The Influence of Rainfall on Paclobutrazol (PP333) Response in the Perennial Ryegrass (*Lolium perenne* L.) Seed Crop.

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ABSTRACT

The requirement for water before activation of the growth retardant paclobutrazol (PP333) occurs was investigated in a field trial in perennial ryegrass cv S.24. PP333 at 0 and 2 kg a.i. ha^{-1} was applied at floret initiation (15 April) to plots which received no rain from 31 March to 21 May because they were continuously sheltered with perspex covers, and to plots which received 65 mm rain over the same time period because the covers were removed in wet weather. In the absence of rain for one month after application, no growth retardant effects were found, while in the presence of water, growth retardant responses were similar to those previously reported.

Seed yield was increased by PP333 application because of increased numbers of fertile tillers, in both the presence and absence of water. However, the response to PP333 in the absence of water was a result of the fungicidal properties of the chemical, as the number of fertile tillers dying as a result of powdery mildew (*Erysiphe graminis* DC) attack were reduced.

Neutron probe data suggested that PP333 application in the absence of water had stimulated root production, as soil water deficits, particularly in the 65-115 cm depth zone were built up earlier than in other treatments. However, PP333 did not reach the root zone as no growth retardant effects were demonstrated. These results require further investigation.

Additional index words: **Paclobutrazol, PP333, perennial ryegrass, seed production, water, soil moisture deficit, neutron probe, crop transpiration, fungicidal properties, growth retardant.**

INTRODUCTION

Recent experiments (Faulkner, 1981; Hebblethwaite, et al., 1982; Hampton and Hebblethwaite, 1985) have demonstrated that application of the growth retardant paclobutrazol (PP333) can substantially increase the seed yield of perennial ryegrass (*Lolium perenne* L.). The most consistent yield increases have occurred after PP333 application at spikelet initiation rather than at floret initiation, when the response was dependent upon subsequent rainfall (Hebblethwaite et al. 1982).

PP333 is xylem mobile (Shearing and Batch, 1982) and its primary route of uptake is via the roots. Foliar uptake is regarded as being of little importance as PP333 accumulates in leaf tissue and little reaches the meristematic area of cell division and extension (Froggatt et al. 1982). Activation of PP333 is thus influenced by soil moisture (Froggatt et al. 1982) and retardation is greater when rainfall is high (Hebblethwaite et al. 1982). A trial in 1981 examined the effects of water availability on PP333 responses in perennial ryegrass cv. S.24.

MATERIALS AND METHODS

The experiment was 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. S.24 was sown on 4 September 1980 at 12 kg ha^{-1} with a row width of 15 cm. In early spring, three blocks each containing four plots, 16 m^2 were marked out. All plots received 120 kg N ha^{-1} on 19 March. Weed control was as previously described (Hebblethwaite and Pierson, 1983).

In an attempt to allow soil moisture deficits to build up, two plots per block were sheltered with a wooden frame perspex cover, from 31 March to 21 May continuously, after which the covers were removed. The covers were positioned at an angle of 15 degrees over the plots so that rainwater could be drained away from the plots. The other two plots per block were also covered, but the covers were removed during wet weather, so that these plots received approximately 65 mm rain from 31 March to 21 May.

Volumetric soil water content was determined at approximately 10 day intervals from 15 April to 13 July using a modified version of the Wellingford neutron probe (Bell, 1969). One aluminum access-tube was installed in each plot and the soil profile monitored at 10 cm intervals to a depth of 120 cm. From these data, soil water deficits, root extraction depths and transpiration rate of the crop were calculated (Hebblethwaite and McGowan, 1977).

PP333 at 2.0 kg a.i. ha^{-1} was applied at floret initiation (15 April) (Hampton and Hebblethwaite, 1985) to two plots per block, one of which received no water for two weeks prior and four weeks after PP333 application (covered continuously until 21 May = 'dry'), and one which

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Table 1. The effect of rainfall (water availability) after PP333 application on total and vegetative tiller numbers.

TREATMENT		TILLER NUMBERS					
Water Availability (31 March - 21 May)	PP333 (kg a.i. ha^{-1})	Total E[1]	Total A[1]	Total F[1]	Vegetative E	Vegetative A	Vegetative F
'dry' = 0 mm	0	5216	3241	5791	3733	1490	4656
	2	4320	2884	6023	2130	1323	4090
'wet' = 65 mm	0	3321	2725	5780	1896	865	4380
	2	6962	5191	4830	4721	2331	2097
s.e. diff. (6 d.f.)	Water Availability	861.2	1016.1	1211.4	646.4*	491.3	786.4*
	Interaction	1012.6	1281.4	1617.6	906.9	694.8	1112.2

[1]E = peak ear emergence (23 May); A = peak anthesis (8 June); F = final harvest (21 July).
*P<0.05

Table 2. The effect of rainfall (water availability) on responses in seed yield and yield components to PP333 application.

