

Paclobutrazol and white clover seed production: a non-fulfilled potential

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Abstract

Seed yield in white clover depends largely on the number of ripe inflorescences per unit area, and the plant growth regulator paclobutrazol has been used in an attempt to both increase and concentrate inflorescence production, and hence increase seed yield. However results reported from both New Zealand and Europe have been inconsistent, with seed yield responses ranging from highly significant increases to no effects. The current high cost of the chemical (\$1280/ha) requires a seed increase of over 300 kg/ha to ensure an economic return. Similarly no consistent effects of paclobutrazol on white clover vegetative and reproductive growth and development have been established. Possible reasons for this variable response of white clover to paclobutrazol application are presented and discussed.

Keywords: inflorescence production, Parlay, reproductive growth, seed yield components, *Trifolium repens*, vegetative growth

Introduction

White clover seed yield depends largely on the number of inflorescences produced per unit area (Clifford 1986; 1987). Management practices should therefore be directed at obtaining the high, uniformly distributed stolon tip density needed by the time of closing the crop so that there is a short but prolific flowering span (Clifford 1985; 1987). However achieving the desired stolon tip density is often difficult and efforts to provide the required amounts of mineral nutrients (Clifford & Rolston 1990) and water (Deschamps & Wery 1988) can result in excessive vegetative growth. This subsequently reduces inflorescence density and fertility due to the shading effects of competitive leaves (Pasumarty & Thomas 1990).

A further complication is the intermittent pattern of inflorescence production (Thomas 1987) which dictates that inflorescences appear over a period of time. Seed production in white clover is therefore typical of indeterminate plants (Hollington et al. 1980) in that the extended flowering period and resultant range of inflorescence ripeness categories in the crop makes the determination of optimum harvest time difficult (Budhianto et al. 1995).

The manipulation of white clover to both increase and condense inflorescence production without necessarily producing excessive vegetative growth could be expected to increase seed yield. This hypothesis has been explored using plant growth regulators (e.g. Budhianto et al. 1994a; 1994b). Internationally the most widely trialled plant growth regulator has been paclobutrazol. In this paper, the effects of paclobutrazol on seed production in white clover are reviewed and discussed.

Effects on vegetative growth

Marshall and Hides (1991a) and Budhianto et al. (1994a) found that paclobutrazol increased nodes per unit area. This response was considered to come from increased stolon production. However, in a study of individual plants in the field, Budhianto (1992) found no increase in main stolon number following paclobutrazol application, but did record a significant increase in the production of fertile secondary and tertiary branches off the main stolons. Whether this occurs in a sward situation is unknown. Both Marshall and Hides (1991a) and Budhianto et al. (1994a) reported an increase in the number of reproductive nodes along main stolons, although Marshall and Hides (1987) and Budhianto (1992) reported that paclobutrazol did not directly induce the initiation of inflorescences.

Paclobutrazol inhibits gibberellin biosynthesis (Hedden 1990) and thus reduces cell elongation. Paclobutrazol reduced white clover petiole length but not peduncle length (Marshall & Hides 1986; Hampton 1991; Budhianto et al. 1994a), the net effect being to elevate inflorescences above the canopy. While new plant organs which develop following paclobutrazol application are often reduced in size, white clover leaf size and total dry matter at peak flowering were not reduced (Budhianto et al. 1994a).

Effects on reproductive growth and seed yield

Paclobutrazol application has produced significant white clover seed yield increases in trials reported from Belgium (Rijckaert 1991), Denmark (Boelt & Nordestgaard 1993), New Zealand (Hampton 1991; Budhianto et al. 1994b) and UK (Marshall & Hides 1991b). These increases have ranged from 13–350%

(Table 1), and in most cases have been explained by an increase in the number of inflorescences at harvest and/or an increase in the number of seeds per floret or inflorescence (Table 2).

Increased inflorescence production in response to paclobutrazol has generally been a consistent feature (Table 3), but increases in seeds per inflorescence have been more variable (e.g. Hampton 1991; Marshall & Hides 1991b). This improvement in floret site utilization has been considered to have resulted from a reduction in seed abortion (Hampton 1991), although this is yet to be substantiated. There has generally been no change in the number of florets per inflorescence or in thousand seed weight, but Budhianto et al. (1994b) did report a significant reduction in thousand seed weight in one of two years of trials at the same site.

Variability of results

While the seed yield responses reported in Table 1 are impressive, nil responses have also been reported. Marshall and Hides (1986) found no increase in cv. Olwen following paclobutrazol application, but also reported (Marshall & Hides 1991b) that paclobutrazol significantly increased the seed yield of cv. Olwen but not cv. Menna in two consecutive years. Similarly while Hampton (1991) reported a significant increase in the seed yield of cv. G. Pitau, Budhianto et al. (1994b) recorded a non-significant increase in one year and a nil response in the following year for the same cultivar at the same site.

