

Growth and Seed Yield Responses to the Timing of Paclobutrazol (PP333) Application in *Lolium perenne* L.¹

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ABSTRACT

The effects of paclobutrazol (PP333) application at three timings, on growth, development and yield of perennial ryegrass (*Lolium perenne* L.) were investigated. PP333 was also applied at double ridge (DR), spikelet initiation (SI) and floret initiation (FI), and the experiments were conducted over two seasons. In both years seed yield was significantly increased by all PP333 applications, and this was associated with increased seed numbers per unit area; caryopsis weights were not significantly affected. In 1984, treatment at FI resulted in a significantly smaller seed yield than DR and SI treatments. All other differences in seed yield between PP333 application times were small and insignificant.

There were no significant differences in tillering patterns between PP333 application times in both years, and no significant difference in dry matter accumulation between treatment times in 1983.

Earlier applications resulted in increased lodging control, and this is discussed in relation to rainfall, and developmental stage at the time of application.

INTRODUCTION

Considerable increases in seed yield with the use of the growth regulator paclobutrazol (PP333) in ryegrass seed crops have been recorded (Faulkner, 1981; Chilcote et al., 1982; Hebblethwaite et al., 1982; Hampton & Hebblethwaite, 1985). Increases have also been associated with modified tillering patterns (Hampton, 1983; Hampton and Hebblethwaite, 1984), increased number of seeds per spikelet (Hampton and Hebblethwaite, 1985), shorter stem lengths and a more erect canopy (Hampton, 1983).

The majority of the above work has tested varying levels of the chemical applied at a single date. Paclobutrazol is known to inhibit gibberellin biosynthesis and reduce cell division and extension. It is taken up by the roots, stems and foliage, but is almost exclusively xylem translocated and therefore root uptake (Lever et al., 1982) and adequate soil moisture to achieve this is particularly important (Hampton, 1983). Consequently, timing of application particularly in relation to soil

moisture could increase the efficiency of the chemical. It is also possible that early applications may have some influence on growth and the potential yield of the crop by increasing tiller number and floret sites.

This paper therefore presents results on the effects of paclobutrazol applied at three growth stages.

MATERIALS AND METHODS

Experiments were carried out on the University of Nottingham Experimental Farm, Sutton Bonington, Loughborough, Leics., on soil of the arrow series, a coarse, loam, fluvial drift overlying keuper marl at a depth of about 1 m (Hebblethwaite and McGowan, 1977). Certified basic seed of perennial ryegrass cv. 524 was sown in the autumns of 1982 and 1983, at a rate of 12 kg ha⁻¹. Details of experimental management are given in Table 1.

Table 1. Experimental details¹

	1982-83	1983-84
Sowing date	23 August 1982	16 August 1983
Previous crop	Potatoes	Potatoes
Plot size	12 m x 1.5 m	12 m x 1.6 m
Row width	15 cm	11.5 cm
Herbicide		
Autumn	2,3,6-TBA, 123 g ha ⁻¹ ; dicamba 103 g ha ⁻¹ ; mecoprop 823 g ha ⁻¹ ; MCPA, 548 g ha ⁻¹ ; ethofumesate, 1.96 kg ha ⁻¹	2,3,6-TBA, 125 g ha ⁻¹ ; dicamba 105 g ha ⁻¹ ; mecoprop 840 g ha ⁻¹ ; MCPA, 560 g ha ⁻¹ ; ethofumesate, 2.0 kg ha ⁻¹
Spring	ethofumesate, 0.98 kg ha ⁻¹	
Nitrogen		
Date	14 March 1983	30 March 1984
Rate	120 kg ha ⁻¹	120 kg ha ⁻¹
PP333		
Dates	1 March 1983 (DR) ¹ 29 March 1983 (SI) 15 April 1983 (FI)	24 February 1984 (DR) 28 March 1984 (SI) 20 April 1984 (FI)
Rate	1 kg a.i. ha ⁻¹	1 kg a.i. ha ⁻¹
Seed harvest (moisture content)	Replicates I and II 12 July (44%) Replicates III and IV 15 July (37%)	18 July (treated, 45%; Control 42%)

¹ DR = double ridge; SI = spikelet initiation, FI = floret initiation.

