

PATENT SPECIFICATION

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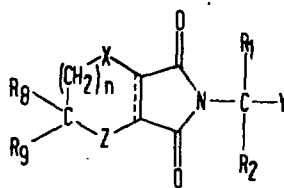
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 WALWORTH

(54) NOVEL CARBOXIMIDE COMPOUNDS AND THEIR USE AS PLANT GROWTH REGULANTS

(71) We, AMERICAN CYANAMID COMPANY, a corporation organised and existing under the laws of the State of Maine, United States of America, of Berdan Avenue, Township of Wayne, State of New Jersey, 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 certain carboximide compounds, to methods for their preparation and to their use as plant growth regulants or as intermediates in the preparation of plant growth regulants.

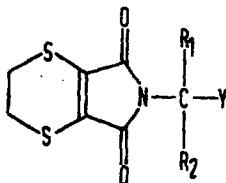
The compounds of the present invention are represented by the formula:



(I)

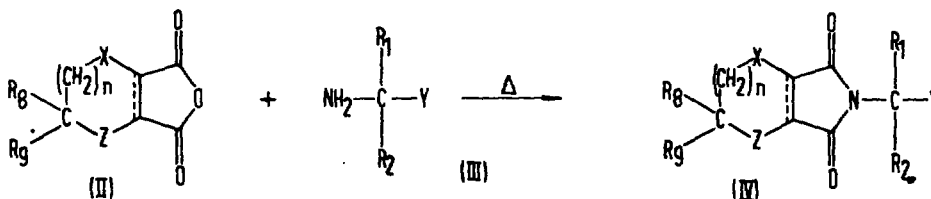
wherein X is CH₂ or S; Z is S, O or SO, provided that when Z is O, X cannot be S; Y is —COOR₃, —CONR₄R₅, —CONHNR₆R₇, —CONHNOR₈R₉R₁₀, halide⁻, CN, —CONHOH or —COR₁₀; n is 0 or 1; R₁ and R₂ each represent alkyl C₁—C₄, or when taken together with the carbon to which they are attached form cycloalkyl C₄—C₈ or methyl-substituted cycloalkyl C₄—C₈; R₃ is hydrogen or alkyl C₁—C₄; R₄ and R₅ each represent hydrogen, alkyl C₁—C₄, phenyl, monohalophenyl, monoalkyl(C₁—C₄)phenyl or monoalkoxy(C₁—C₄)phenyl; R₆ and R₇ are alkyl C₁—C₂; R₈ is hydrogen, alkyl C₁—C₄, phenyl, monohalophenyl, monoalkyl(C₁—C₄)phenyl, monoalkoxy(C₁—C₄)phenyl, mononitrophenyl or trifluoromethylphenyl; R₉ is hydrogen or alkyl C₁—C₄; R₁₀ is halogen; and — represents a single or double bond. These compounds show plant growth regulating properties, while certain of them are useful as intermediates for the preparation of other compounds having plant growth regulating properties. Compounds of the above structure, where Y is —COR₁₀ are primarily useful as intermediates for the preparation of plant growth regulating agents. Similarly, compounds having the above formula, wherein Y is —COOR₃ and R₃ is hydrogen, are also primarily useful as intermediates.

A preferred class of compounds of the present invention have the formula:



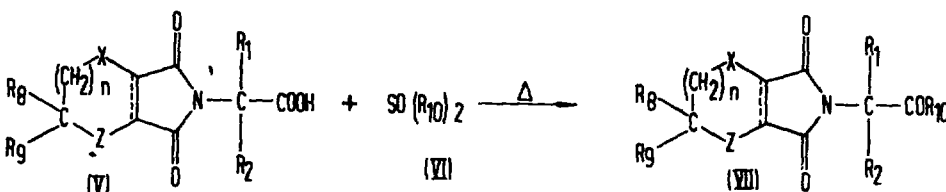
wherein Y is COOR_9 , CONR_6R_7 , $\text{CONHNR}_6\text{R}_7$, $\text{CONHNOR}_6\text{R}_7$, halide $^\ominus$, CN or COR_{10} ; R_1 and R_2 each represent alkyl ($\text{C}_1\text{--C}_4$) or when taken together with the carbon atom to which they are attached form cycloalkyl ($\text{C}_5\text{--C}_6$); R_3 , R_4 and R_5 each represent hydrogen or alkyl ($\text{C}_1\text{--C}_4$); R_6 and R_7 are alkyl ($\text{C}_1\text{--C}_2$), either the same or different; and R_{10} is halogen.

In accordance with the invention, the above-identified dithiindancarboximide, dithiolanedicarboximide, thiapyrandicarboximide and pyrandicarboximide compounds can be prepared by reacting the appropriate α -aminocarboxylic acid with the appropriate dithiindancarboxylic anhydride, dithiolanedicarboxylic anhydride, thiapyrandicarboxylic anhydride or pyrandicarboxylic anhydride, preferably in the presence of an aprotic solvent and a tertiary-amine, such as triethylamine. Among the solvents which are useful in carrying out this reaction are: benzene, toluene, xylene, dimethylformamide and acetic acid. In practice, the reaction is generally conducted at a temperature of from 80°C. to 225°C. , and preferably from 120°C. to 150°C. Alternatively, the required product can be prepared by fusing the α -amino acid or acid derivative and the anhydride, generally at temperatures from 150°C. to 250°C. , but preferably at 180°C. to 210°C. The reaction can be graphically illustrated as follows:



wherein X, Y, Z, n, R_1 , R_2 , R_8 and R_9 are as indicated above, with the exception that Y cannot be COR_{10} or $\text{CONHNOR}_6\text{R}_7$, halide $^\ominus$.

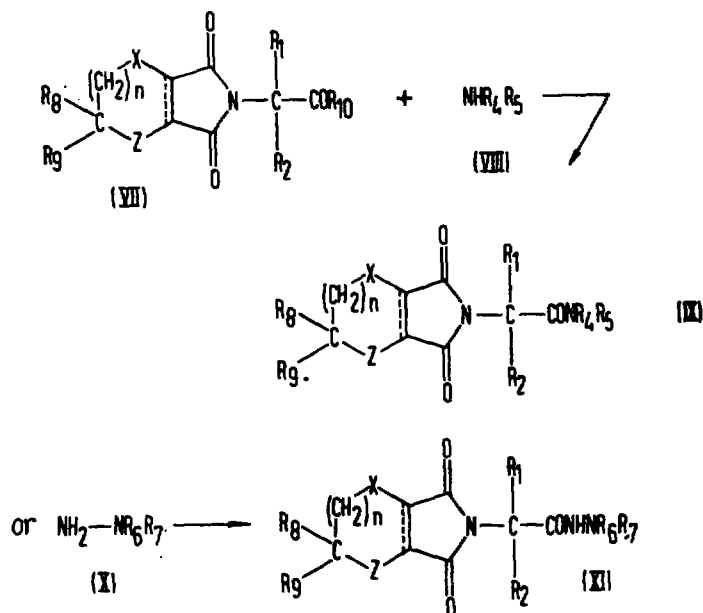
In the case where Y is COOH , the thus-formed acid can then be converted to the corresponding acid chloride or acid bromide by heating the acid with, for example, thionyl chloride, thionyl bromide or phosphorus pentachloride, preferably in the presence of an aprotic solvent, e.g. aromatic or chlorinated hydrocarbons such as benzene, xylene, toluene, methylene chloride, chloroform or dichloroethane. This reaction is graphically illustrated below, wherein thionyl halide, i.e. chloride or bromide, is representative of the halogenating agent employed.



wherein X, Z, n, R_1 , R_2 , R_8 , R_9 , and R_{10} are as described above.

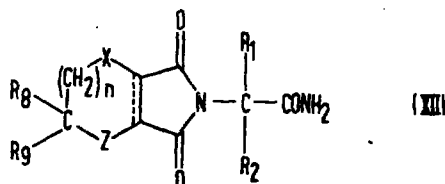
The thus-formed acid chloride or acid bromide can then be converted to the corresponding amide or hydrazide by reaction thereof with ammonia, hydroxylamine, monoalkylamine, dialkylamine or dialkyl hydrazine, e.g. at a temperature of from -20°C. to $+25^\circ\text{C.}$, and preferably -10°C. to $+15^\circ\text{C.}$ This reaction is preferably carried out by dissolving the acid halide in a solvent such as acetone or a water-miscible ether such as tetrahydrofuran or dioxane, and bubbling ammonia

gas through the thus-prepared solution while maintaining said solution in a stirred or agitated condition or by admixing the monalkylamine, dialkylamine or dialkylhydrazine with the thus-prepared solution. Alternatively, the amine, hydroxylamine or hydrazine can be dissolved in the solvent and then added to the acid halide in an aprotic solvent. The reaction can be graphically shown as follows:

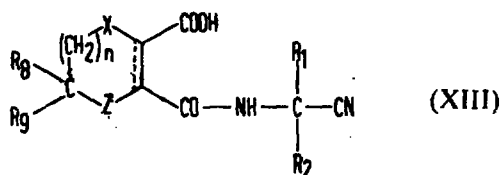


wherein X, Z, n, R₁, R₂, R₄, R₅, R₆, R₇, R₈ and R₁₀ are as defined above.

Alternatively, the dithiindicarboximido amides, dithiolanedicarboximido amides, thiapyrandicarboximido amides and pyrandicarboximido amides having the formula:

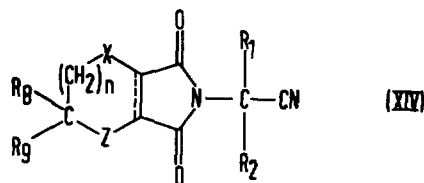


wherein X, Z, n, R₁, R₂, R₈ and R₉ are as described above, may be prepared by reacting the appropriate dithiindicarboxylic acid anhydride, dithiolanedicarboxylic acid anhydride, thiapyrandicarboxylic acid anhydride or pyrandicarboxylic acid anhydride with the appropriate α,α -di-substituted- α -aminonitrile to give the product:



wherein X, Z, n, R₁, R₂, R₈ and R₉ are as defined above. This reaction is generally carried out at temperatures from 20°C. to 60°C. in an inert solvent such as ether, tetrahydrofuran, chloroform, methylene chloride, benzene, toluene or acetonitrile. The thus-formed acid is then cyclized to the corresponding carboximide either thermally or by treating with a dehydrating agent such as acetic anhydride,

acetyl chloride or thionyl chloride, for example at temperatures from 0°C. to 100°C. The resulting product,



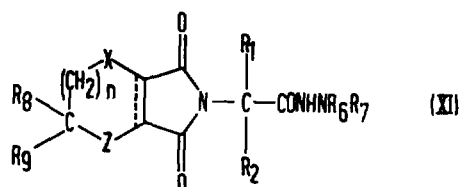
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in which X, Z, n, R₁, R₂, R₈ and R₉ are as defined above, is converted to the active amide by hydration of the nitrile function. This reaction is preferably carried out with a strong acid such as sulfuric acid, preferably in the presence of a non-miscible solvent such as methylene chloride or chloroform, at temperatures from -10°C. to +30°C.

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Where a hydrazinium halide is desired, a hydrazide having the formula:

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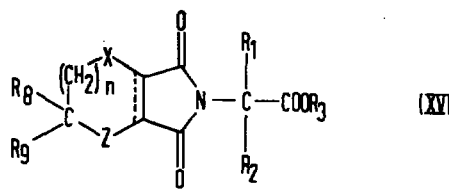
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wherein X, Z, n, R₁, R₂, R₆, R₇, R₈ and R₉ are as defined above, can be treated with an alkyl halide in the presence of a solvent such as tetrahydrofuran, ether, dioxane, benzene or chloroform, at an elevated temperature to yield the desired corresponding hydrazinium halide.

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To obtain the active dicarboximido ester represented by the formula:

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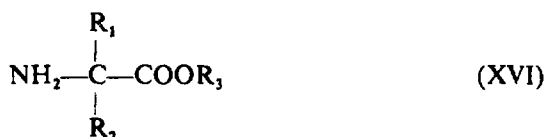


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wherein X, Z, n, R₁, R₂, R₈ and R₉ are as defined above, and R₃ is alkyl C₁-C₄, the corresponding acid, i.e. where R₃ is hydrogen, is treated with a diazoalkane C₁-C₄ in the presence of a solvent such as an ether. This reaction is generally carried out at a temperature of from -10°C to +30°C.