A number of reasons have been suggested for this variability in response to paclobutrazol. They include application rate and time, soil type, cultivar, environmental conditions and time of harvest.

Application rate and time

Rijckaert (1991) recorded significant seed yield increases at paclobutrazol application rates of 0.25, 0.5 and 1.0 kg/ha in two out of three years of trials in Belgium, but Marshall and Hides (1986) found no increase in seed yield at any of these application rates in a trial in UK. Data for paclobutrazol application rate responses are limited, but while most of the significant seed yield responses have come from the 1.0 kg ai/ha application rate, nil responses at this rate have also been recorded.

Table 1: Effect of paclobutrazol on harvested seed yield of seven white clover cultivars, 1987–1990.

Year of harvest	Cultivar	Country	Seed Yield (kg/ha)		% inc	Reference
			nil	paclobutrazol ¹		
1987	Milkanova	Denmark	543	638	13	Boelt & Nordestgaard 1993
1987	Merwi	Belgium	124	558	350	Rijckaert 1991
1987	G. Kopu	NZ	422	877	108	Hampton 1991
1987	G. Pitau	NZ	476	763	60	Hampton 1991
1987	G. Huia	NZ	518	1053	103	Hampton 1991
1987	G. Tahora	NZ	399	716	79	Hampton 1991
1988	Olwen ²	UK	205	578	183	Marshall and Hides 1991b
1989	Merwi	Belgium	909	1200	32	Rijckaert 1991
1989	G. Pitau	NZ	394	498	26	Budhianto et al. 1994b

¹ applied at 1 kg a.i./ha

² potential yield calculated from yield components

Table 2: Major seed yield component increases following paclobutrazol application.¹

Year of Harvest	Cultivar	Increase in seeds/floret or seeds/inflorescence (%)	Increase in inflorescences at harvest (%)
1987	Milkanova	19	– ²
1987	Merwi	60	64
1987	G. Kopu	21	53
1987	G. Pitau	28	83
1987	G. Huia	54	30
1987	G. Tahora	–	76
1988	Olwen	36	61
1989	Merwi	38	21
1989	G. Pitau	–	45

¹ applied at 1 kg a.i./ha

² no increase recorded

Table 3: Effect of paclobutrazol on inflorescence number/m².

Cultivar	Treatment	Year		
G. Pitau ⁵	Nil	1987 ¹	1988 ²	1989 ²
	Paclobutrazol	150	324	588
Olwen ⁶	Nil	210	551	750
		1984 ³	1987 ⁴	1988 ⁴
	Paclobutrazol	643	562	516
		810	703	829

¹Hampton (1991); ²Budhianto (1992); ³Marshall and Hides (1986);

⁴Marshall and Hides (1991b); ⁵data recorded at peak flowering;

⁶harvestable inflorescences.

Application has been generally timed for two crop developmental stages – during peak reproductive initiation, or when the reproductive buds/early flowers first become visible (i.e. a time frame of approximately one month between applications). Seed yield responses to application time have varied significantly between seasons at the same site (Marshall & Hides 1991b), among cultivars in the same seasons at the same site (Hampton 1991), or have produced no significant

differences between application times in the same cultivar over two seasons at the same site (Budhianto et al. 1994b).

Soil type

Pacllobutrazol is relatively immobile in the soil, being bound mainly by organic matter (Lever 1986). It is possible that soil type may affect the pacllobutrazol response, particularly as the chemical is primarily dependant on root uptake (Shearing & Batch 1982). While soil type may influence the amount of pacllobutrazol immediately available for plant uptake, and hence alter the plant response, this does not explain why contrasting results can be obtained at the same site in different seasons (Marshall & Hides 1991b).

Cultivar

Marshall and Hides (1991b) considered that cultivars responded similarly to pacllobutrazol application, although Hampton (1991) did record differing responses among four New Zealand cultivars (e.g. seeds per inflorescence were significantly increased in three cultivars following pacllobutrazol application at the first visible bud stage, but not in a fourth cultivar). The available data suggest greater variability within a cultivar over different seasons than between or among cultivars.

Environment

The environment always has a significant effect on the success of white clover seed production, but has also been suggested as an explanation for variable pacllobutrazol responses, because the chemical requires rainfall during the month after application to enable plant uptake (Hampton & Hebblethwaite 1984). Marshall and Hides (1991b) related the variability in response to pacllobutrazol in two consecutive seasons to the rainfall received in the month after application, but Budhianto et al. (1994b) found different responses in two consecutive seasons when rainfall after application was similar in each season.