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Paclobutrazol (PP333) was applied at the rate of 1 kg a.i. ha⁻¹ in 225 l water ha⁻¹, and at three stages of apical development: double ridge, spikelet initiation, each as defined by Wright (1978). The apical development of the crop was monitored by microscopic dissection. The chemical was applied from a height of 30 cm above the crop, using a knapsack sprayer and boom in 1983, and a tractor mounted sprayer in 1984.

Ear emergence and anthesis were recorded by daily observation; plots were considered to be at peak anthesis when the majority of spikes had exerted anthers. The relative extent of lodging was visually assessed on a scale of 0 (upright) to 10 (densely flattened) at regular intervals throughout the season.

Samples for growth analysis were taken in 1983, at 14 day intervals from treatment application until final harvest, by digging up all plants within a 0.1 m² quadrat. Samples were washed, and a 25% subsample was separated into roots, dead material, and vegetative and reproductive tillers (distinguished by the absence or presence of an emerged ear respectively). The tillers were counted, and further separated into leaf blades, stem and leaf sheaths, and ear. All fractions of the subsample, and the remainder, were dried to a constant weight at 80°C.

At final harvest in 1983, the distance between stem nodes was measured on 25 reproductive tillers per plot. In 1983 and 1984 the stem lengths of 20 reproductive tillers per plot were measured at final harvest.

Seed moisture was determined with an infra-red meter on seed from random-sampled, hand-threshed ears (Hampton and Hebblethwaite, 1985)

Seed was harvested at the moisture contents shown in Table 1, by cutting an area of 2.8 m² in 1983 and 4.4 m² in 1984, with a reciprocating-knife mower. The cut material was placed in cotton bags, and cool air-dried to a seed moisture content of 140 g kg⁻¹. The seed was threshed and cleaned. Seed and straw yields are presented at a moisture content of zero g kg⁻¹.

RESULTS

Lodging and stem measurements. In both years paclobutrazol decreased lodging at all stages of growth, except when applied at FI in 1984. The reduction in lodging was greater at earlier application dates. In untreated plots lodging began earlier than in treated plots in 1983, and was severe by first anthesis in both years (Table 2).

In both years paclobutrazol decreased the stem length at final harvest. There was no significant difference in stem length reduction between dates of application. In 1984, however, there was a consistent trend towards greater stem length reduction at earlier application dates (Table 3).

Stem length decreases were greater in 1983 than in 1984 at all application dates. The decrease in stem length in 1983 was associated with reductions in all except the terminal internode. Internode lengths were not measured in 1984.

Seed yield and yield components. In both years seed yield was significantly increased by all timings of paclobutrazol applications (Table 4). In 1984, the FI treatment resulted in a significantly lower seed yield than DR and SI treatments. Other yield differences between treatments were small, and

Table 2. The effect of PP333 (1 kg a.i. ha⁻¹) application time on the relative extent of lodging, scored on a scale of 0 (no lodging) to 10 (completely flattened canopy), 1983 and 1984.

Application time	FEE ¹	FA	PA	FH
1983				
Double ridge	0	0	0	2.6
Spikelet initiation	0	0	0	3.8
Floret initiation	0	0	2.3	10.0
Control	4.5	9.5	10.0	10.0
1984				
Double ridge	0	1.8	1.0	3.3
Spikelet initiation	0	3.5	3.3	6.0
Floret initiation	0	9.5	9.5	10.0
Control	0	10.0	10.0	10.0

¹ (FEE = first ear emergence; FA = first anthesis; PA = peak anthesis; FH = final harvest)

not statistically significant. Increases in seed yield were associated with increases in seed number per unit area, an increase in fertile tiller numbers in 1983, and increased seed numbers per spikelet in 1984 (Table 4). Caryopsis weights were unaffected by chemical application (Table 4).

