

The Effect of Paclobutrazol and Residue Management on Reed Canarygrass Seed Production

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ABSTRACT

The effects of post-harvest residue treatments plus time and rate of application of the growth retardant paclobutrazol were investigated for reed canarygrass (*Phalaris arundinacea* L.) seed production. In a year with heat and moisture stress (1988), open field burning of the residue after seed harvest (August) produced the highest yield by increasing seed yield per panicle, mature seeds (dark coloured seed), and panicle length. In a normal growing season (1989), no differences in seed yield were recorded following either post-harvest burning, cutting and raking or raking alone. Paclobutrazol application produced no differences in seed yield, but had a small positive effect on panicle morphology by significantly increasing panicle length in 1987 and 1989. In 1988, when applied to plants growing under extreme heat and moisture stress conditions, paclobutrazol reduced dry matter yield and tended to lower seed yield by lowering yield per panicle, although differences were not significant. Based on these results, application of paclobutrazol to reed canarygrass seed production fields in northern Minnesota is not recommended.

Additional index words: burning, cutting, raking, growth regulator, seed yield.

INTRODUCTION

Reed canarygrass is an important cool-season perennial forage grass in the north central USA (Marten, 1985). It is well adapted to many different environments and can tolerate poorly-drained soils and flooding better than other cool-season grasses. The development of low alkaloid cultivars of reed canarygrass such as 'Palaton' and 'Venture' has increased its value as an excellent, high-yielding hay and pasture forage grass producing more than 12 Mg ha⁻¹ dry matter with adequate fertility and a favourable cutting schedule (Kalton, Richardson and Shields, 1989; Kalton, Shields and Richardson, 1989). Reed canarygrass also responds well to liquid manure application and lagoon irrigation. It can withstand irregular water application, is persistent and has a high capacity for N uptake which it utilises to produce high quality, high yielding forage (Marten, Clap and Larson, 1979).

Reed canarygrass is an important species in the grass seed production area of northern Minnesota, ranking third in total acreage behind Kentucky bluegrass (*Poa pratensis* L.) and timothy (*Phleum pratense* L.). However, some limitations exist for the production of reed canarygrass seed. These include poor seedling vigour leading to stand establishment problems, harvesting difficulties because of seed shattering, and a large biomass production leading to residue problems after seed harvest. Proper residue management is critical in order to maintain high yields. To date, little information is available about proper residue management techniques for reed canarygrass seed production fields.

Chemical plant growth regulators have been shown to alter the distribution of assimilates between vegetative and

reproductive organs, to increase economic yield, to change the canopy structure for improved interception of solar radiation, to facilitate harvesting, and to control lodging (Seth, 1986). Growth regulators such as paclobutrazol have previously been shown to be potent growth retardants with a broad spectrum of activity (Lever, Shearing and Batch, 1982). Paclobutrazol reduces vegetative growth by inhibiting gibberellin biosynthesis by blocking the oxidation of kaurene to kaurenoic acid (Danziel and Lawrence, 1984). Uptake and translocation of the compound is passive. It enters through the roots and above ground portions of the plant and moves in the xylem to the leaves, buds, and the sub-apical meristem region. Biological activity has been observed from both soil and foliar sprays. The compound is very stable in both soil and plants but the availability of paclobutrazol for plant uptake varies with both soil types and environmental conditions (Hebblethwaite, 1987). High soil organic matter content will increase the binding of paclobutrazol and poor plant growth conditions will delay crop response to the growth regulator.

