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# CHEMICAL MANIPULATION OF GRASS SEED CROPS

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**Abstract.** The seed yield potential established at anthesis in grass seed crops is usually 5-10 times greater than actual seed yields realised at harvest. Losses in seed yield between anthesis and harvest result primarily from the death of fertile tillers and poor seed site utilisation.

Lodging has been identified as one of the most important factors reducing seed yields, and the use of growth retardants has significantly increased seed yield in perennial ryegrass and tall fescue. The effects of the growth retardant paclobutrazol on the growth, development and seed yield of perennial ryegrass *(Lolium perenne)* are presented and discussed.

Little is known of the effects of leaf and stem diseases on grass seed yields. Recent research has found that fungicide application can substantially increase seed yield in perennial ryegrass through delaying senescence of leaf tissue. Increased leaf area duration is associated with a reduction in seed abortion, resulting in more seeds per spikelet at harvest. The possibilities for fungicide use in the crop are discussed.

**Keywords:** Seed production, grasses, fertile tillers, seed abortion, growth retardants, paclobutrazol, fungicide, senescence.

## INTRODUCTION

Yield in grass seed crops can be divided into two stages:

### a) Establishment of the yield potential

Yield potential is defined as the number of florets per unit ground area of the crop at anthesis, and is dependant on the number of fertile tillers and the number of florets per fertile tiller. Recent reviews by Langer (1980) and Hebblethwaite et *al.* (1980) have discussed management practices which influence the establishment of yield potential.

### b) Utilisation of the yield potential

Utilisation of yield potential is determined by events at and after anthesis: the developmental processes of pollination, fertilisation and seed growth which determine the number of seeds per spikelet and mean seed weight. The effects of conventional management practices and the environment on these processes have also been recently discussed (Hill, 1980; Hampton and Hebblethwaite, 1983).

By determining the number of floret sites per unit ground area at anthesis, and assuming that each one has the capacity to set a seed of mean weight, a number of workers have calculated theoretical potential yields for herbage grasses, e.g., 5-8 t/ha for perennial ryegrass (Hebblethwaite *et al.,* 1980), 5 t/ha for Italian ryegrass (Griffiths *et al.,* 1973), 2 t/ha for tall fescue (from Albeke *et al.,* 1983a). However, actual yields are usually substantially less than these theoretical potentials (e.g., Table 1) and physiologically two reasons can be identified for this — a loss of fertile tillers, and poor seed site utilisation.

**TABLE 1** Potential and actual seed yield components of perennial ryegrass cv. Nui, 1983/84, Palmerston North.

| Potential yield components: | | | | |
|---|---|---|---|---|
| Max[m] fertile tiller number/m[2] | at anthesis: spikelets per tilller | at anthesis: florets per spikelet | TSW[1] g | Yield t/ha (calc.) |
| 1,843 | 22.9 | 6.1 | 1.9 | 5.31 |
| **Actual yield components:** | | | | |
| fertile tillers/m[2] | at final harvest: spikelets per tiller | at final harvest: seeds per spikelet | TSW g | Actual yield t/ha |
| 1,310 | 22.6 | 1.7 | 1.9 | 0.96 |

[1]Thousand seed weight at final harvest used to calculate potential yield.

Recent work has demonstrated that lodging of grass seed crops is one of the major factors limiting seed yield (Hebblethwaite *et al.*, 1978), and the potential for chemical manipulation of grass seed crops, particularly the use of growth retardants, is being evaluated. This paper discusses some' recent findings.

## GROWTH RETARDANTS

Significant seed yield increases resulting from growth retardant application have been reported to date for perennial ryegrass (Hebblethwaite *et* al., 1982; Hampton and Hebblethwaite 1985a), tall fescue (Albeke *et al.*, 1983a) and fine fescue (Albeke *et al.*, 1983b). Responses differ depending on rate and time of application (Table 2 and 3), site and season (Hampton and Hebblethwaite, 1985a), and nil responses have been recorded (K.R. Brown, pers. comm.).

**TABLE** 2 The effect of paclobutrazol application at spikelet initiation on perennial ryegrass seed yield.

| Application rate kg a.i./ha | 1982 (U.K.)' Seed yield g/m² | % increase | 1983/84 (N.Z.)' Seed yield g/m² | % increase |
|---|---|---|---|---|
| 0 | 111.3 | | 165.7 | |
| 1.0 | 222.8 | 100 | 272.5 | 64 |
| 2.0 | 256.3 | 130 | 288.0 | 74 |
| s.e. diff. | 11.2** | | 14.1* | |

[1]Hampton and Hebblethwaite (1985a);
[2]McCloy (unpublished data).

