SESSION 4C

PLANT GROWTH REGULATORS, EFFECTS AND INTEGRATION INTO CROP PRODUCTION SYSTEMS

SESSION ORGANISER MR G. BEAUMONT

RESEARCH REPORTS
(Poster papers) 4C-14 to 4C-25

INVESTIGATIONS INTO THE USE OF FLURPRIMIDOL (EL500) AS A PLANT GROWTH REGULATOR FOR WINTER OILSEED RAPE (BRASSICA NAPUS L.)

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ABSTRACT

Applications of flurprimidol (EL500) have been examined in field trials of winter oilseed rape over three growing seasons. EL500 has been shown to exhibit strong growth regulatory properties at rates between 100 and 500 g a.i./ha. Reductions in crop height of up to 50% have been recorded, the extent of height reduction being dependent on rate and timing. In early experiments seed yields were depressed when 500 g a.i./ha was applied in the autumn. However, lowering the application rate and applying in the spring has now resulted in significant shortening of the crop without incurring a yield penalty.

INTRODUCTION

Recent estimated mean U.K. yields for oilseed rape have not exceeded 3.4 t/ha (MAFF, 1984). Such levels of productivity fall well short of the potential, considered by some to be as high as 7-8 t/ha (Jones, 1983). It is unrealistic to expect that applications of plant growth regulators (PGRs) could substantially reduce the differential between the potential and actual yields but as part of an agronomic package they undoubtedly have a role. From a practical point of view, a PGR with the capacity to reduce crop height could be a valuable management aid. A shorter crop is less likely to lodge which, in turn, reduces wasteful secondary growth and lessens the risk of fungal development within the canopy. A lodged crop is also more difficult to harvest, A short standing crop would allow easier post-anthesis crop management negating the need for specialist high clearance machinery. Also reducing the amount of vegetative material passing through the combine and more even maturity of plants at harvest may further improve the harvesting operations.

On a more fundamental level, it is possible to speculate about physiological changes achievable through PGR use which could increase yields. Mendham & Scott (1975) and Scarisbrick & Daniels (1984) have demonstrated that UK crops sown in early September resulted in floral initiation by early November. A PGR application at this stage may influence subsequent crop development by altering apical development and reproductive hierarchy, thus modifying the components of seed yield. There are also reports of improved winter hardiness from the use of PGRs in rape in eastern Europe (Voskerusa,1972).

Spring applications may be expected to reduce stem extension, thereby changing canopy structure. This could improve light penetration into the canopy and confer benefits for the lower order branches in terms of position and hence contribution to seed yield.

A research programme was initiated at Nottingham University's School of Agriculture in 1981 to investigate the potential of a number of chemicals as PGRs for winter oilseed rape (Brassica napus L.). This report outlines the development of some of the effects of a novel material flurprimidol (α- (1-methyethyl) α[4-(trifluoromethoxy)phenyl]-5-pyrimidine methanol), hereafter referred to as EL500.

MATERIALS AND METHODS

EL500 (supplied by Elanco Products Ltd.) was formulated as a 50% wettable powder and all rates given in the text are of active ingredient. Applications of this chemical were included in replicated randomised block design experiments undertaken on the University Farm between 1981 and 1984. A number of chemicals were assessed but only data for EL500 are presented in this paper. Treatments were applied in a water volume of 250 l/ha with a tractor mounted plot sprayer (1981-82 & 1983-84) or a hand-operated Mystifier Knapsack sprayer (1982-83). Detailed growth analyses were carried out during the course of the first two seasons. Further experimental and sampling details are given in Table 1.

TABLE 1

Experimental and sampling details

	1981-1982 trial	1982-1983 trial	1983-1984 trial
Variety	Jet Neuf & Elvira	Jet Neuf	Bienvenu
Drilling date	25.8.1981.	25.8.1982.	1.9.1983.
Plot dimensions	1.5m x 10m	3m x 15m	2m x 20m
Replication	3	3	4
Growth analysis -			
Sample area (m^2)	0.45	0.30	
Subsample plant no.	10	15	
Final harvest -			
Date	9.7.1982.	26.7.1983.	31.7.1984.
Plot area (m^2)	2.7	18.1	38.0
EL500 application rate (g a.i./ha) and date			
Autumn	500 13.11.1981.	125, 250 } 15.11.1982	
Spring		125, 250 } 1.3.1983.	100, 250 } 20.3.1984.

Photosynthetic green areas were measured using a 'Licor Planimeter' and dry weights of plant components were recorded after drying in an oven at 85 C for 48 h. At crop maturity additional estimates of seed yield were obtained by harvesting of larger plot areas. In 1982 this was done by hand harvesting. After adequate drying in a greenhouse, the plants were put through a stationary thresher. In the following year, the plots were swathed and harvested 13 days later with a Claas Compact plot combine. In 1984 harvesting with the same machine followed crop dessication with diquat (3 l/ha Reglone) with 0.1% Agral wetter.

Assessment of leaf chlorophyll concentration was made by grinding 13.2 mm diameter leaf discs with acid washed sand in 80% aqueous acetone. After centrifugation, the optical densities (OD) of supernatant were measured at wavelengths of 645 and 663 nm with a Unicam SP Spectrophotometer. Total chlorophyll was calculated by using the extinction coefficients obtained by Mackinney (1941).

i.e. Total chlorophyll (μg/ml) = $(20.2 \times OD_{645}) + (8.02 \times OD_{663})$

Visual assessments of crop lodging were made during crop development. The percentages of plants on each plot falling into three categories were estimated. The categories were:-

1. Standing
2. Leaning - stems at an angle > 45 degrees to the ground
3. Lodging - stems at an angle < 45 degrees to the ground

RESULTS

1981-82 trial

No significant interactions were found between variety and PGR treatment. The values presented herein are means of the Jet Neuf and Elvira crops unless otherwise stated. A more detailed report of this trial was given by Dawkins and Almond (1984).

Autumn application of EL500 induced a marked effect on plant morphology which persisted to maturity. Figure 1 shows the extent of stem shortening caused by the chemical. From April onwards, stem length was significantly reduced ($p = 0.001$) and at final harvest a mean reduction of 46% was recorded.

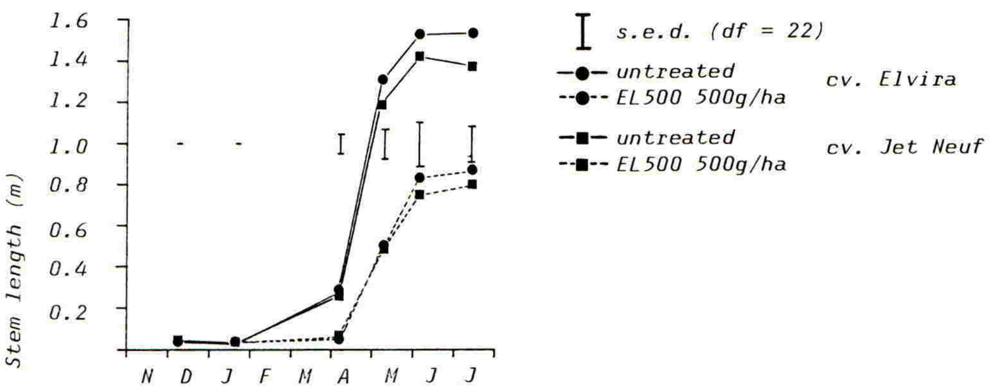


Fig. 1. Effect of autumn application of EL500 on stem length

In November and December, all crops had leaf area indices (LAIs) in the range 3.0-3.2. However, by early April, the mean LAI of the EL500 treated crop (1.4) was 61% lower than the untreated crop. Higher temperatures and lengthening days thereafter were accompanied by an expansion of leaf canopies, although maximum recorded LAIs of 3.5 and 2.9 for control and EL500 crops respectively indicated that the reduction had been maintained.

Photosynthetic area development reflected crop dry matter accumulation. Application of EL500 resulted in reduced above ground biomasss production by the crop. However, in April, a decrease in leaf dry weight of only 32% compared with 61% for LAI suggested that thickening of leaf tissue may have occurred. Plant survival was unaffected by chemical treatment and the lower green areas and dry matters per unit ground area of EL500 crops were attributable to effects on individual plant performance.

EL500 caused a 29% reduction in combine seed yield ($\underline{p}$ = 0.001) (Table 2). The yield depression recorded by growth analysis was not significant at the $p < 5\%$ level, but it did represent a 0.4 t/ha difference in favour of the untreated plots. Lodging was not a problem in this trial and it was unaffected by variety or treatment.

TABLE 2

Seed yield and its components : 1981-1982 trial

	Seed yield (t/ha, d.m.)		Fertile pod no.	Aborted pod no.	Seed no. per pod	Mean seed weight
	Combine yield	Growth analysis	($/m^2$)	($/m^2$)		(mg, d.m.)
Control	3.83	3.87	6517	1734	11.29	5.36
EL500	2.70	3.47	6961	3703	9.50	5.29
s.e.d.(df=22)	0.28	0.66	1122	410	0.73	0.23
significance	***	N.S.	N.S.	**	*	N.S.

1982-83 trial

The effects of both autumn treatments (125 and 250 g/ha) were evident eight weeks after application (Figure 2), the vegetative stems of the control plants being significantly longer ($\underline{p}$ = 0.05). This difference in height, although small, was maintained through the winter period. From March onwards, during a period of rapid stem elongation, retardation of stem extension was related to the rate applied ($\underline{p}$ = 0.001). At maturity, an average height reduction of 21% and 40% resulted from November applications of 125 and 250 g/ha respectively. The dose related effects on stem length were more pronounced with spring application. At harvest height reductions of 30% and 55% were induced by the above rates (Figure 2).

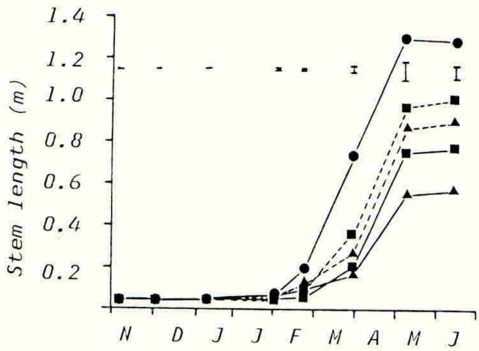


Fig. 2 Effect of EL500 on stem length

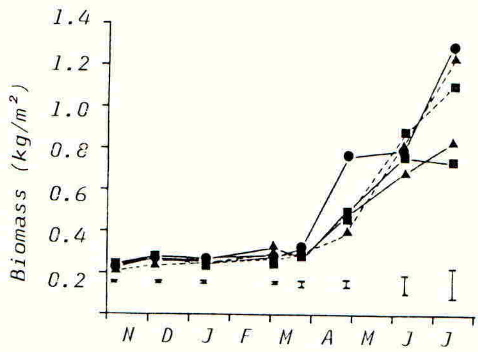
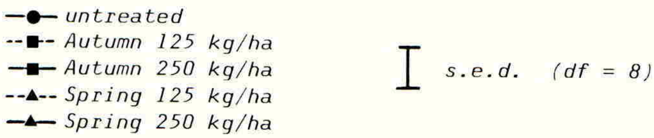


Fig. 3 Effect of EL500 on biomass production per unit area



The effect of EL500 on crop dry matter accumulation was less consistent (Figure 3). A significantly lower biomass and leaf area per unit area was recovered from all chemically treated plots on 28 April ($\underline{p}$ = 0.001). At maturity, the effects due to rate were more pronounced than those by timing. Autumn and spring treatments of 250 g/ha both caused a reduction in biomass ($\underline{p}$ = 0.05). 125 g/ha applied in autumn or spring, although shortening crop height, did not significantly reduce dry matter production. The control crops lodged extensively (Table 3). In all EL500 treated plots lodging was absent. Even on the autumn low rate plots, where only a small height reduction occurred, the rate was sufficient to prevent lodging.

TABLE 3

The influence of EL500 on crop lodging : 12 July, 1983
(After Dawkins & Almond, 1985)

	Proportion of crop (%) :		
	Standing	Leaning	Lodged
Control	1.7	13.3	85.0
Autumn 125 g/ha	81.7	18.3	0.0
Autumn 250 g/ha	70.0	30.0	0.0
Spring 125 g/ha	80.0	20.0	0.0
Spring 250 g/ha	98.3	1.7	0.0

Plants treated with 250 g/ha EL500 had a higher ratio of leaf dry weight to area (Table 4). This suggests an increase in the thickness of the leaf lamina, previously inferred from the 1981-82 data. The *increase in dry weight per unit leaf area was not accompanied by an increase in chlorophyll per unit leaf area (Table 4).*

TABLE 4

The influence of EL500 on leaf lamina weight and chlorophyll content

	Dry weight per unit leaf area (mg/mm^2)	Chlorophyll content per unit leaf weight (g/g d.m.)	Chlorophyll content per unit leaf area (g/mm^2)
Control	0.188	3747	0.694
Autumn 125 g/ha	0.177	3900	0.709
Autumn 250 g/ha	0.206	3230	0.748
Spring 125 g/ha	0.177	4188	0.761
Spring 250 g/ha	0.221	3390	0.758
s.e.d. (df=8)	0.012	279.2	0.044
significance	*	N.S.	N.S.

Apart from a reduction in total biomass neither seed yield or its components were significantly affected (Table 5). With coefficients of variation reaching 19%, this may well reflect the inherent variability found within oilseed rape (Scarisbrick ***et al.****, 1984) rather than the complete absence of treatment effects.*

TABLE 5

Seed yield and its components : 1982-1983 trial

	Seed yield (t/ha, d.m.) Combine yield	Seed yield (t/ha, d.m.) Growth analysis	Fertile pod no. ($/m^2$)	Aborted pod no. (m^2)	Seed no. per pod	Mean seed weight (mg)
Control	2.02	2.53	6565	2615	7.41	5.19
Autumn 125 g/ha	2.12	2.09	6552	3662	6.55	4.93
Autumn 250 g/ha	1.74	1.63	4716	3524	7.14	4.80
Spring 125 g/ha	1.88	2.63	6992	4010	7.22	5.27
Spring 250 g/ha	1.79	1.81	5490	4387	7.13	4.66
s.e.d. (df=14)	0.16	0.33	1076	992	0.78	0.20
cv (%)	10.4	19.1	23.2	33.4	13.5	4.9

Seed yields from combined plot areas and growth analysis samples suggest that the use of EL500 at 250 g/ha, either in autumn or in spring, may depress yield probably because of greater pod abortion, fewer fertile pods and, to a lesser extent, smaller seeds. A lower rate, 125 g/ha, offered more potential especially for a spring application. Here a 30% reduction in stem length and reduced lodging was achieved with little evidence of a concomittant yield depression.

1983-84 trial

Detailed growth analysis data is not available for this trial. The stem length of 10 plants, from each plot, was recorded on 15 June, 1984 and EL500, applied on 20 March at two rates (100 and 250 g/ha), significantly reduced growth and retardation was related to rate (Table 6). In a season when lodging was not a problem, yield responses to EL500 was unaffected (Table 6). Mean seed size was also unaffected.

TABLE 6

Stem length and seed yield : 1983-1984 trial

	Stem length (cm)	Seed yield ex-combine (t d.m./ha)
Control	129.8	3.34
Spring 100 g/ha	100.1	3.51
Spring 250 g/ha	86.8	3.21
s.e.d. (df=21)	2.45	0.21
significance	***	N.S.

DISCUSSION

Evidence accumulated to date demonstrates that EL500 had a potent stem shortening capacity on oilseed rape. However, rates of 250 and 500 g a.i./ha applied either in autumn or spring incurred a yield penalty. 125 g/ha in November improved the standing ability, but was not sufficiently persistent in its dwarfing effect to greatly improve crop management after anthesis. The winter hardiness of present commercial varieties is adequate to survive typical U.K. winters without the need for chemical protection. Attempts to manipulate floral initiation at the plant apex by using autumn applications of chemicals have been hindered by our lack of understanding of the physiology of the rape crop.

The use of EL500 in spring, prior to or during stem elongation, at a rate of 100 - 125 g/ha appears to offer more potential for improving crop management. This combination of timing and rate markedly shortened the crop without reducing seed yield. Practical and tangible benefits in terms of ease of crop management, improved crop morphology and, ultimately, higher seed yields may be accrued by further optimization of concentration and timing of EL500 application. Further evaluation of the chemical is currently being undertaken at Sutton Bonington.

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WINTER OILSEED RAPE GROWTH REGULATORS - ADAS TRIALS 1981-4

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ABSTRACT

The effect on seed yield of chlormequat, ethephon and mepiquat chloride and ethephon was assessed in 25 trials carried out over four years at 18 sites. Treatments were applied in the autumn (chlormequat only) or in the spring at green or yellow bud.

On variety Jet Neuf significant ($P<0.05$) yield benefits occurred in some trials and there was a 54-67% chance of a yield benefit sufficient to cover chemical costs of sprays applied at green bud.

On varieties Bienvenu and Rafal ethephon or mepiquat chloride + ethephon at green bud reduced yields in several trials by 4-14% and the chance of a cost-effective yield benefit from a single growth regulator spray at any timing did not exceed 38%.

On all varieties autumn application of chlormequat was less frequently cost-effective than spring applications.

Growth regulators frequently reduced crop height and in some cases ethephon and mepiquat chloride + ethephon caused flower bud damage.

INTRODUCTION

It has been suggested that growth regulators could benefit the yields of oilseed rape by reducing pod abortion, seed shedding or lodging (Woolley 1982) or by increasing apical dominance of the terminal raceme, which has a greater harvest index than the side branches (Daniels, Scarisbrick, Mahamud 1984). Effects on branching and crop height could influence penetration of light into the canopy, giving better utilisation of available light (Dawkins and Almond 1984). Child (1984) has pointed out that reduced crop height could enable easier spraying and harvesting and that growth regulators which induce abscission of late-opening flowers could give more uniform ripening, leading to less pod shatter and seed losses at harvest. Autumn application of growth regulators may influence floral initiation, leaf size and area at spring regrowth, apical dominance and branch numbers (Dawkins and Almond 1984).

This paper primarily discusses the effect on seed yield of a range of commercially available growth regulators applied in autumn or spring and makes some reference to their effect on crop height and components of yield.

TABLE 1

Plant growth regulators applied

Active ingredient	Product (l/ha applied)		Time of application
Chlormequat+ (CCC) 460 g/l	5 C Cycocel	(3.0-3.5)	S1
Chlormequat (CCC)‡ 645 g/l	New 5 C Cycocel	(2.5-3.0)	S1 or S2
Chlormequat (CCC) + additives	Podquat	(2.3-3.0)	A or S1
Ethephon 480 g/l	Cerone	(1.0)	S1 or S2
Mepiquat chloride 305 g/l + ethephon 155 g/l	Terpal	(2.5-3.0)	S1 or S2

A = mid-October - end November, rosette stage
S1 = mid-February - mid-April, green bud (early stem extension)
S2 = mid-April - early May, yellow bud

\+ 1981-1982 only

‡ 1983-1984 only

Plots were arranged in fully randomized blocks replicated three or four times, sited in commercial crops receiving 200-250 kg/ha N in the spring and adequate pest, disease and weed control. Treatments were applied in 200-250 l/ha solution by CO_2 - pressurized sprayers fitted with 80 or 110° fan nozzles delivering around 1.1 l/min at 2.8 bar. Wetters, as Agral or Citowett, were included with the CCC, ethephon and ethephon + mepiquat chloride at up to 100 ml/100 l solution. The area combined was 30-130 m^2 per plot.

RESULTS

Trial results are presented for Jet Neuf (Table 2), which appears to respond favourably to growth regulators, and for the other varieties tested (Rafal, Lingot, and Bienvenu - Table 3) which seem to react adversely to these growth regulators.

There were relatively few significant ($P<0.05$) effects on seed yield. On the variety Jet Neuf (Table 2) significant yield benefits occurred most frequently with ethephon applied at green bud stage, four trials out of 13 giving a measurable yield increase of 5-10%. Delaying the application of ethephon or mepiquat chloride + ethephon until the yellow bud stage was first tested in two trials in 1984 and in both cases significant yield benefits of 7-13% occurred.

On the varieties Bienvenu, Lingot and Rafal significant yield benefits occurred only when ethephon was applied at yellow bud, with or without CCC at green bud, or when ethephon was applied at green bud and followed by CCC at yellow bud. These benefits were in the range 4-8%. Several trials recorded significant yield reductions of 4-14% where ethephon or mepiquat chloride + ethephon were applied at green bud without a later spray and even greater yield losses (16-24%) occurred in all three trials where ethephon was applied at both green and yellow bud. In many trials these yield reductions were accompanied by flower bud damage on the main and side racemes, increased production of side branches and prolonged flowering on those branches. At Boxworth, where plots were combined direct without desiccation, harvest of these treatments had to be delayed for five days until the pods were ripe. However there were some sites, such as St Ives and Washbrook, where, despite this damage, significant yield benefits were recorded.

Crop heights during or after flowering were measured on some trials and these are presented in Table 5. CCC + wetters in the autumn or spring and CCC in the spring gave small but significant height reductions, averaging 2-3%. Significant height reductions occurred frequently with ethephon and mepiquat chloride + ethephon, averaging 7-10% for both the green and yellow bud timings and 14% where ethephon was applied at both green and yellow bud.

Pods/plant, seeds/pod and thousand seed weight were assessed at Itchen Abbas (1981), Ashampsted (1982) and Boxworth (1982-4). There were no significant effects of growth regulators on these components and no consistent trends occurred.