Tiller dynamics. In 1983, total tiller numbers in treated plots were greater than in control plots until after peak anthesis, but these differences were not significant (Figure 1). The rapid increase in total tiller number after peak anthesis in untreated plots is attributed to the production of secondary vegetative tillers between anthesis and final harvest. In 1983 fertile tiller numbers were significantly greater in treated plots than in untreated from peak anthesis until final harvest, but the time of application did not have a significant effect (Table 4; Figure 2). There were no differences in fertile tiller numbers at final harvest in 1984.

Dry matter accumulation and distribution. Paclobutrazol application at all timings reduced stem dry matter, but there was no effect on leaf or ear dry matter. There was no effect of application time on the dry matter status of stem, leaf or ear (Figure 3).

DISCUSSION

The discrepancy in the effect of paclobutrazol application time on seed yield between the 1983 and 1984 seasons illustrates the unpredictable element in growth regulator studies resulting from seasonal differences. The importance of moisture availability at the time of paclobutrazol application is well documented (Hampton & Hebblethwaite, 1985; Barrett, unpublished); paclobutrazol is almost exclusively xylem translocated and, therefore, root uptake is of great importance (Lever et al, 1982). In 1984, application at floret initiation (FI) was during a particularly dry period (Tables 1 and 5), and this treatment was less effective than expected. Seed yield was significantly lower than for double ridge (DR) and spikelet

Table 3. The effect of PP333 (1 kg a.i. ha⁻¹) application time on internode lengths (1983) and stem lengths (1983 and 1984) at final harvest. Numbers in brackets are the percentage reduction compared with the control.

PP333 application time	Internode length (1983)					Stem length (1983)	Stem length (1984)
	1 (terminal)	2	3	4	5 (basal)		
	----- (cm) -----						
DR ¹	26.5 (9)	12.0 (42)	5.5 (69)	2.5 (77)	0.5 (80)	47.0 (42)	51.8 (32)
DI	24.5 (15)	10.0 (51)	5.0 (71)	1.0 (91)	0.7 (72)	41.2 (49)	56.5 (26)
FI	27.5 (5)	9.0 (56)	4.0 (77)	3.0 (73)	1.0 (60)	44.5 (45)	65.2 (15)
CONTROL	29.0	20.5	17.5	11.0	2.5	80.5	76.7

¹ DR = double ridge; SI = spikelet initiation; FI = floret initiation

Table 4. The effect of PP222 (1 kg a.i. ha⁻¹) application time on seed yield and yield components.

Growth at PP333 application	Yield (gm ⁻²)		Harvest index	No. of fertile tillers (m ⁻²)	No. of spikelets per tiller	No. of seeds per spikelet (calculated)	Caryopsis weight x 10 ³ (g)	Seed number (10 ⁴ m ⁻²) (calculated)
	Seed	Straw						
1983								
DR	225.3	727	0.24	4680	-	-	1.65	13.62
SI	229.6	695	0.25	4152	-	-	1.70	13.57
FI	220.1	835	0.21	3875	-	-	1.76	12.55
Control	148.4	995	0.13	3150	-	-	1.89	7.93
S.E. diff. (9 d.f.)	16.0	67	0.025	320	-	-	0.084	1.19
1984								
DR	265.3	1124	0.19	3826	19.7	1.80	2.04	13.03
SI	260.6	1118	0.21	3401	21.0	2.18	1.94	13.47
FI	173.5	1215	0.13	3554	21.1	1.13	2.12	8.21
Control	127.4	1213	0.10	2978	19.6	1.07	2.05	6.24
S.E. diff. (9 d.f.)	18.2	220	0.032	524.7	1.24	0.39	0.159	0.875

initiation (SI) treatments. In 1983, when there was adequate rainfall (Table 5) throughout the treatment period (March and April), timing of application did not affect seed yield significantly.

