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PP 528 - POSSIBLE USES IN FRUIT TREES AND ARABLE CROPS

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Summary PP 528, ethyl 5-(4-chlorophenyl)-2*H*-tetrazol-2-ylacetate, can usefully improve the growth and branching habit of many varieties of maiden nursery fruit trees. The growth regulating properties have improved early tree shaping, early flowering and early commercial cropping of Bramley's Seedling and Granny Smith apple and Marjorie's Seedling plum. Some potential for chemical pruning in the orchard has been demonstrated with Bramley's Seedling where the necessity for mechanical pruning was substantially reduced but savings with Golden Delicious and Cox were less marked. Flowering of Bramley in the year after treatment has been improved subsequent to the production of more fruit spurs and the induction of a greater percentage of spurs, terminals and short shoots to flower. These effects led to consistent, but non-significant, yield increases of about 30%; similar increases were noted with Cox.

With soyabean the number of pods/plant was frequently increased by PP 528 treatment but it has not proved possible to demonstrate any rate/growth stage combination where this effect was expressed in consistent yield enhancement.

With peanut substantial and significant yield increases have been obtained occasionally, again the pattern of response was inconsistent.

INTRODUCTION

PP 528, ethyl 5-(4-chlorophenyl)-2*H*-tetrazol-2-ylacetate, is a systemic growth retardant which has been undergoing evaluation in a number of crops since 1973. Some of the earlier results were described previously (England 1974) and the data reported here are from trials on fruit trees (mostly apple), soya and peanut.

The fruit tree trials programme was designed to determine any possible commercial uses in nursery tree production, general growth control and reduction in pruning requirements, tree shaping and induction of early cropping, and yield enhancement, whilst the programme with the annual crops was more specifically aimed at improving yield.

METHODS AND MATERIALS

Formulation

In early trials a 'Dricol' formulation JF 3912 containing 50% w/w a.i. was used. This was replaced in 1976 by a 40% w/w 'col' containing only USA Environmental Protection Agency approved constituents.

Application

For fruit trees this was as described previously (England, 1974) except that the surfactant used was Synperonic 16. Tween 20 at 0.1% w/v was used in the Soya and Peanut programmes. Randomised block designs were used in all field trials with the U.K. fruit tree trials having 3-5 trees/plot replicated 4-5 times. Harvested areas from soya and peanut trials ranged from 2 rows x 5' to 2 rows x 40' depending on hand or mechanical harvesting.

RESULTS

Fruit trees

The biological potential of this systemic retardant has been examined for the production of suitably branched (feathered) maiden trees, for improving tree form and early cropping during the first important formative years in the orchard, general growth control in more mature orchards and the flowering and yield response in orchard trees.

Feathering of maiden trees

Very promising results have been obtained by many fruit tree specialists in Europe and elsewhere on a wide range of poorly branching varieties including the apple cultivars Granny Smith (M9), Bramley's seedling (MM106), Spartan (M26, MM106 and MM111) and Crispin (M26); Conference and William pear and Victoria and Marjorie's Seedling plum.

The optimum rate required is a function of variety/rootstock sensitivity, climate and general growing conditions but PP 528 at rates between 100-300 ppm usefully increased the number of laterals at the desired height and angle on the main axis whilst retaining a central leader of reduced apical dominance.

Improving tree form and inducing early cropping

Quinlan (1978) has shown that chemical pruning agents used on Bramley during years 1 and 2 in the orchard (subsequent to previous treatment in the nursery) led to a reduced pruning requirement and a 5-fold increase in the first crop (year 3 in the orchard) and a 3-fold increase in the second crop when compared with conventionally pruned trees.

A more critical trial with PP 528 is now in progress comparing chemical pruning of Bramley on MM106 with hand pruning on M9 at normal M9 density to determine how long they can be kept at high density relying on chemical growth regulation and induction of early cropping. To date PP 528 treated MM106 trees are more compact than hand pruned MM106 trees and fairly similar to the M9 trees (a more dwarfing rootstock) and they possess twice the number of short shoots indicating a greater yield potential for next year.

Villemur, (1977), has shown that nursery treatment of Granny Smith (M9) at 200 to 300 ppm gave temporary inhibition of the terminal shoot and increased the number of spurs and long shoots. These trees were planted without pruning into an orchard at a density of 3570/ha and the enhanced yields obtained in 1976, 2 years after planting, are shown in table 1.

Increased yields were also obtained in a second trial planted in 1973, and treated in 1975, (Table 1).

Similarly, in an ICI trial on 3 year Marjorie's seedling plum, 2-3 fold yield increases were obtained.