TREATMENT		Yield (g m^{-2})						
Water Availability (31 March - 21 May)	PP333 (kg a.i. ha^{-1})	Seed	Straw	Fertile Tillers (m^{-2})	Spikelets per Tiller	Seeds per Spikelet (Calc.)	TSW (g)	Seed Number X10^4 m^{-2} (Calc.)
'dry' = 0 mm	0	50.4	340.0	1135	19.2	0.80	2.90	1.74
	2	109.6	400.0	1933	21.6	0.92	2.85	3.84
'wet' = 65 mm	0	86.9	510.0	1400	21.3	1.04	2.81	3.09
	2	160.8	320.0	2733	20.4	1.18	2.44	6.59
s.e. diff. (6 d.f.)	Water Availability	19.8**	30.9*	189.8**	0.68	0.17	0.27	0.39**
	Interaction	28.1*	43.7	268.4	1.42	0.20	0.39	0.42*

* P<0.05
**P<0.01

received rain both before and after PP333 application (covers removed during rain = 'wet'). The four treatments per block were therefore 'dry' plus and minus PP333, and 'wet' plus and minus PP333.

The environmental conditions produced beneath the covers (*viz* reduced light intensity, reduced air circulation and increased humidity (Hampton, 1983)) encouraged the spread of powdery mildew (*Erysiphe graminis* DC). Using a percentage key (Anon, 1976), 25 tillers selected at random from each plot were scored for mildew infection on 26 May and 9 June.

Growth analyses were carried out at regular intervals, all plants being removed from an area of 0.1 m^2 at each assessment. Details of growth analysis techniques and lodging assessment have been previously published (Hebblethwaite et al., 1978). Seed was direct harvested at 30% moisture content by two passes of a Wintersteiger small plot combine through each plot which gave a harvested area of 12 m^2. After air drying for 15 days, the seed was cleaned and weighed. Yield results are expressed at 0% moisture content.

RESULTS

Stem Extension and Lodging

When PP333 was applied under 'dry' conditions, stem length and lodging score did not differ from that of untreated plants and all plots were lodged before anthesis. In the presence of water, PP333 reduced stem length and prevented lodging until after anthesis (Hampton and Hebblethwaite, 1985).

Tiller Production

In both 'dry' treatments and the 'wet' treatment in the absence of PP333, total tiller numbers fell rapidly until anthesis and then increased as vegetative tillers were produced in response to rain after the covers were removed (Table 1). The PP333 response under 'wet' conditions was similar to that previously reported for 1981 (Hampton and Hebblethwaite, 1985) in that fertile tiller numbers were significantly increased (Table 2) and vegetative tiller production from anthesis on was suppressed (Table 1).

Seed Yield and Yield Components

PP333 application increased seed yield from 50 to 110 g m^{-2} in the 'dry' treatment and from 87 to 161 in the 'wet' treatment, although because of high variation between replicates, only the latter increase was significant (Table 2). Yield responses resulted from dif-ferences in the number of fertile tillers, as treatment effects on the other yield components were not significant. Fertile tiller number

Table 3. The effect of rainfall (water availability) and PP333 application on the percentage of flag leaf tissue with mildew lesions.

TREATMENT			
Water Availability (31 March - 21 May)	PP333 (kg a.i. ha^{-1})	Assessment Date 26 May	9 June
'dry' = 0 mm	0	10.9	63.6
	2	0.1	0.7
'wet' = 65 mm	0	2.4	15.5
	2	0.1	0.1
s.e. diff. (6 d.f.)	Water Availability	0.4**	7.5**
	Interaction	0.5**	10.6**

**P<0.01

differences in the 'dry' treatments were related to the fungicidal properties rather than the growth retardant properties of PP333 (Hampton, 1983), as powdery mildew infection (Table 3) resulted in the death of fertile tillers in untreated plots (Table 2).

Crop Growth

No significant differences in total dry matter accumulation between treatments were found, but the proportion of vegetative and fertile tiller dry matter differed between treatments depending on tiller numbers within each group (Table 1 and 2).