Because of the high value of rapeseed only small yield benefits, which seldom achieve statistical significance, are needed to justify using growth regulators. The results presented in Tables 2 and 3 have been used to generate probabilities of achieving yield benefits sufficient to cover the costs of the various growth regulators (Table 4). Application cost has not been included in these calculations as this varies from farm to farm and it may be possible to avoid this cost altogether by tank mixing a growth regulator with a herbicide or fungicide. In these trials Jet Neuf offered a 54-67% chance of a yield benefit sufficient to at least cover the cost of any of the chemicals tested at the green bud stage. The two trials testing yellow bud applications suggest that this timing is at least as effective. Autumn treatments were cost-effective less frequently. On the varieties Bienvenu, Lingot and Rafal all but two of the treatments tested gave no more than a 38% chance of a cost-effective yield benefit. The exceptions were the sequences of CCC at green bud followed by ethephon at yellow bud or vice versa, although these were tested on only a few trials in one season.

DISCUSSION

Other workers have reported effects on seed yield and crop height similar to those recorded in this paper. Daniels et al (1984) applied CCC or CCC + additives in November but did not record any significant effects on seed yield, although there were some marked non-significant increases from CCC treatments. Spring applications of CCC have produced non-significant reductions in crop height but little or no increase in seed yield (Scarisbrick et al 1982; Daniels et al 1982a) and spring application of CCC + additives did not affect the crop (Daniels et al 1982b). Mepiquat chloride + ethephon applied at green bud has significantly reduced plant height over the three seasons and reduced lodging but has had no significant effect on seed yield (Daniels et al 1982b).

Doubts have been expressed (Bowerman, 1984) that growth regulators can be recommended for winter oilseed rape due to the relatively small yield benefits from CCC and the inconsistency of these benefits from ethephon and mepiquat chloride + ethephon. However the present work suggests that, depending on the variety grown, some of these treatments can be justified commercially since they give a more than even chance of a yield benefit sufficient to at least cover their costs. On Jet Neuf the trials showed a 54-67% chance of a yield benefit sufficient to cover chemical costs when CCC, CCC + additives, ethephon or mepiquat chloride + ethephon were applied at the green bud stage. These probabilities may be sufficiently attractive to growers to use these materials, particularly if they can be tank mixed with a spring fungicide, thus reducing application costs. However on the varieties Bienvenu and Rafal marked yield reductions occurred from the application of ethephon or mepiquat chloride + ethephon at the green bud stage. Only a minority of trials ($\leqslant$38%) showed apparent cost-effective yield benefits from applying a single spray at green or yellow bud. Such treatments do not therefore appear worthwhile commercially. For all varieties autumn application of CCC + additives was less cost-effective than application of CCC or CCC + additives at green bud.

In 1984 two-spray programmes at green and yellow bud of CCC followed, or preceeded, by ethephon were investigated for the first time on variety Bienvenu. They gave useful yield benefits and ADAS investigations of such treatments and other materials and timings are continuing.

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TABLE 2

Effect of growth regulators on seed yield (cv Jet Neuf)

Year		1981	1982					1983						1984		SUMMARY	
Site/County*		IA/H	A/B	B/C	B/C	E/N	W/C	B/S	B/C	PW/H	K/S	K/B	S/C	W/L	S/W	No. of trials	Mean
Untreated yield (t/ha @ 92% DM)		2.49	3.46	3.73	3.15	3.98	3.22	2.91	2.86	2.00	3.19	2.80	4.21	3.61	3.19	14	3.20
Timing/ chemical		Relative yields (untreated = 100; *italics* = significant difference from untreated ($P < 0.05$))															
A	CCC + additives	105	NT	NT	*109*	99	NT	NT	97	NT	97	111	93	NT	NT	7	102
S1	CCC	NT	NT	*104*	NT	NT	104	100	101	NT	98	114	103	101	101	9	103
S1	CCC + additives	106	NT	100	*113*	96	103	NT	107	NT	99	107	93	NT	NT	9	103
S1	Mepiquat chloride + ethephon	*115*	106	102	NT	100	106	105	106	98	103	119	102	95	*112*	13	105
S1	Ethephon	*110*	108	*105*	NT	99	*107*	102	104	93	96	112	98	98	*108*	13	103
S2	CCC	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	104	103	2	104
S2	Mepiquat chloride + ethephon	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	*107*	*111*	2	109
S2	Ethephon	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	103	*111*	2	107
A + S1	CCC + additives	NT	NT	NT	106	101	NT	NT	NT	105	93	114	98	NT	NT	6	103

* A/B Ashampsted, Berks
B/C Boxworth, Cambs
B/S Bridgewater, Somerset
E/N Eakring, Notts
IA/H Itchen Abbas, Hants
K/B Keysoe, Beds
K/S Kelsale, Suffolk
PW/H Preston Wynne, Hereford
S/C Stukeley, Cambs
S/W Salisbury, Wilts
W/C Whittlesford, Cambs
W/L Wragby, Lincs

TABLE 3

Effect of growth regulators on seed yield (cv Bienvenu, Lingot, Rafal)

cv	Lingot	Rafal-Jet Neuf Blend	Rafal		Bienvenu								
Year	1983	1984	1983	1984	1984							SUMMARY	
Site/County*	R/E	R/E	D/NY	D/NY	PW/H	SI/C	W/S	A/B	H/N	B/C	W/K	No. of trials	Mean
Untreated yield (t/ha @ 92% DM)	2.93	3.18	2.57	4.79	3.61	4.85	4.56	4.46	3.24	3.49	4.10	11	3.89
Timing/chemical	Relative yields (untreated = 100; *italics* = significant difference from untreated ($P < 0.05$))												
A CCC + additives	98	NT	92	NT	NT	NT	NT	NT	NT	101	NT	3	97
S1 CCC	97	98	NT	99	94	99	101	NT	102	104	NT	8	99
S1 CCC + additives	97	NT	98	NT	NT	NT	NT	NT	NT	102	NT	3	99
S1 Mepiquat chloride + ethephon	96	104	*81*	96	94+	103	107	NT	93	*91*	100	10	96
S1 Ethephon	100	*104*	*81*	98	*86*	100	104	NT	96	*93*	101	10	96
S2 CCC	NT	99	NT	NT	NT	100	99	99	106	NT	NT	5	101
S2 Mepiquat chloride + ethephon	NT	102	NT	97	NT	101	104	100	94	NT	97	7	99
S2 Ethephon	NT	102	NT	99	110	*104*	*109*	97	90	NT	96	8	101
A + S1 CCC + additives	101	NT	NT	100	NT	NT	NT	NT	NT	NT	NT	2	100
S1 + S2 Ethephon	NT	NT	NT	NT	*87*	NT	NT	*76*	*84*	NT	NT	3	82
S1 + S2 CCC (S1) + Ethephon (S2)	NT	104	NT	NT	NT	*104*	*108*	NT	NT	NT	NT	3	105
S1 + S2 Ethephon (S1) + CCC (S2)	NT	*108*	NT	NT	NT	101	*108*	NT	NT	NT	NT	3	106

+ Mepiquat chloride + ethephon + CCC

* A/B Ashampsted, Berks; B/C Boxworth, Cambs; D/NY Duggleby, N. Yorks; H/N Hawton, Notts; PW/H Preston Wynne, Herefs; R/E Rochford, Essex; SI/C St Ives, Cambs; W/K Wye, Kent; W/S Washbrook, Suffolk

TABLE 4

Cost-effectiveness of growth regulators (based on tables 2 and 3)

Treatment defined as 'cost-effective' when value of the apparent yield benefit $\geqslant$ cost of chemical. Statistical significance and application costs ignored. Prices used: rape seed £270/t; CCC £8.40/ha; CCC + additives £16.70/ha; ethephon £19/ha; ethephon + mepiquat chloride £27/ha.

Timing/Chemical		Jet Neuf trials		Bienvenu/Rafal/ Lingot trials		All trials	
		Total	% Cost-effective	Total	% Cost-effective	Total	% Cost-effective
A	CCC + additives	7	43	3	0	10	30
S1	CCC	9	78	8	38	17	59
	CCC + additives	9	56	3	33	12	50
	Mepiquat chloride + ethephon	13	54	10	30	23	43
	Ethephon	13	54	10	20	23	39
S2	CCC	2	100	5	20	7	43
	Mepiquat chloride + ethephon	2	100	7	14	9	33
	Ethephon	2	100	8	38	10	50
A + S1	CCC + additives	6	33	2	0	8	25
S1 + S2	Ethephon	-	-	3	0	-	-
	CCC(S1) + ethephon(S2)	-	-	3	100	-	-
	Ethephon(S1) + CCC(S2)	-	-	3	67	-	-

TABLE 5

Crop height during or after flowering

Year		1981	1982	1983					1984						SUMMARY	
Site/County*		IA/H	A/B	B/C	K/B	S/C	R/E	D/NY	W/L	S/W	R/E	SI/C	W/S	H/N	No. of trials	Mean
Variety+		JN	JN	JN	JN	JN	L	R	JN	JN	JN-R	B	B	B		
Date measured		16/7	17/7	6/7	18/5	20/5	9/5	20/7	26/7	3/8	26/6	13/7	18/7	7/6		
Untreated height (cm)		144	153	114	165	172	146	112	126	123	136	129	134	131	13	137
Timing/Chemical		Relative heights (untreated = 100; *italics* = significant difference from untreated ($P < 0.05$))														
A	CCC + wetters	*97*	-	-	*98*	*98*	97	-	-	-	-	-	-	-	4	98
S1	CCC	-	-	99	*94*	*98*	*92*	-	99	99	96	*93*	103	98	10	97
S1	CCC + wetters	*97*	-	101	*96*	*97*	*94*	102	-	-	-	-	-	-	6	98
S1	Ethephon	*94*	*83*	98	*93*	*93*	*90*	*94*	*95*	96	*84*	*87*	98	96	13	92
S1	Mepiquat chloride + ethephon	*94*	*87*	101	*94*	*95*	*90*	*94*	98	*95*	*85*	*82*	*94*	99	13	93
S2	CCC	-	-	-	-	-	-	-	99	*95*	97	97	101	98	6	98
S2	Ethephon	-	-	-	-	-	-	-	*90*	*87*	*90*	*92*	*88*	*90*	6	90
S2	Mepiquat chloride + ethephon	-	-	-	-	-	-	-	*91*	*91*	*90*	*95*	*88*	96	6	92
A + S1	CCC + wetters	-	-	-	*96*	*96*	*93*	100	-	-	-	-	-	-	4	96
S1 + S2	Ethephon(S1) + CCC(S2)	-	-	-	-	-	-	-	99	-	*88*	*84*	*96*	-	4	92
S1 + S2	CCC(S1) + ethephon(S2)	-	-	-	-	-	-	-	*95*	-	*90*	*90*	*88*	-	4	91
S1 + S2	Ethephon	-	-	-	-	-	-	-	-	*83*	-	-	-	*90*	2	86

* A/B Ashampsted, Berks
B/C Boxworth, Cambs
D/NY Duggleby, N Yorks
H/N Hawton, Notts
IA/H Itchen Abbas, Hants
K/B Keysoe, Beds
R/E Rochford, Essex
S/C Stukeley, Cambs
S/W Salisbury, Wilts
SI/C St Ives, Cambs
W/L Wragby, Lincs
W/S Washbrook, Suffolk

\+ B Bienvenu
JN Jet Neuf
L Lingot
R Rafal

THE USE OF PLANT GROWTH REGULATORS FOR THE CONTROL OF SWARDS IN TREE FRUIT ORCHARDS

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ABSTRACT

Grass swards are often used in the interrow areas of fruit orchards to aid the movement of machinery and reduce potential soil erosion. To decrease competition with the trees and to aid orchard management the grass needs to be kept short, normally by mowing. Mowing is costly and so chemical control could become important. Paclobutrazol, as a soil treatment, can be effective with its effects persisting for a season after the last of a series of annual applications. Paclobutrazol was most effective when applied in late spring at a rate of 4 kg ha^{-1}. In a dry spring the simultaneous application of paclobutrazol and mefluidide was more effective than either paclobutrazol alone or the application of one material in March and the other in May. The sequence mefluidide-paclobutrazol was more effective than the reverse.

INTRODUCTION

Most top fruit orchards in Western Europe are managed with herbicide treated rows and grassed interrows. This combines a competition free zone adjacent to the tree with an alley which can be used for machinery movement but which is protected against soil erosion. To reduce competition with the tree for water the sward is mown: long grass uses more water than a regularly mown sward (Goode 1956). To maintain a short sward requires up to 20 cuts per year. This is expensive and ties up labour which might more profitably be used for operations like summer pruning. Chemical plant growth regulators offer the potential to reduce the growth of the sward and so eliminate or reduce the need for mowing. The foliar acting materials previously tested, e.g. maleic hydrazide were inconsistent in their degree of control and did not give season long retardation. Soil acting materials such as the triazole paclobutrazol (Lever, Shearing and Batch, 1982) appear to have the potential to give both longer and more reliable control. Boorman, Parr and Marrs (1984) reported that paclobutrazol at rates from 1.6 - 3.2 kg ha^{-1} reduced the growth of both a regularly mown _Lolium perenne_ sward and an unmown sward dominated by _Argostis stolonifera_. Marshall and Craine (1984) found that it affected a range of grass species differently. Preliminary results (Atkinson and Crisp, 1983) suggest that paclobutrazol could also be of value in the control of orchard swards. This paper brings together the results of a series of trials, comparing the efficacy and duration of control by both soil and foliar acting materials, the effect of rate and time of application and the flexibility which can be obtained by applying paclobutrazol in combination with the foliar acting material mefluidide which is also an effective grass retardant (Atkinson, Crisp and Thomas, 1980; Price, 1984.

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MATERIALS AND METHODS

Results were obtained from a series of experiments carried out over the period 1978-1984 on the fine sandy loam soil (Malling series) of East Malling Research Station.

Experiment 1

S50 timothy (Phleum pratense ssp bertolonii) was sown in spring 1977 as a series of 1.5 x 1.5m plots which from 1978-1980 were either left a) untreated or given an annual application of b) paclobutrazol at 4.0 kg ha^{-1} or c) mefluidide at 0.55 kg ha^{-1}. Plots were recorded as described by Atkinson et al. (1980) being left uncut until a single annual harvest in the autumn. All treatments were replicated 6 times in a randomized block design. Although chemical applications ceased in 1980 plots were maintained and harvested in autumn 1981 so as to assess residual effects of the three years of chemical treatment.

Experiment 2

An established mixed species sward dominated by Italian rye grass (Lolium multiflorum) was divided into 3 x 3 m plots and in 1983 each of 5 replicate blocks were either a) left untreated or given an application on 29 April and again on 11 August of b) maleic hydrazide at 5.6 kg ha^{-1} (plus 24D as "Retard"), c) Mefluidide at 1.0 kg ha^{-1}, d) paclobutrazol at 1.5 kg ha^{-1}. Growth was recorded on 3 dates in 1982. At the initial harvest only a part of each plot was cut so that on a second date effects on both cut and previously uncut swards could be assessed.

Experiment 3

A perennial ryegrass sward (Lolium perenne) sown in spring 1982 was treated on 10 March, 7 April or 6 May, 1983 with either 2 or 4 kg ha^{-1} of paclobutrazol. There was also an untreated plot uncut, after mid March except at the times of experimental harvests, (26 May, 17 June and 8 August) and another chemical treatment for which results are not reported but which were used in the statistical analysis. All treated plots were mown before chemical application. Little grass growth occurred between mid March and early May. All treatments were replicated 6 times in a randomized block design.

Experiment 4

In 1984 the plots used for experiment 4 were rerandomized within blocks. Covariance was used to assess residual effects. These were small compared to the effects of the current treatments. At the time of the June 1984 harvest the variance ratio due to old treatments was 4.87 compared to 34.0 for current treatments. Plots were treated either after cutting on 26 March 1984 with paclobutrazol at 2 or 4 kg ha^{-1} or after cutting on 14 May with paclobutrazol at 2 kg ha^{-1}. Paclobutrazol treated plots received applications of mefluidide at 0.5 kg ha^{-1} in May or at 1 kg ha^{-1} in either March or May or no mefluidide. There were untreated plots uncut after either the dates of the March and May treatments except for experimental harvests.

RESULTS

Effects of plant growth regulators on grass growth

Both paclobutrazol and mefluidide significantly retarded grass growth in 1979 in experiment 1 (Table 1). The reduction with paclobutrazol was 56% of control growth. In 1981, the season following the last chemical treatments, growth was retarded by paclobutrazol to a similar extent to its effect in 1979. Mefluidide had no residual effect. Both treatments reduced seed head production although the effect was greater with mefluidide. The proportion of the ground surface covered by grass was increased by the chemical treatments (Table 1).

TABLE 1

The effect of a number of plant growth regulators on the total yield (tonne ha^{-1}) (1979 treated, 1981 untreated). Wt of flower heads (kg ha^{-1}, 1979) and the % of the ground surface covered in 1979. Experiment 1.

Treatment	Yield 1979	Yield 1981	Wt. flowers	% Cover
Control	5.93	4.95	245	74
Mefluidide	3.12	4.87	112	82
Paclobutrazol	2.63	2.88	171	88
SED	0.49	0.69	31	5.4
Significance	**	*	**	**

The same treatments were effective in reducing the growth of a mixed species sward in experiment 2 (Table 2). Assessed early in the season mefluidide, paclobutrazol and the chemical standard, maleic hydrazide, were all equally effective. By 30 July the growth reduction was greater with paclobutrazol than with the other treatments. This trend was more obvious on 4 November when the growth of the paclobutrazol plots was about half that of the others. Over the period 23 June to 4 November the growth of the mefluidide plots was greater than that of the controls.

TABLE 2

The effect of a number of plant growth regulators on the yield (tonne ha^{-1}) of a mixed grass sward. Experiment 2.

Treatment	Date of harvest			
	23 June	30 July previously cut area	30 July previously uncut area	4 November
Untreated	2.81	0.65	3.11	0.72
Maleic hydrazide	1.85	0.62	2.55	0.51
Mefluidide	1.58	0.97	2.68	0.57
Paclobutrazol	1.94	0.48	2.12	0.29
SED	0.44	0.26	0.52	0.17

Assessing the effect of the chemicals on total production over the whole period to 30 July or on the sum of the two cuts gave a similar result.

Effect of time and rate of application for paclobutrazol

Assessed over the whole of 1983 effects were greatest for the 4 kg rate and the May date of application in experiment 3, (Table 3).

TABLE 3

The effect of paclobutrazol on the yield (tonne ha^{-1}) of perennial rye grass in experiment 3. An untreated plot managed as the March plots gave a total yield of 7.17 tonne ha^{-1}.

Rate kg ha^{-1}		Date of application Mar	April	May	SED
	a) Cut 26 May				
2		1.06	0.64	1.30	0.27
4		0.18	0.15	0.60	
	b) Cut 17 June				
2		3.40	2.99	1.98	0.32
4		2.07	2.62	1.13	
	c) Cut 8 August				
2		1.46	1.18	1.15	0.15
4		1.67	1.35	0.94	
	d) Total for 1983				
2		5.94	4.81	4.43	0.50
4		3.92	4.12	2.67	

Effects of paclobutrazol significant (sig) $P < 0.001$ at all dates, rate sig. on 26/5, 17/6 and for total yield. Paclobutrazol rate interaction significant at $P \leq 0.05$ for 17/6 and total yield. Rate, date interaction significant at $P < 0.001$ on 17/6 and < 0.01 for total.

The total retardation due to the 4 kg rate of paclobutrazol applied in May was 63%. Applications in March and April gave similar reductions which were less than that achieved with the May treatment. As paclobutrazol is active by root uptake, in a wet spring like 1983, timing should be relatively unimportant. Other than the good control obtained with the May treatment a 4 kg application in March was as good as any other treatment. At the time of the first cut retardation was greatest for the 4 kg rate applied in March or April. At the 2 kg rate application in April was as effective as at other times. By the June harvest the May application of the 4 kg rate was giving more control than other treatments. A 2 kg application of paclobutrazol in May was also effective in mid season. During the period June to August the 4 kg rate applied in May was the most effective. The dry autumn of 1983 resulted in little growth occurring after August in any treatment.

The effect of combinations of paclobutrazol and mefluidide

In the absence of mefluidide, experiment 4, paclobutrazol applied in March reduced yield by 26% for the 2 kg rate and by 36% for the 4 kg rate (Table 4). The 2 kg rate in May reduced growth by 39%. When mefluidide and paclobutrazol were applied concurrently in March the reduction was 84% regardless of the rate of paclobutrazol. If paclobutrazol was applied in March and mefluidide in May the reduction in growth was smaller than with a simultaneous March application. Where both chemicals were given simultaneously in May the reduction, 73%, was less than that with simultaneous application in March. The combination of mefluidide in March and paclobutrazol in May was more effective than the reverse sequence but less effective than the two materials applied simultaneously in May.

TABLE 4.

The effect of paclobutrazol and mefluidide (kg ha^{-1}) on the total yield (tonne ha^{-1}) of perennial rye grass in experiment 4.

Rate of mefluidide kg ha^{-1}	Time of mefluidide	Rate and month of paclobutrazol application 4 kg March	2 kg March	2 kg May
0		10.14	11.61	4.19
0.5	May	8.44	8.46	1.92
1.0	March	2.58	2.53	3.20
	May	6.03	7.58	1.92

Control plot uncut after March 15.82, uncut after May 6.83

SED = 1.04

Assessed at the time of the first 1984 harvest, 11 June, total growth was least with the two materials applied simultaneously in May. However, relative to the appropriate control plots, the 93% reduction due to May application was slightly less than the 96% reduction resulting from simultaneous application in March (Table 5). The sequence mefluidide in March then paclobutrazol in May reduced growth by 92% compared with a 66% reduction with the reverse sequence. Again combinations of paclobutrazol and mefluidide were much more effective than paclobutrazol alone, a 37% reduction.

TABLE 5

The effect of paclobutrazol (kg ha^{-1}) and mefluidide (kg ha^{-1}) on the yield (tonne ha^{-1}) of perennial ryegrass up to 11 June in experiment 4.