Table 1

Total yield, 1976 (kg/tree)

Treatment	Treated in nursery 1974	Treated in orchard 1975
PP 528 200 ppm	2.1	8.0
PP 528 300 ppm	2.3	11.0
PP 528 400 ppm		10.6
Hand pruned control	1.6	8.6
Untreated control	0.8	8.7

General growth control in mature orchards

Consistent reductions of about 30% in shoot growth have been obtained with 50-300 ppm applied a few weeks after full bloom with Granny Smith, Golden Delicious, Cox's Orange Pippin and Bramley's Seedling.

Activity is usually most pronounced a few weeks after treatment. This is not usually season-long and some recovery growth occurs by mid-season. In contrast to results with Bramley (described under flowering and yield) rates of single applications necessary to give adequate control of growth with Golden Delicious have adversely affected the percentage of spurs and short shoots flowering in the year after treatment, although total yield was not reduced.

Weights of prunings in the winter after treatment correlated well with direct measurements of shoot length. Data for pruning after two successive years of treatment are not yet available but present grower opinion is favourable with Bramley. These young trees, now five years old, are bearing quite heavily and will require little further pruning this winter. With Cox and Golden Delicious, however, any appreciable saving in pruning seems less likely.

Flowering and yield responses in orchard trees

One trial has been established on 4 year Bramley (M9) trees planted at a density of 1600 trees/ha. Seven growth stages (each separated by two weeks) have been treated at 100 ppm or 200 ppm from two weeks after full-bloom onwards. Bramley is a tip-bearing variety and produces fruit largely on terminal shoots, on spurs (< 10 cm) and short shoots (> 10 cm) on 2-year wood. In consequence a chemical such as PP 528 which reduces apical dominance and encourages lateral shoot production may be expected to increase the number of growing apices producing flower and fruit.

The total number of flowers was increased, (Table 2), and in fact doubled with 200 ppm at growth stage (GS.2). This was contributed to by:-

1 A fourfold increase in the number of spurs produced on 1 year wood, (Table 3).

2 A greater percentage of terminal shoots, spurs on 1 year wood and short shoots on 2-year wood actually flowering, (Table 4).

3 An increased number of axillary flowers on 1 and 2-year wood, although those do not normally bear fruit.

Data in Table 5 show enhanced yields, apparently associated with early treatment and more especially at the higher rate. Three untreated plots were included in each replicate but tree to tree variation was such that these data are not significant at the 5% level, (P = 15).

More fruit per tree were produced especially at GS.2, where yield was highest, and this was associated with a reduction of 20% in mean fruit weight.

Yield data from a trial on 7 year Cox (M9) trees are shown in Table 6;detailed flower and shoot data are not yet available. The average yield increase over all treatments was 33% but significance was not attained; mean weight per apple was unchanged. In contrast to Bramley there were indications of reduced yield in the year of treatment at 200 ppm.

No improvement in flowering or yield were obtained with two trials of Golden Delicious (M9) at densities of over 2000/ha.

Table 2

Bramley - No flower clusters per branch (1 and 2 yr wood)

Treatment	Rate ppm	Growth Stage	1	2	3	4	5	6	7
PP 528	100		3.37	*5.04	3.36	4.12	3.05	3.63	*4.90
PP 528	200		3.73	**7.07	4.30	4.26	4.64	4.23	3.76
Untreated			3.14						

S.E. 1.49, C of V = 35%, LSD P = 5%, 1.72, 1% 2.29

* significant at P = 5%
** significant at P = 1%

Table 3

Bramley - No spurs per branch (1 yr wood)

Treatment	Rate ppm	Growth Stage	1	2	3	4	5	6	7
PP 528	100		*0.22	**0.26	**0.22	0.17	0.08	0.11	0.08
PP 528	200		**0.27	**0.28	0.09	0.19	0.08	0.06	0.02
Untreated			0.07						

S.E. 0.11, C of V = 81%, LSD P = 5%, 0.13, 1% 0.17

Table 4

Bramley - % Terminal shoots flowering (Detransformed data)

Treatment	Rate ppm	Growth Stage	1	2	3	4	5	6	7
PP 528	100		43	62	60	62	52	46	47
PP 528	200		60	69	77	57	68	57	62
Untreated			43						
		% spurs flowering on 1 yr wood (Detransformed data)							
PP 528	100		*62	**99	11	9	30	4	5
PP 528	200		51	**89	3	**83	2	8	39
Untreated			6						
		% short shoots flowering on 2 yr wood (Detransformed data)							
PP 528	100		51	**85	73	49	66	66	*78
PP 528	200		75	**86	76	68	**83	72	65
Untreated			58						

Table 5

Bramley - Yield (Kg/tree)

Treatment	Rate ppm	Growth Stage	1	2	3	4	5	6	7
PP 528	100		10.4	13.2	11.5	8.9	11.0	9.3	8.9
PP 528	200		8.8	15.6	11.3	10.5	12.3	12.2	12.9
Untreated			9.4						