Paclobutrazol has increased seed yield of perennial ryegrass (*Lolium perenne* L.) an average of 40 percent by increasing the number of fertile tillers and the number of seeds per spikelet (Hampton and Hebblethwaite, 1985). However, paclobutrazol can produce variable results among seasons and cultivars of perennial ryegrass (Hebblethwaite, 1987). Paclobutrazol rates of 0.5 kg a.i. ha⁻¹ have produced good yield responses in the USA while rates of 0.75 kg a.i. ha⁻¹ have decreased seed yield (Young, Chilcote and Youngberg, 1984). In northern Minnesota, paclobutrazol has shown promise as a fall (autumn) applied treatment for

increasing seed yield of first year Kentucky bluegrass seed crops. In 1987, the seed yield of 'Park' Kentucky bluegrass was increased 75 percent by an October 1986 application of 0.22 kg ha⁻¹ a.i. paclobutrazol (Ehlke, unpublished data). The yield increase was associated with an increase in panicle number and a decrease in the severity of powdery mildew infection. The objectives of this research were to i) determine proper residue management strategies for reed canarygrass production fields and ii) determine the effect of rate and time of application of paclobutrazol on reed canarygrass seed yield and seed yield components.

MATERIALS AND METHODS

Field History

The study was conducted in an established certified seed production field of Palaton reed canarygrass sown in June 1985. In the first production year (1986), 235 kg ha⁻¹ clean seed was produced after yield loss from shattering due to a summer rainstorm. The residue averaged 6.7 t ha⁻¹ dry matter and was cut and removed prior to establishing these studies. On 10 October 1986, the field received 112 kg N, 15 kg P and 46 kg K ha⁻¹, while an additional 34 kg N ha⁻¹ was topdressed on 27 April 1987.

Experiment I:

A study on the effect of paclobutrazol was initiated in May 1987. The experiment was a randomised complete block with 12 replicates. Plot size was 5 m by 30 m. Treatments were paclobutrazol applied on 20 May 1987 just prior to stem elongation at 0.0, 0.56 and 1.12 kg a.i. ha⁻¹ delivered in 187 l water ha⁻¹ at 172 kilopascals using 8003 nozzles with a plot sprayer held 0.6 m above the soil. Plant height was measured and percent heading was visually estimated twice a week in duplicate for each plot from time of application of paclobutrazol until harvest. On 28 and 29 June 1987, four 1 m² samples per plot were harvested for dry matter production, seed yield, and harvest index [seed yield/total above ground matter plant yield) x 100]. Four 0.09 m² samples were harvested to determine fertile panicle number, panicle length, seed yield per panicle, and seed colour as a measure of seed maturity. Colour was rated on a scale of 1 to 5 where 1 = 0 to 20% dark seed and 5 = 81 to 100% dark seed.

Experiment II:

A second study was conducted in the same production field from 1987 through 1989. The experiment was a randomised complete block design replicated four times with a split plot restriction on randomisation. Main plots were three residue treatments and measured 20 m by 30 m; subplots were paclobutrazol applications and measured 5 m by 30 m. The residue treatments were applied after seed harvest by conducting: 1) a post-harvest open-field burn (burn); 2) a short cut to 15 cm stubble height followed by raking off the cut plant material (cut/rake); and 3) a rake treatment where plant material remaining on the field after

combining was raked off leaving a 35 cm stubble without supplemental cutting (rake). Main plot burn treatments were performed on 2 August 1987 and 3 August 1988. Cut-rake and rake treatments were performed on 15 July 1987 and 24 July 1988. Subplots were paclobutrazol applications of 0.0, 0.56 and 1.12 kg a.i. ha⁻¹ in the spring immediately after initiation of plant growth (12 April 1988; 2 May 1989) and 0.56 kg a.i. ha⁻¹ in the fall when the plants were dormant (15 October 1987; 19 October 1988). Paclobutrazol was applied using the method described in Experiment I. On 16 October 1987 134 kg N, 15 kg P and 25 kg K ha⁻¹ was applied and on 20 October 1988, 22 kg P and 42 kg K ha⁻¹ was applied. Two measurements of plant height and visual estimates of percent heading were made biweekly in each plot from time of application of the spring paclobutrazol treatments until harvest. On 30 June 1988 and 10 July 1989, 4 1 m² samples per plot were harvested to a 15 cm stubble height for dry matter production, seed yield, and harvest index. Four 1 m² samples were harvested in 1988 and four 0.09 m² samples were harvested in 1989 to determine fertile panicle number, panicle length, seed yield per panicle and seed colour. In 1988, a burn residue treatment was not completely extinguished and a fire burned across a rake main plot treatment resulting in the loss of data in 1989. The data were analysed according to the methods of Steele and Torrie (1980) using the ANOVA and GLM procedures of SAS (1987).