Rate of mefluidide	Time of mefluidide	Rate and month of paclobutrazol application 4 kg March	2 kg March	2 kg May
0		8.46	9.36	2.28
0.5	May	6.70	6.41	0.40
1.0	Mar	0.76	0.58	1.04
	May	4.60	5.99	0.27

Control plot uncut after March 13.33, after May 4.14
SED = 0.98

Both mefluidide and paclobutrazol treatments increased the dry matter content of the grass (Table 6). The effect was greatest when paclobutrazol was applied in March and mefluidide in May. Simultaneous application in March also had a large effect. This could give a harder wearing turf.

TABLE 6

The effect of paclobutrazol and mefluidide (kg ha^{-1}) on the % DW content of perennial ryegrass on 11 June 1984 in experiment 4.

Rate of mefluidide (kg ha^{-1})	Time of mefluidide	Rate and month of paclobutrazol application 4 kg March	2 kg March	2 kg May
0		23.7	23.8	23.1
0.5	May	24.5	26.0	19.7
1.0	Mar	26.7	27.4	25.9
	May	30.5	25.6	25.4

Control plots uncut after March 21.2, after May 19.1
SED = 2.9

DISCUSSION

Acceptable control of grass growth, using plant growth regulators, can be achieved using a number of materials. However reliable season long control of the range of grass species found in a typical orchard sward can probably be obtained only with a programme based on a soil acting material, e.g. paclobutrazol. In a range of experiments at East Malling paclobutrazol was the single best material. The efficacy of paclobutrazol seemed to vary from year to year being most effective when applied in a wet spring. Boorman *et al*. (1984) found that the efficacy of paclobutrazol was affected by rainfall subsequent to application. In a dry spring, and with a *L. perenne* dominated sward the control they achieved with 1.6 kg paclobutrazol, 20%, was comparable to that found here for experiment 4 (table 4), 26% . Although paclobutrazol reduced grass growth this has not always occurred to the same extent with other soil acting materials. Paclobutrazol gave longer control than with any of the foliar-acting materials tested. In trials with mefluidide Atkin (1984) found that rates up to 0.6 kg ha^{-1} gave good control for about 6 weeks. Duration of control will be important in the orchard situation. Here grass growth before harvest time combined with heavy dewfall gives wet-morning picking conditions, which are disliked by pickers. Mechanical mowing at this point in the season, when the tree branches commonly over-hang the alleys, can however result in crop loss and fruit damage.

Application of chemicals for growth control can be difficult in some springs. Variation in the time of application, prior to the beginning of vigorous grass growth, had a relatively small effect on retardation although application at the beginning of the season was most effective. For maximum effect with paclobutrazol a rate of 4 kg ha^{-1} was needed. Given the decrease in activity with the April application compared to the May treatment and the greater effect with 4 rather than 2 kg ha^{-1} this suggests that maintaining an adequate amount of material near to the soil surface and in a zone with active root growth is important for the uptake of paclobutrazol. Little published data is available but paclobutrazol does seem to be reasonably mobile in the soil (Lever *et al*, 1982).

The combination of paclobutrazol and mefluidide gives good early season control, when soil conditions seem to be suboptimal for paclobutrazol performance. This combination is most effective when applied simultaneously although 1 kg mefluidide in March to reduce growth followed by 2 kg paclobutrazol in May to sustain the reduction was almost as good and was much better than 4 kg paclobutrazol alone in March or 2 kg in May. With a paclobutrazol/mefluidide combination control would have been completely acceptable for the orchard situation and probably for many amenity situations. With this combination mowing could be reduced to a single maintenance cut. The chemical control of grass growth in orchards and in both urban and amenity horticultural situations now seems practical.

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THE ROLE OF PACLOBUTRAZOL AND OTHER GROWTH REGULATORS IN STRAWBERRY CROPPING SYSTEMS

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ABSTRACT

The growth of a range of strawberry varieties was reduced by an application of paclobutrazol at 4 kg ha^{-1}. The magnitude of the effect on the different varieties and its effects on the different parts of the plant, i.e. leaf, stem, root, runners varied. Cambridge Favourite seemed relatively resistant to treatment. In the field a 5 kg application had no effect on yield but increased mean fruit size and delayed the date when 95% of the harvest had been picked. In a high density but not a conventional planting paclobutrazol increased crown density in C. Favourite, Hapil and Pantagruella. Paclobutrazol seems to have potential for growth control in strawberry.

INTRODUCTION

The strawberry varieties currently grown in the UK tend to have a poor harvest index, the ratio of crop to vegetative growth. Excess vegetative growth may either be excessive leaf or runnering production or both. Large numbers of runners use assimilates which could have produced crop and may lead to excessively high crown densities which result in reduced crop quality. Hancock et al. (1982) found that yield per unit area decreased, as a result of effects on the number of trusses per crown, fruit set and mean fruit weights, when crown density, mainly due to the setting of runners, became excessive. An adequate number of crowns are however needed to give optimum crops. Regulation of vegetative growth in strawberry is as important as in other perennial crops.

Paclobutrazol is a growth retardant active on a wide range of perennial crops (Lever, Shearing and Batch, 1982). There are few published reports of its effects on strawberry. Atkinson and Harrison (1984) found that a soil application, equivalent to 4 kg ha^{-1}, reduced the leaf, stem and root growth in young plants of Cambridge Favourite and Hapil. Stang and Weis (1984) found that applications in the range 0.5 - 4.6 kg ha^{-1} reduced root and leaf weight in variety Raritan. Soil applications were more effective than foliar sprays. Crop yield was unaffected although cropping was delayed. Runner production was decreased.

This paper presents the results of preliminary pot and field experiments on the use of paclobutrazol on several UK strawberry varieties. The experiments detail effects on leaf growth, yield, fruit quality, and crown density in intensive and conventional matted row systems. As paclobutrazol inhibits gibberelic acid production the ability of GA_3 application to reverse a paclobutrazol treatment has been tested.

MATERIALS AND METHODS

Experiment 1

Plants of Cambridge Favourite were planted in 12 cm pots on 7 October

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On 24 October they were treated with paclobutrazol at a rate equivalent to either 0, 0.1, 0.5 or 5 kg ha^{-1}, in 50 ml solution per pot. They were grown in a growth room providing a day length of 16 hr and a temperature of 20^{o} day and 16^{o} night (Asamoah and Atkinson 1985). All treatments were replicated 5 times and plants were harvested on 12 December.

Experiment 2

Plants of the varieties C. Favourite, Hecker, Pantagruella, Hapil and Troubadour were planted on 22 November in 12 cm pots and on 19 December were treated with 0 or 4 kg ha^{-1} paclobutrazol. All treatments were replicated 6 times in a glasshouse with supplementary lighting to give a 16 hr day and heating to maintain a day-time temperature of approximately $20^{o}C$. Leaf area, as length x breadth x a constant, was determined at 7 day intervals beginning on 6 January. The plants were harvested on 21 February.

Experiment 3

Plants of Cambridge Favourite were planted on 13 June 1983 at a spacing of 50 cm in the row. On 7 July 1983 and 27 June 1984 some plots were sprayed with 100 ppm GA_3 (as Berelex). On 25 April 1984 plots treated and untreated with GA_3 were either left untreated or given a soil application of 5 or 20 kg ha^{-1} paclobutrazol. All treatments (20 plant units) were replicated 5 times in a randomized block design. Maiden crop was recorded in June 1984. The number of crowns in four 50 cm lengths of row were recorded that autumn. All plants were deblossomed and derunnered in 1983 and managed as matted rows, with runner removal outside the cropping area, in 1984.

Experiment 4

Plants of Cambridge Favourite, Hapil and Pantagruella were planted on 14 October 1983 at an in-row spacing of 15 or 50 cm. In April 1984 half the plots received a soil application of paclobutrazol at 4 kg ha^{-1}. All treatments (20 plant units) were replicated 5 times in a randomized block design. Crop and runner production were recorded as for experiment 3, except crown density was measured on only one unit per plot.

RESULTS

Effect of rate of paclobutrazol

Leaf and stem weight but not root weight were reduced by paclobutrazol at 5 kg but unaffected by lower rates (Table 1). The effect on leaf area and weight were similar and greater than the effect on stem weight.

TABLE 1

The effect of paclobutrazol (kg ha^{-1}) on the growth of Cambridge Favourite. (Experiment 1).

Rate	Leaf area (cm^2)	Leaf wt (g)	Stem wt (g)	Root wt (g)
0	336	2.77	0.74	0.94
0.1	294	2.17	0.66	0.87
0.5	349	2.63	1.07	1.03
5.0	178	1.45	0.59	0.73
SED	64*	0.56*	0.12*	0.21 NS

Response of different varieties to paclobutrazol

The relationship between leaf area and the product of leaf length x breadth was assessed for both paclobutrazol treated and untreated plants in experiment 2 to determine the constant needed to derive leaf area from length x breadth measurements (Table 2). Leaf shape and area within the projected circumference was unaffected by paclobutrazol except with C. Favourite although shape varied greatly between varieties.

TABLE 2

The regression coefficient needed to convert length x breadth data to true leaf area. (Experiment 2).

Treatment	C. Favourite	Hecker	Pantagruella	Hapil	Troubadour
Control	0.746	0.936	0.740	1.01	0.832
Paclobutrazol	0.991	0.967	0.743	1.07	0.850

Treatments significantly different for C. Favourite.
Varieties significantly different at $P < 0.001$.

A reduced leaf area due to paclobutrazol treatment was evident in the initial measurement, 18 days post-treatment (Table 3). The effect increased with time. Leaf area growth varied between cultivars and on some dates there was a treatment/variety interaction due entirely to the response of variety Hecker. If Hecker was removed from the analysis there were no significant interactions.

TABLE 3

The effect of variety and treatment on leaf area log cm^2 with days after treatment. SED = 0.069 to 0.079.

Days after treatment	Treatment	C. Favourite	Hecker	Panta -gruella	Hapil	Troub -adour
18	Paclobutrazol	2.10	1.66	1.94	2.31	1.97
	Control	2.25	2.25	2.12	2.51	2.11
25	Paclobutrazol	2.17	1.74	2.02	2.36	2.00
	Control	2.38	2.37	2.25	2.60	2.21
32	Paclobutrazol	2.25	1.83	2.04	2.43	2.00
	Control	2.49	2.50	2.32	2.70	2.35
46	Paclobutrazol	2.33	1.93	2.11	2.50	2.10
	Control	2.66	2.68	2.54	2.90	2.53
65	Paclobutrazol	2.43	2.12	2.18	2.55	2.13
	Control	2.79	2.84	2.77	3.04	2.67

SED for Hecker/treatment comparisons approximately 0.11.
Effects of variety and treatment significant at $P < 0.001$ for all dates, interactions at $P < 0.05$ for days 18, 32 and 46.

The daily rates of leaf growth calculated from the regression of log leaf area against time, were significantly different for both the effect of paclobutrazol and variety. Growth rate was greatest for Troubadour and least for Hecker (Table 4). In this trial paclobutrazol also reduced leaf number, leaf wt, stem wt, runner wt and root wt. (Table 4). Although total water use was less for treated plants transpiration, which differed between varieties, was unaffected by paclobutrazol (Table 4). Leaf wt was reduced least in C. Favourite and stem and root weight most in Hapil. Leaf number, stem wt and root wt were least affected in Hecker (Table 4). Leaf wt was greatly affected in this variety. C. Favourite and Hecker were the only varieties with substantial runner production. Here paclobutrazol reduced runner wt from 1.45g to 0 and 0.97 to 0.47g respectively.

TABLE 4

The effect of variety and paclobutrazol on leaf growth rate ($\log_{10}$ cm^2, d^{-1}, SED range = 0.00155 - 0.00163), leaf (SED = 0.418), stem (SED = 0.239) and root wt (SED = 0.212) (g) and transpiration (mg cm^{-2}, d^{-1} SED = 16.5). (Experiment 2).

Treatment	C.Favourite	Hecker	Pantagruella	Hapil	Troubadour
			a)	Leaf growth rate	
Paclobutrazol	0.0068	0.0095	0.0048	0.0051	0.0036
Control	0.0114	0.0124	0.0137	0.0115	0.0121
			b)	Leaf wt	
Paclobutrazol	1.55	0.88	1.07	2.21	1.01
Control	3.09	3.06	3.19	6.03	2.98
			c)	Stem wt	
Paclobutrazol	1.04	0.89	1.03	1.37	0.85
Control	1.63	0.90	1.59	3.02	1.39
			d)	Root wt	
Paclobutrazol	1.23	0.69	0.91	0.97	0.70
Control	1.53	0.66	1.33	2.05	0.95
			e)	transpiration	
Paclobutrazol	45	105	73	56	98
Control	49	55	76	55	72

Effect of paclobutrazol sig $P < 0.001$ on leaf growth rate, leaf wt, stem wt, root wt. Variety/treatment interaction significant at $P < 0.05$ for leaf growth and root and at $P < 0.01$ for leaf and stem wt.

Effect of paclobutrazol and GA_3 on C. Favourite

Crop yield was unaffected by paclobutrazol at 5 kg but reduced by the 20 kg rate and by the GA_3 treatment (Table 5). In the maiden crop year the proportion of non grade 1 fruit was small but less for the 5 kg paclobutrazol treatment than with the control plants. GA_3 application had no effect on the % of Class 1 fruit. The number of days from the beginning of harvesting until 95% of the crop had been picked was increased by paclobutrazol treatments, especially at 20 kg, but unaffected by GA_3. The time for 5% and 50% of the crop to be harvested was also delayed with the paclobutrazol treatments. The density of crowns, at the end of the season, was decreased both by paclobutrazol and GA_3, mainly due to effects on runner production.

TABLE 5

The effect of paclobutrazol and GA_3 on yield (kg/plot), % class 1 fruit, number of days from the start of picking till 95% crop harvest and the crown density (no per 0.25 m^2). (Experiment 3).

Treatment	Paclobutrazol 0	5	20	SED
			a) Yield	
Control	11.09	12.08	7.59	
GA_3	9.42	7.34	8.15	1.12
			b) % Class 1	
Control	75	80	70	
GA_3	71	73	70	2.80
			c) days to 95% pick	
Control	16.9	18.9	21.9	
GA_3	16.4	18.9	21.2	0.72
			d) crown density	
Control	15.9	14.1	11.4	
GA_3	13.9	11.8	11.5	1.61

Yield, effect of paclobutrazol significant at $P < 0.01$, GA_3 and interaction at $P < 0.05$: % Class 1 paclobutrazol sig at $P < 0.01$: 95% pick paclobutrazol sig at $P < 0.001$: Crown density paclobutrazol sig at $P < 0.01$ GA_3 at $P < 0.05$.

TABLE 6

The effect of paclobutrazol on the mean weight of Class 1 fruit (g) at intervals. (Experiment 3).

Days after the start of picking	Paclobutrazol rate 0	5	20	SED
3	15.0	17.5	16.8	0.83 P = 0.01
5	13.1	16.0	15.0	1.29 NS
7	12.0	13.7	13.9	0.64 P = 0.01
13	9.9	10.6	11.1	0.35 P = 0.01
15	9.4	10.1	10.0	0.58 NS
19	9.9	9.9	9.7	0.39 NS
22	10.5	12.2	11.4	0.95 NS
27	10.3	11.4	11.2	1.78 NS

The GA_3 treatment had little effect on fruit size and so data on paclobutrazol effects and averaged for the two GA_3 treatments is presented in table 6.

Although cumulative crop was unaffected by 5 kg paclobutrazol mean fruit weight was increased early in the season. Later fruit weight was unaffected. For the dates when size was significantly increased by the 5 kg treatment fruit numbers per plot were 22 and 50, 95 and 144, 60 and 44 for the paclobutrazol and control treatments respectively. For days 3 and 7, the increase could have been due to reduced numbers but not on day 13. On day 15, when fruit weights were not significantly different between treatments, paclobutrazol plants produced 120 fruits compared with 84 for control plants.

Effect of paclobutrazol and planting density

Neither paclobutrazol nor spacing affected the initial yield of C. Favourite, Pantagruella or Hapil in experiment 4 (Table 7). Thus on a per unit area basis crop was greatly increased for the higher density planting. However, as a consequence of late planting, yields are low and so results must be interpreted with care.

TABLE 7

The effect of within-row-spacing (c,) and paclobutrazol on crop (kg per plot) (SED = 0.22) and crown density (no per 0.25m^2) (SED = 1.9).(Experiment 4).

Treatment	C. Favourite 15	C. Favourite 50	Pantagruella 15	Pantagruella 50	Hapil 15	Hapil 50
					a) crop yield	
Paclobutrazol	1.73	1.89	0.93	1.18	2.41	2.54
Control	1.64	1.84	1.25	0.82	2.65	2.75
					b) crown density	
Paclobutrazol	12.8	7.8	17.8	8.4	10.2	5.6
Control	10.0	9.0	12.8	11.4	9.6	7.0

Crop: effect of variety significant at $P < 0.001$, crowns : effect of distance and variety sig at $P < 0.001$ paclobutrazol/distance interaction at $P < 0.001$

Crown density was increased by paclobutrazol at the higher planting density in all varieties but reduced at the lower density (Table 7). This may be the result of an interaction with the management system. Here, as in commercial practice, runners setting outside the designated matted row area were removed.

DISCUSSION

Paclobutrazol is effective in retarding vegetative growth in strawberry. With C. Favourite an application of 0.5 kg ha^{-1} was ineffective. A similar rate reduced the vegetative growth of Raritan (Stang and Weis, 1984). Leaf growth was affected rapidly by an application of 4 kg. The rate of leaf growth in the contrasting range of varieties studied here was similar although the size of the paclobutrazol effect varied. The growth in Hecker was rapidly affected (Table 3).

However averaged over the final 47 days of experiment 2, growth was less affected for this than with other varieties (Table 4). In contrast leaf wt was affected more in Hecker than in the other varieties. The effect of paclobutrazol was relatively small on C. Favourite. Stem wt in the varieties was affected to a similar extent, except with Hecker where it was unaffected and Hapil where it was greatly affected. The effect of paclobutrazol on root weight varied between the varieties. Runner weight, in the varieties which runnered in experiment 2, was greatly reduced. Similarly Stang and Weis (1984) found an application of 0.56 kg almost eliminated runnering in variety Raritan. Paclobutrazol had no effect on transpiration in this study which differs from the large effects found on cherry (Asamoah and Atkinson, 1985). The results of the pot experiments suggest that different strawberry varieties will respond differently to paclobutrazol and may need varied times, rates or types of treatment.

When applied in the field at 5 kg ha^{-1}, a rate similar to that found effective on other crops (Asamoah and Atkinson, 1985) there was no adverse effect upon yield. The size of the adverse effect with 20 kg suggests that the overdosing which does occur during field application would not have overserious consequences. Recalculated on the basis of crop per unit ground area covered the 20 kg treatment had little effect. Extension of the length of the cropping season in varieties like Cambridge Favourite is a major plant breeding objective. Results presented here (Table 5) suggested that paclobutrazol can extend the cropping season. In early season there was an increase in average fruit weight on the 5 kg paclobutrazol plants associated with a reduced number. This suggests that the effect was due to fruit-fruit competition (Swartz et al. 1982). In mid season, however, there was an increase in size despite increased numbers and in late season size was maintained with increased numbers. An increased partition of assimilates to the fruit therefore occurred for part of the season. A detailed analysis of components of yield (Swartz et al. 1982) and for the life of the planting is needed to fully quantify the effects of paclobutrazol on cropping.

Used in an intensive planting at 4 kg ha^{-1} paclobutrazol did not affect crop yield. The density of crowns at the end of the season was increased perhaps giving an increased cropping potential for 1986 (Table 7). At a conventional spacing paclobutrazol reduced crown numbers. The spacing interaction can not be fully explained but may represent better control of assimilate partition to new growth sites superimposed on a restriction of runner production and stolon extension. GA_3 was used in experiment 3 to see if the growth retardation caused by paclobutrazol could be reversed. Although leaf and petiole extension were increased GA_3 adversely affected both fruit and crown production. Thus as a way of modifying a paclobutrazol treatment it will need to be used with care. As a growth control agent in the strawberry crop paclobutrazol needs further study.

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THE USE OF MEPIQUAT CHLORIDE PLUS 2-CHLOROETHYLPHOSPHONIC ACID AS A GROWTH REGULATOR IN WINTER WHEAT.

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ABSTRACT

Small plot trials carried out in 1984 and 1985 have shown that mepiquat chloride plus 2-chloroethylphosphonic acid (BAS 09800W) has given excellent control of lodging in winter wheat. Tested both alone and after earlier application of chlormequat chloride, BAS 09800W gave consistent yield increases on sites where lodging was a problem. Results are reported from trials carried out by both BASF United Kingdom Limited and ADAS with comparisons between BAS 09800W, chlormequat chloride and 2-chloroethylphosphonic acid.

INTRODUCTION

The growing of winter cereals in Western Europe has been the subject of much intensive study in recent years with the aim of increasing the crop's yield potential. Research into plant breeding, nutrition, husbandry and pesticides are all seen as sources of yield improvement (Lever, 1982). The breeding of new cultivars able to make use of high levels of nitrogen fertiliser applications, together with improved disease control, have contributed to higher yields but with associated lodging risks. This is particularly pronounced in areas of high fertility and under adverse weather conditions such as those experienced in 1985.

Early lodging in winter wheat can severely reduce yield but lodging at any time in the season is undesirable for several reasons (Sterry,1980):

1. Loss of yield as the combine harvester is unable to pick up all the crop. Threshing and cleaning are less efficient.
2. Harvesting is quicker in a standing crop. Lodging reduces harvester speed,and increases drying time, especially when weeds have grown through the crop.
3. Grain quality can be reduced with more saprophytic fungal attack and sprouting, particularly during wet harvests.
4. Higher grain moisture increases drying costs.
5. Lodged crops suffer a reduced photosynthetic efficiency. Grain maturity and size is likely to be uneven.
6. Harvester cutter bars must be set lower, with more chance of mechanical damage.