Time of harvest

Wiltshire and Hebblethwaite (1990) reported significant growth regulator x harvest date interactions for seed yield in *Lolium perenne*, and Budhianto et al. (1995) explored the hypothesis that pacllobutrazol may alter the rate of white clover seed development and therefore the optimum harvest date as compared to the control. However, while pacllobutrazol increased inflorescence

number at peak flowering, despite large percentage differences, neither ripe inflorescences or seed yield were significantly increased (Table 4). There was also no evidence to suggest that pacllobutrazol altered seed development, and pacllobutrazol therefore had no effect on optimum harvest time (Budhianto et al. 1995).

Table 4: Effect of pacllobutrazol and time of harvest on ripe inflorescence number and seed yield in white clover cv. G. Pitau.¹

Treatments	Harvest time (days after peak flowering)					Treatment Means
	25	30	35	40	45	
Ripe inflorescences (no./m²)						
control	181	153	188	143	71	147
pacllobutrazol	317	212	279	167	80	211
Harvest means	249	183	234	155	76	
LSD P<0.05: treatment means = NS; harvest means = 63.3; treatment x harvest = NS C.V. main plots = 24%; subplots = 29%						
Seed yield (g/m²)						
control	25.5	20.8	21.1	10.0	6.2	16.7
pacllobutrazol	37.3	28.8	36.7	17.9	9.1	26.0
Harvest means	31.3	24.8	28.9	14.0	7.7	
LSD P<0.05 : treatment means = NS; harvest means = 10.0; treatment x harvest = NS C.V. main plots = 44%; subplots = 38%						
¹ adapted from Budhianto et al. (1995).						

Genotypic effects

As illustrated in Table 4, large percentage differences in seed yield have not always been statistically significant. The high variation recorded (e.g. coefficients of 30% to 75%, Budhianto 1992; Budhianto et al. 1995) may be attributable to plot size and sample size being too small to allow for the diversity to be found in an outcrossing species such as white clover (although Budhianto (1992) found that increasing plot size, sample size and replicate number did not necessarily reduce the variation recorded). However, it may also be possible that responses to a plant growth regulator may differ with genotype, and that inconsistencies in response to pacllobutrazol application may at least in part have been explained by genotypic differences.

Budhianto (1992) examined the effect of pacllobutrazol in three genotypes from within cv. G. Pitau. Inflorescence production per plant averaged 320, 400 and 30 for genotypes I, II and III respectively, but pacllobutrazol significantly increased inflorescence number (+ 32%) for genotype II only. Total mean seed yield per plant was 74, 57 and 4g for genotypes I, II and III respectively, but again, the only significant yield increase following pacllobutrazol application was for genotype II (+ 25%). Thus while one genotype responded to pacllobutrazol application, two other genotypes did not. However although the seed yield of genotype II

was increased by paclobutrazol, it was not greater than that produced by the untreated control for genotype I.

These results highlight the importance of genetic factors in determining white clover seed yield. Whether variable responses to paclobutrazol can be explained by differing genotypic responses remains to be determined.

Conclusion

Although available in New Zealand for horticultural use, paclobutrazol was not released for agriculture, a decision based mostly on concerns about the strong soil residual properties of the chemical and effects on succeeding crops. For white clover this may not be a factor, as Budhianto (1992) reported no effects on vegetative or reproductive growth in plots in year two which had received paclobutrazol at 1.0 kg ai/ha in year one. While Boelt and Nordestgaard (1993) for example, concluded that plant growth regulators had no place in white clover seed production because of inconsistency of results, the collective evidence suggests otherwise. Certainly an improved understanding of how antigibberellins such as paclobutrazol affect white clover vegetative and reproductive growth is required. However, at the present cost of the chemical (\$1280/ha for a 1 kg ai/ha application rate), it is not economic. At this price, a grower would need a guaranteed seed yield increase of 320 kg/ha (at \$4/kg seed) and 640 kg/ha (at \$2/kg seed) just to recoup the chemical costs. This price is that for the horticultural use of paclobutrazol, and presumably if the chemical was to be released for agricultural use, its cost would decrease commensurately. For the present, paclobutrazol in white clover seed production seems destined to remain a non-fulfilled potential.