RESULTS AND DISCUSSION

Experiment I:

Paclobutrazol at 0.56 kg a.i. ha⁻¹ decreased ($P < 0.05$) dry matter production at seed harvest by 22% (from 7689 to 5967 kg ha⁻¹). Both paclobutrazol rates significantly increased panicle length by 4 cm. By 20 June 1987, the high rate of paclobutrazol had reduced ($P < 0.05$) plant height by 4 cm over the untreated plots, but by harvest there were no differences in plant height. No significant differences were detected for seed yield, which averaged 781 kg ha⁻¹, harvest index, panicle number m² or seed colour.

The application of paclobutrazol on 20 May 1988 may have been too late to have a significant effect on plant growth characteristics (Hampton and Hebblethwaite, 1985), as previously reported responses in other grass species have followed application at reproductive initiation. However, the results of the preliminary study were encouraging because the paclobutrazol treatments showed a trend towards shorter plants, higher seed yields and a larger harvest index than the untreated plots.

Experiment II:

In 1988, northern Minnesota experienced severe drought conditions and above normal temperatures which decreased seed yield and seed yield components. Daily temperatures average 4.6°C above normal in June and crop season rainfall was 222.4 mm less than the average precipi-

tation in Roseau, MN (Table 1). One-third of the annual rainfall was recorded in July and occurred during a severe thunderstorm after the reed canarygrass seed harvest. Moisture is important to the activity of paclobutrazol and for normal plant growth and development (Hampton and Hebblethwaite, 1984). Because of the extreme environmental conditions in 1988, the data were analysed separately by year.

1988 Residue Management Response: The burn treatment had panicles which were on average 8 cm longer (11%) than the cut/rake or rake treatments and approximately doubled the seed yield per panicle when compared to the cut/rake and rake treatments (Table 2). However, seed yield did not differ significantly. The burn residue treatment also matured earlier based on seed colour ratings when compared to the cut/rake treatment.

Table 1. Crop season rainfall and temperature data recorded in Roseau, MN from 1987 to 1989. The numbers in parentheses are the departures from normal rainfall and temperature conditions.

Month	1987		1988		1989	
	Rainfall mm	Temperature °C	Rainfall mm	Temperature °C	Rainfall mm	Temperature °C
April	15.0 (-32.7)	10.5 (+7.3)	0.0 (-33.3)	4.1 (+0.9)	2.5 (-30.5)	1.7 (-1.5)
May	111.0 (+53.6)	16.0 (+5.4)	44.2 (-13.2)	14.3 (+3.7)	87.1 (+29.1)	13.0 (+2.4)
June	57.2 (-26.9)	19.7 (+3.6)	34.0 (-50.0)	20.7 (+4.6)	140.5 (+56.5)	16.0 (-0.2)
July	121.9 (+33.8)	21.6 (+2.9)	140.5 (+52.3)	20.8 (+2.1)	48.0 (-40.0)	21.1 (+2.4)
August	56.4 (-22.6)	18.9 (+1.6)	43.2 (-35.8)	19.9 (+2.6)	93.0 (+14.0)	18.6 (+1.3)
September	20.8 (-45.0)	15.0 (+3.6)	56.8 (-9.0)	12.5 (+1.1)	34.3 (-31.7)	13.2 (+1.8)
Departure from normal	-48.2	+3.5 ¹	-222.4	+1.8	-24.2	+0.8

¹ Mean temperature departure from normal averaged over the seven month crop season.

Plant height was influenced by residue treatment with the burn treatment being 14% taller on 6 June 1988 than the other two treatments. This trend continued until harvest on 30 June 1988, where the burn treatment had 20% taller plants than the cut/rake or rake treatments, but total dry matter did not differ (Table 2). The burn plots initiated flowering earlier than the cut/rake or rake plots (Fig. 1), but by final harvest, differences in panicle numbers were not significant (Table 2). The drought conditions of 1988 caused poor plant growth and subsequently resulted in poor panicle production and very low seed yields. These results supported previous research on reed canarygrass which

demonstrated that the proportion of shoots producing inflorescences decreased as favourable growth conditions declined (Ostrem, 1988).

