Effect of Paclobutrazol on Seed Yield of Lucerne (*Medicago sativa* L.) cv. Grasslands Oranga

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ABSTRACT

The effects of the plant growth regulator paclobutrazol on lucerne seed yield and its components were investigated in two field experiments in 1991/93. Paclobutrazol applied at 1.0 kg a.i. ha^{-1} during active vegetative growth significantly increased seed yield by 36% in 1991/92 and 150% in 1992/93. This seed yield response came primarily from a significant increase in the number of harvestable racemes, but pods per raceme were also increased in both seasons, and thousand seed weight was increased in the second season only. Paclobutrazol applied at 1.0 kg a.i. ha^{-1} at first flower bud appearance in 1991/92, or at 0.5 kg a.i. ha^{-1} during active vegetative growth in 1992/93 did not increase seed yield. The implications of these results for lucerne seed production are briefly discussed.

Additional index words: **alfalfa, growth regulator, lucerne, paclobutrazol, pod retention, seed yield components.**

INTRODUCTION

As with other forage legumes, seed production in lucerne (*Medicago sativa* L.) can be limited by the indeterminate flowering habit which leads to uneven seed development and ripening, and consequently difficulties in assessing an optimum harvest time (Askarian, 1993). One approach to overcoming the problem has been through the use of plant growth regulators such as paclobutrazol (eg Li and Hill, 1989; Hampton, 1991; Budhianto, 1992; Tabora and Hill, 1992), although data for lucerne are as yet limited (Kalmer, 1991).

The use of paclobutrazol to improve seed yield in herbage legumes has met with mixed success (eg Supanjani, 1991; Budhianto, 1992; Askarian, 1993), and as with other plant regulators (Davis and Anderson, 1989), both time (ie plant growth stage) and application rate are important. For example in *Lotus uliginosus* Schk., application of paclobutrazol in early spring (September) at the onset of vegetative growth did not increase final seed yield, but application before the onset of the first reproductive buds (October), significantly increased seed yield (Clifford and Hare, 1987; Hampton, Li and Hare, 1989; Tabora and Hill, 1992). Less consistent seed yield responses occurred following paclobutrazol application after reproductive initiation (ie in November and December, Tabora and Hill, 1992).

The objectives of the first trial reported in this paper were to assess the effects of paclobutrazol on lucerne seed yield and its components, and to determine the effect of application time. In the second season the objectives were to firstly confirm the most significant result from the previous season using larger plots, and secondly to investigate the effect of paclobutrazol application rate.

MATERIALS AND METHODS

Trial Site

1991/92

Seeds of the lucerne cultivar Grasslands Oranga were slurry inoculated with *Rhizobium meliloti* (Askarian, 1993) and sown in 4 x 4.5 cm peat pots (3 seeds per pot) on 10 July 1991. Pots were placed in a glasshouse (17–25°C) and plants thinned to one per pot four days after seedling emergence. On 18 August plants were placed outside to harden off before transplanting into the field on 7 September. Three weeks previously the field had been sprayed with glufosinate–ammonium (Buster) at 1 kg a.i. ha^{-1}, ploughed and harrowed. Just prior to the harrowing 150 kg ha^{-1} superphosphate and 2.5 t ha^{-1} lime were applied to the experimental area. Seedlings were planted at a 30 x 30 cm spacing with 20 plants per plot.

1992/93

The stand of lucerne cv. Grasslands Oranga had been sown at 3 kg ha^{-1} in 30 cm rows in 1991 (Askarian and Hampton, 1993) and a seed harvest taken in March 1992 (Askarian, 1993). The area was grazed to ca. 7 cm by sheep on 7 July 1992 and hexazinone (Table 1) applied to control the major weed, white clover (*Trifolium repens* L.), on 30 September 1992.

Treatments

For the 1991/92 trial, paclobutrazol at 1.0 kg a.i. ha^{-1} was applied via knapsack sprayer in 250 l water ha^{-1} during active vegetative growth (1 November 1991) or at the appearance of the first flower bud (1 December 1991). These two treatments, plus the unsprayed control were arranged in a complete randomised block (CRB) with four replicates. Cut 0.5 m widths between plots and 1.5 m widths between blocks were maintained for the duration of the experiment. In the second season paclobutrazol at 0.5 and 1.0 kg a.i. ha^{-1} was applied via a small gas pressure sprayer in 400 l water ha^{-1} at 200 kPa during active vegetative growth (25 October 1992). Treatments were once again arranged in a CRB with four replicates. In both seasons paclobutrazol was applied on windless days but as an extra precaution, adjacent plots were protected from spray drift with a plastic shield. Plot sizes were 1.2 x 1.5 m in 1991/92 and 2.5 x 3 m in 1992/93.