Soil Water Deficits

The covering of plots resulted in a soil water deficit of 17.1 mm in the 0-35 cm zone by 28 April (Figure 1), thirteen days after PP333 application, but by ear emergence, deficits did not differ significantly between treatments (Figures 1 and 2). From anthesis on, the soil water deficit was lowest in the 'dry' plot which had not received PP333, and by final harvest, the difference between this and the other three treatments was significant (Figure 2). Therefore, in 'wet' plots, PP333 had no effect on soil water deficits, but under 'dry' conditions, water deficits were built up more quickly when PP333 was applied, especially in the 65-115 cm zone (Figure 1).

Crop Transpiration

The sum of measured deficits and rainfall the plots received was compared with potential transpiration, calculated using the Penman equation (Hebblethwaite and McGowan, 1977). Initially, transpiration of both 'dry' and 'wet' plots followed that of the potential (Figure 3), but from anthesis on, became progressively less than the potential. In 'wet' plots, PP333 had no effect on transpiration, but in 'dry' plots, transpiration from anthesis on in PP333 treated plots was 10-20 mm greater than from untreated plots.

DISCUSSION

PP333 requires water for activation (Shearing and Batch, 1982), but the degree of activation appears to be influenced

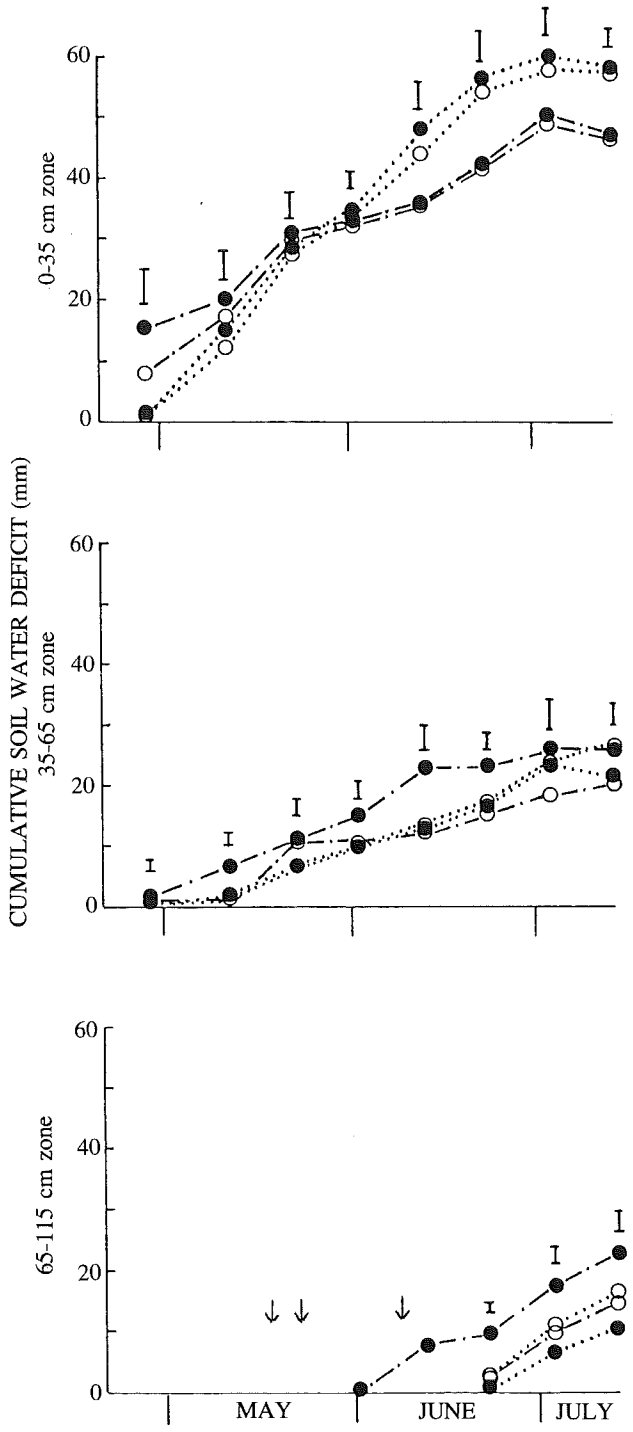


Figure 1. The effect of rainfall (water availability) and PP333 on the culmulative soil water deficit in three zones (O = nil; ● = PP333 2 kg a.i. ha^{-1}; ... = uncovered; .___. = covered plots: CR = covers removed; E = peak ear emergence; A = peak anthesis; I = s.e. diff. all figures.)

