The Effect of Time of Application of the Growth Retardant Flurprimidol (EL500) on Seed Yields and Yield Components in *Lolium perenne* L.[1]

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ABSTRACT

The effects of the growth retardant flurprimidol (EL500) on growth, development and yield of perennial ryegrass (*Lolium perenne* L.) following application at double ridge (DR), spikelet initiation (SI) and floret initiation (FI) were investigated. All EL500 applications significantly increased seed yields in both years. In 1983, no significant differences in stem length, lodging, dry matter accumulation, photosynthetic area index or seed yield were recorded between EL500 application times. However in 1984, lack of rain following the FI application delayed growth retardant activity so that lodging occurred before anthesis, and although fertile tiller numbers were eventually increased, seed yield was significantly lower than that for DR and SI application because of a reduction in the number of seeds per spikelet.

DR application produced the greatest number of seeds per unit area in each year because of an increased production of fertile tillers. Reasons for this are discussed. However, seed yield was not significantly different from that of other application times because of a failure to fill seeds to the same thousand seed weight.

Additional index words: **perennial ryegrass, seed production, double ridge, spikelet initiation, floret initiation.**

INTRODUCTION

Recent reports of stem retardation and lodging prevention in the perennial ryegrass (*Lolium perenne* L.) seed crop have discussed the effects of paclobutrazol (PP333) (Hebblethwaite et al., 1982; Hampton and Hebblethwaite, 1985a). However, other products have also been investigated (Hampton, 1983), one of which is flurprimidol (EL500) = -(1-Methylethyl)- -[4-(trifluoromethoxy) phenyl]-5-pyrimidine-methanol. Like paclobutrazol, flurprimidol is a foliar and root absorbed plant growth regulator which reduces internode enlongation of a broad range of both monocotyledonous and dicotyledonous plants (Anon., 1983). The mode of action involves a reduction in gibberellin biosynthesis.

Hampton and Hebblethwaite (1985b) compared the effects of EL500 and PP333 on perennial ryegrass seed yields and also compared EL500 application rates (1.0 and 2.0 kg a.i. ha $^{-1}$). In this paper we report the effects of time of EL500 application on perennial ryegrass growth, development and seed yield.

MATERIALS AND METHODS

Experiments were carried out at the University of Nottingham experimental farm, Sutton Bonington, Loughborough, Leics., on soil of the Astley Hall series. Certified basic seed of perennial ryegrass cv. S24 was sown in the autum of 1982 and 1983 at 12 kg ha^{-1} with a row width of 15 cm and in plots 1.5 x 12 m. Details of experimental management are given in Table 1.

Table 1. Experimental details.

	1983	1984
Sowing date	23 August 1982	26 August 1983
Previous crop	Potatoes	Potatoes
Herbicide:		
Autumn	Cambilene, 4.91 ha^{-1} Nortron, 9.81 ha^{-1}	Cambilene, 4.91 ha^{-1} Nortron, 9.81 ha^{-1}
Spring	Nortron, 4.91 ha^{-1}	—
Fertilizer:		
Application date	14 April	30 March
Application rate	120 kg N ha^{-1}	120 kg N, 60 kg P, 60 kg K ha^{-1}
EL500 application:		
Double ridge	1 March	24 February
Spikelet initiation	29 March	28 March
Floret initiation	15 April	20 April
Seed Harvest	15 July	18 July

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EL500 was applied at 2 kg a.i. in 250l water ha^{-1} at three crop apical development stages - double ridge (DR), spikelet initiation (SI), and floret initiation (FI), determined by microscopic dissection of tiller apices at frequent intervals (Wright, 1978). Growth retardant treatments plus an unsprayed control were replicated four times in a randomized complete block design.

Growth analyses were carried out at regular intervals in 1983, but only at final harvest in 1984. Techniques used for data accumulation have been previously published (Hampton and Hebblethwaite, 1985a). Seed was harvested at 40% seed moisture content in both years by cutting 2.8 m^2 per plot in 1983 and 4.4 m^2 per plot in 1984 with a reciprocating knife mower (Mayfield). The cut material was placed in cloth bags and cool air dried to 12-15% straw moisture content before the seed was threshed, cleaned and weighed. Yield results are expressed at 0% moisture content.