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Management

Nitrogen fertiliser and irrigation were not applied in either trial. Other management information is provided in Table 1. No pollinators were introduced in 1991/92, but for the second trial, honey bees (9 colonies ha^{-1}) were placed adjacent to the trial site on 24 December 1992 (Askarian, Hampton and Harrington, 1993).

Data Collection

Permanent quadrats (0.25 m^2 in 1991/92 and 0.5 m^2 in 1992/93) were established in each plot and raceme numbers assessed at 5 day intervals by counting all racemes with at least one open floret in each quadrat. The number of floret buds per raceme, florets per raceme and pods per raceme were assessed at first flowering, peak flowering and final harvest using 50 racemes randomly selected from each plot. The percentage of florets retained as pods was calculated from the difference between the number of florets per raceme at peak flowering and pods per raceme at final harvest. The total number of flowers m^2 was obtained by summing the number of new flowers at each five day quadrat count. Plots were harvested when the majority of pods were brown black (Hill, 1975) by cutting all plant material (excluding the border rows) from each plot at ground level in 1991/92, and cutting all plant material from within two randomly selected 0.5 m^2 areas per plot in 1992/93. The number of racemes carrying pods (= harvestable racemes) were counted, and racemes were then left at ambient temperature in open bags for four weeks to dry. Fifty racemes were then randomly selected and the number of pods per raceme and seeds per pod counted. Pods were then hand separated from all harvested racemes, seed extracted by hand rubbing (Askarian, 1993) and cleaned by sieving and vertical column aspiration (Askarian et al., 1993). Thousand seed weight (TSW), seed moisture content (%SMC) and seed viability were determined using internationally approved methodology (ISTA, 1993). Yields are expressed at 7% seed moisture content.

Data Analysis

Data were subjected to analysis of variance using the SAS programme (SAS, 1987) and means separated using a LSD test at $P<0.05$ when the F test was significant. Associations between seed yield and its components were determined using linear correlation.

Table 1. Management and experimental details for the two seasons.

	1991/2	1992/93
Site	Massey University, Palmerston North, New Zealand (40°S. 175°E)	
Soil type	Ohakea silt loam	Manawatu sandy loam
Cultivar	Grasslands Oranga	Grasslands Oranga
Crop	transplanted seedlings	one year old sown stand
Row spacing	30 cm	30 cm
Weed control	hand weeding	hexazinone 1.0kg ai ha^{-1}, 30 Sept
Insect control	fluvalinate 0.1 kg ai ha^{-1}, 10 Dec	fluvalinate, 0.1 kg ai ha^{-1}, 15 Dec
Paclobutrazol rate	0, 1.0 kg ai ha^{-1}	0, 0.5, 1.0 kg ai ha^{-1}
Paclobutrazol date	1 Nov, 1 Dec	25 Oct
First flowering	17 Dec	16 Dec
Peak flowering	2 Jan	27 Jan
Seed harvest	5 Mar	22 Mar

During the 1991/92 summer (October to March) temperatures were slightly cooler than average (Table 2) and below average sunshine hours were recorded in all months except October. Rainfall was 13 mm less than average in December, but 88 mm and 20 mm higher than average in February and March respectively (Table 2). Temperatures in 1992/93 were similar to those of the previous season, but more hours of sunshine were recorded (Table 2); December had 89 h less sunshine than the long term average, and was also very wet (167 mm rain), while November, January and February had below average rainfall (Table 2).

Table 2. Climate data for October to March 1991/92 and 1992/93[1].