**TABLE** 3 The effect of time of paclobutrazol application on tall fescue seed yield', 1980 (USA).

| | Application time | | | |
|---|---|---|---|---|
| | Spikelet Initiation | | Floret Iniation | |
| Application rate kg a.i./ha | Seed yield g/m² | % increase | Seed yield | % increase |
| 0 | 18.9 | | 18.9 | |
| 0.75 | 119.8 | 52 | 129.8 | 65 |
| 1.5 | 137.6 | 59 | 101.0 | 28 |

'Albeke et al. (1983a).

A number of chemicals have been evaluated, but most research results published have been for paclobutrazol = PP333 (ICI, Plant Protection Division, plc). This compound is soil active, xylem-mobile, and inhibits gibberellin biosynthesis (Shearing and Batch, 1982), which leads to a reduction in culm length through inhibition of node elongation, particularly the first and second nodes. The following discussion refers to the effects of paclobutrazol in perennial ryegrass seed crops.

### Lodging

The effect of paclobutrazol on crop lodging is dependant on application rate and timing. When applied at spikelet initiation (beginning of stem elongation), the crop can be kept upright until after anthesis, or until final harvest (Table 4), although the latter response may well be detrimental to seed yield, especially in windy environments.

**TABLE** 4 Effect of paclobutrazol application at spikelet initiation on lodging in perennial ryegrass cv.S24[1].

| Application rate kg ai/ha | Lodging score* at ear emergence | at anthesis | at harvest |
|---|---|---|---|
| 0 | 4.5 | 6.5 | 10.0 |
| 1.0 | 0 | 0.5 | 4.0 |
| 2.0 | 0 | 0 | 0 |

'Hampton (1983)
*based on a scale of 0 = upright, 10 = completely flat

### Yield components

Yield component responses to paclobutrazol application differ with season and time of application. For example, Hebblethwaite *et al.* (1982) found' that the number of seeds per spikelet accounted for 73% of seed yield variance when paclobutrazol was applied at floret initiation (FI) whereas Clemence (unpub. data) found that with spikelet initiation (SI) application, seed yield increases were best explained by increased fertile tiller number. Hampton and Hebblethwaite (1985a) found that yield responses were a result of both increased fertile tiller number and an increase in the number of seeds per spikelet (Table 5).

**TABLE** 5 Effect of paclobutrazol applied at spikelet initiation on seed yield components, cv.S24, 1982'.

| Application rate kg.ai/ha | fertile tillers/m' | spikelets per tiller | seeds per spikelet | thousand seed weight (g) |
|---|---|---|---|---|
| 0 | '2,468 | 20.7 | 1.19 | 1.85 |
| 1.0 | 3,096 | 20.6 | 1.89 | 1.77 |
| 2.0 | 3,285 | 20.3 | 2.21 | 1.76 |
| s.e. diff (15 d.f.) | 282.0* | 0.7 | 0.18** | 0.06 |

'Hampton and Hebblethwaite (1985a).