S.E. 3.0, C of V = 28.2%, P = 15.7

Table 6

Cox's orange pippin - Yield (Kg/tree)

Treatment	Rate ppm	Growth Stage	1 1976	1 1977	2 1976	2 1977	3 1976	3 1977
PP 528	50		8.1	7.2	11.7	6.6	12.0	7.1
PP 528	100		9.9	7.9	13.9	7.0	8.6	6.8
PP 528	200		*6.2	7.2	11.0	4.7	*7.4	7.9
Untreated			12.0	5.2				

1976 S.E. 3.61, C of V = 35.7%,LSD P = 5% 4.5, 1% 5.9
1977 S.E. 2.77, C of V = 43.2%,P = 55.3

Soyabean

During a 1974 field screening trial indications of a 25% increase in pod no./plant were obtained at 1.12 kg/ha. with indeterminate Soya, cultivar Corsoy. A more detailed test in 1975, with the same variety, gave a statistically significant increase in pod set with treatment at growth stage R5.5 (flowering at all nodes with pods developing on lower nodes) and increased 1000 seed weight when treated at R4 (50% of all plants with at least one flower); yield increases, however, did not exceed 4%.

Other small scale trials during 1974/1975 with determinate Soya also showed increased pod set and in one instance a 17% significant yield increase at 0.56 kg/ha. These effects were sometimes noticeable at rates below 0.56 kg/ha where retardant activity was not always observed.

In consequence, yield trials were initiated in 1976 to investigate low rates applied to young growth stages. With the possible importance of fertilizer application at the critical early pod filling stage all treatments were duplicated with foliar application to Iowa State University recommendations.

At growth stage R5.5 0.56 kg PP 528 increased pod set with or without added fertilizer, (Table 7), but this led to a yield reduction and not increase. Most treatments at R4 reduced pod set, by a maximum of 25% at 0.14 kg. Addition of late season foliar fertilizer apparently decreased yields by about 10% due to slight phytotoxicity - a common feature in many soya areas of the USA in 1976.

Further results obtained from the USA in 1976 with one trial on indeterminate soya and four on determinate varieties showed that yield was not consistently affected and increases, where obtained, were small (maximum 15%) and not usually significant at the P = 5% level. Detailed yield parameter assessments on Bragg cultivar showed that although pod number per plant was increased weight of seed per pod and individual seed weights were reduced.

Table 7

Soya - Pods/plants and yield (tonnes/ha)

PP 528 Kg/ha	Growth Stage	R4 →				R5.5 →			
		Pods/plants		Yield		Pods/plants		Yield	
	Fertilizer	−	+	−	+	−	+	−	+
0.56		48.3	*41.0	2.37	2.39	**62.4	**60.3	**2.08	** 1.87
0.28		41.8	43.6	2.43	2.67	*55.1	46.7	2.46	** 2.11
0.14		**35.4	**40.6	2.35	2.24	52.8	45.8	2.26	* 2.18
Fertilizer			41.1		2.33		41.1		2.32
Untreated		47.5		2.59		47.5		2.59	
LSD		5% = 6.2		5% = 0.33					
		1% = 8.3		1% = 0.44					

Peanut

Daminozide has been shown to reduce vegetative growth and prevent vine overlap leading to 5-10% yield increases associated with easier harvesting. In 1976 PP 528 was tested in comparison and although it was very variable in effect it nevertheless frequently showed yield improvement at low rates. A summary of results from 5 trials over a range of growth stages is given in table 8. Only in two instances were the data significant at P = 5%.

Table 8

Peanut - Yield (as % difference from untreated)

Treatment	Location	North Carolina		Georgia	North Carolina	
Kg/ha	Variety	NC2	Florigiant	Florigiant	Florigiant	Florigiant
0.56				+18	+12	+ 6
0.28		**+20	**+23	+23	+21	- 3
0.14		+ 3	+ 6	+33	+ 6	+ 9
C of V		8	9	25.6	17.3	8.0
P				21	97	28
Growth Stage (% pegging)		5-10	5-10	10-15	50-60	60-70

Further attempts in 1977 to show yield effects with low rates over a closely defined range of growth stages between 5 and 35 days after first flower have again showed variation and in general there was no consistent pattern of response.

DISCUSSION

In fruit trees the most likely commercial use for PP 528, albeit a minor one, would be for the preparation of nursery stock where growers are now demanding more adequately branched maiden trees to facilitate the production of a strong primary branch system in the shortest time. PP 528 has proved quite effective on a range of important varieties which are normally difficult to feather.

The logical extension of this growth control into the first years in the orchard has been examined with some success with young (2-4 years) Bramley and Granny Smith where reduction of over-vigorous growth has been followed by enhanced flowering and improved early cropping. This potential use is of increasing importance especially in high density systems where early cash flow can be a problem but, in itself, this is still quite a limited market for a chemical.