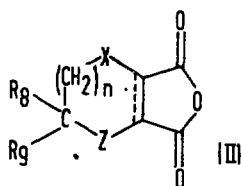
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Alternatively, the appropriate α-amine ester:



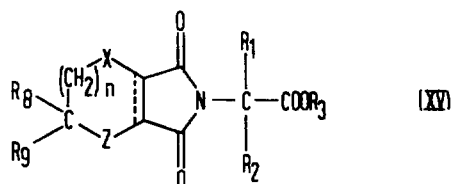
wherein R₁ and R₂ are as defined above and R₃ is alkyl C₁-C₄, can be allowed to react with the appropriate dicarboxylic anhydride:

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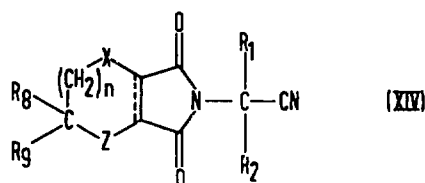
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wherein X, Z, n, R₈ and R₉ are as defined above, to afford the corresponding ester:



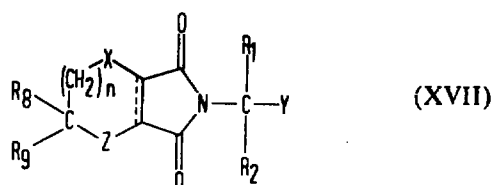
wherein R₃ is alkyl C₁—C₄ and X, Z, n, R₁, R₂, R₈ and R₉ are as previously defined. In yet another procedure, the acid halide, prepared as above, may be treated with a C₁—C₄ alkanol in the presence of an acid acceptor such as pyridine, triethylamine or sodium bicarbonate.

The dicarboximido nitrile:

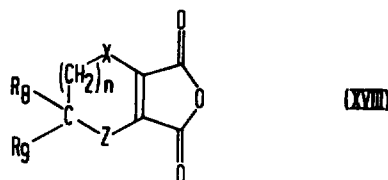


wherein R₁, R₂, R₈, R₉, X, Z and n are as defined above, may be obtained by dehydration of the corresponding amide using titanium tetrachloride, acetic anhydride, phosphorus pentoxide or phosphorus oxychloride, in the presence of a solvent such as benzene or tetrahydrofuran. This reaction is generally carried out at a temperature of from 0°C. to 100°C.

A preferred method of the present invention for the preparation of a compound of the formula:



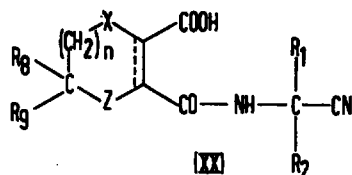
wherein Y is —CN and R₁ and R₂ each represent alkyl C₁—C₄, or when taken together with the carbon to which they are attached form cycloalkyl C₄—C₈; X is CH₂ or S; Z is S, O or SO, provided that when Z is O, X cannot be S; R₈ is hydrogen, alkyl C₁—C₄, phenyl, monohalophenyl, monoalkyl (C₁—C₄) phenyl, monoalkoxy (C₁—C₄) phenyl, mononitrophenyl or trifluoromethylphenyl; R₉ is hydrogen or alkyl C₁—C₄; — is a double or single bond; and n is 0 or 1; is characterized by reacting a compound of the structure:



wherein n, X, Z, R₈ and R₉ are as defined above, with a compound of the formula:

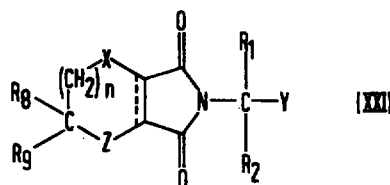


wherein R_1 and R_2 are as defined above in relation to formula (XVII), in the presence of an inert solvent at a temperature of from 20°C. to 60°C. to form a product of the formula:

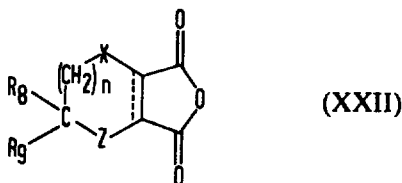


- 5 wherein R_1 , R_2 , R_8 , R_9 , X , Z and n are as defined above in relation to formula (XVII) and thereafter cyclizing the product by heating. 5

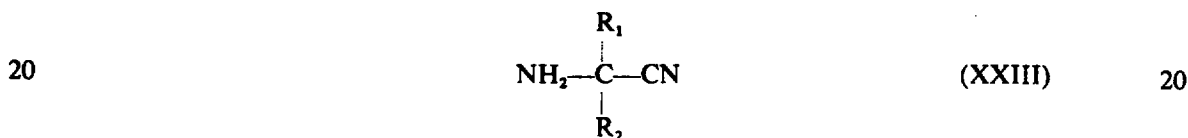
A further method of the present invention involves the preparation of a compound of the formula:



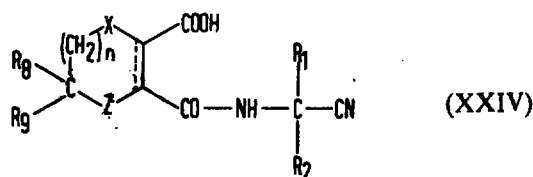
- 10 wherein Y is $-\text{CN}$ or $-\text{CONH}_2$; X is CH_2 or S ; Z is S , O or SO , providing that 10
when Z is O , X cannot be S ; R_1 and R_2 each represent alkyl C_1-C_4 or when taken together with the carbon to which they are attached form cycloalkyl C_4-C_8 ; n is 0 or 1; R_8 is hydrogen, alkyl C_1-C_4 , phenyl, monohalophenyl, monoalkyl(C_1-C_4)-phenyl, monoalkoxy(C_1-C_4)phenyl, mononitrophenyl, or trifluoromethylphenyl; 15
15 R_9 is hydrogen or alkyl C_1-C_4 ; $---$ is a double or single bond; by a method which is characterized by reacting a compound of the formula:



wherein X , Z , n , R_8 and R_9 are as defined above in relation to formula (XXI), with a compound of the formula:



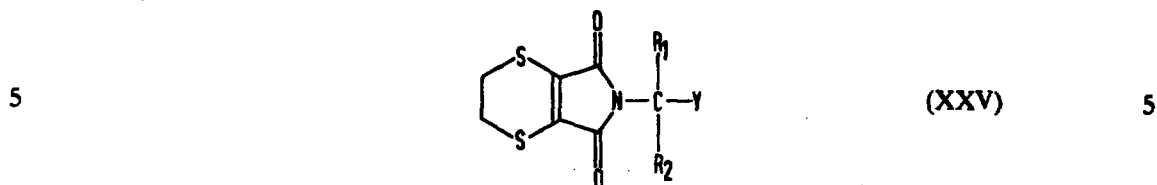
wherein R_1 and R_2 are as defined above in relation to formula (XXI), in the presence of an inert solvent at a temperature of from 20°C. to 60°C. to form a product of the formula:



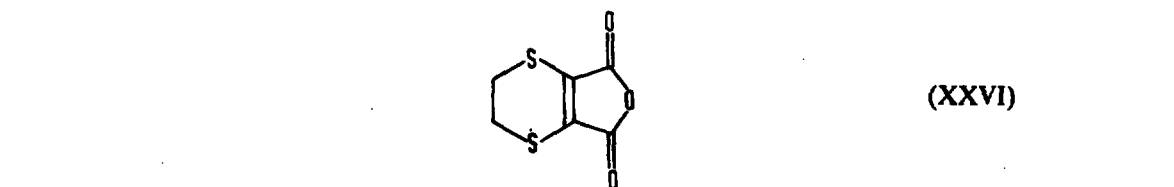
- 25 wherein X , Z , n , R_1 , R_2 , R_8 and R_9 are as defined above in relation to formula (XXI); and thereafter cyclizing the product by heating and treating the thus- 25

formed reaction product with a strong acid at a temperature of from -10°C. to $+30^{\circ}\text{C.}$

A still further preferred method of the present invention involves the preparation of a compound of the formula:



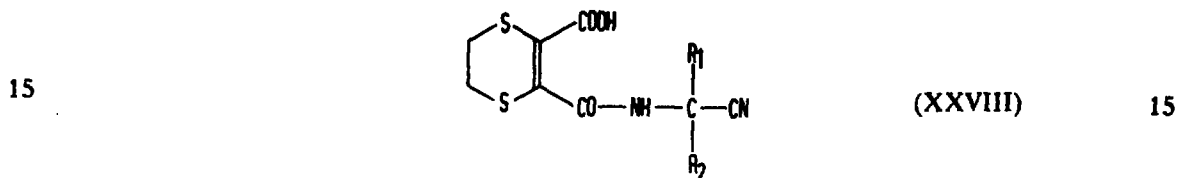
wherein Y is $-\text{CN}$ and R_1 and R_2 each represent alkyl C_1-C_4 or when taken together with the carbon to which they are attached form cycloalkyl C_4-C_8 ; by a method characterized by reacting a compound of the formula:



with a compound of the formula:

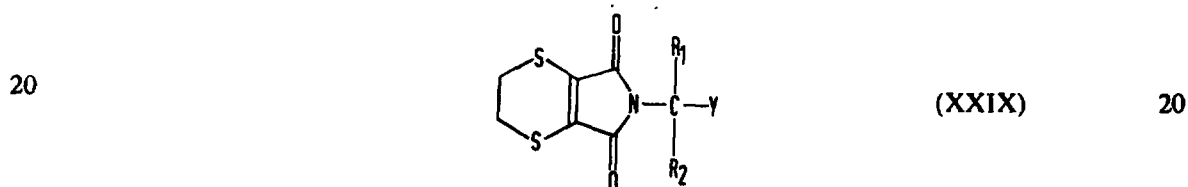


wherein R_1 and R_2 are as defined above in relation to formula (XXV), in the presence of an inert solvent at a temperature of from 20°C. to 60°C. to form a product of the formula:



wherein R_1 and R_2 are as defined above in relation to formula (XXV); thereafter cyclizing the product by heating.

A further preferred method according to the present invention involves the preparation of a compound of the formula:



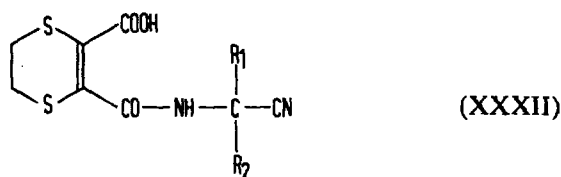
wherein Y is $-\text{CN}$ or $-\text{CONH}_2$; and R_1 and R_2 each represent alkyl C_1-C_4 or when taken together with the carbon to which they are attached form cycloalkyl C_4-C_8 ; characterized by reacting a compound of the formula:



with a compound of the formula:

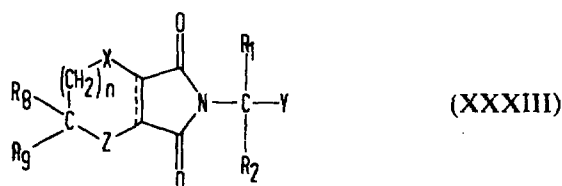


wherein R_1 and R_2 are as defined above in relation to formula (XXIX), in the presence of an inert solvent at a temperature of from 20°C. to 60°C. to form a product of the formula:



wherein R_1 and R_2 are as defined above in relation to formula (XXIX); thereafter cyclizing the product by heating and treating the thus-formed reaction product with a strong acid at a temperature of from -10°C. to +30°C.

The method for regulating the growth of plants according to the present invention comprises applying to the foliage, roots, stems, seeds, seed pieces or to soil in which the plants are grown a compound of the formula:



wherein n , X , Z , Y , R_1 , R_2 , R_8 , R_9 and $---$ are as defined in relation to formula I, with the provisos that Y is not $-\text{COR}_{10}$ nor $-\text{COOH}$.

