# Effect of Time of Fungicide Application on the Second Harvest Seed Yield of Five Cocksfoot (*Dactylis glomerata* L.) Cultivars

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## ABSTRACT

The effects of time of fungicide application on seed yield and its components were determined for second harvest plots of three New Zealand (Grasslands Wana, Grasslands Kara, Grasslands Tekapo) and two Japanese (Akimidori, Makibamidori) cocksfoot (*Dactylis glomerata* L.) cultivars. Tebuconazole (188 g a.i. ha$^{-1}$) was applied either at ear emergence, at ear emergence plus anthesis, and anthesis plus 10 days post anthesis. Disease incidence was <1% for all cultivars, but fungicide treatments significantly increased the percentage green area of the flag leaf, leaf two and leaf three, plus the stem. Seed yield was significantly increased by the ear emergence fungicide application in cv. G. Wana, G. Tekapo and Makibamidori, and by the ear emergence plus anthesis applications in cv. G. Wana, G. Kara, Akimidori and Makibamidori. These yield increases ranged from 14% (cv. G. Kara) to 43% (cv. Makibamidori), and were associated with increased floret site utilisation and increases in thousand seed weight, although these responses were not consistent for all treatments or cultivars.


*Additional index words:* floret site utilisation, green area, seed yield components, tebuconazole.

## INTRODUCTION

In New Zealand, three leaf and/or stem diseases, stripe rust (caused by *Puccinia striiformis* Westend var. *dactylidis* Manners), stem rust (caused by *P. graminis* Pers.) and leaf fleck (caused by *Mastigosporium rubricosum* (Dearn. and Barth. Nannefeldt) are considered to cause trouble in cocksfoot (*Dactylis glomerata* L.) seed production (Skipp and Hampton, 1996), although no quantitative data exist (Latch, 1980). Both Rolston, Hampton, Hare and Falloon (1989) and Wilson, Hampton, Hill and Rolston (1994) have investigated the effect of leaf and stem pathogens on cocksfoot seed yield, but in both trials disease incidence was very low; Wilson *et al.* (1994) for example found stripe rust and leaf fleck infection to be <5% and <1% respectively. However, both sets of authors reported significant seed yield increases following fungicide application. Rolston *et al.* (1989) recorded a 21% seed yield increase in cv. Grasslands Wana, while Wilson *et al.* (1994) recorded seed yield increases ranging from 0 to 101% depending on cultivar. In both trials, this seed yield response was associated with delayed leaf senescence, as green leaf area was significantly increased.

Cocksfoot is slow to establish and seed yields are usually greater in the second harvest year (Niemelainen, 1991) because tiller density is greater. Wilson *et al.* (1994) reported the effects of fungicide application to five cocksfoot cultivars in the first harvest year. In this paper we discuss the effects of time of fungicide application on cocksfoot seed yield and its components in the second harvest of the five cultivars at the same site.

## MATERIALS AND METHODS

The trial was carried out at the AgResearch Grasslands lowland research station near Palmerston North (lat. 40°S) on a Holocene siliceous sandy alluvium soil (Kairanga silt loam). Plots of the five cultivars (Grasslands Wana, Kara and Tekapo, New Zealand; Akimidori and Makibamidori, Japan) had been established following spring (October 1991) and autumn (April 1992) sowings. Details of management up to and including the first seed harvest are provided in Wilson *et al.* (1994).

For the 1993/94 experiment there were 16 plots of each cultivar. Plot size was 3 x 1.2 m. At the end of January 1993 following the first seed harvest, all plots were cut to ca. 5 cm using a rotary mower, and the cut vegetation was removed. Urea (50 kg N ha$^{-1}$) was applied on 25 March, and the plots were then left until 3 August when they were cut back to 10 cm and the cut vegetation was removed. A further 75 kg N ha$^{-1}$ (as urea) was applied on 28 September.

The fungicide tebuconazole was applied at 188 g a.i. ha$^{-1}$. The four treatments were nil, one application at ear emergence (10% of ears emerged), two applications at ear emergence plus anthesis (10% of ears with anthers extruded), and two applications at anthesis plus 10 days after full anthesis (Table 1). Each treatment was replicated four times for each cultivar. A gas pressurised knapsack sprayer which delivered 330 l ha$^{-1}$ was used to apply the fungicide.

On 15 December a 50 cm length of a randomly selected inner row was chosen in each plot and the number of fertile tillers recorded. Twenty tillers were then removed from each plot and florets per tiller determined (Wilson, 1995), as was disease incidence and green leaf area of the flag leaf, leaf 2, leaf 3 and stem (Wilson *et al.*, 1994). Seed was harvested on 23 December (cv. Akimidori), 1 January (cv. G. Tekapo) and 6

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January (cv. G. Wana, G. Kara and Makibamidori) by hand cutting all seed heads from each plot when seed moisture content (SMC) was 40%. Seed heads were placed in hessian bags and ambient air dried to a SMC of 14% before being threshed using a belt thresher. Seed lots were air screen cleaned and from a subsample, pure seed (ISTA, 1996) and inert matter separated by air blast (12 km $h^{-1}$) using a Micro-blower type 35 (ISTA, 1996). The pure seed data were then used to calculate pure seed yield. Floret site utilisation (FSU) was calculated by dividing the number of seeds (from the pure seed yield) by the number of florets and multiplying by 100. Cleaning losses were calculated by subtracting the pure seed yield from the yield after air screen cleaning and dividing by the yield after air screen cleaning. Thousand seed weight was determined using internationally agreed methodology (ISTA, 1996).