BAS 09800W ('Terpal') was introduced to the United Kingdom for field testing in 1977 (Herbert, 1980). It was first developed with the aim of allowing farmers to apply optimum levels of nitrogen fertiliser, and thereby obtain maximum returns from their winter barley crops. Following the success of the product in winter barley and its introduction to the wheat growing systems of other European countries, development of BAS 09800W for the United Kingdom wheat crop began in 1983. In 1985, based on development work carried out in the previous two years and information collected on BAS 09800W since 1977, BASF United Kingdom Limited were able to make a recommendation for its use in winter wheat.

MATERIALS AND METHODS

Results of replicated small plot trials from three sources are reported. Trials carried out by BASF and Agrisearch Field Development Limited were of a replicated (x4) randomised block design. The treatments in these trials were applied by knapsack sprayer using 250 l/ha water and 12 Pa pressure. Small plot trials performed by ADAS were based on a 3 replicate randomised block design and were applied with a knapsack sprayer using 200-225 l/ha water and 9.6 - 14.4 Pa pressure. All trials were carried out on established farm crops.

The following active ingredients have been used in the trials: chlormequat chloride (645 g/l a.c.) with added choline chloride, 2-chloroethylphosphonic acid (480 g/l a.c.), mepiquat chloride plus 2-chloroethylphosphonic acid (305 g/l + 155 g/l a.c.), alkylarylpolyglycol ether (99-100% non-ionic wetter). Throughout the text of this paper mepiquat chloride plus 2-chloroethylphosphonic acid is referred to as BAS 09800W.

BASF trials in 1984 were carried out on Avalon (1), Longbow (1), and Guardian (1). Agrisearch trials in 1985 were carried out on Stetson (3), Mission (1), Longbow (1) and Galahad (1). In 1984 the ADAS National trial series CC68 was carried out to evaluate growth regulator programmes in winter wheat on nine sites. Four of these, all on the variety Norman, included BAS 09800W and the split chlormequat chloride treatments. In addition to straight comparison between the three growth regulators using the farmer's standard nitrogen programme, a second objective was to look at the interaction of growth regulators with nitrogen. Additional nitrogen was applied to some plots (ADAS recommendation + 25%).

In BASF and Agrisearch trials crop height was assessed by measuring 10 randomly selected main tillers in each plot and recording the mean to the nearest centimetre. Where lodging occurred in BASF and Agrisearch trials it was assessed by a two part scale. In the first part the average angle to which the plot had lodged was estimated and converted to a 0-10 score where 0 = 0°, 9 = 90° i.e. flat, and 10 = irreversible lodging. Where severe lodging to more than 45° had occurred the percentage of the plot affected was also recorded. In the series of ADAS trials the percentage of lodging or percentage of heavy leaning was recorded. Yield results were obtained using a small plot combine harvester, all yields being corrected to 85% d.m. Except where otherwise stated, statistical analysis was carried out using Duncan's test; figures in tables with the same suffix letter are not significantly different at the 5% level of probability. All growth stages refer to a decimal code for growth stages of cereals (Zadoks et al 1974).

RESULTS

In 1984 lodging occurred in three BASF winter wheat trials where growth regulators were being studied (Table 1). All treatments reduced crop height but those containing BAS 09800W were generally more effective than chlormequat chloride or 2-chloroethylphosphonic acid. Lodging control and yield response data correlated with the level of crop height reduction obtained.

In six trials carried out by Agrisearch in 1985, the relative performance of the growth regulators was confirmed (Table 2). The lodging scores in these trials ranged from 0.6 to 2.8 with severe lodging of 4 to 35% in the untreated plots. All products reduced crop height and lodging. 2-chloroethylphosponic acid alone was inferior to other treatments. Chlormequat chloride followed by BAS 09800W gave complete lodging control. At both sites with more than 20% severe lodging, significant yield increases were obtained (Table 3). BAS 09800W gave the best yield response of the individual growth regulators applied; optimum response was obtained by 610 + 310 g a.i./ha applied at GS. 32-37. Best yield response overall was given by a programme of chlormequat chloride followed by BAS 09800W. In the 3 non-lodged Agrisearch trials no significant yield responses were obtained.

In the ADAS trials at the standard nitrogen level, all products reduced lodging and increased yield (Table 4). The standard split chlormequat chloride programme was most effective. However, at the higher nitrogen level chlormequat chloride gave only moderate control of the increased lodging (62% mean in untreated plots). The programme of chlormequat chloride followed by BAS 09800W gave virtually complete control of lodging and the maximum yield increase on the sites where it was tested.

At one site where no lodging occurred (Tingrith) no treatment gave a significant yield response.

Table 1 Crop height , lodging and yield - BASF 1984

Variable:			Mean % crop height	Mean lodging score (0-10)	Mean yield (t/ha)	Significance	% relative yield
Number of trials:			3	3	3		
Treatment	GS	g a.i./ha					
Untreated			100(102.4cm)	4.9	7.984	a	100
chlormequat chloride	30	1129	99	4.4	8.492	b	106
BAS 09800W	32-37	458+233	94	3.5	8.441	b	105
BAS 09800W	32-37	610+310	92	3.4	8.741	b	110
BAS 09800W	39-45	458+233	93	2.9	8.641	b	108
chlormequat chloride + BAS 09800W	30 32-37	1129 610+310	91	2.9	8.695	b	109
chlormequat chloride + BAS 09800W	30 39-45	1129 458+233	91	2.3	8.682	b	109
2-chloroethyl- phosphonic acid	39-45	480	95	3.7	8.444	b	106

All BAS 09800W applications were made with the addition of wetter at 100 g a.i./ha.

Table 2: Crop height and lodging - Agrisearch 1985

Variable:			Mean % crop height	'Lodged' sites* Lodging 0-10	'Lodged' sites* Lodging % severe	'Non-lodged' sites* Lodging 0-10	'Non-lodged' sites* Lodging % severe
Number of trials (varieties):			6	2(Longbow,Galahad)		4(Mission,Stetson)	
Assessment date:			8.7.85	25.7.85		25.7.85	
Treatment	GS	g a.i./ha					
Untreated			100(99.7cm)	2.4	33	1.0	9
chlormequat chloride	30-31	1613	93	0.2	5	0.1	1
BAS 09800W	32-37	458+233	91	0.9	11	0.1	1
BAS 09800W	32-37	610+310	91	0.4	4	0.1	1
BAS 09800W	39-45	458+233	92	0.8	10	0.1	1
chlormequat chloride + BAS 09800W	30-31 32-37	1613 610+310	88	0	0	0	0
chlormequat chloride + BAS 09800W	30-31 39-45	1613 458+233	88	0	0	0	0
2-chloroethyl-phosphonic acid	39-45	480	94	1.5	17	0.2	2

*'Lodged sites' have more than 20% severe lodging in the untreated.
All BAS 09800W applications were made with the addition of wetter at 100 g a.i./ha.

Table 3: Yield - Agrisearch 1985

Number of trials:			'Lodged' sites* 2			'Non-lodged' sites* 3	
Varieties:			Longbow, Galahad			Stetson	
Variable:			Mean yield (t/ha)	Significance	% relative	Mean yield (t/ha)	% relative
Treatment	GS	g a.i./ha					
Untreated			8.17	a	100	6.53	100
chlormequat chloride	30-31	1613	8.70	bc	107	6.93	106
BAS 09800W	32-37	458+233	8.70	bc	107	6.83	105
BAS 09800W	32-37	610+310	8.93	cd	109	6.57	101
BAS 09800W	39-45	458+233	8.67	bc	106	6.93	106
chlormequat chloride + BAS 09800W	30-31 32-37	1613 610+310	9.13	d	112	6.93	106
chlormequat chloride + BAS 09800W	30-31 39-45	1613 458+233	9.00	cd	110	6.90	106
2-chloroethyl- phosphonic acid	39-45	480	8.43	ab	103	6.63	102

* 'Lodged sites' have more than 20% severe lodging in the untreated.
All BAS 09800W applications were made with the addition of wetter at 100 g a.i./ha.

Table 4: Lodging control and yield - ADAS 1984

Variable:				Lodged sites: % Lodging			Lodged sites: Yield (t/ha)			No lodging: Yield (t/ha)
Site:				A	B	C	A	B	C	D
Treatment							SED	SED		SED
Nitrogen level	Growth regulator	GS	g a.i./ha				(±0.234)	(±0.258)		(±0.269)
N1	Untreated			20	30	48	10.15	8.69	14.2	9.19
N1	chlormequat chloride x 2	24-29 30	1129 484	0	10	1	11.14	9.48	15.19	9.39
N1	BAS 09800W + wetter	37	610+310 +100	3		14	10.7		14.34	9.16
N1	2-chloroethyl-phosphonic acid	37	480	7		15	10.54		15.14	9.05
N2	Untreated			67	57		10.11	8.32		9.31
N2	chlormequat chloride x 2	24-29 30	1129 484	27	37		10.9	9.44		9.61
N2	chlormequat chloride + BAS 09800W + wetter	24-29 30 37	1129 484 610+310 +100	0	5		11.4	9.94		9.64

Site A = Sandon, Herts: N1 = 170 kg/ha; N2 = 250 kg/ha
B = Belchamp, Essex: N1 = 244 kg/ha; N2 = 300 kg/ha
C = Spalding, Lincs.
D = Tingrith, Bedfordshire: N1 = 200 kg/ha; N2 = 250 kg/ha

DISCUSSION

The application of chlormequat chloride is established as an integral part of the wheat production system in the UK. When applied within the optimum growth stages it has proved a highly cost effective treatment. However, with current trends to reduced margins there is a demand for increased reliability and flexibility of approach, bearing in mind the consequences of inadequate lodging control. Chlormequat chloride is applied at a time of year coincident with high on-farm spraying activity and poor weather conditions. Inevitably, crops are not always treated at the optimum time or may not be treated at all.

The results presented demonstrate that BAS 09800W effectively controls lodging even in situations where a high lodging potential exists.

Timing of BAS 09800W application appears less critical than chlormequat chloride; crop height reduction, lodging control and yield responses have been obtained from GS. 32 to 45. Results also show some flexibility in the rate of application although most reliable results from other European countries have come from a rate of 2.0 l/ha at the earlier timing (610 + 310 g a.i./ha of mepiquat chloride + 2-chloroethylphosphonic acid respectively).

Where lodging is potentially severe the maximum benefits of BAS 09800W have been realised when used in a programme following chlormequat chloride. Even at sites with a very high lodging pressure this treatment has given excellent lodging control and consistent yield benefits. Indications to date are that the application of both components should follow the recommendations for single products.

Selection of the optimum growth regulator programme will depend on the potential lodging problem in each specific crop.

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PACLOBUTRAZOL FOR APPLES AND PEARS - A PRACTICAL AID TO TREE MANAGEMENT AND HIGHER YIELDS

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ABSTRACT

Since 1982 grower trials on Cox and Bramley apples and Conference pears have been instigated in the UK using paclobutrazol applied as a programme of foliar sprays. On Bramley first year applications, giving a total of 1 kg a.i ha^{-1}, reduced tree vigour, left yields unaffected and led to an increase in flowering in the following year. A spray programme giving a total of 0.75 kg a.i ha^{-1} was generally sufficient to maintain the growth control in the second season when yields were increased by over 20% in some orchards. For Cox, rates of 0.75 - 1 kg a.i ha^{-1} were required in the second and third years to maintain control of vigour. Fruit colour was improved and as a result there was a slight increase in the proportion of Class 1 fruit while yields were increased by 15%. Paclobutrazol reduced tree vigour and pruning requirement, facilitated management and gave easier access to both orchard inter-rows and trees.

INTRODUCTION

Paclobutrazol ('Cultar') has been shown to be an effective growth regulator for apples and pears in research trials in the UK and in the USA (Quinlan 1980, Raese 1983). Paclobutrazol inhibits vegetative growth, thus offering considerable scope for reducing pruning. Flower bud induction and flowering were promoted, thereby providing an increased yield potential. (Tukey 1982, Williams 1983). Retardant activity can be achieved by a sequence of foliar sprays applied through the growing season. This allowed reduced rates of application per season, compared to a single high rate application, and seems to provide a practical, controllable approach for grower use (Tukey 1982, Quinlan 1984, Shearing 1985). A carryover of retardant activity into the following season can result from the previous seasons spray application of paclobutrazol and therefore affect the need for retreatment (Quinlan 1984).

Since 1982 a number of grower trials on Cox and Bramley apples and Conference pears have been instigated in the UK using paclobutrazol as a programme of foliar sprays to test the concept in commercial orchards. The trials have tested the practicality of programmed sprays and assessed grower benefits in terms of yield, fruit quality and pruning requirement.

MATERIALS AND METHODS

Trial sites were selected to allow long-term treatment and are detailed in Table 1. The sprays were applied with commercial equipment according to the normal spray application practice for each grower. Trials received normal fungicide and insecticide spray programmes in accordance with standard practice. Paclobutrazol application was frequently applied in a tank-mixture with other products on a 10-14 day schedule post-blossom but in some cases was applied alone. Trial plot sizes were a single 0.5 to 1 ha block for both the untreated and treated areas.

The paclobutrazol application strategy adopted each year was chosen to take account of orchard vigour and the carryover effects of the chemical from the previous seasons use and so the number of applications varied from site to site according to need, as judged by the grower/trial manager. The total rates of paclobutrazol applied each year are given in Table 1.

Each year the first spray application was applied 2 to 3 weeks after petal fall in most trials. In 1982 the product was divided between one to three high rate applications. In 1983 and 1984 the product was applied in smaller more frequent applications at 10-14 day intervals. Pre-blossom applications were made at early green cluster to three Bramley trials in 1983 (Table 1). The formulation was an SC containing 250 g a.i/l paclobutrazol.

Results on growth, yield, fruit grading (ex-store) and pruning were sought. For vegetative growth assessments 40 extension shoots per plot were measured at the end of the season. Pruning costs were estimated by recording the pruning man hours required per plot and calculated according to the cost per hour paid by the grower. The pruning levels for both the untreated and treated blocks was left to the growers judgement and normal practice. Crop yields were assessed from the total crop picked from whole blocks, and are expressed ex-store where grade-out data are available. For trials where grade-out data were not supplied by the grower then yield data are based on total crop weight before storage and grading.

TABLE 1

Details of Trial Sites

Location	Variety/ Rootstock	Planted/ Spacing	Total Paclobutrazol Applied 1982 kg ha^{-1}	1983 kg ha^{-1}	1984 kg ha^{-1}
Sandhurst Kent	Bramley MM106	1975 3.7x5m	-	1 (0.25*,0.13x6)	0.5 (0.13x4)
Collier Street Kent	Bramley MM106	1970 4.6x7.3m	-	1 (0.25*,0.13x6)	0.5 (0.13x4)
Mereworth Kent	Bramley MM106	1978 4.3x6.4m	-	1 (0.25*,0.13x6)	0.38 (0.13x3)
Ash Kent	Bramley M2	1960 6.1x6.1m	1 (0.25x4)	1 (0.25x4)	1.25 (0.25x5)
Faversham Kent	Cox MM106	1976 3.7x5.5m	1.5 (0.75,0.25x3)	0.63 (0.13x5)	0.75 (0.13x6)
Fernhurst Sussex	Cox MM106	1978 3x4m	2 (2x1)	1 (0.25x4)	0.75 (0.13x6)
Hawkhurst Kent	Cox MM106	1970 3.1x4.6m	1 (0.25x4)	0.75 (0.25x3)	1 (0.25x4)
Faversham Kent	Conference QA	1975 1.8x3.7m	0.75 (0.5,0.25)	0.5 (0.13x4)	0.88 (0.25,0.13x5)

Sprays marked with * were applied at green cluster, all other sprays applied post blossom from 2-3 weeks after petal fall.
Details of the application rate sequences for each trial are given in parenthesis.

RESULTS AND DISCUSSION

Apple

Paclobutrazol reduced extension growth in each year on Bramley. The end of the season shoot lengths are given in Table 2 for three of the sites. Table 1 shows that these results were achieved with 1 kg a.i ha^{-1} in the first and 0.38 - 1.0 kg a.i ha^{-1} in the second season. In the one site continued for three years, continued growth control was achieved by applying five applications of 0.25 kg a.i ha^{-1} in 1984. Slight carryover effects giving reduced shoot growth were observed prior to the next seasons post-blossom re-treatment.

TABLE 2

Mean Length of a Shoot Extension (cm) on Bramley

Location		Untreated	Paclobutrazol	% Reduction
Sandhurst	1983	40	26	35
	1984	52	38	27
Mereworth	1983	40	27	32
	1984	36	29	20
Ash	1982	37	24	35
	1983	15	11	25
	1984	32	16	50

Evidence exists that paclobutrazol treatment reduces total shoot growth proportionally more than mean extension growth may suggest (Quinlan, 1984). This is believed to be due to paclobutrazol reducing number of shoots. Total shoot growth has previously been related to pruning costs (Sansavini, 1978). A pruning cost comparison for two of the recorded farms are shown in Table 3. The quicker winter pruning is considered to result from reduced extension growth length and shoot number reductions.

TABLE 3

Pruning cost comparisons at the end of the 1984 season, £ ha^{-1}

Location	Untreated	Paclobutrazol	Saving in Cost
Sandhurst	£271	£197	£74
Mereworth	£160	£148	£12

Yields were unaffected in 1983, the first year of treatment but were increased in 1984 on two of the three sites. This was probably a result of an increase in flower cluster number. Substantially increased crop sales values were achieved, ex-store, (Table 4).

Fruit quality after storage remained good for treated crops. Paclobutrazol sometimes improves fruit calcium levels and as a result reduces the incidence of bitter pit (Greene, 1983). Grade-outs after storage in one of the Bramley trials revealed a lower incidence of bitter pit (Table 5), however data were not available for first size or calcium levels to determine the reason for this. Further work is needed to determine the consistency of this result.

TABLE 4

Yield results on Bramley

Location		Yields t ha^{-1} 1983	1984	Increase in Crop Value £ ha^{-1} 1983	1984
Sandhurst	Paclobutrazol	47.7	41.0	£23	£1036
	Control	45.1	32.6	-	-
Collier Street	Paclobutrazol	44	22.7	-	-
	Control	44.7	23.0	-	-
Mereworth	Paclobutrazol	14.5	16.7	£110	£213
	Control	12.9	12.9	-	-

TABLE 5

% of Fruit Affected by Bitter Pit, Bramley 1982

Location	Untreated	Paclobutrazol
Ash	28	14

Paclobutrazol reduced extension growths on Cox trees treated for three years at Hawkhurst (Table 6). At Fernhurst extension growth was reduced in the first two years but not in the third season. It is suggested that the total application rate in 1984 of 0.75 kg a.i ha^{-1} was insufficient on this site.

TABLE 6

Mean Shoot Extension per season (cm) on Cox

Location		Untreated	Paclobutrazol	% Reduction
Fernhurst	1982	55	27	51
	1983	59	34	42
	1984	32	36	+13
Hawkhurst	1982	49	34	30
	1983	51	25	51
	1984	51	29	44

At the end of 1983 there was a 40% reduction in the time taken for winter pruning at the Fernhurst site. Detailed pruning times are not available for the end of 1984 but even though mean extension shoot length was not reduced, labour requirements were lower due it is thought to fewer shoots. At Faversham pruning costs were reduced from £150 ha^{-1} to £100 ha^{-1} by paclobutrazol treatment.

Yield increases with paclobutrazol treatment averaged 15% in the second and third year of treatment for the two reported sites. This seems to be a consequence of the increase in flower cluster numbers. The better flowering induction on Cox has already (Table 7) been reported by Lever (1985).

TABLE 7

Effect on flower production, of Cox apple (Fernhurst), UK, Spring 1983

Age of Wood	1 year	2 years	3 years
	No. of Flower Clusters per m of Branch Length		
Paclobutrazol 2kg ai ha^{-1} 1982	19	23	17
Untreated	6	19	09

The improvements in fruit yield and percentage Class 1 grade demonstrate that large increases in gross crop values are possible (Table 8). The 2 to 4% increase in Class 1 fruit for the Cox variety is believed to result from improved fruit colour, due to reduced vegetative growth probably leading to better light penetration into the tree.

TABLE 8

Yield Results on Cox

Location		Yields t ha^{-1} 1982	1983	1984	% Class 1 1982	1983	1984	Increase in Crop Value £ ha^{-1} 1983	1984
Faversham	Paclobutrazol:	26.3	37.1	22.7	51	N/A*	62	N/A	1488
	Control:	26.5	33.9	18.5	50	N/A*	58	-	-
Fernhurst	Paclobutrazol:	N/A	24.4	31.0	-	77	N/A	969	N/A
	Control:	N/A	20.8	28.0	-	75	N/A	-	-

N/A - Data not available.
* orchard suffered Hail Damage.

At 1984 UK prices a 15% yield improvement coupled with a 2% increase in Class 1 grade for a 20 ton ha^{-1} crop will give £1050 ha^{-1} extra crop value over one year. The Fernhurst trial site illustrates this with an increased gross crop value of over£900 ha^{-1} in 1983 ex storage in the following spring. Fruit size from paclobutrazol plots have tended to be smaller compared to untreated trees perhaps due to increased fruit load.

It is clear that because of different orchard planting systems, environments and management practices the requirements of a growth regulator such as paclobutrazol will vary for different orchards. For this reason an effective growth control programme needs to have flexibility and a variable sequence of low dose sprays provides for this. The potential for paclobutrazol to give some continued growth control into the following season, further demands flexibility in the number of applications needed. A little and often approach is thus advocated as the most suitable spray method for apples and pears. Other work has shown the value of a green cluster spray for controlling early vigorous growth (Shearing, 1985).