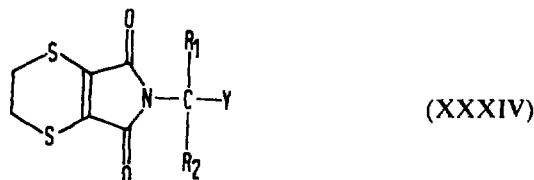
Preferred growth regulating compounds of this invention are those represented by the above formula (XXXIII), wherein X and Z are each sulfur, and Y , n , R_1 , R_2 , R_8 and R_9 are as defined above in relation to this formula; and particularly preferred compounds as those in which n is 1.

Another group of preferred growth regulating compounds are those represented by the above formula (XXXIII), wherein X is CH_2 ; Z is oxygen; and n , Y , R_1 , R_2 , R_8 and R_9 are as defined above in relation to the formula.

A further group of preferred growth regulating compounds are depicted by the above formula (XXXIII), wherein X is CH_2 ; Z is sulphur; and n , Y , R_1 , R_2 , R_8 and R_9 are as defined above in relation to the formula.

A still further group of preferred growth regulating compounds are illustrated by the above formula (XXXIII) wherein X is S ; Z is SO ; and n , Y , R_1 , R_2 , R_8 and R_9 are as defined above in relation to the formula.

Another preferred group of growth regulating compounds of the present invention are those having the formula:



wherein Y is $-\text{COOR}_3$, $-\text{CONR}_4R_5$, $-\text{CONHNR}_6R_7$, $-\text{CONHN}^+R_6R_7R_8$, halide or CN ; R_1 and R_2 each represent alkyl C_1-C_4 or when taken together with the carbon to which they are attached form cycloalkyl C_4-C_8 ; R_3 is alkyl C_1-C_4 ; R_4 and R_5 each represent hydrogen or alkyl C_1-C_4 ; and R_6 and R_7 are alkyl C_1-C_2 , either the same or different.

(18)

9		1,443,669	9
	Particularly preferred growth regulating compounds are 1-(5,6-dihydro- <i>p</i> -dithiin-2,3-dicarboximido) cyclohexanecarboxamide; 1-(5,6-dihydro- <i>p</i> -dithiin-2,3-dicarboximido) cyclopentanecarboxamide; and 1-(5,6-dihydro- <i>p</i> -dithiin-2,3-dicarboximido)-N,N-dimethyl-cyclohexanecarboxamide.		
5	A preferred embodiment of the growth regulating method is where the active compound is applied to the seeds, seed pieces or soil containing seeds or seed pieces of the plants for which plant growth regulation is desired. An alternative preferred embodiment is where the compound is applied to the foliage and stems of the plants for which plant growth regulation is desired, preferably at a rate of		
10	from 0.06 pound to 32 pounds per acre. Another alternative preferred embodiment is where the compound is applied to the roots of the plants for which plant growth regulation is desired.		10
15	The various methods include the use of the above compounds for the treatment of plants wherein the treated plants are agronomic crops and said treatment produces increased crop yields; or the treated plants are agronomic crops planted as seed crops and said treatment accelerates flowering and bolting; or the treated plants are leaf crops and said treatment increases leaf size; or the treated plants are tuberous plants or root crops and said treatment increases root set and/or root size and weight.		15
20	A very surprising aspect of the invention is the finding that although the plant growth regulating effects of the compounds within the generic class described above sometimes varies from plant to plant and from compound to compound, the compounds are often highly active at low rates of application and do not appear to be phytotoxic when applied at relatively high rates. In practice, it will generally be		20
25	found desirable to employ from 0.06 pound to 32 pounds per acre, and preferably 0.06 pound to 4.0 pounds per acre of the active dicarboximido compound in the treated area to obtain the desired plant growth regulant effect.		25
	Among the desired effects obtainable with preferred compounds of the invention are:		
30	(A) Increased internode growth in certain crops evidenced by longer internodes having increased dry weight;		30
	(B) Increased leaf size in certain crops evidenced by both increased leaf area and increased dry weight of leaves;		
35	(C) Induced flowering and/or bolting in certain varieties of plants;		35
	(D) Increased tuber set in tuberous plants;		
	(E) Increased height of certain seedling plants, and dwarfing of other plant species;		
	(F) Delay of senescence, especially in flowering plants;		
40	(G) Enhanced viability or improved germination of seed grown on plants treated with the compounds of the present invention.		40
45	The advantages obtained with increased internode length are many. They include, in addition to a general increase in the total size and weight of the plant, opening or spreading of plant leaves which generally makes the plant less vulnerable to disease through better ventilation. Moreover, increased internode length has particular advantage for crops such as tobacco, sugar cane, timber and seed corn. Elongation of tobacco internodes elevates the lower tobacco leaves from the ground surface sufficiently to prevent their normal destruction or damage by the elements (i.e. abrasion, disease, etc.).		45
50	With sugar cane and timber, longer internodes produce larger cane and trees, resulting in greater yields of sugar and lumber; whereas, longer internodes in seed corn raise the corn tassel, i.e. the male organ of the plant, high enough that it can be removed from all plants in a field with a single cutting before pollination occurs. Controlled pollination, to provide a desired hybrid corn, can then be effected at will.		50
55	The advantage of increasing the leaf size of plants is obvious and of particular importance for those plants wherein the leaves constitute the marketable crop. Tobacco, forage crops and leafy vegetables such as spinach, swiss chard, lettuce and cabbage exemplify such crops.		55
60	Accelerated flowering and bolting is important for crops which are grown for seed including crops such as lettuce, radish, sugar beets, red beets, brussel sprouts, broccoli and carrots. Accelerated flowering effect shows also reduced time to harvest, thus enhancing the possibility of multiple cropping versus single cropping.		60
65	Increased set in tuberous plants such as potatoes is another important advantage obtainable with some compounds at least of this invention, since the treated plants may develop two to three times as many potatoes as the untreated		65

plants. Moreover, the potatoes on treated plants are vastly more uniform than those on untreated plants, although they are only average in size. This, however, is an advantage where the potatoes are to be used for canning. Increased size in certain crops such as sugar beets may also be obtained with the use of the compounds of this invention.

Dwarfing of plants is yet another advantage obtainable with some compounds at least of the present invention and is of particular importance for treatment of ornamental plants and shrubs.

Another advantage is the finding that seeds obtained from plants treated with some compounds at least of the present invention are more viable and germinate better than seeds from untreated plants.

A still further advantage obtainable with some compounds at least of the present invention is the delay of senescence in plants. This effect is especially important to nursery men and florists who desire to extend the life of the blooms in flowering plants.

Several of the above plant regulating effects have been noted to increase yields. Yield increases are also obtained in other crops; for example, soybeans, sugar beets, or the like, either as a result of one or more of the above-enumerated growth regulating effects, or, perhaps, as a result of a more direct influence on yield.

We have also found that the effectiveness of the compounds of the invention as plant growth regulating agents is not in general limited by formulation or method of application. The active compounds may be formulated as dusts, dust concentrates, wettable powders, about 80% by weight of a solid carrier such as kaolin. Suitable equipment for such preparations are ribbon-type blenders and double-cone blenders. It is also obvious that the concentration of active ingredient in dust formulations can be readily varied by adjusting the amount of wettable powder and carrier used. Typical dusts will generally vary from 1% to 15% by weight of active ingredient, although higher concentrations may also be prepared.

An alternative process for preparation of dusts, also dust concentrates, involves blending the active dicarboximide derivative with the solid carrier and passing the uniform blend through an attrition mill to obtain the desired particle size.

A typical granular formulation can be prepared by blending a small amount, i.e. about 0.3% by weight, of a fumed colloidal silica with about 5.6% by weight of the above-said dithiin derivative and air-milling the mixture to a uniform blend. Silica sand, about 85.7% by weight, is then placed in a blender along with about 0.7% by weight of calcium-sodium lignin sulfonate powder and 4.2% of a 1% aqueous solution of calcium-sodium lignin sulfonate. The mixture is blended and then 3.5% by weight of synthetic calcium silicate is added. The mixture is permitted to continue blending for several minutes until the finished product is uniformly coated and free flowing. It is, of course, obvious that the amount of active ingredient in the formulated granular product can be widely varied, preferably from 1% to 15% by weight. This simply requires appropriate adjustment of the amount of granular carrier used and/or adjuvants added. It is likewise obvious that sorptive granular carriers, as well as non-sorptive carriers, can be employed in the preparation of the granular formations.

The invention is illustrated by the Examples which follow. Examples 1, 2 and 14 relate to the preparation of starting materials.

Example 1.

Preparation of 5,6-Dihydro-5-phenyl-*p*-dithiin-2,3-dicarboxylic anhydride.

To a stirred suspension of 18.6 g. of the disodium salt of 1,2-dicyano-1,2-dimercaptoethylene under nitrogen is added 26.4 g. of 1,2-dibromo-1-phenylethane. After stirring at 40°C. for one-half hour, the mixture is heated under reflux for 1.5 hours, cooled, filtered, and the solvent removed under reduced pressure. The residue is crystallized by filtration with carbon tetrachloride to give the product, 2,3-dicyano-5,6-dihydro-5-phenyl-*p*-dithiin, as golden brown crystals, melting point 121.5°C. to 124°C. A purified sample had melting point 125°C. to 126.5°C.

Hydrolysis of the dinitrile is accomplished by stirring 16.0 g. dinitrile in 71 ml. concentrated sulfuric acid and adding slowly 66 ml. water so that the temperature of the mixture reaches approximately 120°C. The mixture is held at this temperature for 5 hours after which it is poured on ice, the resulting precipitate filtered, washed with water and air-dried. This solid is recrystallized from

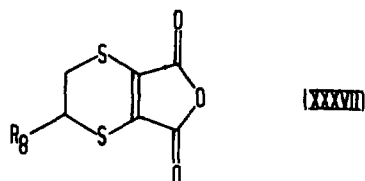
chloroform to give the desired anhydride, melting point 131°C. to 133°C. The analytical sample is obtained from methylcyclohexane and has melting point 139°C. to 139.5°C.

Example 2.

5 Preparation of 5-Substituted-5,6-dihydro-*p*-dithiin-2,3-dicarboxylic anhydrides. 5

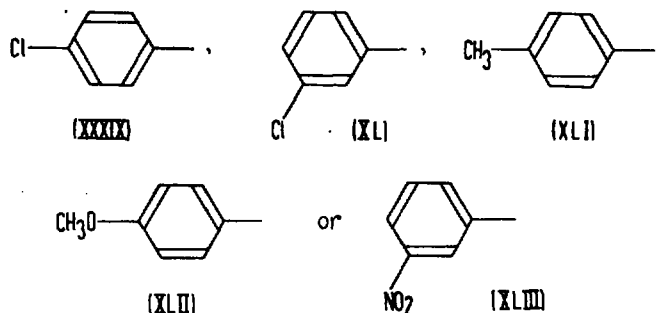
Utilizing the procedure set forth in Example 1, but substituting the appropriate substituted 1-phenyl-1,2-dibromoethane or 1,2-dibromopropane for 1,2-dibromo-1-phenylethane, the following 5,6-dihydro-*p*-dithiin-2,3-dicarboxylic anhydrides are prepared:

10



10

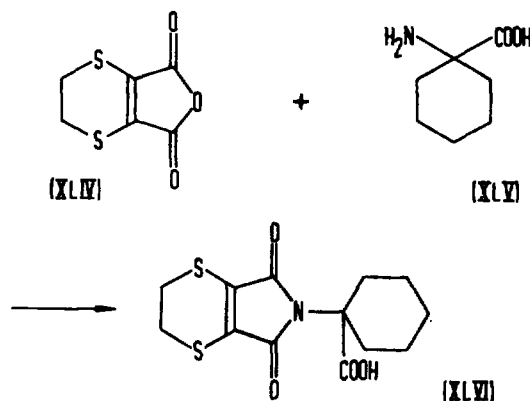
wherein $R_8 = \text{CH}_3$ — (melting point 173°C. to 174°C.) or



15

Example 3.

15 Preparation of 1-(5,6-Dihydro-*p*-dithiin-2,3-dicarboxamido)cyclohexanecarboxylic acid. 15



20

A stirred mixture containing 7.3 g. of 1-amino-cyclohexanecarboxylic acid, 9.4 g. of 5,6-dihydro-*p*-dithiin-2,3-dicarboxylic anhydride and 1 ml. of triethylamine in 150 ml. xylene is heated under reflux under a Dean-Stark water separator for 16 hours. The hot solution is filtered, and the filtrate reduced in volume to 50 ml. The mixture is cooled, and the product, 1-(5,6-dihydro-*p*-dithiin-2,3-dicarboximido)cyclohexanecarboxylic acid, melting point 187°C. to 188.5°C., removed by filtration and air-dried. The crude product is recrystallized from xylene to give an analytically pure sample, melting point 189°C. to 190°C.