		Oct.	Nov.	Dec.	Jan.	Feb.	Mar.
Mean air temp (°C)							
60 yr avg	min.	8.3	9.8	11.6	12.8	12.8	11.7
	max.	16.6	18.5	20.6	21.9	22.3	20.9
1991/92	min.	8.1	8.3	11.3	12.9	12.4	9.5
	max.	16.0	16.2	19.3	21.9	20.9	18.6
1992/93	min.	10.6	10.2	10.8	11.5	11.7	10.0
	max.	20.3	18.0	19.3	19.9	20.8	19.2
Rainfall (mm)							
60 yr avg		88	78	94	79	67	69
1991/92		81	81	81	77	155	89
1992/93		82	52	167	54	49	80
Sunshine (h)							
60 yr avg		158	177	193	209	186	170
1991/92		159	135	119	172	167	136
1992/93		152	169	104	204	198	184

[1] *recorded 1 km from the trial sites.*

RESULTS

In the first season (1991/92) the application of paclobutrazol during vegetative growth (November) significantly increased seed yield (+36%), while application at first flower bud appearance (December) significantly decreased seed yield (–48%), the major difference being in the number of harvestable racemes (3348 versus 1542 m^{-2}, Table 3). The November paclobutrazol application increased ($P<0.05$) the number of pods per raceme, but no significant differences in seeds per pod or thousand seed weight were recorded (Table 3).

Flowering duration was 78 days but did not differ among treatments (data not presented). The November paclobutrazol application significantly increased both the number of flowers at peak flowering (2 January) and the total seasonal production (Table 4), but the December application significantly reduced the total number of flowers produced. Florets per raceme at peak flowering did not differ among treatments, but the percentage of those florets retained as pods (ie present at final harvest) was nearly doubled by the November paclobutrazol treatment (Table 4).

Table 3. Effect of time (1991/92) and rate (1992/93) of paclobutrazol application on seed yield and seed yield components in lucerne cv. Grasslands Oranga.

	Seed yield kg ha^{-1}	Harvestable racemes m^{-2}	Pods per raceme	Seeds per pod	TSW g
1991/92					
Control	466	2458	4.6	3.7	2.43
Paclobutrazol 1 Nov	638	3348	8.0	4.3	2.46
Paclobutrazol 1 Dec	239	1542	6.0	3.9	2.42
LSD $P < 0.05$	140.8	600.3	1.7	NS	NS
% CV	38.9	16.5	16.1	12.1	6.7
1992/93					
Control	129	822	4.7	3.1	1.74
Paclobutrazol 0.5 kg ai 25 Oct	185	1080	5.1	3.0	1.85
Paclobutrazol 1.0 kg ai 25 Oct	325	1853	6.4	3.4	1.93
LSD $P < 0.05$	109.8	554.1	0.9	NS	0.17
% CV	29.8	25.5	10.3	14.1	5.1

Table 4. Effect of time (1991/92) and rate (1992/93) of paclobutrazol application on flower number, florets per raceme and the percentage of florets retained as pods in lucerne cv. Grasslands Oranga.

Treatment	Flowers m^{-2}		Flowers per raceme at peak flowering	Percentage of florets retained as pods
	peak flowering	seasonal total		
1991/92				
Control	646	3101	24.1	19.1
Paclobutrazol 1 Nov	801	3474	24.5	36.8
Paclobutrazol 1 Dec	598	2676	25.3	23.8
LSD $P < 0.05$	69.8	368.4	NS	9.3
% CV	17.3	7.1	18.9	14.2
1992/93				
Control	1300	3310	20.0	22.3
Paclobutrazol 0.5 kg ai	900	2240	20.9	24.4
Paclobutrazol 1.0 kg ai	1355	3937	22.6	28.3
LSD $P < 0.05$	82.5	1261	NS	3.99
%CV	21.2	15.7	5.7	9.1

Peak flowering was recorded on the 27 January 1993, at which time the 0.5 kg a.i. ha^{-1} paclobutrazol treatment had fewer flowers ($P < 0.05$) than the other two treatments (Table 4). However, the flowering duration of 75 days and the total number of flowers produced did not differ among treatments. Paclobutrazol at 1.0 kg a.i. ha^{-1} increased ($P < 0.05$) the percentage of florets retained as pods (Table 4).

The number of harvestable racemes m^{-2} was strongly correlated with seed yield in both seasons ($r = 0.81$, $P < 0.05$ in 1991/92 and $r = 0.94$, $P < 0.01$ in 1992/93), as were the number of pods per raceme ($r = 0.77$, $P < 0.05$ in 1991/92 and $r = 0.74$ $P < 0.05$ in 1992/93). Associations between seed yield and seeds per pod and thousand seed weight were not significant in either season.

Paclobutrazol treatments did not affect germination in either season, with seed viability ranging from 97–99% (data not presented).