more strongly by rainfall after application than by the soil moisture status at the time of application. Froggatt et al. (1982) commented that activation of PP333 was influenced by soil moisture status, but in the present trial, differences

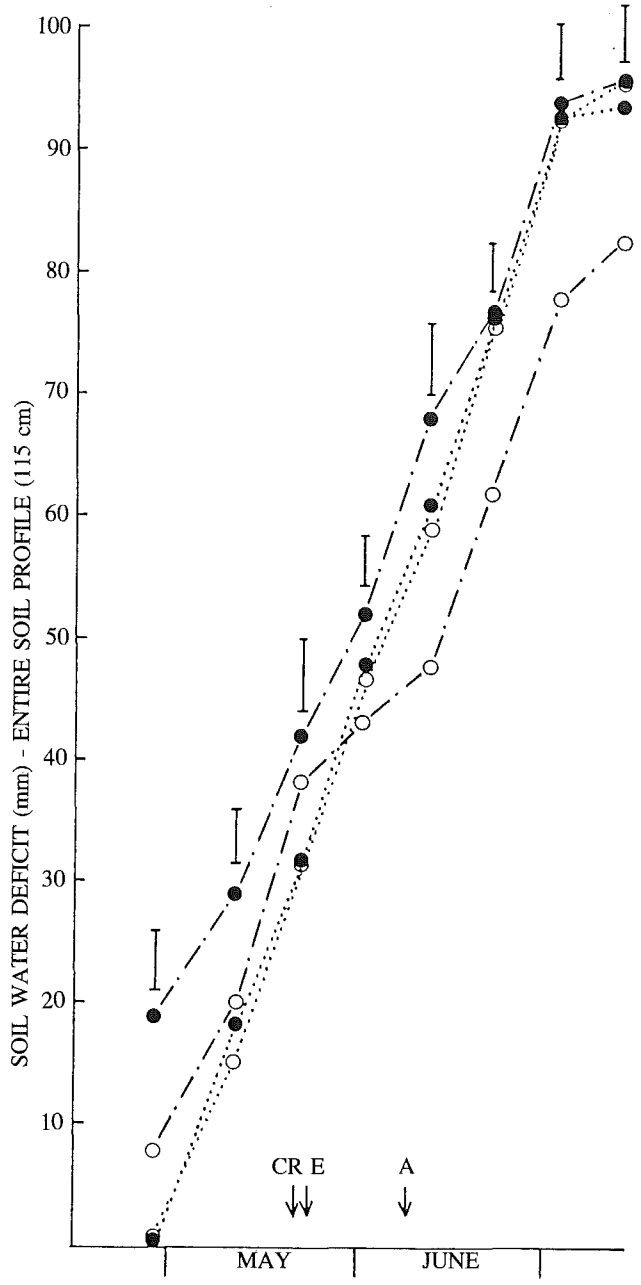


Figure 2. The effect of rainfall (water availability) and PP333 application on the soil profile water deficit (O = nil; ● = PP333 2 kg a.i. ha^{-1}; ... = uncovered; .___. = covered plots.)

in soil moisture deficits between treatments at the time of PP333 application were small, and by ear emergence were not significant. The lack of activation of the retardant found in the 'dry' conditions was thus more likely to be related to the fact that no water was allowed to reach the soil surface and wash the chemical into the root zone. Hebblethwaite et al. (1982) found that in the dry spring of 1982, response in the ryegrass seed crop to PP333 application at floret initiation was delayed until rain fell during ear emergence. To reduce the chances of a poor response to PP333 application because of low rainfall, the chemical should be applied around spikelet initiation rather than at floret initiation (Hampton and Hebblethwaite, 1985).

PP333 is known to have fungicidal as well as growth retardant properties (Froggatt et al. 1982; Hampton, 1983), and this was demonstrated in the present trial when powdery mildew infection was controlled under both 'dry' and 'wet' conditions. Under the 'wet' conditions, the chemical would