From experience in these trials it is suggested that for apple that application rates of 0.25 kg ai ha^{-1} can be applied pre-blossom at the early green cluster stage followed by further sprays at two weekly intervals, from 2 to 3 weeks after petal-fall. Where orchards have been treated in a previous year and carryover likely to reduce early season vigour then first sprays are probably best delayed until 2 to 3 weeks after petal-fall with further treatments as needed according to vigour.

Pears

Growth control, pruning reductions and yield increases are achievable with Conference pears, using paclobutrazol as a post-blossom application. Large yield increases have been produced in the second and third years of treatment (Table 9).

TABLE 9

Yield Results on Conference (t ha^{-1})

Location		1982	1983	1984
Faversham	Paclobutrazol:	15.6	32.1*	55.1
	Control:	17.5	26.6*	36.9

* orchard suffered Hail Damage.

For Conference pears post-blossom spray applications of 0.125 kg a.i ha^{-1} paclobutrazol were used in the trial at Faversham. This rate applied sequentially from two to three weeks after petal-fall is suggested as a basis for vigour control. Any spray applications of paclobutrazol earlier than this timing, pre-blossom, full-bloom or up to two weeks after petal-fall can be detrimental to fruit development (Browning, 1985) and are therefore considered unsuitable.

CONCLUSIONS

Paclobutrazol applied by the practical method of sequential sprays to apple and pear orchards for vigour control can lead to reductions in tree growth, contributing to lower pruning time and cost savings. The reduced vigour has also given benefits of better flowering, improved cropping and increased fruit colour on the Cox apple variety. These effects have contributed to better crop sales returns for growers.

Besides these direct benefits there are other advantages which become apparent for orchards treated into the second and third years. Tree containment gives better access between rows, easier access to trees for harvest and pruning, and may permit improved penetration of insecticide and fungicides.

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EFFECTS OF CHLORMEQUAT AND NITROGEN ON THE GROWTH, DEVELOPMENT AND YIELD OF WINTER BARLEY

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ABSTRACT

The response of winter barley, cv. Igri, to chlormequat (2-chloroethyltrimethyl ammonium chloride) and to nitrogen was investigated in a replicated multifactorial field trial in 1982/83. Single or sequential chlormequat treatments increased yields at all four nitrogen levels examined. The mechanism by which chlormequat achieved these yield increases depended on the time of application and on nitrogen level. Chlormequat controlled severe early lodging at the highest nitrogen level of 200 kg N/ha. The yield increases at the lower levels of nitrogen were attributed to small increases in all three yield components (ear number per plant, grain number per ear and grain weight). Analysis of the ear number response suggested that a single application of chlormequat at GS 31 improved tiller survival, and earlier sequential applications at GS 13 and 22 had their effect on the number of tillers produced per plant.

INTRODUCTION

In the early work on chlormequat reviewed by Humphries (1968), chlormequat was found to be ineffective in the prevention of lodging in spring barley. More recently commercial development work suggested some potential for the control of early lodging in winter barley (Williams et al. 1982). Chlormequat has also been shown to modify the growth of both spring and winter barley and produce yield increases in the absence of lodging which were largely attributed to an increase in ears per plant (Matthews et al. 1981). Herbert (1983) has emphasised the need to study the interaction between chlormequat and nitrogen in order to achieve greater reliability in the use of growth regulators both in the prevention of lodging and in growth modification.

In an attempt to identify the circumstances when chlormequat could control lodging or increase yields in the absence of lodging a series of trials were initiated to investigate the interaction between chlormequat applied at different plant growth stages with spring applied nitrogen. This paper reports the results of the first of these trials.

MATERIALS AND METHODS

Winter barley (cv. Igri) was sown at 200 kg seed/ha at Craigiebuckler, Aberdeen on 16 September 1982 producing a pre-winter plant population of 520 plants/m^2 with no measurable losses over winter. Chlormequat was applied either as equal sequential treatments or singly ((1) control - untreated, (2) sequentially at GS 13 (8 Nov.), GS 22 (31 March) and GS 31 (10 May), (3) at GS 22 and 31, and (4) at GS 31). All treatments received a total of 1.5 kg a.i./ha of chlormequat as Arotex Extra. Nitrogen was applied as nitrochalk at 80, 120, 160 and 200 kg N/ha; 40 kg N/ha of which was applied on 23 Feb. and the balance on 11 March.

Basal fertiliser was combine-drilled to supply 25, 75 and 75 kg N, P_2O_5 and K_2O respectively. A broad-spectrum herbicide containing mecoprop, bromoxynil, ioxynil and linuron together with fenpropimorph was sprayed, at recommended rates, on 14 April. The crop was harvested on 11 August.

All treatments were combined factorially in three blocks with a plot size of $45m^2$ from which up to nine $0.5m^2$ samples were taken during the growing season and $18m^2$ cut by combine-harvester at maturity. Total dry mass, tiller and ear number/m^2, plant growth stage, tiller position and size and apical development were recorded (Dyson, 1977 and Thomson et al. 1984).

RESULTS AND DISCUSSION

Chlormequat and nitrogen both increased grain yields (Table 1). Chlormequat was equally effective in increasing yields when applied singly or in a sequence and it reduced the incidence of lodging. High rates of nitrogen, particularly 200 kg N/ha, increased it.

TABLE 1

Grain dry matter yield (t/ha), and area of crop lodged (%) at final harvest.

Chlormequat treatment	Nitrogen treatment (kg N/ha) 80	120	160	200	Mean	Mean(80-160)
1	3.94(0)	3.62(53)	4.71(27)	1.80(100)	3.52(45)	4.09(27)
2	4.06(0)	4.37(0)	5.17(0)	4.68(7)	4.57(2)	4.53(0)
3	4.29(0)	4.34(0)	4.98(0)	4.77(17)	4.60(4)	4.54(0)
4	3.99(0)	4.81(0)	4.93(7)	5.22(17)	4.74(6)	4.58(2)
Mean	4.07(0)	4.29(13)	4.95(8)	4.12(35)		
Mean(2-4)	4.11(0)	4.51(0)	5.03(2)	4.89(14)		

S.E. within table, 0.39; means, 0.20

There was a highly significant interaction (P = 0.001) between the effects of nitrogen and chlormequat on both yield and lodging. At 200 kg N/ha with chlormequat lodging was reduced to relatively low levels which only occurred late during grain filling. Without chlormequat, all plots completely lodged early during the grain filling period, and subsequently were seriously damaged by birds.

Increasing the level of applied nitrogen to 160 kg N/ha increased yield. In the chlormequat-treated plots there was a small decrease in yield, associated with some lodging, at 200 kg N/ha.

A major component in the effect of chlormequat on yield was its control of early lodging. This was particularly marked at high nitrogen levels. These observations on lodging control can be related to the effect of both chlormequat and nitrogen on main stem height at harvest (Table 2). Plant height increased with increasing nitrogen and decreased with the use of chlormequat, either singly or sequentially, and was directly related to the degree of lodging observed. A similar observation was made for winter barley by Knittel and Behrendt (1982) using plant growth regulators based on mepiquat chloride and ethylphosphonic acid. Stem weight per unit length was generally increased indicating that chlormequat increased stem thickness giving shorter and thicker stems.

TABLE 2

Main stem height (cm) and dry weight per unit length (mg/cm) at harvest. Stem height based on sample size of three replicates of 25 plants.

Chlormequat treatment	Main stem height Nitrogen treatment (kg N/ha) 80	120	160	200	Dry weight per unit length Nitrogen treatment (kg N/ha) 80	120	160	200
1	64.4	68.4	70.2	75.7	8.96	8.45	8.50	8.71
2	61.8	67.0	69.0	72.2	8.61	8.91	8.83	8.84
3	60.8	65.4	68.1	69.1	9.56	8.90	8.71	8.60
4	62.1	67.3	69.1	70.9	9.32	8.43	9.06	9.31

S.E. : 1.76 S.E. : 0.464

The effect of chlormequat on yield at the 200 kg N/ha level is clearly linked to some lodging control. This effect is omitted from an analysis of yield components. As there were no consistent differences in yield between the three chlormequat treatments yield component responses are considered on a plus or minus growth regulator basis.

TABLE 3

Effects of nitrogen, and chlormequat on ear number/plant, grain number/ear and wt/grain (mg). Based on sample size of three replicates of 25 plants.

Chlormequat treatment	Nitrogen treatment kg/ha 80	120	160	Mean
Ear number/plant:				
1	1.91	2.23	2.08	2.07
2-4	2.13	2.30	2.44	2.29
Mean	2.08	2.28	2.36	
S.E.within table, 0.154				
Grain number/ear:				
1	14.07	14.56	15.04	14.56
2-4	14.60	14.95	15.54	15.03
Mean	14.34	14.76	15.29	
S.E.within table, 0.61				
Wt/grain mg:				
1	35.08	33.38	35.48	34.66
2-4	35.91	34.83	35.79	35.51
Mean	35.70	34.47	35.71	
S.E.within table, 0.931				

TABLE 4

Total tiller number per plant (incl. main stem), and maximum spikelet primordium number (per main stem) 28 April 1982. Means based on sample size of six replicates of ten plants.

Nitrogen level (kg N/ha)	Chlormequat treatment	Total tiller number	Maximum spikelet primordium number
80	1+4(untreated)	3.10	34.8
	2+3	3.23	34.4
120	1+4(untreated)	3.47	34.5
	2+3	3.54	34.9
160	1+4(untreated)	3.10	34.9
	2+3	3.45	35.2
200	1+4(untreated)	3.67	35.2
	2+3	3.77	35.3
S.E.		0.114	0.31

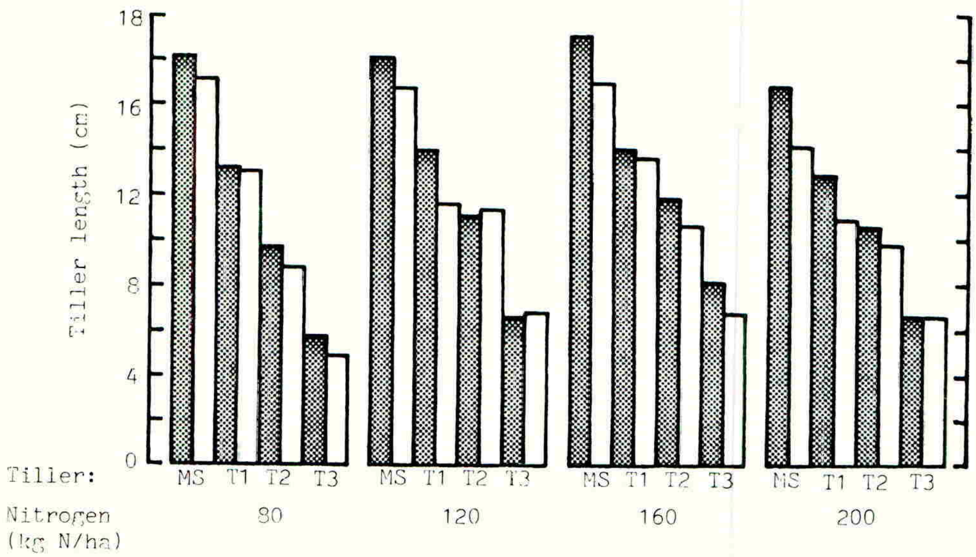

Fig. 1. Effect of chlormequat (shaded - control; unshaded - treatments 2 and 3) and nitrogen on tiller length (cm) on 28 April. Means based on sample size of six replicats of ten plants. MS : main shoot; T1, T2 and T3 : primary tillers arising in axil of leaves 1, 2 and 3 respectively. S.E. for MS, T1, T2 and T3 : 0.74, 0.72, 0.47 and 0.58 respectively.

Chlormequat treatment increased the three yield components (ear number per plant, grain number per ear, and grain weight) over the control plants (Table 3), and at all three nitrogen levels. All the individual effects were relatively small so it is difficult to relate them back to earlier events during plant growth and development. A sample (28 April) taken approximately one month after the growth regulator application at GS 22 showed that total tiller number (including main stem) had been slightly increased by chlormequat at all nitrogen levels (Table 4), and that the maximum spikelet primordium number was not consistently influenced by growth regulator treatment. Neither tiller number nor spikelet number were consistently influenced by the level of nitrogen. Chlormequat reduced tiller height at all tiller positions while nitrogen had no consistent effect (Fig. 1).

It has been suggested previously that growth regulators such as chlormequat (Matthews et al., 1981) and mepiquat chloride (Cartwright and Waddington, 1981) produce a more uniform plant in which the later formed primary and early secondary tillers are more similar, in size, to the main shoot and early primary tillers. In this trial although tiller lengths were reduced this occurred at all tiller positions and there was little evidence of a more uniformly-structured plant. Data for total tiller numbers indicate that the early applications of chlormequat, at GS 13 and 22, slightly increased the final tiller number per plant and this was reflected in the higher ear number at harvest. Tiller survival was only slightly improved as a result of early applications, but the single chlormequat treatment at GS 31 increased the proportion of tillers which survived to form ears, at all three nitrogen levels, to 77% compared with 65% for the control plants.

It would therefore appear that although all three chlormequat treatments resulted in increased yields, at all nitrogen levels, the mechanism by which these greater yields were produced differed depending on time of application and on nitrogen level. At the highest nitrogen level (200 kg N/ha) the increased yield was largely attributable to the control of early lodging whereas at lower nitrogen levels lodging control was less important. All three yield components (ear number per plant, grain number per ear and grain dry weight) were increased and it is suggested that the mechanism by which chlormequat influenced ear numbers depended on the time of application such that the single treatment at GS 31 influenced tiller survival. The two sequential treatments in which chlormequat was applied either at GS 13 and 22 or at GS 22, in addition to GS 31, appeared to produce an increase in total tiller numbers per plant.

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THE INCORPORATION OF TILLER MANIPULATION BY CHLORMEQUAT INTO WINTER BARLEY PRODUCTION SYSTEMS

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ABSTRACT

The grain yield of winter barley is shown to be strongly correlated with grain number (GN)/m^2 for each of the cultivars Igri, Tipper and H. Otter. The higher densities were associated with increased ear number (EN)/m^2 and reduced mean grain weight (MGW). The higher yield of the early sowings is attributed to increased EN/m^2. Over all cultivars and sowing dates, chlormequat applied Pre GS30 increased ears/plant resulting in a significant increase in EN/m^2. The effect of chlormequat on EN/m^2 was particularly evident in the higher tillering cultivar H. Otter and not seen in the low tillering cultivar Tipper. The effect of chlormequat on EN/m^2 was generally similar at both sowing dates of each cultivar.

INTRODUCTION

The grain yield of temperate cereals can often be related to crop sink size (ie grain number (GN)/m^2) at harvest. This has been well documented for winter wheat (eg Biscoe and Willington, 1983; Green, 1984), spring barley (eg Gallagher et al 1975; Dyson 1977) and is also likely to be true for winter barley although less information has been published.

Ear number (EN)/m^2 and GN/ear are the components of GN/m^2. Choice of cultivar (Kirby 1967), earliness of sowing and timely application of growth retardent chemicals (Matthews et al 1982) have been shown to influence EN/m^2 and are all under control of the grower. Mean GN/ear cannot usually be increased by agronomic practice but commonly decreases along with mean grain weight (MGW) with increasing EN (Green et al 1984). However in North East Scotland long daylengths coupled with low daytime temperatures favour long periods of grain fill thus allowing a large number of adequately filled grains /m^2 to be produced. Thus the potential to increase grain yield by manipulating sink size may be more readily realized in such environments.

Plant Growth Regulators such as chlormequat can be applied during tillering to increase the EN of winter barley at harvest. However results from field trials have often been inconclusive, yield increases are generally small though often economically worthwhile. This was shown in trials by the Scottish Agricultural Colleges 1979-82 (Paterson et al 1983) in which chlormequat produced a significant yield increase in only 18% of treatments but an economic return in 65% of treatments on winter barley.

This paper reports a multifactorial field trial designed to elucidate the role of cultivar, sowing date and various chlormequat applications in yield formation of winter barley. Detailed analyses of yield components at harvest permit the identification of those treatment combinations where chlormequat produced the greatest benefits.

MATERIALS AND METHODS

A multifactorial field trial was set up to include all combinations of:

a) cultivar (Igri, Tipper or Maris Otter)
b) sowing date (Early (21/9/83) or Late (20/10/83)) and
c) chlormequat (control (none), Pre-GS30 or GS30).

The trial was drilled with 2 replicate randomised blocks. Plots were 3m by 1.2m and contained 10 rows. Fertiliser (35-35-35 kg/ha N-P-K) was applied prior to drilling, 100 kgN/ha were applied on 5/3/84 and a further 50 kgN/ha at GS30. Chlormequat (0.78 l/ha chlormequat chloride (644 g/litre) + choline chloride as Arotex Extra (ICI) + 75 cm^3/ha Agral (ICI) in 300 l/ha water) was applied either Pre GS30 to early sown plots on 14/3/84 (GS: Igri 16.0, 23.3; Tipper 15.4, 21.8; M. Otter 15.5, 22.8) or to late sown 21/4/84 (GS: Igri 14.8, 22.9; Tipper 14.0, 22.0; M. Otter 14.2, 22.4) or at GS30. Weed, disease and pest control measures were applied as necessary following standard agronomic practice. Lodging was prevented in all plots by the use of string supports. A central $1m^2$ portion from each plot was harvested on 12/8/84 and the yield components recorded.

Statistical analyses utilised the GENSTAT statistical package on the Aberdeen University computer. Analyses of variance revealed no statistically significant ($P < 0.05$) 2nd or 1st order interaction between the three main factors cultivar, sowing date and chlormequat application with respect to sink components.

RESULTS

The effect of modifying sink size

In this experiment with a wide range of grain densities (13000-24000 grains/m^2) significant correlations between yield and GN were observed for each of the three cultivars (fig 1.) The difference in grain yield between cultivars at comparable grain densities arose from differences in mean grain weight (MGW) (table 1.).

The negative correlation between MGW and GN was strong, and for all cultivars indicated partial compensation in MGW in response to increased GN/m^2 (fig 2.). The slopes of the regression lines were however small, indicating that the positive effect of high GN was only slightly offset by reduced MGW.

The effect of cultivar

Igri outyielded Tipper which significantly outyielded M. Otter (table 1). EN/m^2 was significantly ordered M. Otter > Tipper > Igri although GN/m^2 was significantly ordered Tipper > M. Otter > Igri, the change in order was because Tipper had more grains/ear and M. Otter fewer. The relationship between GN and grain yield was not the same for all cultivars because of differences in differences in MGW (table 1).

The effect of sowing date

Late sowing significantly reduced yield because of significantly fewer grains/m^2 which resulted from fewer ears/m^2 not grains/ear (table 2). Late sowing significantly increased MGW.

TABLE 1

Effect of cultivar on yield components at harvest. Means of all sowing dates and chlormequat treatment.

Yield component	Cultivar			LSD (< 0.05)
	Igri	Tipper	M. Otter	
Grain yield g dm/m^2	808	772	661	58.7
Grains/m^2 x 10^{-3}	162	20.2	18.3	1.27
Ears/m^2	835	917	1257	65.0
Grains/ear	19.4	22.0	14.5	0.76
MGW mg dm	50.2	38.4	36.3	0.893

TABLE 2

Effect of sowing date on yield components at harvest (means of all cultivar x chlormequat treatments).

Yield component	Sowing date		LSD (P < 0.05)
	Early	Late	
Grain yield g dm/m^2	817	676	47.9
Grains/m^2 x 10^{-3}	20.1	15.8	1.03
Ears/m^2	1116	887	53.2
Grains/ear	18.9	18.4	ns
MGW mg dm	40.0	43.2	0.728

The effect of chlormequat

Chlormequat applied Pre GS30 increased yield through an increase in ears per plant leading to a significant increase in EN/m^2 and hence GN/m^2 (table 3). GN/ear and MGW were slightly reduced. Chlormequat applied at GS30 slightly reduced yield because of a reduction in MGW despite a small increase in ears/m^2 and grains/ear.

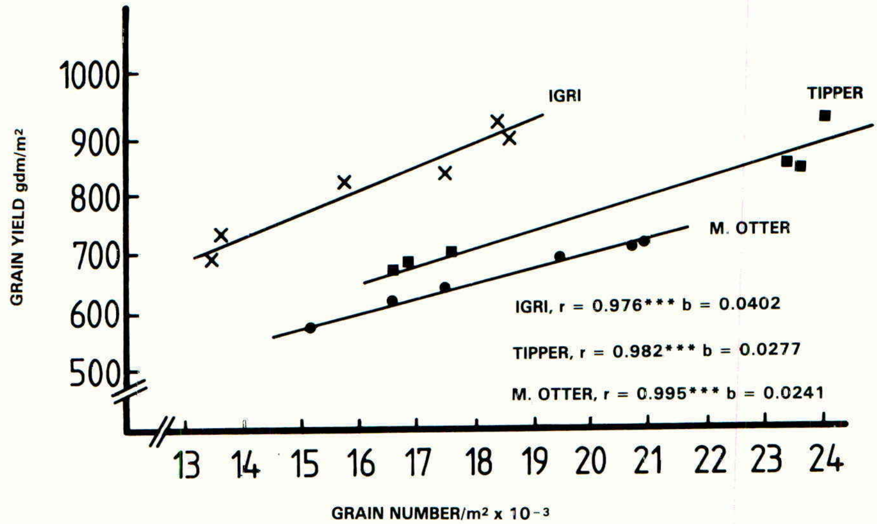

Fig. 1. Grain number and grain yield for Igri, Tipper and M. Otter (Each point is a treatment mean of two $1m^2$ samples).