DISCUSSION

When applied at 1.0 kg a.i. ha^{-1} during active vegetative growth, paclobutrazol increased lucerne seed yield from 466 to 638 kg ha^{-1} in the first season and from 129 to 325 kg ha^{-1} in the second season. Yield did not increase when paclobutrazol was applied at a later growth stage in the first season, or at a lower rate in the second season. The major yield response came from an increased number of harvestable racemes, and this arose because of a stimulation of primary lateral shoot production (from 5802 m^{-2} to 7010 m^{-2} in 1991/92 and from 3613 m^{-2} to 5047 m^{-2} in 1992/93, Askarian, 1993). In contrast, paclobutrazol applied in December 1991, or at 0.5 kg a.i. ha^{-1} in 1992 did not alter the number of primary lateral shoots (Askarian, 1993) and no paclobutrazol treatment altered the number of main shoots, secondary lateral shoots or tertiary lateral shoots in either season (Askarian, 1993). These results are similar to the effects on shoot production reported for *Lotus corniculatus* L. (Li and Hill, 1989) and *L. uliginosus* Schk. (Tabora and Hill, 1992) following paclobutrazol application at 1.0 kg a.i. ha^{-1} during active vegetative growth. Later application may promote lateral branch growth, but these branches are usually infertile (Li and Hill, 1989).

The number of harvestable racemes m^{-2} also explained most of the large difference in seed yield between the two seasons, as pods per raceme and seeds per pod were similar. While it is not possible to directly compare the two trials, because of the differences in establishment method, stand age and particularly plot size, it would appear that the transplanted plants in the 1991/92 trial had a greater ability for shoot production than the more closely spaced plants in the 1992/93 trial. Askarian, Hampton and Hill (1994) have recently shown that at the same site, seed production in a second year lucerne crop was greater from a 1 kg ha^{-1} rate than from 3, 6 and 12 kg ha^{-1} sowing rates, because more harvestable racemes were produced at the 1 kg ha^{-1} rate.

Paclobutrazol application did not affect the duration of lucerne flowering in either season, a result in contrast to that reported for *Lotus uliginosus* (Tabora and Hill, 1992) and *Trifolium repens* (Hampton, 1991) where flowering duration was shortened. Paclobutrazol also did not increase the total number of flowers produced during the season, unlike responses recorded in lotus (Li and Hill, 1989; Tabora and Hill, 1992) and white clover (Hampton, 1991), although in the first season paclobutrazol applied in November did increase the number of flowers present at peak flowering.

Askarian (1993) calculated potential seed yields of over 1000 kg ha^{-1} in both seasons, compared with the 120–640 kg ha^{-1} actually harvested. Much of this loss of potential seed yield came from poor floret site utilisation, both in terms of retention of florets and floret fertility. Around 20% of the florets present at peak flowering were retained as pods, and from an average of 9.3 ovules per carpel at peak flowering (Askarian, 1993), only

around 3.2 seeds per pod reached maturity. These data in percentage terms are very similar to those reported for *Lotus uliginosus* (Tabora and Hill 1992). Paclobutrazol application did not alter the losses of potential seeds per pod, a result also found for *Lotus uliginosus* (Tabora and Hill, 1992) and white clover (Budhianto, 1992). Precisely what causes these losses is unclear, although assimilate shortages during ovule provisioning often result in higher seed abortion (Clifford, 1986). However, paclobutrazol did increase floret retention (or conversely, decreased pod loss), particularly in 1991/92. Tabora (1991) also found that paclobutrazol reduced pod loss per umbel in mid season flowers of *Lotus uliginosus*. Once again, pod abortion has been attributed to assimilate shortages (Tabora and Hill, 1991), particularly during periods of active vegetative growth. Whether paclobutrazol is capable of altering assimilate production and/or distribution in forage legumes is yet to be established. There was a suggestion that this did occur in 1992/93 where the 1.0 kg a.i. ha^{-1} rate increased thousand seed weight, but no seed weight differences were recorded in 1991/92, and paclobutrazol also did not increase seed weight in *Lotus corniculatus* (Li and Hill, 1989) or *L. uliginosus* (Tabora and Hill, 1992).

At a site not favoured for lucerne seed production (Askarian, 1993), paclobutrazol significantly increased seed yield in two seasons. However, the response was both application rate and application time dependent. To recover the cost of paclobutrazol application for New Zealand growers, seed yield would have to be increased by around 120 kg ha^{-1}. Thus in both seasons, the use of paclobutrazol was cost effective. However, before any recommendations could be made, this work would need to be repeated at other sites and with more effective pollinators, to determine whether these responses to paclobutrazol application are consistently repeatable.

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