In periods of extreme moisture stress, the burn residue treatment may conserve valuable moisture by reducing plant growth in the fall which in turn would reduce the moisture requirements of the crop. In addition, the lack of residue on the plots would increase light penetration in the fall potentially increasing tiller initiation (Marten, 1985) and in the following spring allow the plants to initiate growth earlier in the season while moisture and temperature conditions were more favourable.

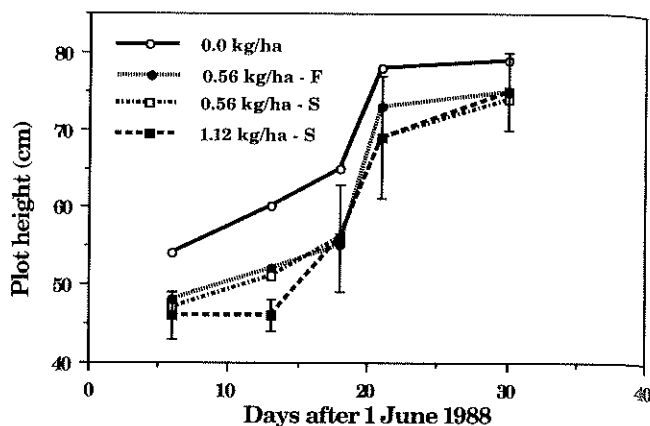
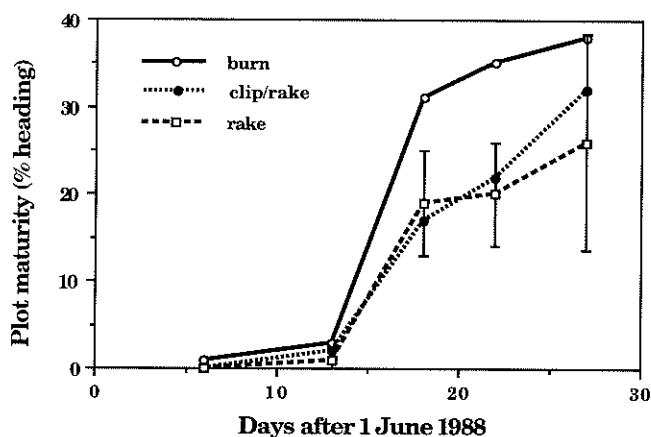


Figure 1. The effect of post harvest residue management on reed canarygrass plot maturity during 1988. Error bars indicate significant differences at the $P < 0.05$ level.

Figure 2. The effect of paclobutrazol applications on reed canarygrass plot height during 1988. Paclobutrazol rates are kg a.i. ha⁻¹ applied in the fall (F) of 1987 or the spring (S) of 1988. Error bars indicate significant differences at the $P < 0.05$ level.

Table 2. Mean seed yield and seed yield components of reed canarygrass for post harvest residue management treatments and paclobutrazol in 1988 and 1989.