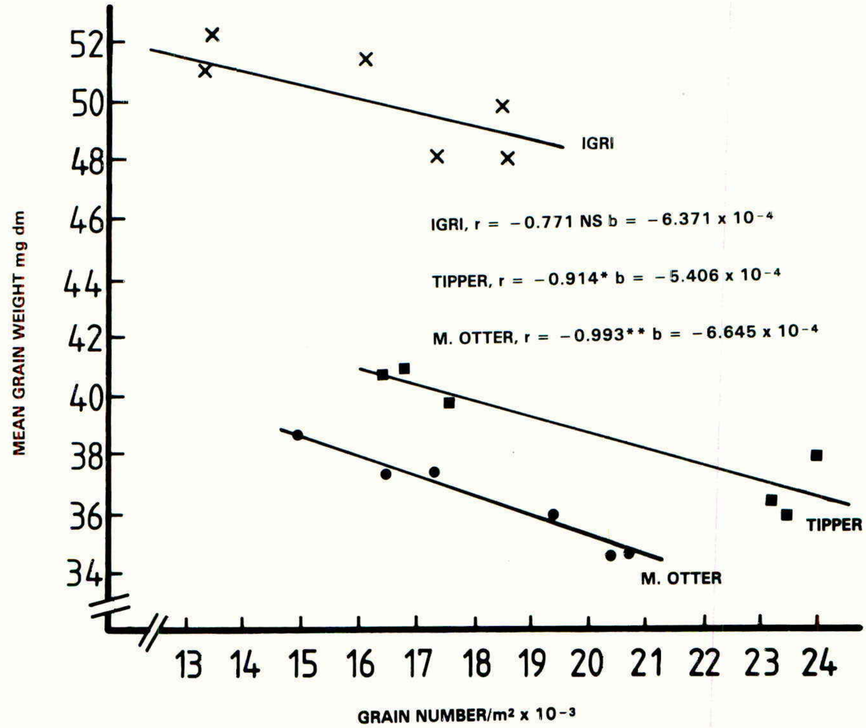

Fig.2. Grain number and mean grain weight for Igri, Tipper and M. Otter (each point is a treatment mean of two $1m^2$ samples).

TABLE 3

Effect of chlormequat on yield components (means of all cultivars x sowing date treatments).

Yield component	Chlormequat			LSD (P < 0.05)
	None	Pre GS30	GS30	
Grain yield g dm/m^2	738	774	728	ns
Grains/m^2 x 10^{-3}	17.9	18.8	18.0	ns
Ears/m^2	972	1055	981	65.0
Ears/plant	2.84	3.09	2.96	ns
Grains/ear	18.7	18.4	18.8	ns
MGW mg dm	42.0	41.7	41.2	ns

TABLE 4

Effect of chlormequat on EN/m^2 of Igri, Tipper and M. Otter sown early and late.

Cultivars	Sowing date	Chlormequat		
		None	Pre-GS30	GS30
Igri	Early	901	991	912
	Late	704	811	694
Tipper	Early	1057	1056	1034
	Late	811	784	757
M. Otter	Early	1279	1447	1372
	Late	1083	1243	1118

(Cultivar x sowing date x chlormequat) LSD (P<0.05) = ns

The increase in GN/m^2 from early sowing or chlormequat applied Pre GS30 is largely associated with increased EN/m^2 and not GN/ear. Thus ear density would appear to be a good indicator of sink size and hence potential yield. Table 4 shows the effect of chlormequat on EN/m^2 of Igri, Tipper and M. Otter when sown early and late and thereby allows us to describe the situation when chlormequat may produce the most consistent increase in EN/m^2.

Late sowing reduced EN/m^2 similarly for each cultivar x chlormequat treatment. Chlormequat applied Pre GS30 increased EN/m^2 when applied to all sowings of Igri and M. Otter but not Tipper. Chlormequat applied at GS30 also increased EN/m^2 in early and late sown M. Otter, however Igri only when sown early showed a small increase in EN/m^2. Chlormequat applied at GS30 to early and late sown Tipper appeared to reduce EN/m^2.

DISCUSSION

The correlation between yield and GN/m^2 suggests that increasing GN/m^2 may be an effective method of increasing the grain yield of winter barley. This relationship occurred over a wide range of grain densities ($13000-24000/m^2$). Thus scope may exist for the increase of grain yield even within potentially high yielding crops by enhancing GN. This may be a feature of crops grown in north-east Scotland where grain filling potential appears to be high and the lack of a compensating fall in MGW has resulted in higher grain yields.

No significant interaction between chlormequat and sowing date with respect to sink size was detected. Thus chlormequat appeared not to have the potential to boost the tiller survival of late sown crops and negate the effects of late sowing when applied at these stages. It is however possible that application at an earlier growth stage to late sown crops is necessary to stimulate earlier and more synchronous tiller emergence and growth and thereby to enhance survival to harvest. However these data do indicate that the beneficial effects of chlormequat are not precluded by dates of sowing.

Decrease in MGW of barley may be undesirable in crops grown for malting, intervention or seed production, thus the observed small reduction in MGW resulting from high EN may reduce marketability. However in crops grown for animal feed this may not be important. From these data it would appear that cultivars differ in response to chlormequat, this was shown by the consistent increases in EN/m^2 from M. Otter and the consistent reduction from Tipper. Thus chlormequat may be equally useful in the production of high ear density within both early and late sowings but may produce more consistent increases in EN/m^2 when applied to the higher tillering cultivars like M. Otter.

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THE USE OF MEFLUIDIDE ON PRODUCTIVE GRASSLAND

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ABSTRACT

The influence of cutting (time and frequency) on the effectiveness of mefluidide, applied at 150 g a.i. ha^{-1} in March to suppress flowering in seven grasses, was studied in a field experiment. The mefluidide inhibited flowering in all species, except _Lolium perenne_ and, to a lesser extent, _Holcus lanatus_. In general, delaying the time of the first cut complemented the mefluidide effect, especially in combination with frequent cutting. Maximum rates of mid-season growth were obtained by delaying the first cut, followed by cutting at monthly intervals.

In a second experiment, carried out at 10 contrasting sites, mefluidide brought about a substantial shift in herbage growth (peaking in mid-season) on most sites, especially those with a high proportion of _L. perenne_.

INTRODUCTION

Mefluidide, a foliar-absorbed plant growth regulator, has been shown to suppress seedhead formation in a range of grasses when applied in early spring (Haggar and Standell, 1982). The potential benefits of this to animal production (in terms of fibre content, N and soluble carbohydrate levels) have been demonstrated (Glen _et al_., 1980) and increases of 27% in animal productivity per hectare from tall fescue (_Festuca arundinacea_), sprayed in spring at 273 g ha^{-1}, have been reported (Robb _et al_., 1981).

There is little information on how the timing of the first cut and the frequency of subsequent cuts influences the effect of mefluidide on the growth of various grass species. It is also not known how mefluidide affects grass growth on different types of swards under normal grazing practices. Hence the two following experiments were carried out. In both experiments a single dose of 150 g a.i. ha^{-1} was applied in March, as previous work (Haggar and Isaac, 1985) had shown this to suppress seedhead formation without causing excessive growth suppression under grazing conditions.

METHODS AND MATERIALS

Experiment 1

In autumn 1983 monocultures of seven grass species (see Table 1) were established from seed sown in main plots measuring 1.5 x 30 m. Each species was replicated four times in a fully randomised design. The 28 main plots were divided into two replicates. Each main plot was subdivided into four plots measuring 1.5 x 6 m, which were randomly allocated to the defoliation treatments indicated in Table 1.

The whole area was sprayed with mefluidide at 150 g a.i. ha^{-1} at 246 1 ha^{-1} on 2 April 1985 using a tractor mounted sprayer. The weather was fine at spraying with a short shower 6 h later. Fertiliser was applied at 70 kg N ha^{-1} on all plots on 15 April, 16 May and 11 July.

TABLE 1

Treatment combinations used in experiment 1

Species		Date of first cut		Cutting frequency
Agrostis capillaris Dactylis glomerata Festuca arundinacea Festuca rubra Holcus lanatus Lolium perenne (cv Melle) Phleum pratense	X	22 May 29 May 5 June 12 June	X	2 weeks 4 weeks

Seedhead counts were taken, using a 30 x 30 cm quadrat, before each plot was harvested. Plots were cut with a Haldrup plot harvester to a height of 5 cm. The herbage was weighed and 250 g samples taken for dry weight determination.

Experiment 2

Ten sites of different sward types were chosen (Table 2). At each site two plots were marked out , each 3 x 15 m. One was sprayed with mefluidide at 150 g a.i. ha^{-1} at 300 $l\ ha^{-1}$, between 25 March and 3 April 1985. One grazing exclusion cage (1 m^2) was placed on each plot and moved after each harvest. The plots were managed under normal grazing practice as for the whole field. A quadrat (70 x 70 cm) was cut monthly under the cage and the cage moved to a fresh, trimmed position.

The herbage was weighed and sampled for dry weight determination.

TABLE 2

Site details of experiment 2

Location		Sward Type	L. perenne (%)	Grazing System
North Wyke	A	L. perenne/Agrostis spp.	80	Cattle
Hurley	A	L. perenne/Trifolium repens	80	Cattle
Hurley	B	L. perenne/Poa spp.	75	Sheep
Begbroke Hill	A	L. perenne/Poa spp.	60	Cattle
Bronydd Mawr	A	L. perenne/Agrostis spp.	45	Sheep
Bronydd Mawr	B	L. perenne/Poa spp./Agrostis spp.	40	Sheep
Long Ashton	A	L. perenne/Poa spp./Agrostis spp.	30	Cattle
Begbroke Hill	B	Agrostis spp./L.perenne/Poa spp.	20	Cattle
Long Ashton	B	H.lanatus/Agrostis spp./D. glomerata	0	Cattle
North Wyke	B	Agrostis stolonifera	0	Cattle

RESULTS

Experiment 1

Flowering

The only species to flower profusely before the first harvest was L. perenne . On 22 May there were an average of 28 seedheads per quadrat, rising to 57 by 12 June. By comparison, maximum values recorded on 12 June for F. rubra, H. lanatus and F. arundinacea were 11, 4 and 1 seedheads per quadrat, respectively, whilst the three remaining species produced no seedheads at all.

Once seedheads of L. perenne were removed at the first harvest, no further seedheads appeared under the two-weekly cutting regime but some seedheads were produced under monthly cutting, especially when the first cut was made in May.

With H. lanatus, cutting in May also proved too early to prevent seedheads from forming under the monthly cutting regime. For example, cutting on 22 and 29 May resulted in 64 and 61 seedheads per quadrat respectively in mid- to late June. However, cutting on 5 or 12 June virtually stopped all subsequent flowering in this species. With F. rubra, cutting after 22 May completely inhibited seedheads from forming. The flowering response of A. capillaris to the defoliation regimes proved variable, albeit with few seedheads being produced.

Primary growth

L. perenne was the earliest growing species (Fig. 1) although by mid-June the growth rate of H. lanatus was approaching that of L. perenne. The extent to which mefluidide reduced the primary growth rate of L. perenne can be seen by comparison with the growth of unsprayed L. perenne cv Melle (Haggar (1976), Fig. 1).

Mid-season growth

Herbage accumulated during the period 15 June to 31 July was calculated using mean daily growth rates. D. glomerata produced the most growth during this period, whilst L. perenne was the least productive (Table 3). With H. lanatus, maximum rates of mid-season growth resulted from the first cuts taken on 29 May. With F. rubra and P. pratense, the optimum date was 5 June; the remaining species showed more indeterminate responses to time of first cutting. In general, delaying cutting until 12 June reduced mid-season production of all species except F. arundinacea.

On average, increasing the cutting interval from 2 to 4 weeks increased mid-season growth.

Total herbage harvested

Date of first cut did not have any effect on the total herbage harvested but the monthly cutting regime increased total herbage compared with cutting at two-weekly intervals. The highest yielding species was D. glomerata and the lowest yielding species was A. capillaris (Table 4).

Experiment 2

Mefluidide caused a reduction of 26% in total herbage harvested on the sprayed plots compared with the unsprayed plots (Table 5). During April, May and June mean yields from the unsprayed plots exceeded those of the sprayed plots. However in July, six of the ten sites produced more grass on the sprayed plots than on the unsprayed plots. The most responsive site was North Wyke A, where the yield from the treated plot in July was 230% of that

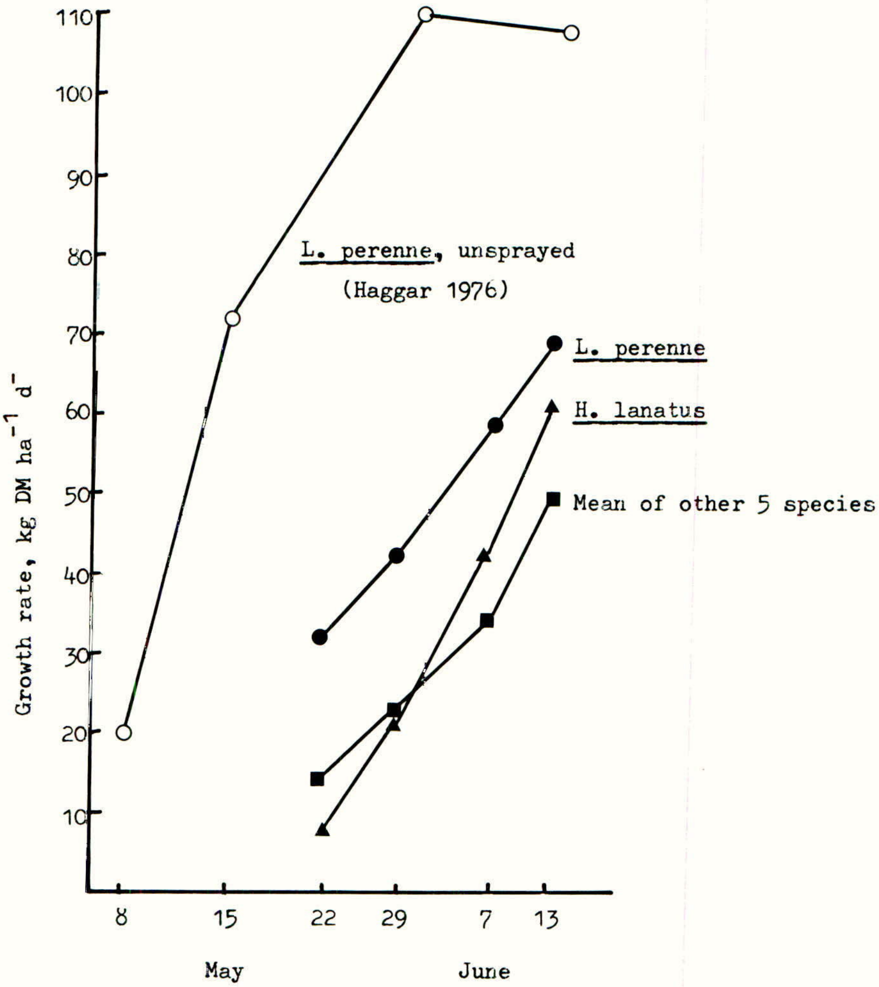

Fig. 1. Rates of uninterupted growth of various grasses sprayed with mefluidide (experiment 1)

Table 3

Effect of date of first cut and cutting frequency on herbage harvested in mid season (DM t ha^{-1},15 June to 31 July).

Species	Date of first cut					Frequency				
	22May	29May	5June	12June	s.e.	2wk.	4wk.	s.e.	Mean	s.e.
A.capillaris	1.43	1.18	1.32	0.88	0.178	0.97	1.43	0.126	1.20	0.102
D.glomerata	1.90	1.70	1.82	1.39	0.108	1.20	2.20	0.076	1.70	0.156
F.arundinacea	1.57	1.62	1.49	1.55	0.155	1.22	1.89	0.081	1.56	0.115
F.rubra	2.64	1.62	1.48	0.95	0.661	1.58	1.77	0.468	1.67	0.340
H.lanatus	1.55	1.78	1.37	1.33	0.232	1.17	1.84	0.164	1.51	0.168
L.perenne	0.81	0.72	0.81	0.46	0.064	0.45	0.94	0.045	0.70	0.079
P.pratense	1.24	1.63	1.84	1.05	0.286	1.00	1.87	0.202	1.44	0.200
mean	1.59	1.46	1.51	1.09		1.09	1.71			
s.e.	0.200	0.130	0.130	0.106		0.110	0.082			

Table 4

Effect of date of first cut and cutting frequency on total herbage harvested (DM t ha^{-1}, upto 14 August).

Species	Date of first cut					Frequency				
	22May	29May	5June	12July	s.e.	2wk.	4wk.	s.e.	mean	s.e.
A.capillaris	4.55	2.95	3.59	3.73	0.275	3.41	3.99	0.195	3.70	0.207
D.glomerata	5.14	4.20	4.92	5.07	0.297	4.21	5.46	0.147	4.83	0.207
F.arundinacea	4.70	4.30	4.00	5.19	0.185	4.12	4.97	0.131	4.55	0.220
F.rubra	4.75	4.19	4.36	4.54	0.235	3.91	5.01	0.166	4.46	0.187
H.lanatus	4.63	4.16	4.04	5.27	0.214	4.06	4.99	0.151	4.52	0.258
L.perenne	3.55	3.40	4.31	4.92	0.138	3.74	4.35	0.098	4.04	0.195
P.pratense	4.23	4.39	4.18	3.92	0.235	3.57	4.79	0.166	4.18	0.230
mean	4.51	3.94	4.20	4.66		3.86	4.79			
s.e.	0.200	0.180	0.134	0.160		0.103	0.112			

from the untreated plot. At this site the L. perenne content was 80%. Conversely, at North Wyke B, where no L. perenne was present, the yield from the sprayed plots was only 73% of that from the untreated plots. There was a significant linear relationship between the percentage content of L. perenne ( ) and the gain in mid-summer growth (y) of the form: y = 91.7 x 0.63 (P$\frac{1}{8}$ 0.001).

Table 5

Effect of mefluidide on herbage harvested at monthly intervals (t DM ha^{-1}). Mean of ten sites.

	Treatment			
Harvest	Unsprayed	s.e.	Sprayed	s.e.
April	0.70	0.223	0.36	0.126
May	1.95	0.484	1.70	0.443
June	2.45	0.213	1.89	0.215
July	2.23	0.205	2.47	0.202
Total	7.13	0.776	6.25	0.444

DISCUSSION

Mefluidide worked as expected in the cutting experiments, inhibiting seedhead production in all species, although not preventing seedhead formation in L. perenne and, to a lesser extent, F. rubra and H. lanatus. Previous work (Haggar and Isaac, 1985) has shown that L. perenne is relatively less affected by mefluidide compared with a range of other grasses.

Experiment 1 showed that mefluidide effects on seedhead inhibition can be complemented by careful timing of the first harvest cut. For example, delaying cutting H. lanatus until the first week in June resulted in a virtual absence of flowerheads appearing either before or after cutting. Cutting frequency, too, had an important effect, with frequent cutting inhibiting seedhead appearance in all species except L. perenne and, to a much lesser extent, H. lanatus.

No unsprayed plots were included since this would have involved a doubling of the size of the experiment. Hence, it was not possible to measure the extent to which mefluidide altered the normal growth curve of the grasses. However, comparisons with growth curve data published elsewhere (Anslow and Green, 1967; Haggar, 1976), as shown in Fig. 1, indicate that mefluidide caused a substantial delay in the commencement of growth in early May and reduced daily growth rates throughout May by at least 50%.

The delay in spring growth caused by mefluidide meant that peak rates of uninterrupted growth occurred in mid-June rather than in late May. Although there appeared to be little scope of using the time of first defoliation for further transferring growth to late June, the experiment did emphasise the importance of cutting frequency in modifying mid-season growth. For instance, growth during the period mid-June to the end of July was approximately doubled by the monthly cutting regime, compared with the more frequent cutting treatment.

In experiment 2, monthly comparisons of growth from the mefluidide-sprayed and unsprayed swards at the 10 sites showed that the general trend for mefluidide to increase mid-season growth (as had previously been demonstrated, albeit on monocultures, e.g. Haggar and Isaac, 1985) applies over a wide range of sward types but especially those containing a high proportion of L. perenne.

It can therefore be concluded that for grassland systems in which mid-season growth is at a premium (as is often the case following heavy conservation cuts, especially in swards dominated by L. perenne), mefluidide could be used to produce high quality, vegetative herbage for conservation in early June, followed by rotational grazing at monthly intervals during the summer months.

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A REVIEW OF TRIALS AT LONG ASHTON ON THE EFFECTS OF SOME PLANT GROWTH REGULATORS AND HERBICIDES ON ORCHARD SWARDS AND TREES

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ABSTRACT

The paper describes the effects on both orchard swards and trees of experiments between 1965 and 1982 to control the growth of swards by chemical means rather than by mowing. Single or repeated applications of plant growth regulators and herbicides were used alone or in combination. The most effective were mefluidide, maleic hydrazide and paclobutrazol.

Mefluidide gave the best suppression of seed heads; paclobutrazol the best long-term control of grass growth. Maleic hydrazide was occasionally phytotoxic to grasses producing bare patches which were colonised by broad-leaved weeds unless a selective hormone weed killer was also used. When used on the alleyway grass of a conventional grass alley/bare tree-row system, chemical control was as effective as regular mowing, and produced no adverse effects on the orchard trees. Chemical control of grass swards extending to the base of apple trees was effective under 12 year old trees, but under newly planted trees grass competition was severe, resulting in reduced apple vigour and yield.