With high labour costs and increasing acreages of intensively planted orchards there is a need for general growth control in the mature orchard, although it is extremely unlikely that any chemical will eliminate completely the need for manual or mechanical pruning. At present such an outlet for PP 528 is problematic in that control is not necessarily season long and simply raising the dose for a single application could have adverse effects. To establish a suitable recommendation much further work of a long-term nature would be required. It would be necessary to investigate the effect of serial treatment at low rates and the use of mixtures with other growth regulators, on a range of important cultivar/root stock combinations in the multiplicity of different pruning and management techniques practised world-wide.

Stutte and Rudolph (1971) reported increased soya yield with 2,3,5 triiodobenzoic acid (TIBA). Brittain (1967) has reported increased peanut yield associated with daminozide treatment in conjunction with higher planting densities;

Hammerton (1976) showed little effect on yield. PP 528 was compared with these compounds on soya and peanut for growth retardant activity. The number of pods per soya plant was frequently raised but it has not proved possible to translate this potential into yield promotion. Attempts to alleviate any possible nutrient deficiency at the critical pod filling stage by foliar or granular fertilizer application were also ineffectual. Data from the trial with Bragg showed individual seed weight and seed weight per pod were both reduced. Plant Protection Division tests with Fiskeby V, Boize, (1977), have shown more smaller pods at each node, some with fewer seeds of harvestable quality. Additionally there were signs of premature pod dehiscence. It would appear that PP 528 detrimentally affects seed and/or pod maturation. In contrast quality grading and kernal weights of peanuts were not adversely affected but this year's trials, although covering the early growth stages and low rates where previous increases were obtained, were unsuccessful.

In general, with soya and peanut, results have been inconsistent, they have not shown any obvious rate response and the yield increases, where obtained, have not usually attained statistical or commercial significance. No further development of PP 528 appears warranted on soya and peanut.

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THE EFFECT OF 7-METHYLINDOLE AS A SUGAR CANE RIPENER

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Summary In several field trials on sugar cane in South Africa and Brazil, sprays of PP757 (7-methylindole) caused retardation of new leaf and stem growth followed by significant increases in juice quality and the quantity of stored sugar. The results are reported as further evidence that inhibitors of sugar cane growth can lead to successful assimilate diversion. Because of variability in the results of these and other trials and insufficient cost effectiveness, PP757 was unsuitable for commercial development.

INTRODUCTION

In routine herbicide screening 7-methylindole (PP757) was noticed to inhibit plant growth and in subsequent testing for growth regulatory activity, the compound was found to retard the growth of both new stem and leaves in apical meristems of several monocotyledons such as wheat, barley, sugar cane and various grass species without severe phytotoxicity but to have little or no effect on dicotyledons (3). In the field, sprays of the chemical at 1 - 3kg/ha retarded the growth of turf grass particularly when they were applied in England in either spring or autumn. 7-chloro and 7-bromo substituted indoles were more active than PP757 (4) but more expensive to manufacture.

PP757 was first successfully used as a sugar cane ripener in a field test conducted by Dr. P.D. Lawler in Brazil in 1973. A further experiment in Brazil and trials by co-operators in South Africa and Florida all indicated that PP757 could improve the quality characteristics of sugar cane but results on the activity of the compound were insufficient to justify a full-scale programme of development. The series of field experiments in South Africa and Brazil which are described in this paper were designed to determine further the significance and reliability of the response.

METHODS

South Africa

Five trials were set up on 10-month old canes of the variety NCo376 growing under irrigation in Eastern Transvaal, following the findings of Rostron (7) that the best responses to chemical ripeners are observed when young vigorously growing cane is treated. Plots consisted of 5m lengths of 3 adjacent cane rows and there were 3 - 5 replicate plots per treatment according to the experiment. Sprays were applied at the equivalent of 1000 l/ha during the period 11 - 17 March 1975 using a boom held horizontally above the foliage (4m above the ground) by means of a long aluminium lance. PP757 was sprayed as a diluted emulsifiable concentrate without wetter. Solutions of Polaris, a formulation of glyphosine (N, N-bis (phosphonomethyl) glycine), (Monsanto Chemical Company) which was used as a standard, were prepared from a soluble powder.

Random samples of 12 stalks, topped in a standard fashion, were removed from the centre rows of the trial area for juice analysis shortly before spraying. Further similar samples were taken at 25 - 27 days and again at 72 - 77 days after treatment. Separate samples of canes were taken from the plots in some trials to determine the juice quality in the top one third of stalks.

Cane analysis was carried out by the National Cane Testing Service of the South African Sugar Industry Central Board according to standard methods (1).