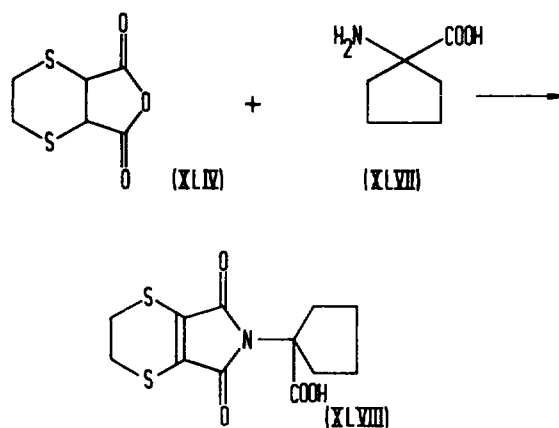
20

25

Analysis: Calculated for $\text{C}_{13}\text{H}_{15}\text{NO}_4\text{S}_2$: C, 49.82; H, 4.82; N, 4.47. Found: C, 50.19; H, 4.59; N, 4.28.

25

Example 4.
Preparation of 1-(5,6-Dihydro-*p*-dithiin-2,3-dicarboximido)cyclopentanecarboxylic acid.



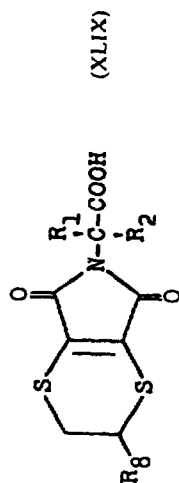
5 Following the procedure described in Example 3, but substituting 1-amino-
cyclopentanecarboxylic acid for 1-aminocyclohexanecarboxylic acid, the product,
1-(5,6-dihydro-*p*-dithiin-2,3-dicarboximido)cyclopentanecarboxylic acid is
obtained, which can be recrystallized from toluene, melting point 169°C. to
170°C.

10 Analysis: Calculated for $C_{12}H_{13}NO_4S_2$: C, 48.15; H, 4.38; N, 4.68. Found: C, 48.52;
H, 4.25; N, 4.64.

15 Other 5,6-dihydro-*p*-dithiin-2,3-dicarboximidocarboxylic acids which can
be prepared by the above procedure, but substituting the appropriate α -amino-
carboxylic acid for 1-aminocyclopentanecarboxylic acid, are reported in Table I
below.

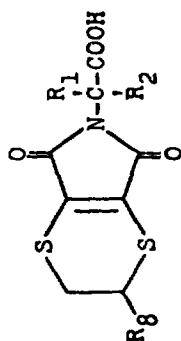
22

TABLE I



Compound No.	R ₈	R ₁	R ₂	Solvent	Melting Point °C
1	H	CH ₃	-CH ₂ CH(CH ₃) ₂	Xylene	
2	H	CH ₃	-CH ₂ CH ₂ CH ₃	Xylene	
3	H		-(CH ₂) ₇ -	Xylene	
4	H		-(CH ₂) ₆ -	Toluene	
5	H	CH ₃	-CH(CH ₃) ₂	Toluene	188.5-189.5
6	H	C ₂ H ₅	-C ₂ H ₅	Xylene	
7	H	C ₂ H ₅	-CH(CH ₃) ₂	Xylene	

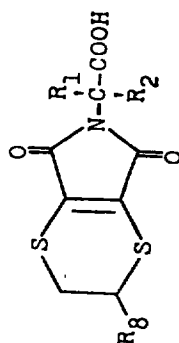
TABLE I (continued)



Compound No.	R ₈	R ₁	R ₂	Solvent	Melting Point °C
8	H	C ₂ H ₅	-CH ₂ CH(CH ₃) ₂	Toluene	
9	H	C ₃ H ₇	-C ₃ H ₇	Toluene	
10	H		-(CH ₂) ₃ -	Xylene	
11	H	CH ₃ -CH ₂ -CH-CH ₂ -CH ₂ -CH ₂ -		Xylene	222-223
12	CH ₃		-(CH ₂) ₅ -	Xylene	

(24)

TABLE I (continued)



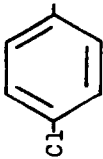
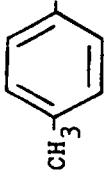
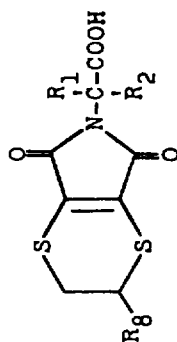
Compound No.	R_8	R_1	R_2	Solvent	Melting Point $^{\circ}C$
13	C_6H_5		$-(CH_2)_5-$	Acetic Acid	
14			$-(CH_2)_5-$	Acetic Acid	
15			$-(CH_2)_5-$	Acetic Acid	

TABLE I (continued)



Compound No.	R_8	R_1	R_2	Solvent	Melting Point $^{\circ}\text{C}$
16			$-(\text{CH}_2)_5-$	Acetic Acid	
17			$-(\text{CH}_2)_5-$	Acetic Acid	

66

Example 5.

Preparation of 1-(5,6-Dihydro-*p*-dithiin-2,3-dicarboximido)cyclohexanecarbonyl chloride.

5 A stirred mixture containing 6.0 g. of 1-(5,6-dihydro-*p*-dithiin-2,3-dicarboximido)cyclohexanecarboxylic acid and 1.8 ml. thionyl chloride in 50 ml. benzene is heated under reflux for 3.5 hours. The solvent and excess thionyl chloride are removed under reduced pressure, and the residual oil, characterized only by its infrared spectrum, is essentially pure 1-(5,6-dihydro-*p*-dithiin-2,3-dicarboximido)cyclohexanecarbonyl chloride. 5

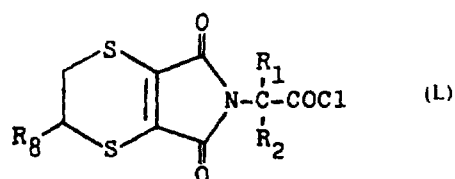
Example 6.

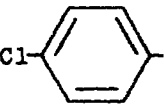
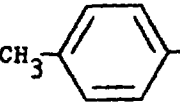
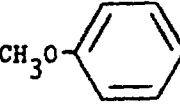
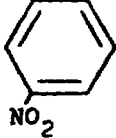
10 Preparation of 1-(5,6-dihydro-*p*-dithiin-2,3-dicarboximido)cyclopentanecarbonyl chloride. 10

15 Using the procedure set forth in Example 5, but substituting 1-(5,6-dihydro-*p*-dithiin-2,3-dicarboximido)cyclopentanecarboxylic acid for 1-(5,6-dihydro-*p*-dithiin-2,3-dicarboximido)cyclohexanecarboxylic acid, the product, 1-(5,6-dihydro-*p*-dithiin-2,3-dicarboximido)cyclopentanecarbonyl chloride is obtained, characterized only by its infrared spectrum. 15

20 This procedure is repeated, but substituting the appropriate acid for 1-(5,6-dihydro-*p*-dithiin-2,3-dicarboximido)cyclopentanecarboxylic acid to yield the compounds given in Table II below. 20

TABLE II



Compound No.	R ₈	R ₁	R ₂
1	H		-(CH ₂) ₇ -
2	H		-(CH ₂) ₆ -
3	H		-(CH ₂) ₃ -
4	H	CH ₃	-CH(CH ₃) ₂
5	H	CH ₃	-CH ₂ CH(CH ₃) ₂
6	H	CH ₃	-CH ₂ CH ₂ CH ₃
7	H	C ₂ H ₅	-C ₂ H ₅
8	H	C ₂ H ₅	-CH(CH ₃) ₂
9	H	C ₃ H ₇	-C ₃ H ₇
10	H		$\begin{array}{c} \text{CH}_3 \\ \\ -\text{CH}_2-\text{CH}-\text{CH}_2-\text{CH}_2-\text{CH}_2- \end{array}$
11	CH ₃		-(CH ₂) ₅ -
12	C ₆ H ₅		-(CH ₂) ₅ -
13			-(CH ₂) ₅ -
14			-(CH ₂) ₅ -
15			-(CH ₂) ₅ -
16			-(CH ₂) ₅ -

68

Example 7.

Preparation of 1-(5,6-Dihydro-*p*-dithiin-2,3-dicarboximido)cyclohexanecarboxamide.

5 The 1-(5,6-dihydro-*p*-dithiin-2,3-dicarboximido)cyclohexanecarbonyl chloride prepared in Example 5 is dissolved in 100 ml. tetrahydrofuran and cooled to 5°C. Ammonia gas is bubbled through the stirred solution until a slight excess is added. The mixture is filtered to remove inorganic salts, the filtrate concentrated at reduced pressure and the residue crystallized from methanol to give 1-(5,6-dihydro-*p*-dithiin-2,3-dicarboximido)cyclohexanecarboxamide, melting point 188°C. to 189.5°C. 10
Analysis: Calculated for $C_{13}H_{16}N_2O_3S_2$: C, 49.98; H, 5.16; N, 8.97. Found: C, 50.02; H, 5.08; N, 8.85. 10

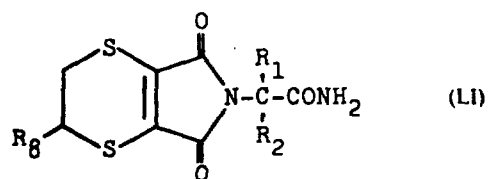
Example 8.

Preparation of 1-(5,6-Dihydro-*p*-dithiin-2,3-dicarboximido)cyclopentanecarboxamide.

15 Using the procedure set forth in Example 7, but substituting 1-(5,6-dihydro-*p*-dithiin-2,3-dicarboximido)cyclopentanecarbonyl chloride for 1-(5,6-dihydro-*p*-dithiin-2,3-dicarboximido)cyclohexanecarbonyl chloride, the product, 1-(5,6-dihydro-*p*-dithiin-2,3-dicarboximido)cyclopentanecarboxamide, is obtained, melting point 195°C. to 196°C. 15
Analysis: Calculated for $C_{12}H_{14}N_2O_3S_2$: C, 48.30; H, 4.73; N, 9.39. Found: C, 48.44; H, 4.72; N, 9.46. 20

25 The carboxamides of Table III below are prepared by the above procedure, but substituting the appropriate acid chloride for 1-(5,6-dihydro-*p*-dithiin-2,3-dicarboximido)cyclopentanecarbonyl chloride. 25

TABLE III



Compound No.	R ₁	R ₂	R ₈	Melting Point °C
1		-(CH ₂) ₃ -	H	
2		-(CH ₂) ₇ -	H	
3		-(CH ₂) ₆ -	H	
4	CH ₃	-CH ₂ CH ₂ CH ₃	H	
5	C ₂ H ₅	-C ₂ H ₅	H	
6	CH ₃	-CH(CH ₃) ₂	H	184-186.5
7	CH ₃	-CH ₂ CH(CH ₃) ₂	H	163-164
8	C ₂ H ₅	-CH(CH ₃) ₂	H	
9	C ₃ H ₇	-C ₃ H ₇	H	
10		$\begin{array}{c} \text{CH}_3 \\ \\ -\text{CH}_2-\text{CH}-\text{CH}_2-\text{CH}_2-\text{CH}_2- \end{array}$	H	238-239
11		-(CH ₂) ₅ -	CH ₃	129-131
12		-(CH ₂) ₅ -	C ₆ H ₅	100-112 (decomp.)
13		-(CH ₂) ₅ -		
14		-(CH ₂) ₅ -		
15		-(CH ₂) ₅ -		
16		-(CH ₂) ₅ -		

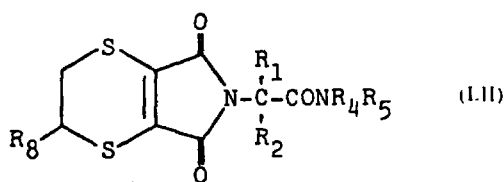
Example 9.