INTRODUCTION

In most British dessert apple orchards the tree rows are kept weed free by herbicides, but the alleyway between the rows is usually either sown or allowed to tumbledown to grass. A grass sward improves the texture and organic matter content of the soil and helps to retain moisture and to mobilise phosphorus and potassium (Wallace 1953) so that fruit from grassed orchards often keeps better in store (Montgomery & Wilkinson 1962). Spraying, harvesting and other agronomic practices are more easily carried out on a grass sward than on bare soil. However, the sward requires regular mowing throughout the season. A reduction in the labour and maintenance costs by the use of plant growth inhibitors would be of economic value (Stott 1972a).

In cider orchards the grass sward beneath the trees facilitates mechanical harvesting and helps to keep the fruit clean. Maintaining a short sward by mowing after July when the branches are weighed down with fruit is often not practicable and the use of a chemical inhibitor to control grass growth throughout the autumn would interest cider apple growers.

As far back as 1960 an attempt was made at Long Ashton Research Station to control grass growth in the alleyways with low rates of TCA and dalapon, two of the few herbicides then available which killed grasses selectively. These were rejected in favour of maleic hydrazide (MH), but in experiments in the early 1960s rates as high as 13.4 kg a.i./ha MH failed to give consistent and worthwhile results (Stott 1972b).

Fortunately, working with experimental formulations designed to confer rapid absorption and a degree of weather-proofing, Willis & Yemm (1966) were able to show that repeated annual applications of MH and 2,4-D could modify the composition and control the growth of vegetation along roadside verges and so, in 1965, we initiated the series of experiments reviewed below.

Experiment 1 Dessert Apple Orchard

MATERIALS AND METHODS

The experimental site has been described in detail (Stott 1972b) but essentially it consisted of 160 12-year old dwarf pyramid trees of Cox's Orange Pippin on M11 spaced 1.2 m apart in rows 6 m apart giving a plot size of 9.5 m x 6 m. The naturally seeded grass sward extended right up to the trees and had been mown monthly each season for the previous 10 years with occasional hand cutting round the base of the trees. The sward was composed essentially of *Agrostis stolonifera* and *Poa pratensis*, with some *Elymus repens* and *Phleum pratense*. The latter two species tended to be localised, *E.repens* particularly in the shade under the trees. Occasional herbs, such as *Taraxacum officinale*, *Rumex* spp. and *Ranunculus repens* were present.

In 1965 maleic hydrazide (MH) was applied at 5.6 kg a.i./1000 ℓ/ha in late April and early July either alone, (treatment 2) or with 2,4-D at 1.4 kg a.e./ha in the April spray (treatment 3) or separately in October (treatment 4). From 1970 new formulations were used which were effective at lower concentrations. MH was applied at 3.9 kg a.i./1000 ℓ/ha and in mixture with 2,4-D at 3.9 kg a.e./ha. The rate of MH applied in July was usually 2.8 kg a.i./ha but was varied according to the response made to the spring application (Stott 1972b). Treatments were applied by a tractor sprayer using cone nozzles and a pressure of 200 kPa. Control plots (treatment 1) were cut monthly throughout the season by tractor driven roto-scythe, with occasional hand cutting round the base of the trees.

From 1966 to 1971 annual records were taken on each experimental tree of apple blossom density, crop weight, size and grade; of shoot extension and stem diameter. Selected leaves from the middle of extension shoots were sampled in August for the analysis of N, P and K.

The growth and flowering of the components of the sward and their reactions to the herbicides and to cutting were recorded throughout the season. To assess the area covered by each species a quadrat 0.3 m square was thrown at random 20 times in each plot in August of the years 1965 - 1968.

RESULTS

Initial treatments caused unacceptable sward damage, and in subsequent years the July application of maleic hydrazide was halved. This régime proved adequate to check growth, and maintain the sward at about 10 cm high throughout seven years, similar to monthly cutting from April to September. The natural height of the flora was about 35 cm. Measurements showed that the area occupied by *Agrostis stolonifera* and *Dactylis glomerata* was halved but that of *Elymus repens* and *Phleum pratense* was not so reduced, particularly under the trees. After four years, about 10% of the area of treated plots was bare, ten times as much as on mown plots, and this allowed the ingress of herbaceous weeds unless 2,4-D was applied in April or October.

In general, treatments had little effect on apple stem diameter and shoot extension growth was unaffected. In the early years, treated trees had noticeably darker foliage, and significantly increased leaf nitrogen content (%dry matter) in 1966 and 68, but not thereafter. In contrast, leaf phosphorus declined significantly compared with control plots throughout the experimental period. Leaf potassium was unaffected. In one year (1969) treated trees showed a slight increase in the number of blossom clusters, but there were no significant effects on percentage set, number, size or weight of fruit.

Though sward growth was controlled by the sprays as effectively as by mowing, the plots looked ragged and untidy with clumps of E. repens and P. pratense outstanding. Hence in the large scale orchard soil/sward management trial that we subsequently planted (Stott 1976) we sought to overcome these problems by sowing a 50/50 mixture of Poa pratensis and Festuca rubra, grasses that had become dominant in the low sward produced in roadside trials of maleic hydrazide (Willis & Yemm 1966).

Experiment 2 Dessert Apple Orchard

MATERIALS AND METHODS

Cox's Orange Pippin and Golden Delicious apples on MM106 were planted in spring 1970 at a spacing of 4 x 2.75m in bare ground and kept weed-free with simazine. Grass swards were sown in autumn 1970 as a 50/50 mixture of meadow grass, Poa pratensis and red fescue Festuca rubra. Of the eight treatments replicated five times (Stinchcombe & Stott 1983), the following three compared the effects of grass retardants. (1) control, alley grass sward cut, tree row weed-free (bare); (2) alley grass sward suppressed by MH+2.4-D at 3.9 + 3.9 kg a.i./1000 ℓ/ha applied in April and July and (3) alley and tree row grass sward suppressed by overall MH+2,4-D at the same rates and times. Treatments started in 1972 and all received normal applications of fertilizer until 1974 (N and K at 75 and P at 24 kg/ha/yr). By 1974 there were such pronounced differences that the fertilizer regime was modified.

Each treatment plot consisted of 10 trees, 5 of each variety, and was guarded on all sides by a row of Cox's Orange Pippin. Annual records were taken from each experimental tree of diameter and extension growth, blossom density; leaf N,P,K; and number, weight, grade, colour and storage quality of fruit.

RESULTS

In treatment 3 the growth of grass was suppressed during the first three years of the trial, but not enough to prevent competition with the young trees, causing a significant reduction in stem diameter, leaf nitrogen and yield (Table 1). Hence in 1974 the sward in the tree row was eliminated by repeated applications of paraquat. However, six years after competing grass had been eliminated Cox's Orange Pippin trees in treatment 3 were still smaller than in the mown-alleyway grass/bare tree row of treatment 1, despite the annual application of double the normal rate of Nitrogen fertilizer. In contrast, Golden Delicious recovered more quickly following the elimination of grass competition from the tree row, and responded to double N so that over the period 1974-79 yields were higher than in the other alleyway grass/bare row treatments (1 and 2). This illustrates the varying response of different cultivars of the same species to competition,and shows that in some, growth does not recover even when the competition is removed (Stinchcombe & Stott 1983).

TABLE 1

Effect of sward treatments for two years on stem diameter, number of flower clusters, fruit set, yield and leaf nitrogen of COP and GD apples in 1973

Treatment	Stem diameter (mm)		Number of flower clusters per tree		Total fruit set per total no.of flowers per tree (%)		Fruit wt (kg/tree)		Leaf nitrogen (% D.M.)	
	COP	GD	COP	GD	COP	GD	COP	GD	COP	GD
1. Alley sward cut	41	49	164	142	13	25	12	24	2.65	2.35
2. Alley sward controlled MH+2,4-D	40	45	166	118	17	25	15	20	2.61	2.37
3. Overall sward controlled MH+2,4-D	33	39	124	35	6	19	4	3	2.19	1.76
SED	1.59	1.93	16.3	31.9	1.5	1.9	1.9	2.3	0.087	0.131

The use of grass retardants on the alley was more promising and over the 9-year period an acceptable sward was achieved in which the proportion of the two sown grasses P.pratensis and F.rubra was maintained, but in the mown plots other grasses (A.stolonifera, P.pratense, D.glomerata and clover Trifolium repens invaded and reduced the total proportion of P.pratensis and F.rubra to about 40%. Tree stems in the mown alley plots (treatment 1) were slightly thicker than where MH was used, but not significantly so; growth, yield and leaf nutrients were unaffected by MH (Table 1). Thus the choice of management system depended largely on relative costs of mowing and the use of grass retardants. Initially chemical grass control was cheaper but by 1975 increased prices of herbicides favoured mowing. Subsequently the discovery of a number of new growth retardants revived interest and from 1978 a further series of trials were established at Long Ashton supplemented by trials on growers holdings (Stinchcombe and Stott 1980).

Experiment 3 Dessert Apple Orchard

MATERIALS AND METHODS

This experiment began in 1979 and utilized part of the Cox and Golden Delicious orchard described in Experiment 2. The trees were grown in a weed-free tree row (herbicide strip) with a grassed alleyway. The grassed alleys which had maintained the 50/50 mix of meadow grass and red fescue were divided into randomised plots measuring 8 x 2 m and sprayed with the following treatments:(1) mefluidide at 0.5 and (2) at 1.0 kg a.i./ ha, (3) MH with 2,4-D at 3.7 plus 3.7 kg a.i./ha and(4) unsprayed controls.

The chemicals were applied on 31 May 1979, using an Oxford Precision sprayer. A repeat application was made to one half of each plot on 2 July 1979. Each treatment was replicated four times. The grass was mown 3 days before spraying: thereafter each treatment was mown when the grass was 10-15 cm high. The number of cuts, and fresh and dry weight of mowings were recorded.

RESULTS

There was little difference between a rate of 0.5 and 1.0 kg a.i./ha of mefluidide on grass growth. Overall, the effect of a single application of mefluidide was to reduce grass dry matter by 46% compared with the untreated sward. Maleic hydrazide + 2,4-D reduced dry matter by 22% (Table 2). Applications in May and again in late July reduced sward dry matter production by 81% (mefluidide) and 47% (MH) from August to November (Table 3). All mefluidide treatments gave a dense compact acceptable sward and repressed flowering but two applications of MH + 2,4-D discoloured or killed some grasses (mainly Agrostis spp.) producing bare patches which allowed the ingress of undesirable coarser grasses e.g. E.repens.

TABLE 2

The effect of growth retardants applied on 31/5 on grass growth (June to November)

Treatment	Rate a.i. (kg/ha)	No. cuts/ season	Total fresh wt g/m^2	Total dry wt g/m^2
Mefluidide	0.5	3	531	147
	1.0	3	500	139
MH + 2,4-D	3.7+3.7	5	753	209
Unsprayed (control)	-	6	963	267
	-	-	- SED	21

TABLE 3

The effect of 2 applications of growth retardants (31/5 and 2/7) on grass growth (late July to November)

Treatment	Rate a.i. (kg/ha)	No. cuts late July - November	Total fresh wt g/m^2	Total dry wt g/m^2
Mefluidide	0.5	1	100	28
	1.0	1	88	24
MH + 2,4-D	3.7+3.7	2	259	72
Unsprayed (control)	-	2	494	137
	-	-	- SED	10

The data in Table 3 contains any residual effect of the first treatment applications, as described in Table 2.

Experiment 4 Cider Apple Orchard

MATERIALS AND METHODS

The orchard in Somerset consisted of 4-year-old cider trees of several cultivars on MM106 planted at 3.7 x 5.5 m, grown in a herbicide strip with a grassed alley. The "tumbledown" sward consisted mainly of Agrostis spp. The grassed alleys were divided into plots measuring 4 x 3 m for each of the 10 treatments listed in Table 4. Mefluidide and MH were applied on 5 May 1980 using an Oxford Precision sprayer and to half the plots again on 22 July 1980. The grass was mown and mowings weighed as in Experiment 3.

RESULTS

In this cider orchard where Agrostis predominated, single applications of mefluidide at four rates (0.25, 0.5, 0.75, 1.0 kg a.i./ha) reduced sward dry matter production by 24, 42, 45 and 60% respectively compared with the untreated sward. Comparable figures for 2 applications of mefluidide at these rates were 53, 84, 89 and 91% respectively. A single application of maleic hydrazide at 6.0 kg a.i./ha reduced sward dry matter production by 22% and two applications by 83% compared with the untreated sward (Table 4).

In experiments 3 and 4, all treatments reduced the number of mowings required to maintain an acceptable sward (Tables 2,3,4). The results suggest that two applications of mefluidide at rates in excess of 0.5 kg a.i./ha in cider orchards would maintain a low sward until the end of the harvest period and facilitate the ground collection of healthy, unsoiled fruit. To further investigate the possible advantages of chemical sward control, three more experiments were laid down at Long Ashton to compare a range of retardants applied at different rates and dates (Stinchcombe 1982).

TABLE 4

The effect of application of mefluidide and MH on grass growth in a cider orchard

Treatment	Rate kg a.i./ha	No. appli-cations	Month cut June	July	August	Total dry wt g/m^2
1 Mecluidide	0.25	1		+	+	190
2 Mefluidide	0.5	1		+	+	144
3 Mefluidide	0.75	1		+	+	138
4 Mefluidide	1.0	1		+	+	100
5 Mefluidide	0.25	2		+	+	118
6 Mefluidide	0.5	2		+		40
7 Mefluidide	0.75	2		+		28
8 Mefluidide	1.0	2		+		22
9 Maleic hydrazide	6.0	1		+	+	194
10 Maleic hydrazide	6.0	2		+		68
11 Unsprayed	-	-	+	+	+	250
(control)	-	-			S.E.D.	19

Experiment 5 Dessert Apple Orchard

MATERIALS AND METHODS

This experiment began in 1979 and as in Experiment 3 utilized randomised plots measuring 8 x 2 m laid down in the predominently meadow grass and red fescue swards of alleyways in the Cox and Golden Delicious orchard. Each plot was sprayed with one of the eight treatments listed in Table 5 to compare, proxazalon, MH + 2,4-D, mefluidide, paclobutrazol and a mixture of aminotriazole and'Banlene'(Banlene contains MCPA, dicamba and CMPP).

Time of application

Three separate trials were conducted. The chemicals were applied using an Oxford Precision sprayer on:-

Trial 1, 31 May 1979 and 27 May 1980
Trial 2, 31 May and 16 July 1979
27 May and 18 July 1980
Trial 3, 18 July 1980

In each experiment, treatments were replicated six times in a randomised block design.

Records

The grass was cut 5 days prior to spraying, thereafter each treatment was mown when it reached 10-15 cm high. The number of cuts and dry weight of mowings were recorded. To monitor possible effects on the trees (Trial 2), in Spring 1980 the number of blossom clusters were counted on two Cox's Orange Pippin trees adjacent to each treatment. In November 1980, shoot extension on two Cox trees adjacent to each treatment was measured on 6 shoots per tree selected at random.

RESULTS

Single Applications Trial 1

The results over 2 years (Table 5) showed that a single application of aminotriazole plus Banlene, mefluidide at 1.0 kg a.i./ha or MH + 2,4-D in May reduced grass dry matter production by 40% and the number of cuts over a full season to 4 compared with 7 for the unsprayed sward. However, paclobutrazol was the most effective grass retardant and a single application in May at the higher rate (4.0 kg a.i./ha) produced a prostrate sward and reduced the dry weight production over a season by 70% compared to the untreated sward, and the number of cuts required to two Proxazalon, and the lower rate of mefluidide at 0.5 kg a.i./ha were the least effective treatments.

Repeated Applications Trial 2

Two applications per year of aminotriazole plus Banlene, mefluidide at 1.0 kg a.i./ha or MH + 2,4-D reduced grass dry matter production by 60%. Paclobutrazol in May and July at either rate stopped grass growth completely and gave a 90% reduction in dry matter production compared with the unsprayed sward and reduced the number of cuts to two. Shoot extension growth and blossom cluster numbers were unaffected by any treatment (Table 6).

The first spraying of aminotriazole plus Banlene or MH + 2,4-D (May applications, Trial 2) resulted in a discolouring of the grass and a second application in July killed some of the grass, producing bare patches which allowed the ingress of undesirable broad leaved weeds. In contrast spraying with mefluidide gave a dense compact sward with little or no seedheads.

TABLE 5

Effect of growth retardants applied in May 1979 and 1980 on grass growth from May-October (mean for 1979 and 1980)

Treatment	Rate a.i. kg/ha	Total dry wt g/m^2 May - October	% reduction from unsprayed (May - October)	No. cuts
Proxazalon	2	314	19	6
	3	318	20	6
Aminotriazole (+ Banlene)*	0.84	228	42	4
MH + 2,4-D	3.7 + 3.7	221	44	4
Mefluidide	0.5	301	24	5
	1.0	214	46	4
Paclobutrazol	2	142	64	3
	4	89	77	2
Unsprayed	-	395	-	7
S.E.D.	-	16.2	-	-

TABLE 6

Effect of growth retardants applied May and July in 1979 and in 1980 on grass growth (1979+80 mean) and blossom density and shoot extension on Cox's Orange Pippin (1980 season)

Treatment	Rate a.i. kg/ha	Total dry wt g/m^2 (May - Oct)	% reduction from unsprayed	No.cuts (May - October)	Blossom cluster number/ tree	Shoot extension (cm)
Proxazalon	2	265	33	6	217	61.8
	3	259	34	6	223	62.1
Aminotriazole (+ Banlene)*	0.84	165	58	3	248	61.4
MH + 2,4-D	3.7 + 3.7	166	60	3	256	62.4
Mefluidide	0.5	264	33	5	260	60.3
	1.0	146	63	3	231	61.3
Paclobutrazol	2	52	87	2	251	60.9
	4	38	90	1	242	63.1
Unsprayed	-	395	-	7	238	61.7
S.E.D.	-	17.6	-	-	ns	ns

ns = Not significant

*The rate of Banlene applied contained MCPA 1.06, dicamba 0.08 and CMPP 0.355 a.i./kg/ha.

Paclobutrazol produced a dense, prostrate, dark green sward which had a coarse appearance. The altered appearance of the sward is not important in an orchard, but may be unacceptable in an amenity area. Seedheads were reduced following paclobutrazol treatments but not eliminated. Although some retardation of broad-leaved weeds was achieved, total numbers increased in paclobutrazol treated swards compared with unsprayed swards. The invasion of bare patches by broad leaved weeds, or their increase due to the removal of grass competition following growth regulator treatments, can be controlled by later applications of a hormone weedkiller such as 2,4-D.

Late Season Application Trial 3

A single application of aminotriazole plus Banlene, mefluidide at 1.0 kg a.i./ha or MH + 2,4-D in July 1980 significantly reduced dry matter production by over 40% and the number of cuts between July and late October by 67%. Paclobutrazol at either rate stopped grass growth completely (Table 7).

TABLE 7

Effect of growth retardants applied in late July on subsequent grass growth

Treatment	Rate a.i. kg/ha	Total dry wt g/m^2 (July - October)	% reduction from unsprayed	No. cuts (July - October)
Proxazalon	2	138	10	3
	3	128	16	3
Aminotriazole (+ Banlene)*	0.84	84	45	1
MH + 2,4-D	3.7 + 3.7	80	47	1
Mefluidide	0.5	125	18	2
	1.0	88	43	1
Paclobutrazol	2	0	100	0
	4	0	100	0
Unsprayed	-	152	-	3
S.E.D.	-	8.2	-	-

*The rate of Banlene contained MCPA 1.06, dicamba 0.08 and CMPP 0.355 a.i./kg/ha.

DISCUSSION

These trials over many years show that significant reductions in growth and dry matter production of orchards swards, can be achieved by the use of some plant growth regulators and that the number of necessary mowings can be halved.

The choice between mowing and spraying turns on cost and to what extent discolouration, uneven growth and patchiness are acceptable. In dessert orchards, aminotriazole + Banlene or maleic hydrazide + 2,4-D may be acceptable treatments but if appearance has to be considered, we would favour mefluidide for reasonable repression of growth and suppression of seedheads, or paclobutrazol for longer lasting effectiveness. To control sward growth throughout the season, two applications of aminotriazole +

Banlene or MH + 2,4-D would be essential and would be preferable for mefluidide, but with paclobutrazol a single spring application at 4 kg/ha would suffice.

Cider apple growers who mow the grass sward until July could thereafter best inhibit grass growth until the November harvest with a simple application of paclobutrazol, though adequate suppression may be achieved with mefluidide at 1.0 kg or MH + 2,4-D at 3.7 x 317 kg a.i./ha.

In these experiments growth regulators applied only to the alley sward, in orchards up to 12 years' old of Cox's Orange Pippin and Golden Delicious with the aim of controlling grass growth, caused no deleterious effects on the trees. More recent work at Long Ashton has shown that when applied to the weed-free soil along the tree rows, high rates (4.0 kg a.i./ha) of paclobutrazol can limit tree growth (Stinchcombe *et al.* 1984). Apple shoot growth was reduced, particularly in the season following application, flowering date was advanced and blossom clusters on one-year-old wood were increased though yield was not affected. Because paclobutrazol is both persistent and root absorbed (Pickard *et al.* 1982) it is feasible that repeated annual applications to the grass alley to control sward growth could also lead to beneficial effects on the trees, if as Stinchcombe *et al.* report, tree vigour were reduced (and hence pruning costs) and flower production increased.

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EFFECTS OF SOME EXPERIMENTAL TRIAZOLE RETARDANTS ON YIELD OF OILSEED RAPE

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ABSTRACT

Significant improvements in yield of oilseed rape cv. Jet Neuf were obtained as a result of treatment with the experimental 'triazole' retardants: UK 140 (Bayer A.G.) and BAS 11100W (BASF Aktiengesellschaft). Yield increases occurred following treatments at the beginning of and during stem extension and as a result of application of BAS 11100W to different parts of the canopy. Yields were lower in plots which received no additional fungicide programme.