Treatments	n	Dry matter yield	Seed yield	Harvest index	Panicle number	Seed yield panicle ⁻¹	Panicle length ¹	Seed colour
		kg ha ⁻¹	kg ha ⁻¹	%	no m ²	g panicle ⁻¹	cm	score
1988 Residue Management								
Burn	64	2331	30	1.2	61	0.046	81	1.4
Cut/rake	64	1970	14	0.7	49	0.026	72	1.1
Rake	64	1970	11	0.6	41	0.024	74	1.0
LSD (0.05)		NS	NS	NS	NS	0.012	5	0.3
1989 Residue Management								
Burn	64	5807	389	6.7	169	0.318	107	3.4
Cut/Rake	64	5692	379	6.4	147	0.303	104	3.3
Rake	48	5539	387	7.1	190	0.285	115	2.6
LSD (0.05)		NS	NS	NS	NS	0.025	NS	0.4
1988 Paclobutrazol Rates								
0.00 kg ha ⁻¹	48	2234	24	1.0	56	0.036	76	1.3
0.56 kg ha ⁻¹ - Fall	48	2138	24	1.0	54	0.035	75	1.3
0.56 kg ha ⁻¹ - Spring	48	1946	14	0.7	47	0.028	76	1.2
1.12 kg ha ⁻¹ - Spring	48	1826	13	0.7	44	0.028	75	1.1
LSD (0.05)		324	NS	NS	NS	NS	NS	NS
1989 Paclobutrazol Rates								
0.0 kg ha ⁻¹	44	6049	418	6.9	173	0.326	105	3.3
0.56 kg ha ⁻¹ - Fall	44	5563	375	6.6	177	0.291	108	3.2
0.56 kg ha ⁻¹ - Spring	44	5575	365	6.4	162	0.302	105	3.0
1.12 kg ha ⁻¹ - Spring	44	5580	381	6.8	155	0.295	113	3.0
LSD (0.05)		NS	NS	NS	NS	0.022	5	0.3

¹ For panicle length in 1988, n = 320 for residue management treatments and n = 240 for paclobutrazol rates and in 1989 n = 320 for the burn and cut/rake residue management treatments, n = 240 for the rake residue management treatment and n = 220 for paclobutrazol rates.

1988 Growth Regulator Response: Plots treated with 1.12 kg a.i. ha⁻¹ paclobutrazol in the spring produced less dry matter than untreated plots (Table 2). However, no differences were recorded for harvest index, seed yield, panicle number, seed yield panicle⁻¹, panicle length or seed colour among treatments.

Paclobutrazol initially reduced plant height (Fig. 2), but by harvest plant height did not differ among treatments. Paclobutrazol treated plots ranked from tallest to shortest as follows: untreated < 0.56 kg a.i. ha⁻¹ fall application > 0.56 kg a.i. ha⁻¹ spring application > 1.12 kg a.i. ha⁻¹ spring application rate.

Moisture stress appeared to have a detrimental effect on the activity of paclobutrazol applied to reed canarygrass and was similar to the response observed in perennial ryegrass (Hampton and Hebblethwaite, 1984). The lack of moisture is likely to have prevented the continued uptake and translocation of paclobutrazol in the plants. However, since the observed response of the spring applications of paclobutrazol differed from the untreated plots, it was likely that reed canarygrass responded negatively to the activity of paclobutrazol when applied during that period of moisture and heat stress (Hebblethwaite, 1987).

1989 Residue Management Response: Post harvest residue management did not significantly affect dry matter yield, seed yield, harvest index, panicle number or panicle length in what could be considered a more 'normal' season. Plants from the burn treatment yielded more seed per panicle and matured earlier than the rake treatment. Burn treatments produced inflorescences earlier in the growing season, but by harvest no differences in heading were detected (Fig. 3). The burn and cut/rake treatments were earlier maturing than the rake treatment as measured by seed colour (Table 2). The burn and cut/rake plots had less regrowth in the fall which allowed better light penetration to the crowns resulting in earlier spring growth, but despite this, panicle number and hence seed yield did not differ.

1989 Growth Regulator Response: The untreated plots produced more seed per panicle than the three paclobutrazol treatments (Table 2). The 1.12 kg a.i. ha⁻¹ spring application of paclobutrazol produced longer panicles than the other three treatments (Table 2), but paclobutrazol application did not influence dry matter production, seed yield, harvest index or panicle number.

Paclobutrazol treatments showed a trend towards decreased dry matter production which was a positive and anticipated response to the growth regulator; however seed yield did not increase as paclobutrazol treatments significantly decreased seed yield panicle⁻¹. Reed canarygrass appeared to compensate when changes in seed yield components were detected. For example, the 1.12 kg a.i. ha⁻¹ paclobutrazol spring application rate had significantly longer panicles but produced fewer panicles m⁻².