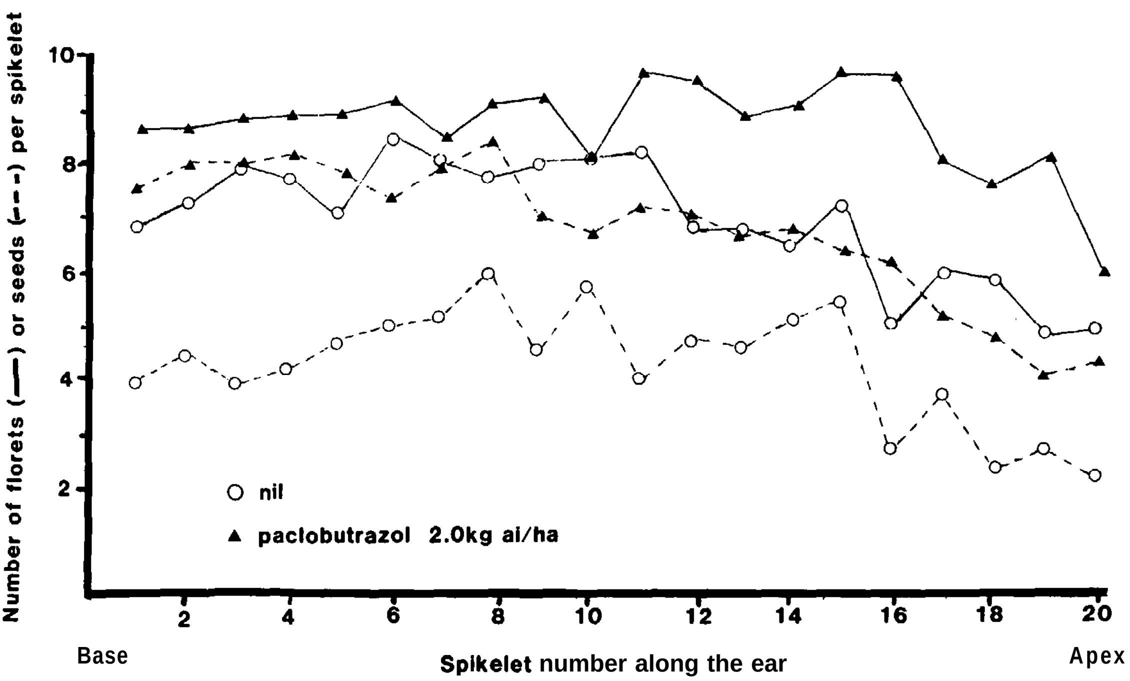


FIGURE 1. The effect of paclobutrazol application on the number of florets and the number of seeds within each spikelet of the ear at one harvest date (1.7.82).

***Fertile tiller number***

Hebblethwaite *et al.* (1980) considered that prevention of lodging would decrease fertile tiller death by reducing competition for light and nutrients. However, Hampton and Hebblethwaite (1985a) showed that fertile tiller survival did not differ markedly between lodged and non-lodged plots, and that differences at final harvest resulted from increased tiller production following paclobutrazol application. Paclobutrazol is known to reduce apical dominance and hence increase tillering, the response being greatest when the growth retardant is applied early in the phase of tiller development (Froggatt *et al.*, 1982). Hampton and Hebblethwaite (1985a) found the SI application resulted in more fertile tillers than did FI application, and Hebblethwaite *et al.* (1982) found that with FI application, fertile tiller numbers did not differ from those of untreated plots.

***Seeds per spikelet***

Paclobutrazol application at SI altered the distribution of florets and seeds per spikelet in cv.S24 (Figure 1), and more seeds were retained at each spikelet position from the base to the apex of the ear. The weight and germination of seeds from terminal spikelets was increased by paclobutrazol. $^{14}C$ studies showed that in untreated plants, assimilate recovery was significantly reduced from the terminal section of the ear, while in paclobutrazol treated plants no difference in assimilate recovery were found between basal, intermediate or terminal ear sections (Hampton and Hebblethwaite, 1985b).

Hebblethwaite et *al.* (1980) suggested that reductions in the number of seeds per spikelet associated with lodging of the crop resulted primarily from abortion of developing seeds, because insufficient assimilate was available to satisfy the demands of seed growth at all pollinated sites. Recent results have offered support for this theory:

(i) Lodging has been shown to restrict light interception and reduce the efficiency of photosynthesis (de Wit, 1965), and Woledge (1972) showed that shading of photosynthetic tissue reduced the longevity of grass leaves and increased the rate of decline of net photosynthesis in response to age. Prevention of lodging by paclobutrazol application increased the photosynthetic area of reproductive tillers from anthesis through to final harvest in cv.S24, and increased reproductive leaf area duration by 13-15 days in the two seasons monitored (Hampton and Hebblethwaite, 1985a). A greater photosynthetic capability, either because of increased photosynthetic area, or possibly increased net photosynthesis rate, (Jaggard *et* al., 1982), would allow paclobutrazol treated plants to better supply the demands for assimilate from the various competing sinks.

(ii) Vegetative tillers present in the ryegrass seed crop can compete strongly with the developing ears for assimilate exported from the leaves and stem (Hampton, 1983; Clemence and Hebblethwaite, 1984). For example, when the flag leaf was fed with $^{14}CO_2$ 17 days after anthesis in cv.S24, 11% of the assimilated $^{14}C$ exported was recovered from the ear, and 61% recovered from vegetative tillers . in lodged plants, while in paclobutrazol treated plants 31% of the assimilated $^{14}C$ was recovered from the ear and only 16% from vegetative tillers (Hampton, 1983). Because the crop does not lodge, paclobutrazol treatment may reduce the number, of vegetative tillers produced after anthesis, but in the season reported above, equal numbers of vegetative tillers were present in lodged and non-lodged plots. While it appears that the ear in paclobutrazol treated plants is able to compete more strongly for assimilate than that in lodged plants, regrowth tillering tends to dominate the assimilate supply from all sources except the ear in the final stages of crop growth (Hampton and Hebblethwaite, 1985b). Any treatment which could slow down or suppress the formation of such tillers would be of benefit for seed production.