Brazil

In two field trials, PP757 and glyphosine (Polaris) were sprayed in 500l/ha onto a non-irrigated first ratoon crop of variety CB4114. Methods were otherwise similar to those used in South Africa except that samples of 20 stalks per plot were removed and subsampled for analysis at various intervals between 44 and 90 days after treatment.

RESULTS

Phytotoxity

At 5kg/ha and above, PP757 caused some brown lesions on the sprayed leaves of CB4114 (similar to those caused by Rynchosporium) and in South Africa, high volume sprays of PP757 at 5 and 7.5kg/ha caused necrotic black areas on the spindle leaves at the point where they entered the sheath at the last visible ligule. These marks were presumably due to the chemical suspension running down the apical leaves and accumulating at the base. Two to three weeks after treatment the marks had moved due to differential growth of the various leaves. Phytotoxity was reduced or eliminated by using spray volumes less than 1000l/ha. or by the addition of spraying oil to the diluted emulsion, and on CB4114 was much less than that induced by glyphosine.

Growth Inhibition

Visible signs of apical growth inhibition first appeared 17 - 20 days after chemical treatment. It was then noticed that many of the PP757 treatments had delayed leaf emergence at the apex. Retardation of CB4114 eventually resulted in the development of side shoots at the apex of isolated canes. Growth retardation continued to be apparent in all trials in plots treated with 5 or 7.5kg/ha PP757 until 76 days after treatment. A typical result is shown in Table 1.

Juice Quality

In three experiments where the top third of canes was sampled 25 - 90 days after treatment, the total quantity of stored sugar (estimated by pol % dry matter) was significantly increased by 5 - 7.5 kg/ha PP757 sprays, although there was no improvement in the quality of whole stalks sampled at the same time. However, in two other trials analyses conducted 25 - 27 days after the sprays had been applied, indicated that juice purity of whole stalks had been significantly improved. In general the results from 3 - 4 week samplings were inconsistent.

More reliable improvements in measured juice quality and total sugar content due to 7-methylindole treatment were obtained in samples cut 60 - 90 days after treatment (Fig. 1) and on both NCo 376 and CB 4114 the chemical was as effective a ripener as glyphosine at equivalent rates.

Table 1 Percentage of canes showing severe retardation (arbitrary scale) 72 days after treatment.

		%	Arcsine Transformation
Control-unsprayed		0	0
2.5 kg/ha PP757		2.8	9.7
5 kg/ha PP757		16.6	24.1
7.5 kg/ha PP757		48.1	43.9
L.S.D.	P = 0.05	-	17.1
	P = 0.01	-	23.0

The average of juice quality measurements on untreated canes and on canes sprayed with 7.5 kg/ha PP757 during the course of three experiments in South Africa is shown in Table 2. It will be seen that compared to the untreated controls, there had been a more rapid increase in the sugar content of treated canes during the period up to 26 days after treatment and that this had continued, in absolute terms (but not in proportion to the improvement due to natural ripening) up to 75 days.

Table 2 Mean cane quality values for controls (0) and 7.5kg/ha PP757 treatments from three trials at different sampling intervals.

Days after treatment	Pol % Cane		Purity		Pol % D.M.	
	0	7.5	0	7.5	0	7.5
0	5.9	-	59.3	-	28.9	-
26	7.3	7.8**	65.0	67.0*	32.8	34.4*
75	11.1	11.9	82.5	83.4	43.9	45.4

Asterisks indicate significant differences from respective control figures
* P = 0.05 ** P = 0.01

DISCUSSION

In sugar cane, the partition of photosynthetic assimilates between vegetative growth and sucrose storage is influenced by environmental conditions. The rapid accumulation of stored sugars in natural ripening is enhanced by sub-optimal temperatures, and nutrient and water deficiency. However, treatments which desiccate sugar cane can simply concentrate the sugars in the stem and so cause an apparent increase in sugar content. Chemicals which have this effect are less valuable than those which can bring about a genuine improvement in the harvestable sugar (estimated by pol % dry matter). Although many compounds have been reported to have some effect as cane ripeners (6), those which have been found so far to be particularly reliable in causing real increases in sugar yield are ethephon and glyphosine (6, 7). These compounds, together with some others such as 7-methylindole which can cause a true increase in total sugar content, generally have the property of retarding new leaf growth at the apex without damaging fully expanded leaves. There now seem to be sufficient examples of effective growth inhibitors to be confident that, as originally suggested by the work of Hartt et al. (5), chemicals which divert assimilates from the production of new leaf and stem tissue during conditions otherwise favouring active growth, can result in the accumulation of more sugars in the stem. Growth retardants such as maleic hydrazide which are not good cane ripeners, probably not only arrest leaf growth but also influence other metabolic processes affecting sucrose storage.