The seasonal differences between 1983 and 1984 are also reflected by the lodging and stem length data. In 1983, paclobutrazol application at FI controlled lodging (compared with untreated plots) more effectively than in 1984 when conditions were dry at FI. Similarly, stem length was decreased much less in 1984 by application at FI. In 1983 and 1984 application at FI was less effective in controlling lodging at anthesis when a lodged canopy is most detrimental to final yield (Hebblethwaite et al., 1980). In a lodged crop at anthesis light penetration is restricted, as is the movement of airborne pollen through the canopy, thus reducing fertilization and increasing abortion of fertile embryos in an environment which increases competition for assimilate (Hampton, 1983).

Table 5. Rainfall data, February-July, Sutton Bonington, 1983 and 1984

Month	RAINFALL (mm)		
	Mean, 1916-1982	1983	1984
Feb	41	27.0	45.4
Mar	45	32.9	58.3
Apr	39	87.7	7.4
May	49	78.6	59.5
Jun	48	8.4	73.4
Jul	51	28.6	24.0

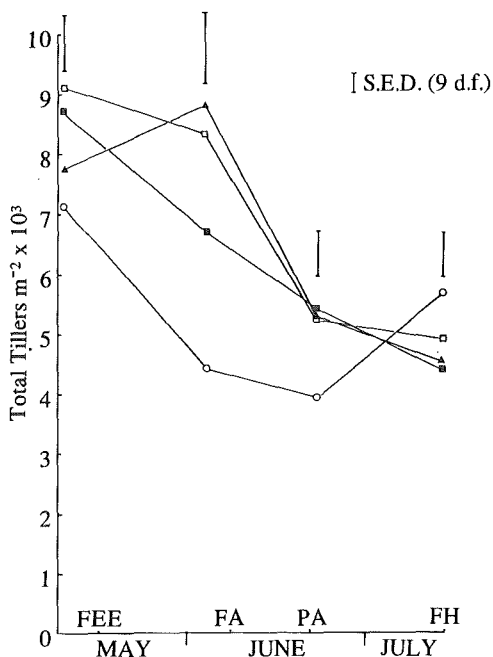


Figure 1. The effect of PP333 (1 kg a.i. ha⁻¹) application time on total tillers m⁻², 1983 (○ control; □, double ridge; ■, spikelet initiation; ▲ floret initiation. FEE = first ear emergence; FA = first anthesis; PA = peak anthesis; FH = final harvest)

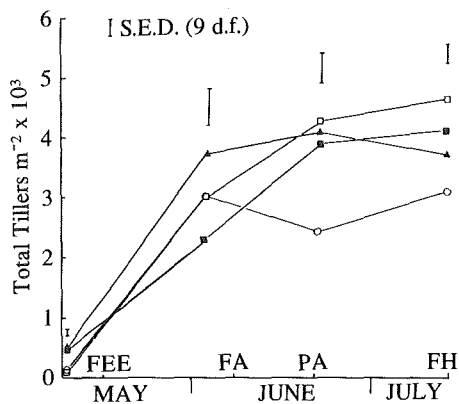


Figure 2. The effect of PP333 (1 kg a.i. ha⁻¹) application time on fertile tillers m⁻², 1983 (○ control; □, double ridge; ■, spikelet initiation; ▲ floret initiation. FEE = first ear emergence; FA = first anthesis; PA = peak anthesis; FH = final harvest)

These results are in agreement with the findings of Hampton (1983) who compared SI and FI treatments. At FI it has been observed by the authors that the onset of rapid stem elongation has begun in early cultivars, whilst DR and SI are before the onset of rapid stem elongation. It is hypothesized that this contributes to greater lodging control by the DR and SI treatments. Lodging control is mediated by stem thickening as

