred.

The phosphonic acid compounds used in the process of this invention are generally soluble in water. In instances where these compounds are not appreciably water soluble, it

has been found that contact with water frequently causes sufficient hydrolysis to result in a soluble product thereby obviating the necessity of utilizing sophisticated formulations containing surfactants, dispersing agents, extenders, etc. However, if desired, the compounds used in the process of this invention may be absorbed onto solid carriers such as vermiculite, attaclay, talc and the like for application via a granular vehicle.

Application may be by any conventional means which provides uniform application of the plant growth regulator, such as a hand-held CO<sub>2</sub> charged sprayer system, backpack sprayer system, tractor-drawn sprayer, or other conventional ground or aerial application system when the active compounds are in solution and conventional solid material application systems when the active compounds are absorbed onto solid carriers.

Compositions useful in this invention can be prepared by conventional mixing methods. Suitable liquid diluents or carriers include water, petroleum distillates, or other liquid carriers with or without surface active agents. Due to the good solubility of phosphonic acid compounds in water, water is preferred.

The required amount of the active ingredient contemplated herein may be applied along with inert carrier

at a rate per acre of from about 1 to about 300 gallons of liquid carrier and/or diluent or of from about 5 to about 500 pounds of inert solid carrier and/or diluent. Higher rates may also be used. The concentration in the liquid concentrate will usually vary from about 5 to about 95 percent by weight and in the solid formulation from about 0.5 to about 90 percent by weight.

Formulations useful in the present invention can also contain other optional ingredients such as stabilizers or other biologically active compounds. It is preferable that optional ingredients do not harm the plant being treated and do not impair or reduce the activity of the active ingredient. Biologically active compounds include, for example, one or more insecticidal, herbicidal, fungicidal, nematocidal, mitocidal, plant growth regulators or other known compounds. Such optional ingredients may be used for their known purpose as well as for any synergistic effect they may provide.

Treatment of rice crops in accordance with the present invention promotes

- increase in number of panicles per unit land area;
- increase in number of panicles per plant;
- increase in grain weight;
- increase in number of grains per panicle;
- increase in plant height;

increase in straw stiffness; and  
reduction in number of sterile florets per panicle.

In accordance with the present invention, the  
phosphonic acid compound is applied to rice crops at rates  
5 from about 50 to about 750 grams per hectare, preferably  
about 100 to about 500 grams/ha, more preferably from about  
200 to about 400 grams/ha, and even more preferably from  
about 240 to about 360 grams/ha. Application is during the  
rice crop growth stage between about the start of tillering  
10 and initiation of panicle primordia and preferably between  
the end of effective tillering and initiation of panicle  
primordia. More preferably application is about 7-10 days  
before initiation of panicle primordia. Application after  
initiation of panicle primordia period of time between the  
15 end of effective tillering and initiation of panicle  
primordia occurs between about 45 and about 90 days after  
seeding.

The end of effective tillering is defined as the period  
when the tillering number reaches that of eventual panicle  
20 number at maturity. It immediately precedes the period when  
the plant has a maximum number of tillers. This period is  
often observed when vegetive growth slows markedly and  
floral development begins, and is defined for a given rice  
crop variety. Weather conditions do not significantly  
25 change the timing of this rice crop growth stage period.

ETHREL (R) 480 ethephon is one of several suitable sources of ethephon. It has a concentration of ethephon of 480 grams active ingredient per liter solution.

Suitable rice varieties which may be treated according to the present invention include but are not limited to IRRI cultivar saturn, INIAP 415 [F1(IR930X-IR579)XF2(IR930XIR22)], CR-1113, and Ecuador Juma 57.

#### EXAMPLES

##### EXAMPLE 1

10 Saturn variety rice was planted (May 13, 1981 near Rosa, Louisiana, Prior to planting, 20-40 -60 units of N-P-K were applied. On June 1, 1981, 4 pounds ai/ac of propanil were applied. On July 9, 1981, 160 units of ammonium nitrate were applied, and on July 24, 1981, ETHREL (R)  
15 ethephon was applied in amounts of either 114 g ai/ac or 227g ai/ac. A control planting having no ETHREL (R) ethephon treatment was also maintained. The aforementioned treatments were separated by permanent soil levees, and replications or sub-plots were separated on all sides by 3-  
20 foot alley ways. Each plot was 6 feet by 30 feet.

The treatment solution was applied using a hand-held CO<sub>2</sub> charged 2-gallon sprayer system. This system has a two-

row boom equipped with Tee-jet diaphragm check valve nozzles having 8004 HSS flat fan tip and 100 mesh screens.

The number of panicles per unit area was determined by placing a 9 ft<sup>2</sup> frame over the rice crop and removing all panicles from plants within this area. Each panicle was cut 1/4-1/2 inch below the last joint. The average weight per panicle was then determined.

The weight of individual seeds was determined by treatment. These 1000 grains were weighed, and the mean weight per seed was calculated.