PP757 was not developed for sales, because, both as a sugar cane ripener and as a grass growth retardant, it was inconsistent in action. Results of some other sugar cane trials not covered by this paper gave less favourable results than those described. Moreover, on sugar cane, observed increases in sugar content were insufficiently large to cover the cost of treatment and on grass there was the added disadvantage that treated foliage became pale green in colour. A high level of grass growth inhibition in the field was noticed to be associated with cool temperatures following PP757 application and in growth room experiments with grass and cereals, it was confirmed that retardant activity was markedly reduced by allowing sprays deposits to dry at 28°C rather than 12 - 13°C. Volatility of the compound was discovered to be high (vapour pressure 2.35×10^{-1}Pa at 25°C) and losses from surfaces by volatilisation occurred rapidly and were considerable at temperatures above 25°C within one hour of application. 7-methylindole is also degradable by light and oxidation (2). No doubt these factors contributed strongly to the variability of field trial results and to the relatively high and uneconomic rates of 5 - 10 kg/ha which were found to be required to induce cane ripening in the tropics.

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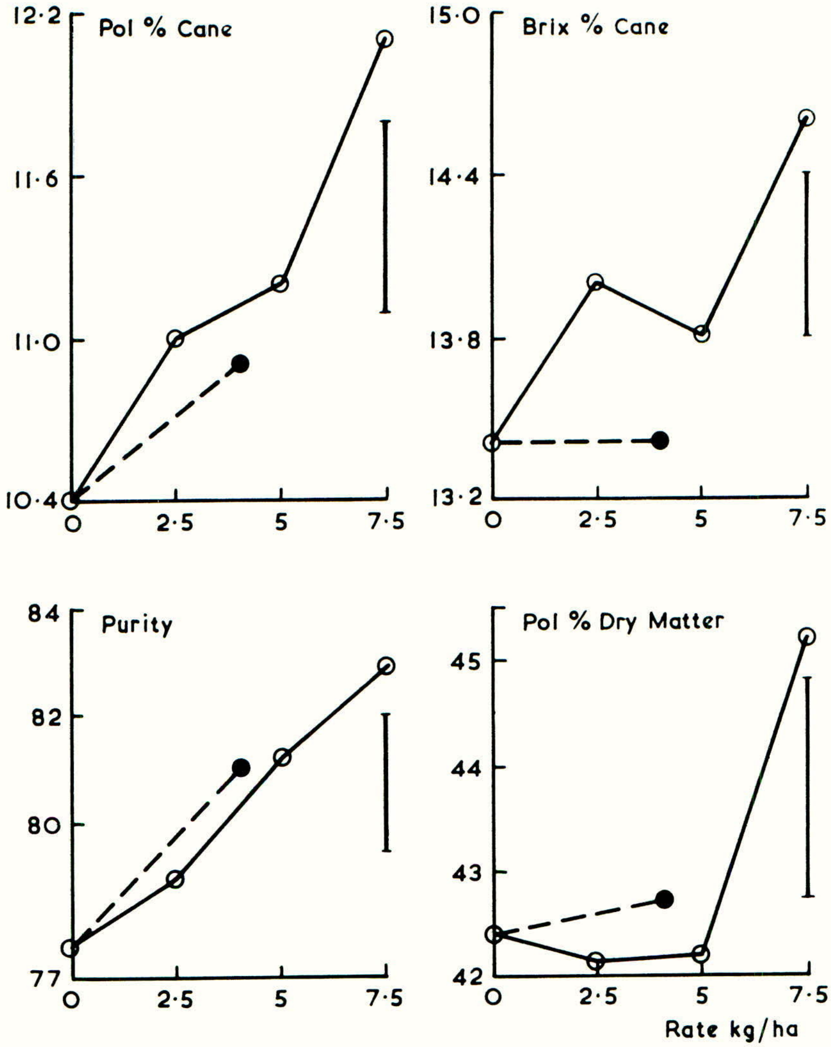
Fig. 1. The effect of PP757 (open circles) and glyphosine (closed circles) sprays on juice quality of canes in a South African trial harvested 76 days after treatment.

Vertical bars indicate least significant differences ($P = 0.05$).



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THE PLANT GROWTH REGULATORY PROPERTIES OF A GROUP OF N-CARBAMOYLIMIDAZOLES

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Summary BTS 34 723 is the selected member of a series of N-carbamoyl-imidazoles which show marked growth regulatory properties on a wide range of crop species, including small grain cereals, sugar cane, soy-beans and other legumes. The plant response is a retardation of vegetative growth which is exerted through an effect on the root system and leads to a reduction in growth of the shoot. No foliar activity has been detected to date.