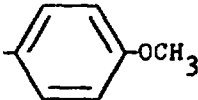
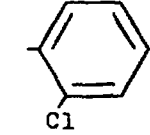
Preparation of 1-(5,6-Dihydro-*p*-dithiin-2,3-dicarboximido)-*N,N*-dimethylcyclohexanecarboxamide.

A solution containing 10 g. of 1-(5,6-dihydro-*p*-dithiin-2,3-dicarboximido)-cyclohexanecarbonyl chloride in 50 ml. tetrahydrofuran is cooled to 10°C. to 15°C., and while stirring, gaseous dimethylamine is bubbled into the solution until saturated. After a further 5 minutes, the mixture is filtered to remove salts and the solvent removed from the filtrate to give the above-named product, melting point 169°C. to 170.5°C.

The *N*-substituted carboxamides of Table IV, below, are prepared using essentially the same procedure described above.

TABLE IV



Compound No.	R ₁	R ₂	R ₄	R ₅	R ₈	Melting Point °C
1	-(CH ₂) ₄ -		CH ₃	CH ₃	H	-
2	-(CH ₂) ₆ -		CH ₃	CH ₃	H	-
3	-(CH ₂) ₅ -		H		H	225-226
4	-(CH ₂) ₅ -		H		H	129-130
5	-(CH ₂) ₅ -		H	CH ₃	H	178-179

Example 10.

Preparation of 1-(5,6-Dihydro-*p*-dithiin-2,3-dicarboximido)cyclohexanecarboxylic acid, 2,2-Dimethylhydrazide.

To an ice-cold solution of 1-(5,6-dihydro-*p*-dithiin-2,3-dicarboximido)-cyclohexanecarboxylic acid chloride in tetrahydrofuran is added dropwise two equivalents of 1,1-dimethylhydrazine. After stirring a further 0.5 hour, the solids are removed by filtration and the solvent removed *in vacuo* from the filtrate to give the above-named product, melting point 149°C. to 150°C.

Example 11.

Preparation of 2-[1-(5,6-Dihydro-*p*-dithiin-2,3-dicarboximido)cyclohexylcarbonyl]-1,1,1-trimethylhydrazinium bromide.

To the dimethylhydrazide prepared as in Example 10, is added excess methyl bromide and the mixture stirred in a pressure bottle for two days. Excess methyl bromide was removed by evaporation to leave the above quaternary bromide, melting point 176°C. to 177°C. The bromide can be converted to the corresponding chloride by passing a 50% aqueous ethanol solution of the salt

slowly down a column packed with Amberlyst A21, an organic ion exchange resin, in its chloride form, and evaporating the eluent. The residue is crystallized from ethanol-ether to give the chloride salt.

Example 12.

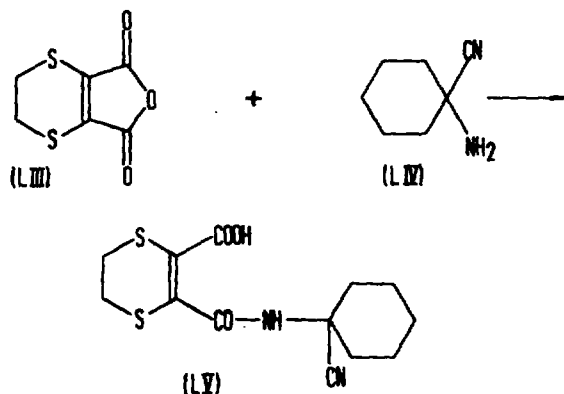
5 Preparation of Ethyl 1-(5,6-Dihydro-*p*-dithiin-2,3-dicarboximido)cyclohexanecarboxylate.

An excess of an ether solution of diazoethane is added to a solution of 1-(5,6-dihydro-*p*-dithiin-2,3-dicarboximido)cyclohexanecarboxylic acid in ether. After standing for one hour at room temperature, the solution is washed with excess aqueous sodium carbonate solution, followed by two water washes. The organic phase is dried and the solvent evaporated under reduced pressure to give the above-named product.

Alternatively, this ester can be prepared by the action of ethanol and pyridine on the acid chloride, described in Example 5.

Example 13.

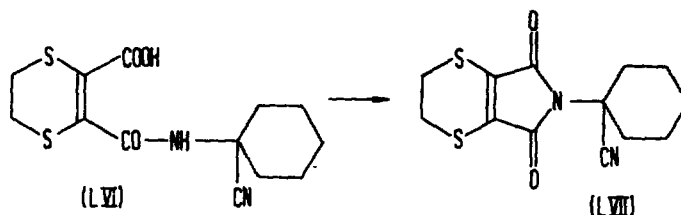
15 Preparation of 3-[N-(1-cyanocyclohexyl)carbamoyl]-5,6-dihydro-*p*-dithiin-2-carboxylic acid.



To a stirred suspension of 1.88 g. anhydride in 50 ml. ether is added 1.24 g. of the aminonitrile. The mixture is heated under reflux for 5 hours. The crystalline product is removed by filtration, washed with acetonitrile and dried to give the title compound, melting point 133°C. to 134°C. (decomp.).

Example 14.

25 Preparation of 1-(5,6-Dihydro-*p*-dithiin-2,3-dicarboximido)cyclohexanecarbo-nitrile.



A suspension of the acid in acetonitrile is heated under reflux for 3 hours. The colorless solid dissolves to give a bright yellow solution. The solvent is removed and the residue crystallized from methanol to give the title compound, melting point 123°C. to 124°C. Analysis Calculated for $C_{13}H_{14}N_2O_2S_2$: C, 53.04; H, 4.79; N, 9.52. Found: C, 53.31; H, 4.94; N, 9.58.

Example 15.

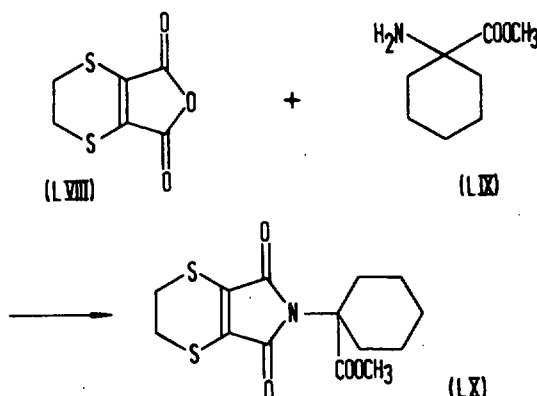
35 Preparation of 1-(5,6-Dihydro-*p*-dithiin-2,3-dicarboximido)cyclohexanecarbox-amide.

To 300 mg. of the nitrile prepared in Example 14 in 5 ml. methylene chloride is added with vigorous stirring 10 drops concentrated sulfuric acid. After 0.5 hour

ice and more methylene chloride is added. The organic phase is separated, washed with water, dried and the solvent evaporated leaving a crystalline residue of the title compound, melting point 187°C. to 189°C.

Example 16.

Preparation of Methyl 1-(5,6-dihydro-*p*-dithiin-2,3-dicarboximido)cyclohexanecarboxylate.



A mixture containing 18.8 g. of 5,6-dihydro-*p*-dithiin-2,3-dicarboxylic anhydride, 15.7 g. of the amino ester and 1.3 ml. triethylamine in 300 ml. xylene is heated with stirring for 6 hours under a Dean-Stark water separator. The solvent is removed, the residue taken up in ether, filtered, and the filtrate washed with sodium bicarbonate solution. The organic phase is separated, dried, and the solvent removed to leave a crystalline residue of the desired product, melting point 96°C. to 99°C.

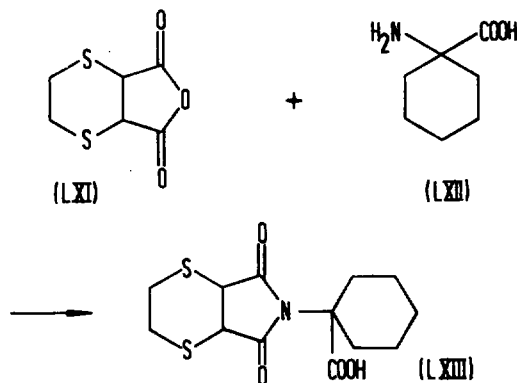
Example 17.

Preparation of 1-(5,6-Dihydro-*p*-dithiin-2,3-dicarboximido)cyclohexanecarboxamide 5-oxide.

To a stirred suspension of 6.25 g. of 1-(5,6-dihydro-*p*-dithiin-2,3-dicarboximido)cyclohexanecarboxamide in 30 ml. acetic acid is added 2.5 g. of a 30% aqueous solution of hydrogen peroxide. After 16 hours at 25°C., the solvents are removed *in vacuo* and the residue taken up in chloroform which is dried and evaporated. The crystalline residue is recrystallized from a 1:1 mixture of chloroform and acetonitrile to give the 5-oxide, melting point 133°C. to 136.5°C. (decomposition).

Example 18.

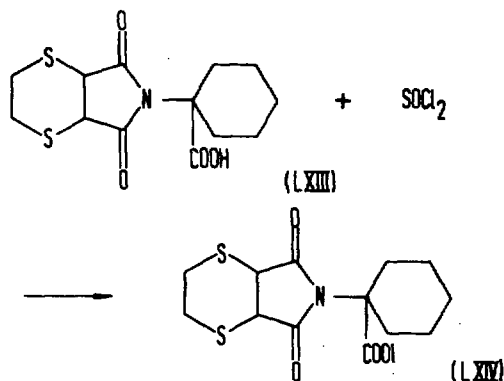
Preparation of 1-(Tetrahydro-*p*-dithiin-2,3-dicarboximido)cyclohexanecarboxylic acid.



Following the procedure described in Example 3, but substituting tetrahydro-*p*-dithiin-2,3-carboxylic anhydride for 1-(5,6-dihydro-*p*-dithiin-2,3-dicarboxylic anhydride and benzene for xylene as the solvent, the product described in the title is prepared, melting point 63°C. (decomposition).

Example 19.

Preparation of 1-(Tetrahydro-*p*-dithiin-2,3-dicarboximido)cyclohexanecarbonyl chloride.



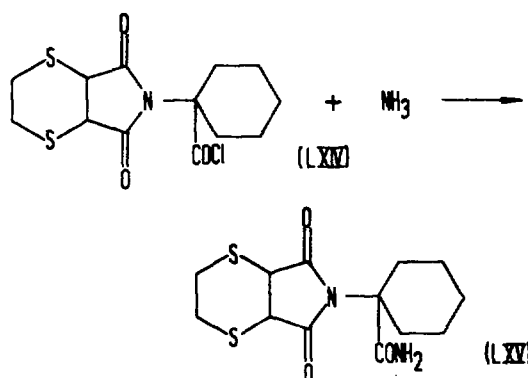
5 Using the procedure set forth in Example 5, but substituting 1-(tetrahydro-*p*-dithiin-2,3-dicarboximido)cyclohexanecarboxylic acid for 1-(5,6-dihydro-*p*-dithiin-2,3-dicarboximido)cyclohexanecarboxylic acid, the product described in the title is obtained, characterized only by its infrared spectrum.

5

Example 20.

10 Preparation of 1-(Tetrahydro-*p*-dithiin-2,3-dicarboximido)cyclohexanecarboxamide.

10

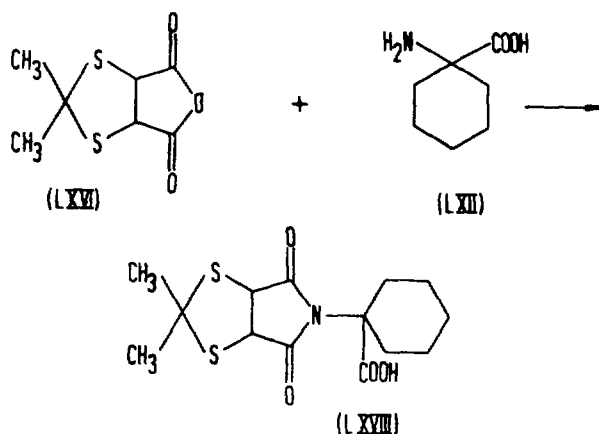


15 Using the procedure set forth in Example 7, but substituting 1-(tetrahydro-*p*-dithiin-2,3-dicarboximido)cyclohexanecarbonyl chloride for 1-(5,6-dihydro-*p*-dithiin-2,3-dicarboximido)cyclohexanecarbonyl chloride, the product described in the title, melting point 188°C. is obtained.