To make appropriate plant measurements, twenty-five plants were selected at random from each plot on September 21 and used to determine panicle to flag leaf measurements. Two measurements were recorded on each plant. The first was the length from the flag leaf to the base of the panicle, and the second was the length from the flag leaf to the tip of the panicle.

The entire plot, less the area used to determine number of panicles per unit area, was harvested on Oct. 2, 1981 using a small plot combine. The rice seed from each plot was weighted.

## Results

The measurements from the tip and base of the panicle to the flag leaf are presented in Table II. Variation in lengths among panicles within the plots was considerable.

5 Table III presents information on panicle numbers, the weights of each panicle, the weight of 1000 grains and the yield of rice product by each treatment. The plots with 227 g ai/ac of ETHREL (R) ethephon produced a significantly heavier panicle than the plots with 114 g ai/ac ETHREL (R) ethephon or the control plots. Also the plots with 227 g  
10 ai/ac of ETHREL (R) ethephon had a higher weight per 1000 grains (25.15 gms) and yielded significantly more rice than the other plots.

TABLE II

Treatment	(g ai/ac)	Length (cm) of flag leaf to panicle		
		base of panicle	tip of panicle	overall
ETHREL (R)	114	2.5	21.6	24.1
ETHREL (R)	227	2.7	21.7	24.4
Control	-	3.1	21.0	24.1

TABLE III

Treatment	(g ai/ac)	Yield <sup>a</sup> (lb/ac)	Weight/ 1000 grains(g)	Number panicles per 9 ft <sup>2</sup>	Weight panicles (g)
ETHREL (R)	114	2498.3 b	24.12 b	491.9	0.445 c
ETHREL (R)	227	3398.4 a	25.15 a	462.4	0.656 a
Control	-	2341.3 b	24.02 b	452.5	0.507 b

Means followed by the same letter in the same column do not differ significantly at the 5% level of probability according to Duncan's multiple range test.

No phytotoxicity was observed during these treatments  
5 with ETHREL (R) ethephon.

## EXAMPLE 2

INIAP 415 [F1 (IR930XIR579)XF2(IR930XIR22)] variety  
rice was planted in April, 1982 in Ecuador. Crops were  
treated with ETHREL (R) 480 ethephon in June 1982, at rates  
10 of either 500 or 1000 ml/ha. A control planting having no  
ethephon treatment was also maintained. Plot size for each  
of the treatments was 5000 m<sup>2</sup>. Soil type used in the  
experiment was clay, and precipitation was about 170  
mm/month. Urea fertilizer (46% ai) was used at 500 lb/ha in  
15 three applications. Weed control was maintained by applying  
a mixture of 5 liters propanil, 3 liters butachlor and 600

ml 2,4-DP, Dichloroprop per hectare ten days after transplanting.

Phytotoxicity was measured by observing chlorosis, necrosis, color change of roots, root deformation, height reduction of plants, reduction of stand, etc. A numerical scale of 1 (no phytotoxicity) to 5 (total kill) was used to represent degree of phytotoxicity. Number of tillers per square meter was measured using a 0.25 m<sup>2</sup> frame thrown 4 times at random in the test plot. A similar procedure was used to determine number of panicles/m<sup>2</sup> at the time plants were physiologically normal. Plant height at harvest was measured from the ground to the top of the flag leaf. Four random measurements per plot were made. Yield was taken by harvesting the total plot area, and is represented in MT/ha with 14% grain moisture.

## Results

Table IV presents data of the experiment.

TABLE IV

PARAMETER	Control	ETHREL (R) (g ai/ha)	
		240	480
Phytotoxicity	-	None	None
No. of tillers/m <sup>2</sup>	309	309	308
No. of panicles/m <sup>2</sup>	246	278	292
Sterile panicles (%)	8.4	5.6	5.0
Plant height (cm)	104	113	117
Grain yield (MT)	5.8	8.1	8.2

Application of ETHREL (R) ethephon at both concentrations significantly increased panicle number, plant height, and grain yield, and substantially decreased the percentage of sterile panicles.

5

## EXAMPLE 3

Ecuador developed rice variety rice No. 1001, also called Juma 57, was planted in Ecuador during the dry season and harvested during the wet season of 1985. ETHREL (R) 480 ethephon treatment was done 67 days after planting, at the  
 10 stage when the flower primordia was just formed (about 5 mm. in length). Application rates were either 120, 240 or 360 g/ha (0.25, 0.5 or 0.75 l/ha). The average day temperature was 23°C., precipitation was 300 mm, and relative humidity 87%. Pregerminated seed was broadcast. Weed control was  
 15 done using a mix of 6 liters STAM (R) LV10 and 0.5 liter agrozone (MCPA, ICI) per hectare. Urea fertilizer was

applied at 200 kg/ha. Application of ETHREL (R) ethephon was done using a knapsack sprayer.