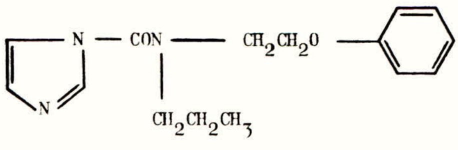
A large number of plants are affected but practical uses are probably restricted to those crops where the chemical can be readily applied to the root system. Two major crops, sugar cane and rice have been identified for further work; BTS 34 723 has shown ripening properties on sugar cane when applied in irrigation water and is showing activity as a potential anti-lodging agent in rice.

INTRODUCTION

Commencing in 1969, a programme of chemical synthesis around the area of N-carbamoylimidazoles was undertaken by The Boots Company. This led to the discovery of a group of compounds with plant growth regulatory activity and from these BTS 34 723 was selected as one of the more active members of the series. The activity is characterised by a retardation of vegetative plant growth with little or no effect on the formation of reproductive organs. The primary effect of the compound is to retard the growth of the root system which leads to a reduction in the growth of the shoot. Because of the mechanism of action, potential practical use is seen in those crops where the chemical might be applied to the root system and in particular irrigated sugar cane and paddy rice.

Chemical and Physical Properties

The compound is chemically 1-/N-(2-phenoxyethyl)-N-propylcarbamoyl7-1H-imidazole (IUPAC) or N-(2-phenoxyethyl)-N-propyl-1H-imidazole-1-carboxamide (C.A.), and its structure is as follows:-



Molecular formula -	-	$C_{15}H_{19}N_{3}O_{2}$
Molecular weight	-	273
Physical form	-	colourless, viscous liquid
Boiling point	-	209°C/1.0 mm Hg
Melting point	-	31-32°C
Miscibility	-	Miscible with aromatic hydrocarbons, ketones and chlorinated hydrocarbons but immiscible with aliphatic hydrocarbons and water
Wiswesser line formula	-	T5N CNJ AVN3&2OR

Toxicology

The acute toxicity of BTS 34 723 has been determined as follows:-

Species	Route	LD_{50} (mg/kg)
Mouse (male)	Oral	500
Rat (male)	Oral	500-1000
Rat (male)	Dermal	>4000

MATERIALS AND METHODS

Preliminary evaluation of chemicals within the group was carried out in glasshouses but further investigations also used controlled environment rooms. For most experiments plants were grown in 9 cm or 12.5 cm diameter flower pots in a growing compost medium consisting of 6 parts loam, 1½ parts grit and 1½ parts sand.

Temperatures in glasshouses were set to give a minimum of 15°C and 24°C according to the crop plants under study.

Treatments were applied either as an aqueous foliar spray with ethylan PB added as a surfactant, or as a root drench when the chemical suspended in water was simply poured onto the soil.

RESULTS

Spectrum Studies

Seeds of a number of temperate and sub-tropical crop species were sown in pots and grown on for 2-3 weeks. The young seedlings were treated with BTS 34 723 either as a foliar spray at rates of 4000, 2000, 1000 and 500 mg/l or as a root drench at rates of 30, 15, 7.5 and 3.75 mg/pot. The following species showed a 25% or greater reduction in plant height within four weeks of treating the roots with 15 mg of chemical.

Tomato (Moneymaker)	Maize
French bean (Canadian Wonder)	Sorghum (NK 220Y)
Wheat (Maris Dove)	Soybean (Merit)
Barley (Proctor)	Rice
Oats (Astor)	
Sunflower (Tall mixed)	

No species showed any significant response when the chemical was applied to the foliage. This may represent either a specific effect on the roots or that the chemical failed to reach a site of action in the shoot. Repeated attempts to achieve activity with foliar applied chemical by the addition of a range of additives to the spray solution have to date been unsuccessful. However, further studies are required to resolve the reasons for specific activity on the root system. These preliminary observations have been examined in more detail and are described in the following experiments.

The effect of BTS 34 723 on the growth of barley and soybeans

Barley seedlings (cv Proctor) were grown in 9 cm pots in a mixture of sand and vermiculite (3 : 1) in a controlled environment cabinet. Conditions in the cabinet were a photoperiod of 16 hours with a day temperature of 18°C and a night temperature of 12°C. Plants were watered daily with half strength Hoaglands solution. Light was provided by a bank of fluorescent tubes supplemented by tungsten filament bulbs to give an irradiance of 118 W/m^2 at plant height.

When the plants had developed on average 5 leaves their roots were drenched with BTS 34 723 at rates of 15 and 7.5 mg/pot. Three weeks after treatment plants were harvested and measurements of plant height, and shoot and root weight were made (Table 1).

Table 1 Effect of BTS 34 723 on the growth of barley. 6 replicates per treatment

	Dose (mg/pot)	Total plant height (cm)	Dry weight shoot (g)	Dry weight root (g)
BTS 34 723				
	15	49.2 ± 2.71	1.91 ± 0.13	1.06 ± 0.12
	7.5	52.3 ± 2.26	2.93 ± 0.21	1.71 ± 0.21
Control		61.5 ± 2.74	4.22 ± 0.21	2.46 ± 0.22

Application of BTS 34 723 also resulted in a delay of 3-4 days in the appearance of the ear, although there appeared to be no significant reduction in the size of the ear at harvest.