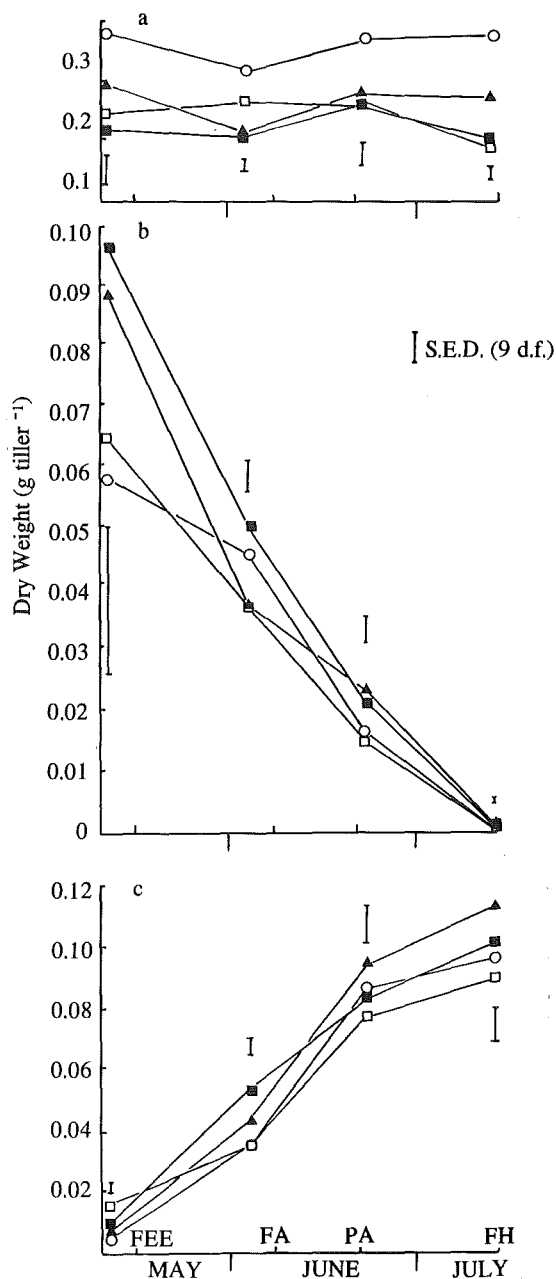


Figure 3. The effect of PP333 (1 kg a.i. ha⁻¹) application time on distribution of dry weight within fertile tillers. (a), stem; (b) leaf; (c), ear. 1983 (○ control; □, double ridge; ■, spikelet initiation; ▲ floret initiation. FEE = first ear emergence; FA = first anthesis; PA = peak anthesis; FH = final harvest)

well as stem length reduction (Hampton, 1983), and for these reasons we consider it is important that the growth regulator is available to the plant when rapid stem growth begins. In 1984, the trend towards greater stem length reductions with earlier applications can be attributed to the dry weather in April restricting the availability of the chemical to actively growing roots in the upper soil horizon; in 1983 when rainfall

was adequate, there was no such trend. The residual nature of paclobutrazol in the soil (Barrett, unpublished) is such that availability continues after application, and thus it is probable that in 1983 the dry weather in April (Table 5) restricted the effectiveness of the DR and SI applications.

A further consideration which must be made in relation to the control of lodging is the ease of harvesting. The greater severity of lodging at final harvest in crops treated at FI, makes harvesting more difficult than in crops treated at DR or SI.

In 1983 there was a trend towards fewer fertile tillers at final harvest with later applications. Since there were no significant differences in seed yield, the ability of the crop to compensate for different fertile tiller populations is recognized.

The results do not suggest any disadvantages of DR or SI applications compared with FI applications. This is supported by the dry matter distribution data and the total tiller numbers, which show no significant differences ($P < 0.05$) between paclobutrazol timing treatments. However, it is considered that FI application may in some seasons incur a yield penalty compared with DR or SI applications, and an application "window" between DR and SI (2-5 weeks depending on the season) is recommended. Within this application window we suggest that it would be beneficial to apply paclobutrazol shortly before rain is forecast.

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