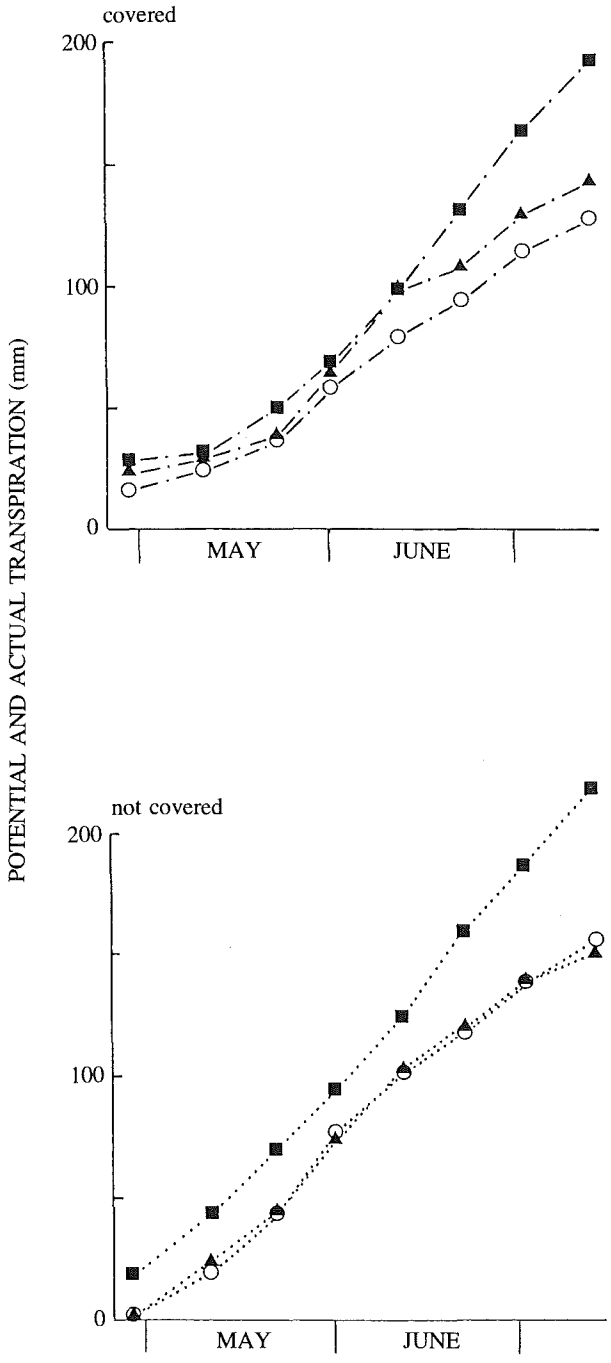


Figure 3. The effect of rainfall (water availability) and PP333 application on potential and actual transpiration (O = nil; ▲ = PP333 2 kg a.i. ha^{-1}; ■ = potential (Penman).)

have moved systemically through the plant, but this did not occur under 'dry' conditions, as no retardant effects were found. Although foliar uptake of PP333 is regarded as being of little importance for growth retardation (Shearing and Batch, 1982), the accumulation of the material in the leaves (Froggatt et al. 1982) was sufficient to prevent the spread of mildew.

PP333 applied under dry conditions did not affect the above ground growth of the plant. However, soil water deficits, particularly in the 65-115 cm zone were built up earlier than in other treatments, implying some effect on root growth. Hampton and Hebblethwaite (1985) found that PP333 applied at spikelet initiation increased root dry matter accumulation at all rooting depths, but this was associated with above ground retardation of stem length. While root dry matter data were not collected in the present trial, roots from PP333 treated plants under 'dry' conditions were extracting water from the 65-115 cm zone by anthesis, some 20 days earlier than the untreated plants under 'dry' conditions. This effect on root growth may have occurred after the covers were removed, allowing chemical to be washed into the soil. However, the data suggest that soil water deficits were usually larger, though not always significantly so, in plots with PP333 applied under dry conditions, implying that the roots reached a greater depth more quickly than those of other treatments. It is possible that this resulted from greater root development per fertile tiller, because of reduced competition from vegetative tillers between ear emergence and anthesis, but this hypothesis requires further investigation.

Under the artificial environmental conditions induced by covering of plots, seed yield was 117% greater in plots which had received PP333. Some of this difference may have been accounted for by differing rates of seed shedding between the treatments (Hampton, 1983), but the major response was a difference in the number of fertile tillers at final harvest. Previous work has shown that PP333 application stimulates tillering and may lead to an increased number of fertile tillers at harvest (Hampton and Hebblethwaite, 1985). However, PP333 application under 'dry' conditions had no effect on tiller production during the season, the differences in tiller number at final harvest being a result of greater survival of tillers in PP333 treated plots. Increased tiller survival may have resulted from lower moisture stress in the PP333 treated plots because of more rapid root growth and greater water uptake from lower zones of the profile; from control of powdery mildew by PP333; or from a combination of both factors, in that severly infected tillers would be less able to withstand moisture stress than healthy tillers. While the effects of either moisture stress or mildew attack on seed yield can not be determined individually, collectively these two factors severely depressed seed yield.

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