15

Example 21.

Preparation of 1-(2,2-Dimethyl-1,3-dithiolane-4,5-dicarboximido)cyclohexanecarboxylic acid.

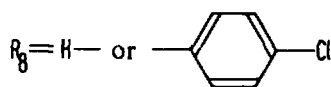
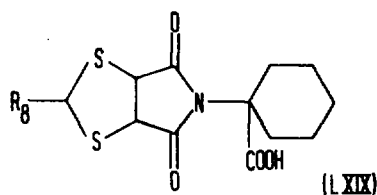


20

20

A stirred mixture of 10.2 g. of 2,2-dimethyl-1,3-dithiolane-4,5-dicarboxylic anhydride and 7.1 g. of amino acid in 170 ml. benzene and 0.5 ml. triethylamine is heated under reflux under a Dean-Stark water separator for 48 hours. The solvent is removed and the residue crystallized from aqueous methanol to give the title product, melting point 188°C. to 189°C.

Other 1,3-dithiolane-4,5-dicarboximidocarboxylic acids which can be prepared by the above procedure, but substituting the appropriate anhydride for 2,2-dimethyl-1,3-dithiolane-4,5-dicarboxylic anhydride, are reported below.

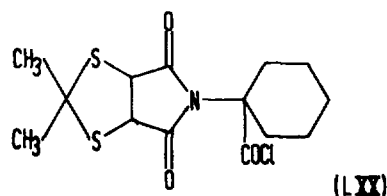
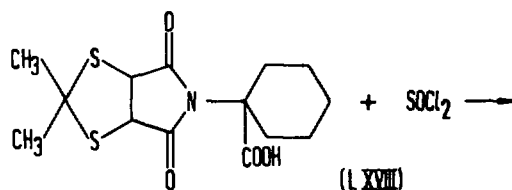


10

Example 22.

Preparation of 1-(2,2-Dimethyl-1,3-dithiolane-4,5-dicarboximido)cyclohexanecarbonyl chloride.

10

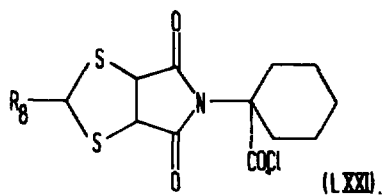


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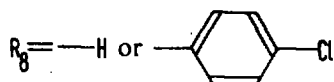
Using the procedure set forth in Example 5, but substituting 1-(2,2-dimethyl-1,3-dithiolane-4,5-dicarboximido)cyclohexanecarboxylic acid for 1-(5,6-dihydro-*p*-dithiin-2,3-dicarboximido)cyclohexanecarboxylic acid, the product described in the title is obtained, characterized only by its infrared spectrum.

15

By substituting the appropriate acid described in Example 21, the following carbonyl chlorides are prepared.



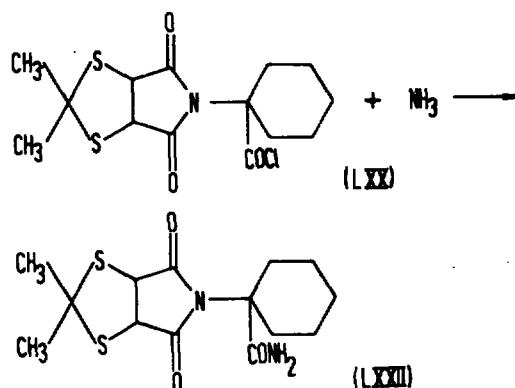
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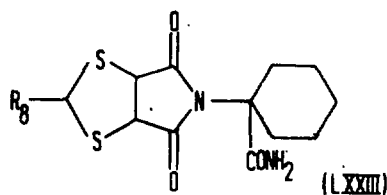
Example 23.

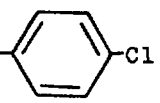
Preparation of 1-(2,2-Dimethyl-1,3-dithiolane-4,5-dicarboximido)cyclohexanecarboxamide.



5 Using the procedure set forth in Example 7, but substituting 1-(2,2-dimethyl-1,3-dithiolane-4,5-dicarboximido)cyclohexanecarbonyl chloride for 1-(5,6-dihydro-*p*-dithiin-2,3-dicarboximido)cyclohexanecarbonyl chloride, the product described in the title is obtained, melting point 163°C. to 164.5°C.

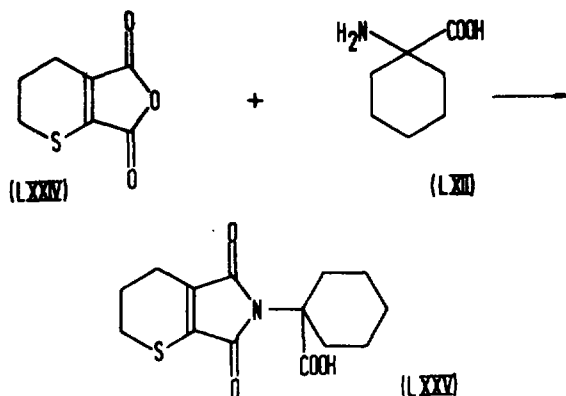
10 The carboxamides below are prepared by the above procedure by substituting the appropriate carbonyl chloride of Example 22 for 1-(2,2-dimethyl-1,3-dithiolane-4,5-dicarboximido)cyclohexanecarbonyl chloride.



R	Melting Point °C
H	185-186.5
	140 (decomposition)

Example 24.

15 Preparation of 1-(5,6-Dihydro-4*H*-thiapyran-2,3-dicarboximido)cyclohexanecarboxylic acid.



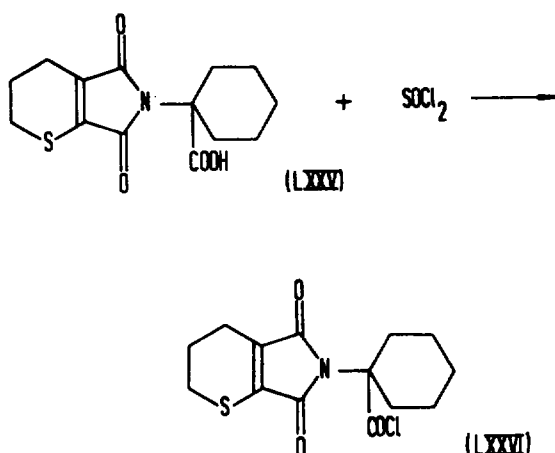
Following the procedure described in Example 3, but substituting 5,6-dihydro-4*H*-thiapyran-2,3-dicarboxylic anhydride for 5,6-dihydro-*p*-dithiin-2,3-dicarboxylic anhydride, the product described in the title is obtained as a gum and characterized only by its infrared spectrum.

5

Example 25.

5

Preparation of 1-(5,6-Dihydro-4*H*-thiapyran-2,3-dicarboximido)cyclohexanecarbonyl chloride.



10

Using the procedure set forth in Example 5, but substituting 1-(5,6-dihydro-4*H*-thiapyran-2,3-dicarboximido)cyclohexanecarboxylic acid for 1-(5,6-dihydro-*p*-dithiin-2,3-dicarboximido)cyclohexanecarboxylic acid, the product described in the title is obtained, characterized only by its infrared spectrum.

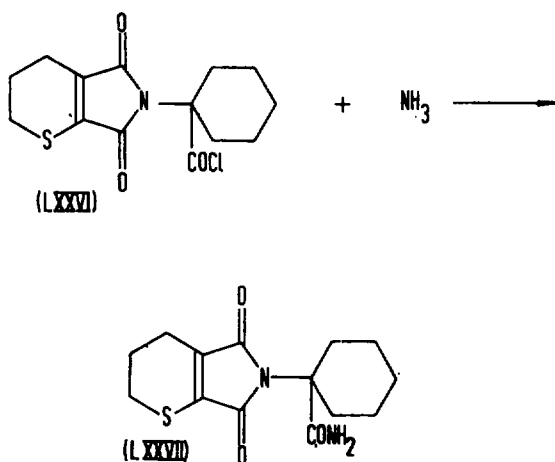
10

15

Example 26.

15

Preparation of 1-(5,6-Dihydro-4*H*-thiapyran-2,3-dicarboximido)cyclohexanecarboxamide.



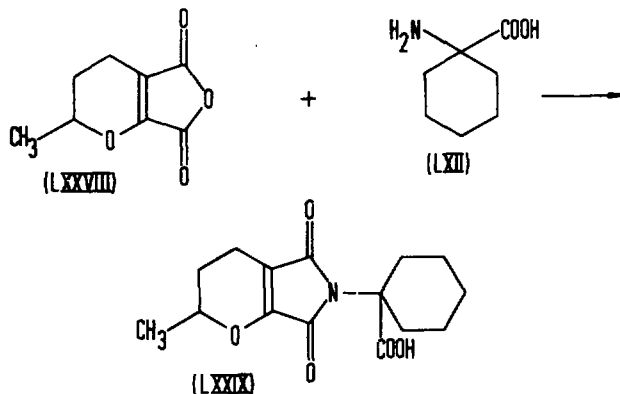
20

Using the procedure set forth in Example 7, but substituting 1-(5,6-dihydro-4*H*-thiapyran-2,3-dicarboximido)cyclohexanecarbonyl chloride for 1-(5,6-dihydro-*p*-dithiin-2,3-dicarboximido)cyclohexanecarbonyl chloride, the product named in the title is obtained as a crystalline solid, melting point 178°C. to 180.5°C.

20

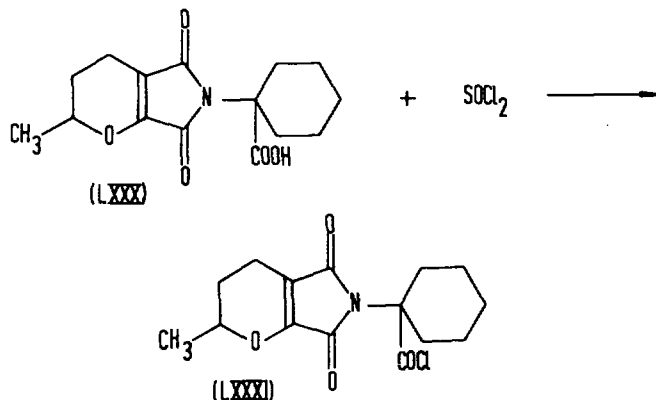
27

Example 27.
Preparation of 1-(6-Methyl-5,6-dihydro-4*H*-pyran-2,3-dicarboximido)cyclohexane-carboxylic acid.



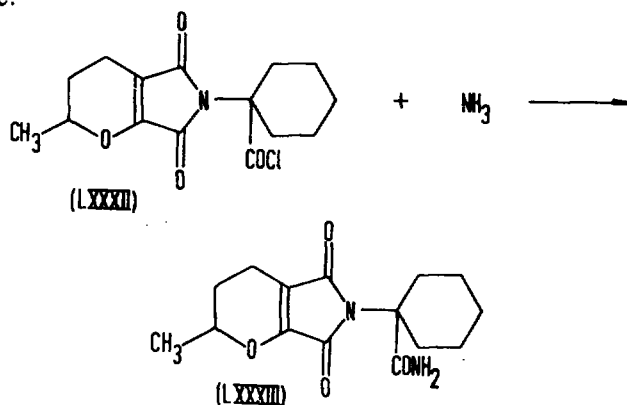
5 Following the procedure set forth in Example 3, but substituting 6-methyl-5,6-dihydro-4*H*-pyran-2,3-dicarboxylic anhydride for 5,6-dihydro-*p*-dithiin-2,3-dicarboximidocarboxylic anhydride, the product described in the title is obtained as a tan solid identified by infrared spectrum. 5

10 Example 28.
Preparation of 1-(6-Methyl-5,6-dihydro-4*H*-pyran-2,3-dicarboximido)cyclohexane-carbonyl chloride. 10



15 Following the procedure set forth in Example 5, but substituting 1-(6-methyl-5,6-dihydro-4*H*-pyran-2,3-dicarboximido)cyclohexanecarboxylic acid for 1-(5,6-dihydro-*p*-dithiin-2,3-dicarboximido)cyclohexanecarboxylic acid, the product described in the title is obtained and characterized only by its infrared spectrum. 15

Example 29.
Preparation of 1-(6-methyl-5,6-dihydro-4*H*-pyran-2,3-diboximido)cyclohexane-carboxamide.