The following results were obtained in an experiment where young soybean plants (cv Merit) at the two true leaf stage were treated with BTS 34 723, applied as a drench to the root system. Measurements were taken four weeks after treatment (Table 2).

Table 2 Effect of BTS 34 723 on the growth of soybeans. 8 replicates per treatment

Dose (mg/pot)	Total plant height (cm)	Dry weight shoot (g)	Dry weight root (g)
BTS 34 723			
15	29.33 ± 1.72	1.23 ± 0.12	0.63 ± 0.09
7.5	30.67 ± 1.81	1.50 ± 0.13	0.85 ± 0.09
Control	37.15 ± 1.93	2.10 ± 0.14	1.02 ± 0.1

Because of the absence of activity with this chemical by foliar application, further work continued only in those areas where application to the root system would be feasible on a large scale. Two situations were identified where a commercial potential might exist, irrigated sugar cane and paddy rice. The objective in sugar cane is to introduce the chemical to the root system where the effect on retarding growth of the root and shoot systems might lead to an enhancement of ripening. In rice there is potential for a chemical that will reduce plant height and thereby act as an anti-lodging agent.

Experiments with sugar cane

Sections of mature stem of sugar cane (var B 49119) were obtained from the Sugar Industry Research Institute, Jamaica and single nodes planted in compost in 18 cm diameter pots and grown in controlled environment rooms where the photo-period was 12 hours with a day temperature of 30°C and a night temperature of 21°C. Light conditions were similar to those previously reported.

When the shoots were approximately 5 cm tall BTS 34 723 was applied as a drench to the soil at rates of 30 mg and 15 mg/pot. There were eight replicates per treatment. After three weeks further growth, the length of individual internodes was measured and comparisons made with control plants (Table 3).

Table 3 Effect of BTS 34 723 on the growth of sugar cane. Length of first 6 internodes (cm)

BTS 34 723		Control
30 mg	15 mg	
11.77 ± 0.91	12.43 ± 0.96	18.13 ± 1.12

As a result of the confirmation of growth retardant activity on sugar cane, BTS 34 723 was evaluated in a simulated irrigation system on mature field grown cane. In this situation the chemical was applied at a rate equivalent to 4 lb/a and measurements of sucrose concentrations and juice purity were made four and seven weeks after application on juice extracted from the uppermost internodes. The following results were obtained (Table 4).

Table 4 Effect of BTS 34 723 on sucrose concentration and juice purity of sugar cane

Weeks after application	Sucrose concentration % F.W. cane BTS 34 723 4 lb/ac	Control	Juice purity % BTS 34 723 4 lb/ac	Control
0	-	5.6	-	59.9
4	10.27	7.12	76.16	64.56
7	11.22	10.58	76.71	76.48

Further experiments have confirmed the effect of BTS 34 723 on increasing sucrose concentration and juice purity in field grown cane when the chemical was applied to the roots.

Experiment with rice

Rice plants were grown in containers in the glasshouse and at approximately 15 days before heading BTS 34 723 was applied as a soil drench at rates of 800, 400 and 200 g a.i./10a. Measurements of stem length, date of heading and ear weight were recorded and results can be seen in Table 5.

Table 5 Effect of BTS 34 723 on the growth of rice

	Dose (g/10a)	Plant height cm	Delay in heading time (days)	Weight of ear g
BTS 34 723				
	800	44.82	5	1.71
	400	55.61	3	2.45
	200	67.23	2	2.31
Control		83.0	-	2.50

Data by courtesy of Nissan Chemical Industries Ltd.

The results clearly indicate that marked reductions in stem length can be achieved in rice with only a slight delay in heading out and no significant effect on the weight of the ear. Further glasshouse and field trial work is in progress to investigate these effects in more detail.

DISCUSSION

BTS 34 723 is one of a series of compounds which when applied to the root system of many species of plants exert marked growth retardant effects. Root growth itself is suppressed and this presumably, leads to a retardation of growth of the shoot. Spraying the chemical onto the foliage in a number of formulated systems has failed to elicit a response in the plants examined.

Because the response to BTS 34 723 is restricted by application to the root system, the practical use of the compounds is limited to specific crops where it would be relatively easy to apply the chemicals to the root system. These have been identified as rice and sugar cane and evaluation of activity in these crops is in progress.

No work has to date been undertaken on the biochemical mode of action of this group of chemicals but it seems likely that it may differ from that of know plant growth retardants where an effect on the metabolism of endogenous gibberellins seems likely.

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