INTRODUCTION

Although commercial formulations of plant growth regulators (pgrs) are currently used as management aids in the production of some high value arable crops, a beneficial and reliable role for such chemicals has yet to be established in the production of oilseed rape. Growth retardants offer potential value to the farmer by reducing stem height, and thereby increasing access for spraying and reducing the amount of straw for disposal. Treatments which shorten and strengthen stems during early regrowth might also reduce early lodging risk. Chlormequat has been found to have a temporary effect on stem growth but effects on yield have not been significant or consistent (Scarisbrick et al., 1982; Bowerman, 1984). Effects on stem height and branch length which might have consequences for yield because of changes in canopy structure and density depend on time of application of the retardant and its persistence. Thus chlormequat applied during early stem extension retarded stem growth but not terminal raceme and branch growth. Final height was similar to unsprayed plants (Child, 1984). Retardant treatment applied towards the end of stem growth before flowering, permanently reduced terminal raceme and branch growth; daminozide ('Alar'), but not chlormequat applied at this time also significantly increased pod number (Child, 1984). However, increased pod number did not result in increased seed yield under the conditions of these experiments with widely-spaced pot-grown plants.

Sustained retardance of growth, which produces a lower, more compact canopy in a field crop may also result in increased pod number thereby providing the basis for possible yield increase. The triazole retardants UK 140 (triapenthenol, supplied by Bayer AG) and BAS 11100W (1-phenoxy-3-(1H-1,2,4-triazol-1-yl)-4-hydroxy-5,5-dimethylhexane supplied by BASF Aktiengesellschaft) were known (Lürssen, (Bayer) and Rademacher, (BASF) personal communication) to be powerful growth retardants. We therefore investigated the effects of the time of their application on yield at Long Ashton Research Station (LARS) in 1985 and compared their effects with chlormequat (5C Cycocel) and Terpal (containing ethephon and mepiquat chloride) and daminozide.

It is known that growth responses to some triazoles are greatest when uptake is via the roots. It is also possible to vary site of deposition within the canopy and on the soil surface by varying droplet size, spray volume and by employing charged spray particles. We therefore compared the effects of application techniques on yield. In addition, the consequences of growth regulator treatment to yield in the absence of a programme of disease control with fungicides were compared with that obtained from plots in which a fungicide programme was carried out.

MATERIALS AND METHODS

The winter oilseed rape cv. 'Jet Neuf' was sown at 7.5 kg seed/ha (row spacing of 114 mm) on 25 August, 1984 into a well prepared soil bed which had received five cultivations previous to sowing and basal fertilizer (0:24:24) at 260 kg/ha. A top dressing of nitrochalk equivalent to 127 kg N/ha was applied on 28 February, 1985 and a further dressing equivalent to 104 kg N/ha on 9 March.

In Experiment I we examined the effect of applying a single treatment at three different stages of development. BAS 11100W was applied at 3.3 l/250 l/ha on (i) 27 March when two-three internodes were visible and the stems were approximately 5-10 cm in height (Code 2,02 on the Sylvester-Bradley (1984) growth stage key), (ii) 16 April, when the flower buds were visible and stems were approximately 30-35 cm in height (Code 3,3) or (iii) 1 May when branches were beginning to extend and stems were approximately 70 cm in height (Code 3,6).

In addition 5C Cycocel at 3.0 l/250 l/ha or Terpal at 3.0 l/250 l/ha were applied to other plots separately or in combination on 16 April.

In Experiment II UK 140 was applied at 700 g/250 l/ha on the same dates and compared with Alar applied at 1 kg/ha on 16 April.

In both these experiments the treatments were replicated in six randomized blocks. Light leafspot (Pyrenopeziza brassica) was present in significant amounts during spring and summer in unsprayed plots but was controlled by prochloraz applied at 500 g ai/ha on 15 April and iprodione at 500 g ai/ha plus carbendazim at 250 g ai/ha on 15 June.

In Experiment III all treatments in Experiments I and II were repeated in four randomized blocks, but no fungicides were applied to these plots. The unsprayed control had double replication.

In Experiment IV BAS 11100W was applied at 3.3 l/ha by different spray techniques and spray volume rates at a stage, Code 4,1, when less than 20% of the flowers were open. Treatments are shown in Table 1.

These treatments were selected to deposit different doses of BAS 11100W in different parts of the crop canopy. Deposits were quantified in the top, middle and base of the canopy and on whole plants by measuring sodium fluorescein added to the sprays at 100 g/ha.

TABLE 1

Spray application techniques in Experiment IV.

Treatment	Nozzle(1)	Spray quality	Spray speed (m/sec.)	Electrostatic charging	Spray volume (l/ha)	Non-ionic wetter (%)
a	F110/0.73/2.5	medium	1.0	no	242	no
b	"	medium	1.0	no	242	0.5
c	F110/0.69/4(2)	fine	1.94	yes	118	0.5
d	"	fine	1.94	no	118	0.5
e	F110LP(3)1.49/ 1.1	coarse	1.94	no	255	0.5
f	CDA(4)	fine	1.94	yes	10	no

(1) F = flat fan, 110 = fan angle/l per min per nozzle/spray pressure in bar.
(2) hydraulic electrostatic spray system (EX) from Crop Control Products Ltd.
(3) LP = low pressure nozzle
(4) CDA = experimental induction charged micromax spinning disc from Micron Sprayers Ltd. Disc speed 500 rpm; drop size c 90 um.

In Experiments I, II and III plots were 12 x 4 m and in Experiment IV were 24 x 4 m. A small-plot combine was used to harvest a strip 1.8 m wide and approximately 9 m long in the centre of each plot between 6 and 8 August when moisture content of the pods was approximately 27%. This information was used to calculate equivalent yields in tonnes/ha at 8% moisture given in Tables 2, 3 and 4.

RESULTS

Significant increases in yield of 20-30% were obtained by treatment with UK 140 and BAS 111000W for each time of application and for daminozide (Table 2). Chlormequat and mepiquat chloride + ethephon were without significant effect.

In Experiment III, yields were generally lower - because of the absence of a fungicide programme to reduce disease incidence (Table 3). However, both BAS 11100W and UK 140 at all dates significantly improved yield and gave the greatest increase as a result of treatment on 16 April (mid-stem extension). It was observed that the incidence of light leafspot was greatly reduced by both chemicals.

Application of BAS 1110OW by different spray techniques produced similar yields. Response to the chemical applied as a high volume spray with large droplet size was similar to that obtained with low volume spray as electrostatically charged particles(Treatments c and e, Table 4). The high volume spray would have deposited considerable amounts on the soil whereas the electrostatic spray remained mainly on the tips of the branches and flowers.

TABLE 2.

Effect of time of application of triazole retardants and of daminozide, chlormequat and mepiquat chloride+ethephon on yield (t/ha) in oilseed rape cv. Jet Neuf at LARS in 1985 (corrected to 8% moisture).

	Time of application			
	0	27 March	16 April	1 May
Experiment I				
Unsprayed	2.54	-	-	-
BAS 11100W	-	3.00	3.27	3.03
Chlormequat	-	-	2.72	-
Mepiquat chloride and ethephon	-	-	2.55	-
Chlormequat + mepiquat chloride and ethephon	-	-	2.71	-

S.E.D. (30 df) = 0.142
Coefficient of variation (%): 8.7

	0	27 March	16 April	1 May
Experiment II				
Unsprayed	2.23	-	-	-
Triapenthenol	-	3.12	2.85	3.12
Daminozide	-	-	2.84	-

S.E.D. (30 df) = 0.211
Coefficient of variation (%): 13.4

TABLE 3.

Effect of time of application of triazole retardants on yield (t/ha) in oilseed rape cv. Jet Neuf in the absence of fungicides (corrected to 8% moisture).

	Time of application			
	C	27 March	16 April	1 May
Unsprayed	2.06(0.48,0.17)*	-	-	-
BAS 11100W	-	2.59 (0.41)	2.63 (0.64)	2.46 (0.57)
UK 140	-	2.48 (0.64)	2.67 (0.18)	2.37 (0.75)

S.E.D. (unsprayed vs control) = 0.133)
S.E.D. (two treatments) = 0.157) 36 df
Coefficient of variation (%): 9.3

* Additional yield obtained from plots with fungicide programme given in brackets.

TABLE 4.

Effect of method of application of BAS 11100W on yield (t/ha) of oilseed rape cv. Jet Neuf (corrected to 8% moisture).

Treatment	Spray quality	Electrostatic charge	Wetter added	Spray volume (l/ha)	Yield (t/ha)
unsprayed	-	-	-	-	2.53
a	medium	-	-	242	2.88
b	medium	-	+	242	2.35
c	fine	+	+	118	3.08
d	fine	-	+	118	2.67
e	coarse	-	+	255	3.09
f	fine	+	-	10	2.37

S.E.D. (18 df) = 0.175
Coefficient of variation (%): 9.2

DISCUSSION

The increase in yield due to treatment with UK 140 and BAS 11100W represented very significant improvements. Consistent increases of this order would raise levels of production of oilseed rape. However, it is possible that the response will vary year to year due to seasonal differences. We do not know how other cultivars will respond. In addition, agronomic factors which influence vigour such as plant density and time and rate of application of nitrogen may affect response. Furthermore some of the wide fluctuations in yield may be reduced by adequate control of the interactions between these variables.

The significant increase in yield in response to depositing the spray mainly at the top of the crop canopy (Treatment c, Table 4) indicates that BAS 11100W is readily taken up via the pod, leaf or stem surface. A similar increase was obtained when large droplets, which deposited much of the spray at the base of the leaf canopy or stems or on the soil surface, were applied.

Our finding that daminozide increases yield in the field contrasts with results with pot-grown plants (Child, 1984),and suggests that a mechanism by which retardants increase yield in the field may be associated with larger numbers of branches and pods. It might be expected that increased pod density would cause shading resulting in failure to achieve the yield potential due to retardant treatment. If this is correct, pod density and distribution in our crop of Jet Neuf in 1985 may have been below that required for maximum light interception. In addition, shorter branches may allow improved light penetration to the main stem leaves and so increase and prolong assimilate production which leads to increases in pod numbers (Tayo and Morgan, 1975). It is also possible that the triazole retardants improve yield by reducing disease incidence. The differences between plots sprayed and those unsprayed with fungicides suggest that this might be so.

In these trials both chlormequat and mixture of ethephon and mepiquat chloride had non-significant effects on yield but in 1984 at LARS some improvements in yield were recorded (Child, 1985). However, effects of plant growth regulators on senescence may account for apparent differences in response and this is under investigation.

The mechanisms of effects on yield underlying the increases reported in this paper now require investigation in order to provide understanding of possible interaction with factors described here. Effects of treatment with triazoles on pod and seed distribution, canopy structure and incidence of disease are under continuing investigation at LARS and will be reported elsewhere.

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IMPROVING WINTER HARDINESS IN WINTER OATS BY SEED TREATMENT WITH TETCYCLACIS

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ABSTRACT

Winter hardiness is one of the main factors affecting harvestable yields in winter oats. The experimental plant growth regulator tetcyclacis applied to the seed improved winter hardiness at all four sowing depths. The treatment resulted in the crown of the plants over-wintering deeper in the soil. Soil temperature measurements showed the number of hours to which the crowns of plants were subjected to sub-zero temperatures decreased with depth. Thus the added protection against winter damage afforded by tetcyclacis may be attributable to the small increases in crown depth.

INTRODUCTION

Winter hardiness is one of the main factors affecting harvestable yields in winter oats (Lawes et al. 1982). Whilst the main breeding objective is to produce cultivars having potential for high yields combined with good standing ability and stress tolerance, in practice the combination of these characters is usually accompanied by a reduction in yield. Until plant breeders overcome this problem, the application of plant growth regulators (pgrs) might provide a means of improving winter hardiness in winter oats through the inhibition of subcrown internode extension which might decrease exposure of susceptible tissues to damaging temperatures.

The pgr used in this investigation was the experimental norbornenodiazetine derivative tetcyclacis which inhibits gibberellin biosynthesis by blocking the oxidative reactions from ent-kaurene to ent-kaurenoic acid (Rademacher et al. 1984). The possible improvement of winter hardiness by applying tetcyclacis as a seed treatment to winter oats sown at four different depths was investigated.

MATERIALS AND METHODS

Two winter oat cultivars used were Peniarth and the higher yielding but less winter hardy Bulwark. Graded seed (maximum 2.2 mm) was soaked for 16 h in solutions containing 0, 0.2x and 1.0x the suppliers recommended concentration (0.1 g experimental sample (not a.i.)/kg seed/1.8 litre water) of tetcyclacis. The wetter 'Agral' was added at 0.1% in all solutions. After soaking seeds were surface dried before sowing in 27 cm plastic pots containing John Innes Potting Compost Number 3 on 5 October 1984. Six replicates of each seed treatment were sown at 2, 4, 6 and 8 cm deep, twenty seeds per pot. Following sowing the pots were plunged in an ash bed outdoors so that the level of the soil in the pots was level with that of the ash. The layout within each cultivar was a split plot design.

Soil temperatures in the pots were measured with thermocouple probes during December 1984 and January 1985. Four probes were used, each having copper-constantan junctions at the soil surface and at depths of 2, 5, 11 and 21 cm. The thermocouples were used to measure temperature differences within a single pot which, in turn, were referenced to an ice bath. Readings were recorded every 15 minutes using a data logger and subseqently averaged over each hour.

Counts of emerged seedlings were done on a per pot basis at two to three day intervals from the first sign of emergence (15/10/84) until seedlings had stopped emerging (2/11/84). Two replicates were destructively sampled on 19 November 1984 to determine the over-wintering position of the crown by measuring the length of the subcrown internodes from the seed to the base of the crown. A third replicate was destructively sampled on 5 March 1985 to determine the extent of winter damage by visually assessing the percentage brown (dead) tissue on individual plants. In addition, the main stems of six randomly selected plants from each pot were dissected and the health of the apices recorded.

RESULTS

Emergence

Increasing both sowing depth and tetcyclacis concentration slowed emergence in both cultivars, Bulwark being the slower to emerge (Table 1). However, approximately two weeks after the first signs of emergence, in

TABLE 1

Effect of tetcyclacis seed treatment and sowing depth on the percentage emergence in winter oats

Cultivar	Concn of tetcyclacis	15 October 1984 Sowing depth (cm)				2 November 1984 Sowing depth (cm)			
		2	4	6	8	2	4	6	8
Bulwark	0	90	91	83	76	96	98	94	94
	0.2x	66	64	9	0	97	94	92	91
	1.0x	13	0	0	0	92	91	89	59
Peniarth	0	93	89	81	73	94	94	99	95
	0.2x	97	89	78	47	97	97	95	94
	1.0x	79	13	0	0	95	94	95	88

only one case (1.0x tetcyclacis at 8 cm in Bulwark) was final emergence appreciably below 90% of sowing density.

Subcrown internode lengths

In both cultivars, tetcyclacis concentration and sowing depth had significant effects on subcrown internode lengths (Table 2). At all sowings subcrown internode lengths were reduced with increasing tetcyclacis concentration; the higher the concentration, the shorter the internodes. Within tetcyclacis treatments subcrown internode lengths increased with deeper sowing. However, at all sowing depths, tetcyclacis seed treatment resulted in the crowns of the plants over-wintering deeper in the soil thus gaining some thermal insulation against winter damage.

Variation of soil temperature with depth

On two occasions when the soil in the pots was frozen, a significant gradient of temperature with depth persisted in the frozen layer. Over these periods, the change of temperature with depth was often more pronounced near the soil surface than for deeper layers.

TABLE 2

Effect of tetcyclacis seed dressing and sowing depth on subcrown internode lengths (cm) in winter oats

Cultivar	Concn of tetcyclacis	Sowing depth (cm) 2	4	6	8
Bulwark	0	1.73	2.22	4.02	5.82
	0.2x	0.89	0.74	2.53	5.01
	1.0x	0.20	0.48	2.02	3.91
			SED	± 0.19	
Peniarth	0	0.97	3.16	4.50	5.53
	0.2x	0.80	2.02	4.02	5.09
	1.0x	0.04	0.77	2.99	4.94
			SED	± 0.18	

When measurements of soil temperature were made over a freeze-thaw cycle lasting 5 days (14-20 January 1985), significant changes with depth occurred both in the total number of hours that soil temperature was below $-2^{o}C$ and in the cumulated degree-hours below $-2^{o}C$ (Figure 1). The number of hours during which the crowns of plants were subjected to temperatures less than $-2^{o}C$ during the freeze-thaw cycle are presented in Table 3.

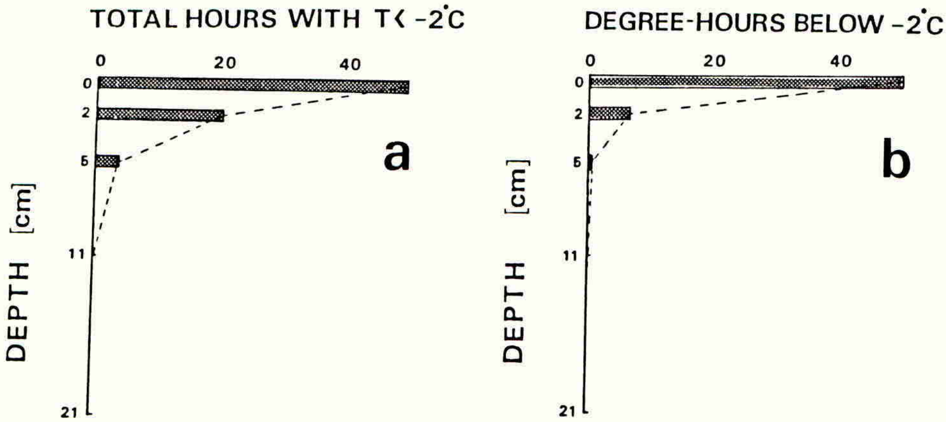

Fig. 1. Variation with depth of (a) total hours with soil temperature $<-2^{o}C$, (b) cumulative degree-hours $<-2^{o}C$ over a 7-day freeze-thaw cycle in January 1985.

TABLE 3

Number of hours to which crown of winter oat plants arising from tetcyclasis-treated seed and sown at different depths were subjected to temperatures of below -2^{o}C over a 5 day freeze-thaw cycle

Cultivar	Concn of tetcyclacis	Sowing depth (cm) 2	4	6	8
Bulwark	0	45	22	20	19
	0.2x	33	16	11	14
	1.0x	22	11	8	7
Peniarth	0	34	36	27	17
	0.2x	31	20	20	15
	1.0x	20	13	14	14

Winter damage

Although Bulwark suffered more winter damage expressed as percentage brown (dead) tissue, than Peniarth, the pattern was similar for both cultivars (Table 4). The data could be divided into two distinct groups

TABLE 4

Effect of tetcyclacis seed dressing and sowing depth on percentage brown (dead) tissue in winter oats recorded 5 March 1985

Cultivar	Concn of tetcyclacis	Sowing depth (cm) 2	4	6	8
Bulwark	0	52.8	54.4	56.1	37.8
	0.2x	57.8	54.4	23.9	23.1
	1.0x	16.7	14.7	13.9	14.4
			SED ±	4.9	
Peniarth	0	37.2	28.3	35.6	24.4
	0.2x	31.1	35.6	15.6	12.8
	1.0x	12.9	14.4	11.7	13.1
			SED ±	4.4	

according to the amount of damage sustained. Within each group there was little, if any, significant difference between treatments. In the group which suffered least winter damage (Group 1) were all plants arising from seed treated with the high concentration of tetcyclacis and deep sown (6 cm and 8 cm) plants arising from seed treated with the low concentration. In the other group which suffered extensive winter damage (Group 2) were all plants arising from untreated seed and shallow sown (2 cm and 4 cm) plants arising from seed treated with the low concentration of tetcyclacis.

From the sample of main stem crowns dissected to determine the health of the apices, 72% and 47% of Group 2 plants in Bulwark and Peniarth, respectively had dead apices. The corresponding figures for Group 1 plants were 6% and 0%.

DISCUSSION

Soaking seeds of winter oats in solutions of the experimental plant growth regulator tetcyclacis before sowing at different depths resulted in a reduction of subcrown internode lengths. This happened at all four sowing depths. In the shallow sowings the mesocotyl was the only subcrown internode to extend. In the deeper sowings, extension of the coleoptile internode and of the main stem internode between leaves one and two compensated to some extent for the reduction in mesocotyl length. However, even with this added extension, tetcyclacis seed treatment resulted in the crowns of plants over-wintering at a greater depth in the soil.

Temperature measurements confirmed that soil layers near the surface experienced a larger diurnal variation in temperature, freezing sooner and more often than those at greater depth, though the deeper layers often took longer to thaw. At all sowing depths, the crowns of plants arising from untreated seed over-wintered within the top 2.5 cm of soil, in the region in which these large variations in soil temperature occurred. By contrast, the crowns of plants arising from tetcyclacis-treated seed (except those sown at 2 cm) over-wintered in the soil below 2.5 cm and were thus subjected to less variation in soil temperature. Therefore, small increases in the depth at which crowns over-wintered appeared to decrease the risk of frost damage.

The beneficial effects of tetcyclacis on increasing winter hardiness, apparently by altering crown depth, were reflected in the amount of damage sustained by the plants during winter. Group 1 plants sustained little damage. Within Group 2 plants damage was so severe that a high percentage of the main stem apices were killed. Apex death rarely occurred in Group 1 plants. However, death of the main stem apex need not result in the non-productivity of the whole plant, as tillers may survive the winter and proceed to ear.

As long as yields are not adversely affected following the tetcyclacis seed treatment, the effects observed in this experiment have proved to be important factors in increasing winter hardiness in winter oats.

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