Using the procedure set forth in Example 7, but substituting 1-(6-methyl-5,6-dihydro-4H-pyran-2,3-dicarboximido)cyclohexanecarbonyl chloride for 1-(5,6-dihydro-*p*-dithiin-2,3-dicarboximido)cyclohexanecarbonyl chloride, the product described in the title was obtained as a crystalline solid, melting point 185.5°C. to 189°C.

Example 30.

Plant Growth Regulant Evaluation of Biologically Active Compounds.

Test solutions are prepared by dissolving the test compound in a 50/50 acetone/water mixture and adding thereto 0.4% of a polyoxyethylene sorbitan monolaurate surfactant. A sufficient amount of this solution is then applied to seeded pots or to the foliage of test plants to provide from about $\frac{1}{4}$ lb./acre to 8.0 lb./acre of test compound.

Containers used for preemergence treatments are prepared the day before application of the test compounds. Appropriate amounts of soil are placed in the containers to bring the soil level to within $\frac{1}{4}$ inch of the tops of the containers. Seeds of the plant species are placed on the soil surface after which the seeds are covered with $\frac{1}{4}$ inch of soil. A tamper is used to level the soil surface and to firm the soil.

Plant species used for postemergence testing are planted about 17 days before treatment in appropriate containers, as described for preemergence plantings.

Treatments

Each compound is applied preemergence and postemergence to a variety of plant species. Containers containing the eight plant species are assembled in a galvanized metal flat (14"x22"), one flat for each rate of each compound. Treatment consists of spraying the test solutions at a rate of 86 gallons per acre (gpa) with a nozzle moving over the metal flat at a constant speed.

Untreated plants of each species serve as controls in each test. Plant species employed in preemergence evaluations are corn (Dekalb), lima bean (Henderson bush) and soybean (Amsoy). Plant species used in postemergence evaluations are radish (Cherry Belle), cucumber (Marketer), fescue (Kentucky 31) and rice (Nato).

All plant species are observed daily after treatment for changes in physiology and morphology as compared to control plants. Growth changes of interest included are:

- (1) Delay or acceleration of leaf or flower senescence,
- (2) Change in sex of cucumber flowers,
- (3) Advances in flowering of dicot species,
- (4) Increased or decreased axillary bud or tiller growth,
- (5) Dwarfing or growth stimulation of stems and leaves,
- (6) Advances in emergence of species treated with preemergence applications,

- (7) Toxic effects on all species.

Such effects were recorded when they occur.

Final data or visual observations are made at 14 days after treatment for radish and fescue and at 25 days after treatment for rice, cucumber, lima beans, soybeans, barley and corn. Table V presents quantitative data and ratings of observable growth effects obtained.

TABLE V
Postemergence Evaluation

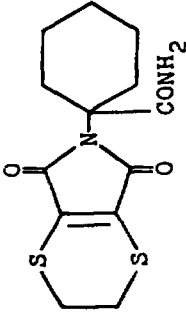
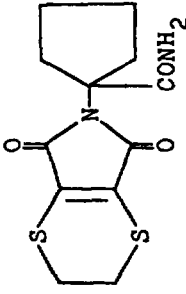
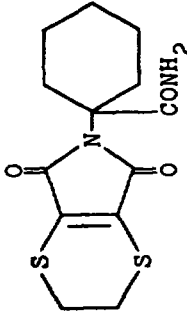
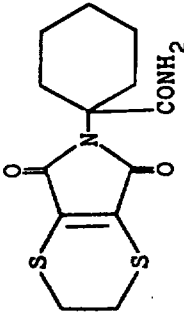
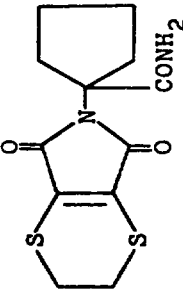
Structure	Rate lb/acre	Plant Species	Observations
	0.125 0.5 2.0 8.0	Radish	Leaves much larger than untreated controls at all rates of application. 20% Total plant weight increase over untreated controls at 0.5 lb/acre rate, 25% plant weight increase at 2 lb/acre rate and 37% plant weight increase at 8 lb/acre rate.
	0.125 0.5 2.0	Radish	40% Increase in total plant weight over untreated controls at 0.125 lb/acre rate, 35% increase in plant weight over untreated controls at 0.5 lb/acre rate and 45% increase in plant weight over untreated controls at 2 lb/acre rate. 50% Root weight increase at 0.125 lb/acre, 45% root weight increase at 0.5 lb/acre and 57% root weight increase at 2 lb/acre.
	0.5 2.0	Cucumber	Sex expression, 1 female flower produced at 0.5 lb/acre rate and 2 female flowers produced at 2 lb/acre rate. Untreated controls did not flower.

TABLE VII
Plant Growth Regulating Effects of Test Compounds

Structure	Rate lb/acre	Corn			
		Avg. Height (cm)	% Height Increase	Avg. Weight (gram)	% Weight Increase
Acetone/Water Control	-	Replicates { 61 57	- -	110 101	- -
	1	68	15	147.5	39.8
	2	67	13	139	31.7
	4	66	11.8	142	34.6
	8	70	18.6	141.5	34.1
	1	70	18.6	140	32.7
	2	60	1	114.5	8.5
	4	60	1	131	24.1
	8	68	15	127.5	20.8

Example 32.

Enhanced Bolting and Improved Attitude of Leaves on Sugar Beet Plants.

Following the procedure of Example 30, but substituting sugar beet seeds for corn seeds, it was observed that sugar beet plants emerged in a manner similar to untreated plants. However, the plants treated with 1-(5,6-dihydro-*p*-dithiin-2,3-dicarboximido)cyclohexanecarboxamide and 1-(5,6-dihydro-*p*-dithiin-2,3-dicarboximido)cyclopentanecarboxamide, at the 1, 2, 4 and 8 pound per acre rates, all grew faster than the untreated controls. It was also observed that the attitude of the leaves of treated plants was more upright and better positioned to intercept light energy for manufacturing food during photosynthesis. The leaves of untreated plants were drooped. It was further found that all treated plants were caused to bolt. This phenomenon is important and unexpected since sugar beets normally require two years to bolt and seed. This occurrence is especially significant to the farmer who grows sugar beets for seed yield.

5

10

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Example 33.

Evaluation of Test Compounds for Plant Growth Enhancement.

In these tests, containers are filled to within $\frac{1}{4}$ inch of the top with greenhouse potting soil and tamped. The pot is then filled to the top with soil in which Kentucky 31 Fescue seeds have been mixed in an amount sufficient to provide each pot with approximately 625 Fescue seeds.

To prepare the test compounds, 20 mg. of the compound is placed in a two-ounce, wide-mouth glass bottle and dissolved or dispersed in a 50/50 acetone/water mixture sufficient to prepare a 1,000 ppm solution or suspension.

An addition of 5 ml. of the 1,000 ppm solution in each cup is equivalent to 10 lb./acre.

Just prior to the application of the compounds, the test pots are lightly watered to prevent formation of air pockets and channeling routes during application which would prevent even distribution of the test compound in the soil. Application is accomplished by dispensing 5 ml. of solution or suspension evenly over the surface of the soil with a pipettor. Three replications are used for each compound.

Each test includes 5 ml. of 1:1 acetone:water controls, 5 ml. water controls as a standard for comparison of activity from test to test. The treated plants are benched in the greenhouse and normal watering practices are followed. Minimum day and night temperatures of 65°F. are maintained during cooler portions of the year. Normal daily temperature fluctuations occur during the summer season. Data obtained are reported below.

Data Recording

Initial observations are made at three to five days after treatment for early germination of both test species. Physiological or morphological changes from the norm are noted during the test period. Final observations are made at two to three weeks after treatment (dependent on time of year). At this time, measurements of the height of plants are made.

TABLE VIII

Effect of Test Compounds on Height of Fescue

Compound	Rate lb/Acre	Height of Fescue (cm)
Water	-	16
1-(5,6-dihydro- p-dithiin-2,3- dicarboximido)cyclo- hexanecarboxamide	10	27
1-(5,6-dihydro- p-dithiin-2,3- dicarboximido)cyclo- pentanecarboxamide	10	19
1-(5,6-dihydro- 5-methyl-p-dithiin- 2,3-dicarboximido)- cyclohexanecarboxamide	10	25

Example 34.

Evaluation of Test Compounds for Increasing the Internode Length and/or the Height of Plants.

The growth-enhancing activity of the compounds of this invention is exemplified by the following tests in which the seeds of a variety of mono-

- 5 cotyledonous and dicotyledonous plants are separately mixed with potting soil and a $\frac{1}{4}$ inch layer of this seed-soil mix is placed on top of approximately $1\frac{1}{4}$ inches of potting soil in separate $2\frac{1}{4} \times 2\frac{1}{4}$ plastic pots. After planting, the cups are sprayed with an aqueous-acetone solution containing test compound in sufficient quantity to provide the equivalent of 10 pounds per acre of test compound per cup. The treated cups are then placed on greenhouse benches, watered and cared for in accordance with greenhouse procedures. Three or four weeks after treatment, the tests are terminated and each cup is examined and rated. The results are set forth below.

Plant Species Used in These Evaluations

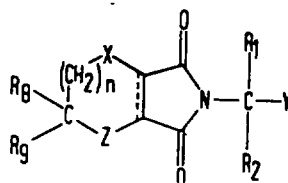
Common Name	Abbreviation	Scientific Name
Nutsedge	NS	<i>Cyperus rotundus</i>
Lambsquarters	LA	<i>Chenopodium album</i>
Wild Mustard	MU	<i>Brassica kaber</i>
Pigweed	PI	<i>Amaranthus retroflexus</i>
Ragweed	RW	<i>Ambrosia artemisiifolia</i>
Morningglory	MG	<i>Ipomoea purpurea</i>
Barnyardgrass	BA	<i>Echinochloa crusgalli</i>
Crabgrass	CR	<i>Digitaria sanguinalis</i>
Green Foxtail	FO	<i>Setaria viridis</i>
Wild Oats	WO	<i>Avena fatua</i>
Tomato	TO	<i>Lycopersicon esculentum</i>
Velvetleaf	VL	<i>Abutilon theophrasti</i>

Test Results

Compound	Plant Species Elongated	Approximate Increase in Height
1-(5,6-Dihydro- <i>p</i> -dithiin-2,3-dicarboximido)cyclohexanecarboxamide	NS BA CR TO VL	2X 2X 2X 2X 2X
2,3,5,7-Tetrahydro- α -isobutyl- α -methyl-5,7-dioxo-6 <i>H</i> - <i>p</i> -dithiin-2,3-c]pyrrole-6-acetamide	NS MG	2X 2X
1-(5,6-Dihydro-5-methyl- <i>p</i> -dithiin-2,3-dicarboximido)cyclohexanecarboxamide	NS LA BA CR FO TO VL	3-4X 3-4X 3-4X 3-4X 3-4X 3-4X 3-4X
1-(6-Methyl-5,6-dihydro-4 <i>H</i> -pyran-2,3-dicarboximido)cyclohexanecarboxamide	NS BA WO	2X 2X 2X
1-(3,4-Dihydro-2 <i>H</i> -thiopyran-5,6-dicarboximido)cyclohexanecarboxamide	NS LA MG BA CR FO WO TO VL	3-4X 3-4X 3-4X 3-4X 3-4X 3-4X 3-4X 3-4X 3-4X

WHAT WE CLAIM IS:—

1. A compound of the formula:



(I)

5 wherein X is CH₂ or S; Z is S, O, or SO, provided that when Z is O,
 X cannot be S; Y is —COOR₃, —CONR₄R₅, —CONHOH, —CONHNR₆R₇,
 —CONHN⁺R₈R₉, halide⁻, CN or —COR₁₀; n is 0 or 1; R₁ and R₂ each
 10 represent alkyl C₁—C₄, or when taken together with the carbon to which they
 are attached form cycloalkyl C₄—C₆ or methyl-substituted cycloalkyl C₄—C₆; R₃
 is hydrogen or alkyl C₁—C₄; R₄ and R₅ each represent hydrogen, alkyl C₁—C₄,
 phenyl, monohalophenyl, monoalkyl(C₁—C₄)phenyl, or monoalkoxy(C₁—C₄)-
 phenyl; R₆ and R₇ are alkyl C₁—C₂; R₈ is hydrogen, alkyl C₁—C₄, phenyl, mono-