RESULTS

Lodging and Stem Length

In both years, lodging in untreated plots had begun by ear emergence and plots were fully lodged by anthesis (Table 2). Differences in lodging in EL500 treated plots were related to date of application; DR and SI application prevented lodging until after anthesis in both years, but the response to application at FI differed - in 1983, lodging began after anthesis, but in 1984, the degree of lodging did not differ from that of untreated plots (Table 2).

Hampton and Hebblethwaite (1985b) described the effect of EL500 application at SI on stem and internode length. Stem length was significantly reduced by EL500 at all 3 application times in both years (Table 3), but in 1984, the reduction in stem length was not as great for FI application as it was for DR and SI application. EL500 did not reduce ear length (Table 3).

Table 3. The effect of time of EL500 application on stem and ear length at final harvest, 1983 and 1984.

Application time	Stem length (cm)		Ear length (cm)	
	1983	1984	1983	1984
Nil	74.6	76.7	21.1	18.8
DR	44.8	43.6	18.0	17.9
SI	44.6	43.4	18.6	17.3
FI	38.7	59.2	20.4	19.4
S.E. diff. (9 d.f.)	5.6	4.9	1.9	1.3
LSD .05	12.7	11.1	NS	NS

Tiller Production

Tiller production data were collected in 1983 only. EL500 at all 3 application times increased total tiller production over that of untreated plots up to ear emergence, and at anthesis, vegetative tiller numbers were significantly greater than those for untreated plots (Hampton and Hebblethwaite, 1985b). However, fertile tiller numbers did not differ between treatments. At final harvest, vegetative tiller numbers were reduced in all EL500 treated plots (Table 4) but fertile tiller

Table 2. The effect of time[1] of EL500 application on lodging[2], 1983 and 1984.

	Application time	Crop development stage				
		First ear emergence	Peak ear emergence	First anthesis	Peak anthesis	Final harvest
1983						
	Nil	4.1	6.2	10.0	10.0	10.0
	DR	0	0	0	0	0
	SI	0	0	0	0	0
	FI	0	0	0.5	3.5	5.2
	S.E. diff. (9 d.f.)	-	-	0.63	0.36	0.54
	LSD .05	-	-	1.4	0.8	1.2
1984						
	Nil	0	6.3	10.0	10.0	10.0
	DR	0	0	0	0	0.3
	SI	0	0	0.3	0.3	1.3
	FI	0	4.8	9.3	9.0	9.5
	S.E. diff. (9 d.f.)	-	1.97	0.83	0.47	0.68
	LSD .05	-	4.4	1.9	1.1	1.5

[1]Crop apical development stages: double ridge (DR), spikelet initiation (SI), and floret initiation (FI).

[2]Assessed by eye on a O (upright) to 10 (densely flattened) scale (Hebblethwaite et al., 1980).

Table 4. The effect of time of EL500 application on vegetative tiller numbers at final harvest, 1983 and 1984.

Application time	Vegetative tiller numbers m-2	
	1983	1984
Nil	2454	4283
DR	1004	1769
SI	65	1050
FI	810	4954
S.E. diff. (9 d.f.)	612.8	1009.5
LSD .05	1385	2281

numbers were increased (Table 5), although this difference was significant only for the DR application. At final harvest in 1984 vegetative tiller numbers were significantly lower for the DR and SI application times (Table 4), but the tiller numbers for the FI application time differed from the previous year in that both vegetative and fertile tiller numbers were increased (Tables 4, 5).

Dry Matter Accumulation and Distribution

The dry matter (DM) accumulation of vegetative tillers was increased by EL500 application at all 3 times prior to anthesis, but at anthesis, differences were not significant. Vegetative tiller DM was significantly reduced at final harvest in both years for the DR and SI application times, but in 1984, vegetative tiller DM for the FI application did not differ from that of untreated plots.

EL500 effects on fertile tiller DM accumulation were similar to those previously reported for PP333 (Hampton and Hebblethwaite, 1985a; 1985b), in that fertile tiller stem DM was reduced, but leaf and ear DM were not. Time of EL500 application did not significantly alter DM accumulation or distribution within fertile tillers in 1983, but in 1984, fertile tiller stem DM, while still reduced from that of untreated plots, was greater than that for DR and SI plots.