### Results

Table V presents data of the experiments:

TABLE V

ETHREL (R) (g ai/ha)	Number of Panicles/m <sup>2</sup>	100 Grain weight in grams	Yield kg/ha
120	485	25.9	3,272
240	550	28.1	4,560
360	535	27.5	5,288
Control	465	25.4	3,344

- 5        Periodic observations indicated that ETHREL (R) ethephon produced a significant hardening or stiffening of the stem tissue. The number of panicles/m<sup>2</sup>, grains per panicle, and grain weight was higher for crops treated with ethephon at rates of 240 and 360 g a.i./ha for control crops.
- 10       Furthermore, a significant increase in yield was obtained at rates of 240 and 360 grams per hectare.

### EXAMPLE 4

- 15       The experiment was carried out in Nobol, Ecuador, using 77 day-old transplants of rice cultivar INIAP 415. Each treatment was conducted on 10 hectare plots.

Transplanting was done on September 20, 1984. Ten weeks after transplanting, plots were sprayed with ETHREL (R) ethephon at rates of 240 and 360 g/ha using a knapsack spray system. At this time, flower primordia length is 5 mm.

- 5 Three applications of nitrogen were made (112 kg urea, 112 kg urea and 21 kg ammonia sulphate). Herbicides e.g. propanil, insecticides and miticides were used during the test to control weeds, armyworms, and mites.

#### Results

- 10 ETHREL (R) 480 applied at rates of 240 and 360 g/ha, produced significantly higher yields than the control. Results are shown in Table VI.

TABLE VI

Treatments	(g ai/ha)	Grain Yield/ha Kg	Increase over Control (%)
ETHREL (R) 480	240	5.485	14.7
ETHREL (R) 480	360	7.340	53.49
Control	-	4.782	-

#### EXAMPLE 5

- 15 Rice crop was planted in Ecuador on Dec. 20, 1984, and harvested June 6, 1985. ETHREL (R) 480 ethephon treatment was done 65-76 days after planting, at the stage when the

flower primordia was just formed (about 2-3 mm in length). Application rates were either 240 or 360 g/ha (0.25 or 0.75 l/ha). Application of ETHREL (R) ethephon was done using backpack sprayer.

5

## Results

Results are shown in Table VII.

TABLE VII

ETHREL (R) (g ai/ha)	Plant Height Before Application	Plant Height At Harvest	Number of Panicles/m <sup>2</sup>	
240	66 cm.	92 cm.	474	
360	64	88	414	
Control	66	80	390	

ETHREL (R) (g ai/ha)	Panicle Length	Number Grains Per Panicle	1000 Grain Weight	Yield
240	25 cm	169	22.8 g	8.381 kg/ha
360	24	196	20.7	7.740
Control	22	187	22.8	7.052

Plant height at harvest, number of panicles, and yield were significantly greater when ETHREL (R) was applied.

## EXAMPLE 6

10

ETHREL (R) ethephon was applied to rice crop (rice variety CR-1113) in Costa Rica. About 16 hectares were treated from the air with a dosage of ETHREL (R) ethephon 480 of 500 ml/ha at the time the flower primordia was first

formed. ETHREL (R) ethephon was tankmixed with fungicides and foliar fertilizers. A control of approximately 16 hectares was maintained. Weed control was done with arrosols and hormonals.

- 5 The crop was affected by draught which reduced the number of tillers per Plant. Harvesting was done on Nove. 28, 1984.

#### Results

Table VIII shows experimental results.

TABLE VIII

ETHREL (R) 480	Number of Panicles/Plant	Number Grains Per Panicle
0.5 (1/ha)	3.4	9.2
Control	2.4	66.25

- 10 The number of panicles per plant and number of grains per panicle were significantly greater with application ETHREL (R) 480.

What is claimed is:

1. A method of increasing the yield of rice plants, comprising applying ethephon to said plants, when said plants have progressed to a growth stage between about the end of effective tillering and about the initiation of panicle primordia, at rates from about 100 to about 500 grams per hectare.
2. A method as defined in claim 1, wherein said rates are from about 200 to about 400 grams per hectare.
3. A method as defined in claim 1, wherein said rates are from about 240 to about 360 grams per hectare.
4. A method as defined in claim 1, wherein application of ethephon is done by hand-held CO<sub>2</sub> charged sprayer.
5. A method as defined in claim 1, wherein application of ethephon is done by backpack sprayer.
6. A method as defined in claim 1, wherein application of ethephon is done by tractor-drawn sprayer.
7. A method as defined in claim 1, wherein application of ethephon is done by aerial sprayer.

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8. A method as define in claim 1, wherein the plants are at a growth stage about 7-10 days before initiation of panicle primordia.

5 9. A method as defined in claim 1, wherein the plants are at a growth stage about 7-10 days before maximum tillering.

10. A method as defined in claim 1, wherein the plants are at a growth stage of initiation of panicle primordia.

ABSTRACT

Foliar application of a phosphonic acid plant growth regulator to rice crop plants, when the plants are at a growth stage of between about the start of tillering and initiation of panicle primordia, at about 50 to about 750  
5 grams per hectare, results in rice yield significantly greater than untreated rice crops. The invention promotes manipulation of certain physiological processes at vegetative growth stages, thereby reducing decline in tiller number and increasing the number of seed producing tillers.

Received By:

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