5

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* C L M S *

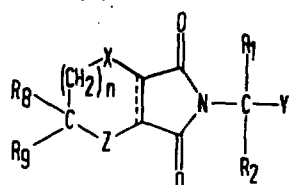
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Test Results

Compound	Plant Species Elongated	Approximate Increase in Height
1-(5,6-Dihydro- <i>p</i> -dithiin-2,3-dicarboximido)cyclohexanecarboxamide	NS	2X
	BA	2X
	CR	2X
	TO	2X
	VL	2X
2,3,5,7-Tetrahydro- α -isobutyl- α -methyl-5,7-dioxo-6 <i>H</i> - <i>p</i> -dithiino-[2,3- <i>c</i>]pyrrole-6-acetamide	NS	2X
	MG	2X
1-(5,6-Dihydro-5-methyl- <i>p</i> -dithiin-2,3-dicarboximido)cyclohexanecarboxamide	NS	3-4X
	LA	3-4X
	BA	3-4X
	CR	3-4X
	FO	3-4X
	TO	3-4X
	VL	3-4X
1-(6-Methyl-5,6-dihydro-4 <i>H</i> -pyran-2,3-dicarboximido)cyclohexanecarboxamide	NS	2X
	BA	2X
	WO	2X
1-(3,4-Dihydro-2 <i>H</i> -thiopyran-5,6-dicarboximido)cyclohexanecarboxamide	NS	3-4X
	LA	3-4X
	MG	3-4X
	BA	3-4X
	CR	3-4X
	FO	3-4X
	WO	3-4X
	TO	3-4X
	VL	3-4X

WHAT WE CLAIM IS:—

1. A compound of the formula:



(I)

5 wherein X is CH₂ or S; Z is S, O, or SO, provided that when Z is O,
 X cannot be S; Y is —COOR₃, —CONR₄, —CONHOH, —CONHNR₆R₇,
 —CONHN⁺R₈R₉, halide⁻, CN or —COR₁₀; n is 0 or 1; R₁ and R₂ each
 10 represent alkyl C₁—C₄, or when taken together with the carbon to which they
 are attached form cycloalkyl C₄—C₆ or methyl-substituted cycloalkyl C₄—C₆; R₃
 is hydrogen or alkyl C₁—C₄; R₄ and R₅ each represent hydrogen, alkyl C₁—C₄,
 phenyl, monohalophenyl, monoalkyl(C₁—C₄)phenyl, or monoalkoxy(C₁—C₄)-
 phenyl; R₆ and R₇ are alkyl C₁—C₂; R₈ is hydrogen, alkyl C₁—C₄, phenyl, mono-

5

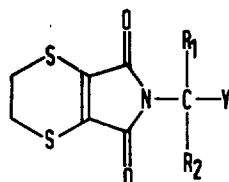
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halophenyl, monoalkyl(C_1-C_4)phenyl, monoalkoxy(C_1-C_4)phenyl, mononitrophenyl or trifluoromethylphenyl; R_9 is hydrogen or alkyl C_1-C_4 ; R_{10} is halogen, and $----$ represents a single or double bond.

2. A compound according to Claim 1, of the formula:

5



(XXV)

5

wherein Y is $COOR_3$, $-CONR_4R_5$, $-CONHNR_6R_7$, $-CONHN^+R_6R_7R_7$, halide $^-$, CN or $-COR_{10}$; R_1 and R_2 each represent alkyl C_1-C_4 or when taken together with the carbon atom to which they are attached form cycloalkyl C_4-C_8 ; R_3 , R_4 and R_5 each represent hydrogen or alkyl C_1-C_4 ; R_6 and R_7 are alkyl C_1-C_2 , either the same or different; and R_{10} is halogen.

10

10

3. A compound according to Claim 1, wherein X and Z are each sulfur, and Y, n, R_1 , R_2 , R_8 and R_9 are as defined in Claim 1.

4. A compound according to Claim 1, wherein X is CH_2 ; Z is oxygen, and n, Y, R_1 , R_2 , R_8 and R_9 are as defined in Claim 1.

15

5. A compound according to Claim 1, wherein X is CH_2 ; Z is sulfur, and n, Y, R_1 , R_2 , R_8 and R_9 are as defined in Claim 1.

15

6. A compound according to Claim 1, wherein X is S; Z is SO; and n, Y, R_1 , R_2 , R_8 and R_9 are as defined in Claim 1.

20

7. A compound according to Claim 3, wherein $----$ is a double bond.

8. A compound according to Claim 3, wherein $----$ is a single bond.

20

9. A compound according to Claim 7, wherein Y is $-CONR_4R_5$.

10. A compound according to Claim 7, wherein Y is $-COOR_3$.

11. A compound according to Claim 7, wherein Y is $-CONHNR_6R_7$.

25

12. A compound according to Claim 7, wherein Y is $-CONHN^+R_6R_7R_7$, halide $^-$.

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13. A compound according to Claim 7, wherein Y is $-COR_{10}$.

14. A compound according to Claim 9, and which is 1-(5,6-dihydro-*p*-dithiin-2,3-dicarboximido)cyclohexanecarboxamide.

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15. A compound according to Claim 9 and which is 1-(5,6-dihydro-*p*-dithiin-2,3-dicarboximido)cyclopentanecarboxamide.

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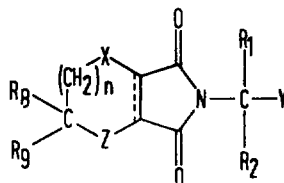
16. A compound according to Claim 9 and which is 1-(5,6-dihydro-*p*-dithiin-2,3-dicarboximido)-*N,N*-dimethylcyclohexanecarboxamide.

17. A compound according to Claim 9 and which is 1-(5,6-dihydro-4*H*-thiapyran-2,3-dicarboximido)cyclohexanecarboxamide.

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18. A method for regulating the growth of plants comprising applying to the foliage, roots, stems, seeds, seed pieces or to soil in which the plants are grown, a compound of the formula:

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wherein n, X, Z, Y, R_1 , R_2 , R_8 , R_9 and $----$ are as defined in Claim 1, with the first proviso that Y is not $-COR_{10}$ and with the second proviso that Y is not $-COOH$.

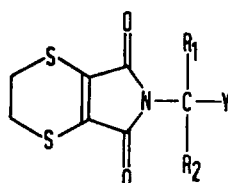
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19. A method according to Claim 18, wherein X and Z of the formula are each sulfur.

20. A method according to Claim 19, wherein n is one.

21. A method according to Claim 19, wherein the compound is of the formula:

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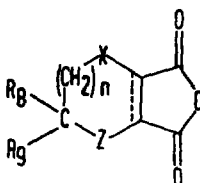
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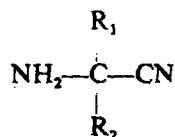
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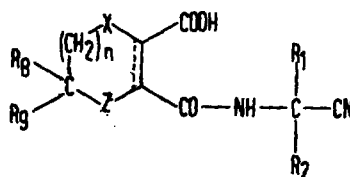
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wherein n, X, Z, R₈ and R₉ are as defined above, with a compound of the formula:

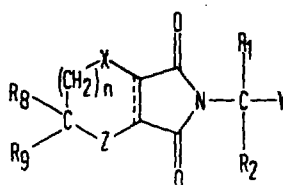


wherein R₁ and R₂ are as defined above, in the presence of an inert solvent at a
5 temperature of from 20°C. to 60°C. to form a product of the formula:

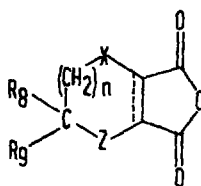


wherein R₁, R₂, R₃, R₄, X, Z and n are as defined above; and thereafter cyclizing the product by heating.

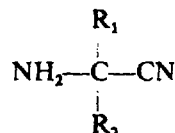
38. A method for the preparation of a compound of the formula:



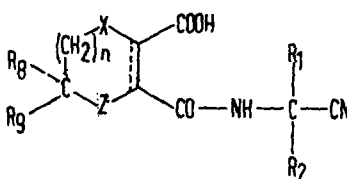
wherein Y is —CN or —CONH₂; X is CH₂ or S; Z is S, O or SO, provided that when Z is O, X cannot be S; R₁ and R₂ each represent alkyl C₁—C₄ or when taken together with the carbon to which they are attached form cycloalkyl C₄—C₈; n is 0 or 1; R₃ is hydrogen, alkyl C₁—C₄, phenyl, monohalophenyl, monoalkyl(C₁—C₄)-phenyl, monoalkoxy(C₁—C₄)phenyl, mononitrophenyl, or trifluoromethylphenyl; R₄ is hydrogen or alkyl C₁—C₄; — is a double bond or single bond; comprising reacting a compound of the formula:



20 wherein X, Z, n, R₈ and R₉ are as defined above, with a compound of the formula:

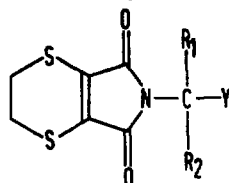


wherein R_1 and R_2 are as defined above, in the presence of an inert solvent at a temperature of from 20°C. to 60°C. to form a product of the formula:

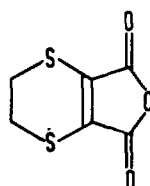


wherein X, Z, n, R₁, R₂, R₃ and R₄ are as described above; and thereafter cyclizing the product by heating and treating the thus-formed reaction product with a strong acid at a temperature of from -10°C to +30°C.

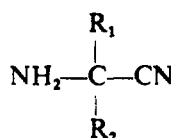
39. A method for the preparation of a compound of the formula:



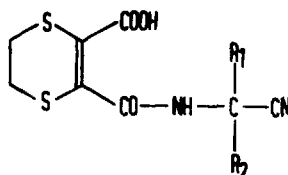
wherein Y is —CN and R₁ and R₂ each represent alkyl C₁—C₄ or when taken together with the carbon to which they are attached form cycloalkyl C₄—C₈; characterized by reacting a compound of the formula:



with a compound of the formula:

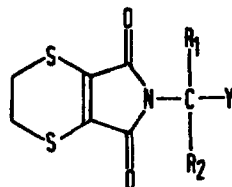


wherein R₁ and R₂ are as defined above, in the presence of an inert solvent at a temperature of from 20°C. to 60°C. to form a product of the formula:

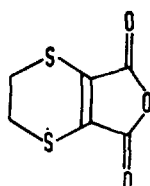


wherein R₁ and R₂ are as defined above; and thereafter cyclizing the product by heating to produce the desired compound.

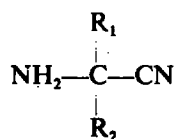
40. A method for the preparation of a compound of the formula:



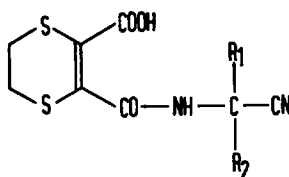
wherein Y is —CN or —CONH₂; and R₁ and R₂ each represent alkyl C₁—C₄ or when taken together with the carbon to which they are attached form cycloalkyl C₄—C₈; characterized by reacting a compound of the formula:



with a compound of the formula:



wherein R_1 and R_2 are as defined above, in the presence of an inert solvent at a temperature of from $20^\circ C.$ to $60^\circ C.$ to form a product of the formula:



wherein R_1 and R_2 are as defined above; thereafter cyclizing the product by heating and treating the thus-formed reaction product with a strong acid at a temperature of from $-10^\circ C.$ to $+30^\circ C.$ to form the desired product.

41. A compound according to Claim 1, substantially as described in any one of Examples 1—29 herein.

42. A method for regulating the growth of plants, according to Claim 18 and substantially as described in any one of Examples 30—34 herein.

43. A method for the preparation of a compound according to Claim 1, substantially as described in any one of Examples 1—29 herein.

44. A compound according to Claim 1 whenever prepared by a method according to any one of Claims 37—39 or 42.

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