Photosynthetic Area Index

Data were collected in 1983 only. No significant differences in total photosynthetic area index (PAI) between untreated and EL500 treated plots, or between EL500 application timings were recorded. Within fertile tillers, PAI did not differ significantly between EL500 application times for either stem, leaf or ear PAI. At anthesis, EL500 had reduced stem PAI, but increased fertile tiller leaf PAI. At final harvest, stem PAI was significantly less than that of untreated plots, and ear PAI was significantly increased.

Seed Yield-Potential, Actual and Components

At anthesis in both years, potential seed yield was similar for all treatments, as no significant differences were recorded in the number of fertile tillers, florets per spikelet or spikelets per tiller (Batts 1984; Hampton and Hebblethwaite, 1985b). Actual seed yield was significantly increased for all three EL500 application times in both years (Table 5) as a result of increased tiller numbers and significant increases in the number of seeds per spikelet for the DR and SI application times. In 1983, seed yield did not differ between EL500 application times, but in 1984, the seed yield from the FI application was significantly lower than that from the DR and SI applications. In both years, the greatest number of seeds was produced from the DR application (Table 5), but because thousand seed weight was significantly reduced each year, the DR application did not consistently outyield the later application times. The 1984 FI seed yield differed from the other EL500 responses, in that the increase over that of

Table 5. The effect of time of EL500 application[1] on seed yield and yield components, 1983 and 1984.

Application Time	Yield g m-2 Seed	Yield g m-2 Straw	Harvest index	Fertile tillers (m-2)	Spikelets per tiller	Seeds per spikelet (calc)	TSW (g)	Seed number m-2 x 10^4 (calc)
1983								
Nil	148.8	994.7	0.13	3146	19.9	1.25	1.89	7.85
DR	217.6	610.4	0.26	4498	17.7	1.69	1.61	13.52
SI	225.2	792.0	0.22	3735	19.9	1.76	1.72	13.09
FI	226.2	793.0	0.22	3388	—[2]	—[2]	1.73	13.08
S.E. diff. (9 d.f.)	16.3	50.3	0.02	439.9	(6 df) 1.35	(6 df) 0.14	0.08	1.17
LSD .05	36.8	113.7	0.05	994	3.2	0.33	0.18	2.64
1984								
Nil	127.4	1213.2	0.09	2978	19.6	1.06	2.05	6.21
DR	275.5	963.8	0.22	3932	19.2	2.23	1.63	16.90
SI	262.9	1000.6	0.21	3593	18.6	1.95	2.02	13.01
FI	192.8	1203.4	0.14	4173	20.4	1.11	2.03	9.49
S.E. diff. (9 d.f.)	16.9	181.9	0.03	455.5	1.23	0.32	0.16	2.29
LSD .05	38.2	411.1	0.07	1029	2.8	0.72	0.36	5.18

[1]2 kg a.i. applied per hectare.

[2]data not recorded.

the untreated plots was a result solely of increased fertile tiller numbers, as the number of seeds per spikelet was not increased.

DISCUSSION

The objective of applying growth retardants to perennial ryegrass seed crops has been to prevent lodging (Hebblethwaite et al., 1980) and increase seed yield by reducing seed abortion (Hampton et al., 1985). However, seed yield increases following growth retardant application have also resulted, either partly or solely, from increased fertile tiller production (Hampton and Hebblethwaite 1985a). For example, PP333 is known to reduce apical dominance and increase tillering, the response being greater when the growth retardant is applied early in the phase of tiller development (Froggatt et al., 1982). Hampton (1983) suggested that growth retardant application prior to apical differentiation may lead to a greater synchronous emergence of tillers and a greater proportion of fertile tillers, as previously demonstrated in wheat (Hofner and Kuhn, 1982) and barley (Matthews et al., 1982).