(iii) During stem elongation, the ear and stem are in direct competition for available assimilate, and Clemence and Hebblethwaite (1984) found that in lodged plants, the ear was exporting assimilate to the elongating stem. The importance of the stem as a sink for assimilate exported from the flag leaf is also well documented (Ong *et al.,* 1978). Paclobutrazol reduces stem size, and Hebblethwaite *et al.* (1982) suggested that this reduction in stem sink capacity may, through reduced competition, allow more seeds to be retained per spikelet. This hypothesis has yet to be confirmed, and the precise nature of the relationship between the sinks in reproductive *Lolium perenne* still remains unclear. Further assimilate distribution studies are required.

*Thousand seed weight*

Although differences have not been significant, the seed weight from paclobutrazol treated plants has often been lower than that from untreated plants (e.g., Table 5). One reason for this is that early paclobutrazol application allows the maturation of increased numbers of spring initiated fertile tillers which tend to have smaller seeds (Langer, 1980). Also, seed weight is often negatively correlated with the number of seeds per spikelet, suggesting that assimilate supply is not great enough to meet the extra demands of the increased numbers of seeds in ears of growth retardant treated plants.

**The future**

At present, growth retardants are not registered for use in grass seed crops. Although paclobutrazol is to be-registered for use in USA in 1985, a decision has not as yet been made for New Zealand (W.F. Leonard, pers. comm.), one of the problems being that the compound has soil residual activity which could affect succeeding crops (Hampton and Hebblethwaite, 1985a), and data are being collected for application rates lower than those previously evaluated. Work in U.K. (Hampton 1983) and New Zealand (Clemence, unpub. data) has shown that another experimental growth retardant, EL500 (Elanco Ltd) has produced yield responses in perennial ryegrass similar to those reported for paclobutrazol, but the future of this chemical is not known. Work is currently underway re-evaluating the effects of chlormequat chloride (CCC) in herbage seed crops, after McCloy (unpub. data) recorded an economic yield response (+ 164 kg/ha) in G. Nui in the 1983/84 season. Further New Zealand research is evaluating the potential for growth retardants in other grass seed crops, such as prairie grass, cocksfoot, tall fescue, paspalum and phalaris (K.R. Brown, J.G. Hampton, M.P. Rolston, unpub. data).

## FUNGICIDES

Latch (1980) suggested that over the last twenty years, diseases have not greatly affected the yield and quality of herbage seeds harvested in New Zealand, but as Labruyere (1980) commented, the specific diseases of grass grown for seed are a neglected field of study, and little is known of their importance. Latch (1980) considered that rust, particularly stem rust (*Puccina graminis* Pers.) was the most important disease of ryegrass, cocksfoot and timothy, and work is currently underway to quantify the effects of this pathogen on grass seed production (R.E. Falloon, pers. comm.).

Recent work has, however, investigated the effects of fungicide application to the ryegrass seed crop. Hebblethwaite et al. (1980) suggested that death of fertile tillers in a lodged ryegrass crop was a result of rotting at the stem base, and that lodging created a microclimate favourable to the growth of both pathogenic and saprophytic fungi (Griffiths, 1969) which may also affect seed yield. The following discussion refers to results obtained in U.K. (Hampton and Hebblethwaite, 1984) and in New Zealand (Hampton, unpub. data) using a broad spectrum fungicide mixture (triadimefon 6.25%, carbendazim 10%, captafol 40%) applied at 2 kg product/ha in 250 litres water.

**Seed yield and yield components**

Hampton and Hebblethwaite (1984) found that fungicide application at monthly intervals from spring tillering until seed harvest increased seed yield of perennial ryegrass cv.S24 by 15% in 1981 (6 applications) and 43% in 1982 (5 applications). Further work in New Zealand (Table 6) produced a similar response in cv. G. Nui in the 1983/84 season. In all three trials, the seed yield increase was accounted for by an increase in the number of seeds per spikelet and small increases in thousand seed weight (Table 6) (Hampton and Hebblethwaite, 1984). Tiller numbers did not alter significantly.