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References

- Boelt, B.; Nordestgaard, A. 1993. Growth regulation in white clover (*Trifolium repens* L.) grown for seed production. *Journal of Applied Seed Production* 11: 1–5.
- Budhianto, B. 1992. Chemical manipulation of white clover (*Trifolium repens* L.) grown for seed production. PhD thesis, Massey University, Palmerston North, New Zealand.
- Budhianto, B.; Hampton, J.G.; Hill, M.J. 1994a. Effect of plant growth regulators on a white clover (*Trifolium repens* L.) seed crop. I. Plant growth and development. *Journal of Applied Seed Production* 12: 47–52.
- Budhianto, B.; Hampton, J.G.; Hill, M.J. 1994b. Effect of plant growth regulators on a white clover (*Trifolium repens* L.) seed crop II. Seed yield components and seed yield. *Journal of Applied Seed Production* 12: 53–58.
- Budhianto, B.; Hampton, J.G.; Hill, M.J.; Thomas, R.G. 1995. Effect of time of harvest and paclobutrazol on seed yield in white clover cv. Grasslands Pitau. *New Zealand Journal of Agricultural Research* 38: 1–6.
- Clifford, P.T.P. 1985. Effect of cultural practice on potential seed yield components of 'Grasslands Huia' and 'Grasslands Pitau' white clover. *New Zealand Journal of Experimental Agriculture* 13: 301–306.
- Clifford, P.T.P. 1986. Interaction between leaf and seed production in white clover (*Trifolium repens* L.). *Journal of Applied Seed Production* 4: 37–43.
- Clifford, P.T.P. 1987. Producing high seed yields from high forage producing white clover cultivars. *Journal of Applied Seed Production* 5: 1–9.
- Clifford, P.T.P.; Rolston, M.P. 1990. White clover – genetic variability and environmental factors affecting seed production. *Journal of Applied Seed Production* 8: 54–58.
- Deschamps, M.D.; Wery, J. 1988. Effect of drought stress and mineral nitrogen supply on growth and seed yield of white clover in Mediterranean conditions. *Journal of Applied Seed Production* 6: 14–19.
- Hampton, J.G. 1991. Effect of paclobutrazol on inflorescence production and seed yield in four white clover (*Trifolium repens* L.) cultivars. *New Zealand Journal of Agricultural Research* 34: 367–373.
- Hampton, J.G.; Hebblethwaite, P.D. 1984. The influence of rainfall on paclobutrazol response in the perennial ryegrass (*Lolium perenne* L.) seed crop. *Journal of Applied Seed Production* 2: 8–12.
- Hedden, P. 1990. The action of plant growth retardants at the biochemical level. pp. 322–332. In: Pharis R.P.; Rood, S.P. (eds). *Plant growth substances* 1988. Springer – Verlag, Berlin.
- Hollington, P.A.; Marshall, A.H.; Hides, D.H. 1989. Effect of seed crop management on potential seed yield of contrasting white clover varieties. II. Seed yield components and potential seed yield. *Grass and Forage Science* 44: 189–193.
- Lever, B.G. 1986. 'Cultar' – a technical overview. *Acta horticultrae* 179: 459–466.
- Marshall, A.H.; Hides, D.H. 1986. Effect of growth regulators on seed yield components of white clover. *Journal of Applied Seed Production* 4: 5–7.

- Marshall, A.H.; Hides, D.H. 1987. Modification of stolon growth and development of white clover (*Trifolium repens* L.) by growth regulators, and its influence on flower production. *Journal of Applied Seed Production* 5: 18–25.
- Marshall, A.H.; Hides, D.H. 1991a. Effect of the plant growth regulator Parlay on the seed production of the white clover cvs. Menna and Olwen. I. Stolon growth and development. *Journal of Applied Seed Production* 9: 73–80.
- Marshall, A.H.; Hides, D.H. 1991b. Effect of the plant growth regulator Parlay on the seed production of the white clover cvs. Menna and Olwen. II. Yield components and potential seed yield. *Journal of Applied Seed Production* 9: 81–86.
- Pasumarty, S.V.; Thomas, R.G. 1990. The effect of canopy structure and light intensity on seed production in white clover. *Proceedings of the New Zealand Grassland Association* 52: 107–110.
- Rijckaert, G. 1991. Application of growth regulators in seed crops of white clover (*Trifolium repens* L.) under Belgian climatic conditions. *Journal of Applied Seed Production* 9: 55–62.
- Shearing, S.J.; Batch, J.J. 1982. Amenity grass retardation – some concepts challenged. pp. 467–483. In: McLaren, J.S. (ed.). *Chemical manipulation of crop growth and development*. Butterworths, London.
- Thomas, R.G. 1987. Reproductive development. pp. 63–123. In: Baker, M.J.; Williams, W.M. (eds). *White clover*. Wallingford, CAB International.
- Wiltshire, J.J.J.; Hebblethwaite, P.D. 1990. Harvest timing in *Lolium perenne* L. seed crops treated with the growth regulator triapenthenol. *Journal of Applied Seed Production* 8: 12–20. ■