In both 1983 and 1984, the greatest number of seeds, though not necessarily the greatest seed yield, resulted from EL500 application prior to apical differentiation. In 1983, fertile tiller number increases were consistent with EL500 application time i.e. greatest with the earliest application, and it is possible that the same pattern would have followed in 1984. However a dry April (Table 6) meant that growth retardant activity following the FI application (20 April) was delayed - stem length reductions were not as great as the previous year, and the lodging pattern followed that of untreated plots. EL500's requirements for water before soil activation are similar to those of PP333 (Hampton and Hebblethwaite, 1984a). However, once water became available (at ear emergence), the response was an increase in tiller production in plots already lodged, similar to that reported in the 1982 season (Hampton and Hebblethwaite, 1984b). Although fertile tiller numbers were significantly increased, seed yield was reduced because of a reduction in the number of seeds per spikelet.

EL500 application at DR allowed the production of more fertile tillers, but not a greater proportion of fertile tillers as suggested by Hampton (1983). In both years, the greatest proportion of fertile tillers was achieved with SI application, as fewer vegetative tillers were produced. However, tiller number differences between DR and SI application times were not significant, and the proportion of fertile tillers for both times was over 75%, compared with around 50% for untreated plots, a result also reported for PP333 (Hampton and Hebblethwaite, 1984b).

Hofner and Kuhn (1982) suggested that in wheat, growth retardant application, by altering the balance between GA3 and GA3 inhibitors, may influence apical differentiation by synchronizing and reducing the growth rate of individual spikelets, and lead to an increase in the number of spikelets and of seeds per spikelet. EL500 application prior to apical differentiation had no effect on the number of spikelets per tiller in either year, and differences in the number of seeds per spikelet were not significant from that of EL500 applied at SI. While the number of seeds per spikelet for FI plots was reduced in 1984, Hampton and Hebblethwaite (1985a) obtained more seeds per spikelet from FI application of PP333 than from SI application. In perennial ryegrass, increases in the number of seeds per spikelet are more likely to result from reduced seed abortion because of reduced competition for assimilates than any 'antigibberellin' effects of growth retardants (Hampton and Hebblethwaite, 1985c).

Table 6. Rainfall data, February-July; longterm average, 1983 and 1984, Sutton Bonington.

Month	Rainfall (mm)		
	Longterm average[1]	1983	1984
February	41	27.0	45.4
March	45	32.9	58.3
April	39	87.7	7.4
May	49	78.6	59.9
June	48	8.4	73.4
July	51	28.6	24.0

[1]1916-1982

EL500 application at DR produced the greatest number of seeds per unit area in each year, but this potential was not achieved in terms of seed yield because of reduced thousand seed weight (TSW). This suggests either that plants treated at DR could not support the number of seeds retained in each spikelet, or that maturity was delayed even more than the 3-5 days recorded for SI application (Hampton, 1983) so that DR plots were harvested before adequate seed filling had been allowed to occur. This requires further investigation. Seed yield results did not show any significant differences between DR and SI application times, but the 1984 results confirm the possible inconsistency of FI application (Hampton and Hebblethwaite, 1985a) for growth retardants which require water for activation.

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A Comparison of the Effects of the Growth Retardants Paclobutrazol (PP333) and Flurprimidol (EL500) on the Growth, Development and Yield of *Lolium perenne* Grown for Seed[1]

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ABSTRACT

Application of the growth retardants paclobutrazol (PP333) and flurprimidol (EL500) to perennial ryegrass (*Lolium perenne* L.) seed crops at spikelet initiation can substantially increase ryegrass seed yields. The mode of action of these two products is similar, both being gibberellin inhibitors, which results in stem internode retardation.

A comparison of the effects of these two growth retardants demonstrated that at the same rate of active ingredient, plots treated with PP333 outyielded plots treated with EL500, primarily because of a greater retention of seeds per spikelet. The greater activity of PP333 allowed less lodging, and prolonged reproductive photosynthetic leaf area. For comparable effects on perennial ryegrass plant growth and seed yield, EL500 had to be applied at double the active ingredient rate of that required for PP333.

Additional index words: **perennial ryegrass, seed production, growth retardants, seed abortion.**

INTRODUCTION

The use of growth retardants to increase seed yield in perennial ryegrass crops through the prevention of lodging

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