**TABLE** 6 The effect of fungicide application on seed yield and yield components of perennial ryegrass cv. Nui, 1983184.

| Treatment | seed yield g/m² | fertile tillers/m* | spikelets per tiller | seeds per spikelet | thousand seed weight (g) |
|---|---|---|---|---|---|
| Nil | 82.6 | 1,111 | 22.4 | 1.73 | 1.89 |
| ear [1] | 115.5 | 1,117 | 22.9 | 2.28 | 2.09 |
| full' | 123.1 | 1,092 | 22.1 | 2.55 | 2.10 |
| s.e. diff (10 d.f.) | 10.2** | 189.2 | 0.46 | 0.11** | 0.14 |

'2 applications on 13.10.83 and 15.11.83
²4 applications on 28.9.83, 13.10.83, 15.11.83, 15.12.83

**Pathogens**

The incidence of leaf pathogens in 1981 and 1982 was low, and only rarely was more than 10% of any leaf area infected at any time during the growing season. Similarly in New Zealand, no leaf pathogens were recorded, and stem rust did not appear in the crop until mid December, reaching a maximum of 7% of tillers infected in untreated plots.

**Leaf senescence**

The major effect of fungicide application was in delaying leaf senescence. At anthesis in all three trials, sprayed plots had double the amount of reproductive leaf dry matter (Table 7) and monitoring in the U.K. trials showed that leaf area duration was increased by 8 days in 1981 and 14 days in 1982 (Hampton and Hebblethwaite, 1984). Leaf area duration accounted for around 56% of the variation in seed yield recorded in both these years, and delay in ieaf tissue senescence accounted for 78% of the variation in leaf area duration (Hampton and Hebblethwaite, 1984).

**TABLE** 7 The effect of fungicide application on reproductive leaf dry matter accumulation (g/m*) at anthesis and final harvest.

| | Treatment | Anthesis | Final Harvest |
|---|---|---|---|
| 1981' | Nil | 55 | 0 |
| | Full | 127 | 1 |
| | s.e. diff (15 d.f.) | 16.4** | 0.1 |
| 1982' | Nil | 45 | 1 |
| | Full | 100 | 19 |
| | s.e. diff (12 d.f.) | 15.8"" | 4.9** |
| 1983 | Nil | 43 | 1 |
| | Full | 84 | 9 |
| | s.e. diff (10 d.f.) | 10.6** | 3.2* |

'Hampton and Hebblethwaite (1984).

At anthesis in each of the trials, no differences in yield potential existed between treatments, yet at final harvest, the number of seeds per spikelet was significantly reduced in untreated plots. In the absence of fungicide, greater abortion of developing seeds occurred. These results support the assimilate shortage theory proposed by Hebblethwaite et *al.* (1980) to explain seed abortion losses in lodged ryegrass crops.

Delayed senescence of leaf tissue after fungicide application has been reported in other crops, and the topic has been discussed recently by Hampton and Hebblethwaite (1984). There appear to be two possible explanations — one is that fungicide application has a direct effect on leaf microflora which play an active part in the senescence process (Dickinson, 1973); the second is that carbendazim has been shown to delay senescence by retarding the breakdown of chlorophyll (Staskawicz et al., 1978).

The results reported are not a recommendation for five or six applications of fungicide to a ryegrass seed crop. However, they have given a lead as to the possibility of using critically timed applications to produce an economic response in seed yield. It is becoming apparent that assimilate production and storage between ear emergence and anthesis has a big influence on subsequent seed yield, and further research is progressing to confirm this. Fungicide application to prolong the active photosynthetic life of plant tissue over this period, whether by delaying senescence, controlling pathogens, or both, may well be a mangement tool for the future, in perennial ryegrass and other grass seed crops.

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## DISCUSSION

Q. ***What are the least susceptible crops a farmer could grow following a previous application of growth regulator?***

A. Carry over effects are not serious in establishing pasture. Tiller lengths of cereals will be reduced. (Brassica crops are very susceptible to carry over effects).

Q. ***At what rate and at what time should growth regulator be applied to have minimum carry over effect?***

A. A rate of 0.75-1.00 1 a.i. at spikelet initiation is recommended i.e. end of August to early September.

Q. ***Do other growth regulators such as Mefluidide have similar effects to PP333?***

A. Mefluidide tends to have the reverse effect in that it inhibits seedhead formation and hence seed production.

Q. ***Do growth regulators reduce root as well as foliage growth?***

A. PP333 increases root growth by up to 25% above control plants.

Q. ***Have you followed through the carry over residual effects of growth regulators on second year herbage seed yields?***

A. No. All the work has been done on single year crops.

Q. ***Will growth regulators affect grazing before closing date for seed production?***

A The growth regulator is applied after the paddock is closed and therefore will not affect grazing.

Q. ***Are crops delayed in their maturity with growth regulators?***

A With 2.0 kg ai/ha of PP333 maturity is delayed three to five days over control plots.