Paclobutrazol application reduced plant height throughout the growing season (Fig. 4). Paclobutrazol

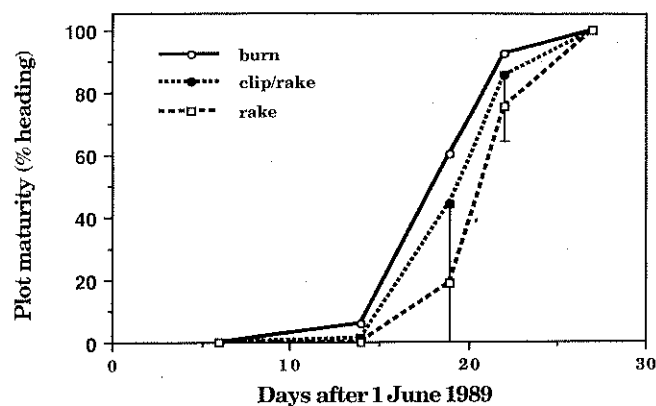


Figure 3.

The effect of post harvest management on reed canarygrass plot maturity during 1989. Error bars indicate significant differences at the $P < 0.05$ level.

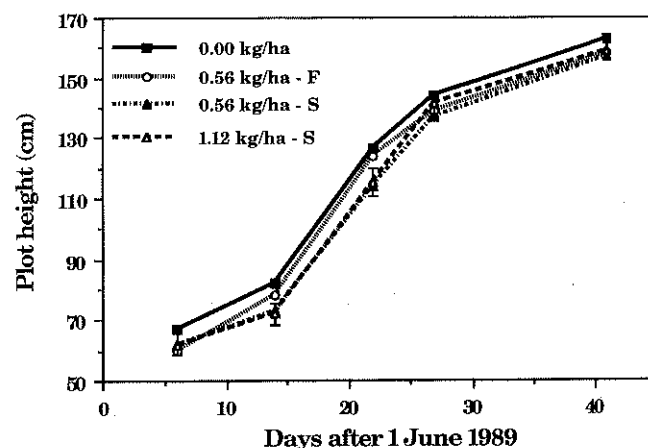


Figure 4.

The effect of paclobutrazol applications on reed canarygrass plot height during 1989. Paclobutrazol rates are kg a.i. ha⁻¹ applied in the fall (F) of 1988 or the spring (S) of 1989. Error bars indicate significant differences at the $P < 0.05$ level.

treatments delayed heading; for example on 19 June 1989 when untreated plots were at 53% heading compared with 40% for the three paclobutrazol treatments. Paclobutrazol treatments in turn delayed seed maturity with the untreated plots having a significantly higher seed colour rating than the spring paclobutrazol treatments (Table 2). While paclobutrazol treatments consistently reduced plant height and delayed plot maturity, the reduction in plant height was minimal.

CONCLUSIONS

In a normal growing season (ie 1989), the three post harvest residue managements produced similar results. Open-field burning and clipping the residue short and removing the plant material from the field are considered good options for seed producers. Burning also improves crop hygiene by removing potential pests and diseases. Particularly during years of moisture stress, open-field

burning appears to be a better residue management strategy. However, few conclusions can be drawn from the trial conducted in 1988 because of the drought conditions, as seed yields were decreased to such an extent that an economic harvest was not achieved.

Overall, paclobutrazol applications had little effect on seed yield or seed yield components. Although plant height was initially reduced, this effect had disappeared by heading, and unlike responses recorded in perennial ryegrass (Hebblethwaite, 1987), reproductive tiller numbers were not increased. In 1987 and 1989 panicle length was increased by the high paclobutrazol rate, but this was offset by a reduction in seed yield per panicle. The observed changes in seed yield components often resulted in no detectable difference in overall seed yield. Application of paclobutrazol to reed canarygrass seed production fields in northern Minnesota is not recommended.

ACKNOWLEDGEMENTS

The author would like to express sincere appreciation to Michael Baumgartner, Roseau, MN for providing use of two acres of his certified Palaton reed canarygrass seed production field for the three years this research was conducted.

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