However, pure seed yield was significantly increased by the ear emergence fungicide application in cv. G. Wana, G. Tekapo and Makibamidori, and by the ear emergence plus anthesis application in cv. G. Wana, G. Kara, Akimidori and Makibamidori. The anthesis plus post anthesis applications did not significantly increase seed yield for any cultivar (data not presented). The yield increases recorded ranged from 14% (cv. G. Kara) to 43% (cv. Makibamidori).

Cleaning losses ranged from 20 to 29% within the three New Zealand cultivars, and did not differ for cultivar or fungicide. Losses were only 7% for cv. Makibamidori, and highest for cv. Akimidori, where fungicide application increased cleaning losses (Table 3).

**Table 1. Fungicide application dates for the ear emergence, anthesis and post anthesis treatments.**

| Cultivar | Ear Emergence | Anthesis | Post Anthesis |
|---|---|---|---|
| G. Wana | 2 Nov. | 30 Nov. | 10 Dec. |
| G. Kara | 2 Nov. | 30 Nov. | 10 Dec. |
| G. Tekapo | 27 Oct. | 26 Nov. | 6 Dec. |
| Akimidori | 9 Oct. | 9 Nov. | 19 Nov. |
| Makibamidori | 1 Nov. | 28 Nov. | 9 Dec. |

## RESULTS

Disease incidence was low, <1% for all cultivars, and data are not presented. The green area of the flag leaf was significantly increased by all three fungicide treatments in all five cultivars (Table 2), the one exception being the anthesis/post anthesis application in cv. G. Kara. The same fungicide timing/cultivar response was recorded for leaf 2 (data not presented), while for leaf 3, the first two fungicide treatments increased GA in all five cultivars, but the anthesis/post anthesis treatment did not in cv. G. Wana and G. Kara (Table 2). Stem GA was also increased by the fungicide treatments in all cultivars (data not presented). The ear emergence/anthesis applications produced the greatest GA of all three leaves for all five cultivars (Table 2). There were significant fungicide x cultivar interactions for the GA of all three leaves and the stem, with the greatest response coming from cv. Akimidori.

Fungicide application had no significant effect on the number of fertile tillers or florets per tiller (data not presented).

Thousand seed weight was increased by the first two fungicide treatments for cv. Tekapo and Makibamidori, and by the ear emergence plus anthesis treatment for cv. G. Kara, G. Tekapo, Akimidori and Makibamidori, but did not differ for cv. G. Wana (Table 3). Floret site utilisation varied among cultivars, was reduced by the ear emergence plus anthesis fungicide application in cv. G. Kara, but was significantly increased by the first two fungicide treatments in cv. G. Wana, G. Tekapo and Makibamidori, and by the ear emergence treatment in cv. Akimidori (Table 3). Neither TSW nor FSU were increased by the anthesis plus post anthesis fungicide treatment (data not presented).

## DISCUSSION

For the first seed harvest of these five cocksfoot cultivars, Wilson *et al.* (1994) recorded seed yields ranging from 311

Table 2. Effect of fungicide application on green area of five cocksfoot cultivars (assessed 5 December).

| **Cultivar** | **Fungicide[1]** | | | |
|---|---|---|---|---|
| | **nil** | **ear** | **ear/anth** | **anth/post** |
| **1. Flag leaf** | | | | |
| G Wana | 63 | 78 | 85 | 69 |
| G. Kara | 61 | 72 | 79 | 61 |
| G Tekapo | 42 | 59 | 69 | 48 |
| Akimidori | 7 | 49 | 55 | 35 |
| Makibamidori | 24 | 56 | 67 | 40 |
| LSD P<0.05 cultivar = 3.5; fungicide = 3.2. Pr >F (cv. x fung) = 0.001 | | | | |
| **2. Leaf 3** | | | | |
| G. Wana | 41 | 58 | 78 | 44 |
| G. Kara | 36 | 43 | 63 | 39 |
| G. Tekapo | 11 | 35 | 40 | 30 |
| Akimidori | 2 | 6 | 23 | 15 |
| Makibamidori | 6 | 15 | 54 | 16 |
| LSD P <0.05 cultivar = 3.8; fungicide = 3.4. Pr> (cv. x fung) = 0.001. | | | | |

[1] *For treatments see Table 1.*

kg ha$^{-1}$ for cv. Makibamidori to 712 kg ha$^{-1}$ for cv. G. Wana. Seed yields from the second year harvest were from 57% (G . Tekapo) to 115% (G. Kara, Makibamidori) greater than in the first season, because fertile tiller numbers had increased by between 70 to 190% (Wilson, 1995). As in the first season, cocksfoot leaf and stem diseases failed to develop, possibly because temperatures at the site were from 1.5 to 3.0°C lower than the 20 year average in September, and 0.5 to 1.0°C lower in October, while rainfall in October was 19.3 mm below average (Wilson, 1995). However, fungicide application, particularly at ear emergence and again during anthesis, significantly increased both leaf and stem green area, a result also previously reported in cocksfoot (Rolston *et al.*, 1989; Wilson, *et al.*, 1994).

The delaying of leaf senescence after fungicide application and an increase in grass seed yield is now well documented (Hampton and Hebblethwaite, 1984; Hampton, 1986; Horeman, 1989; Rolston *et al.*, 1989; Wilson *et al.*, 1994) and Warringa (1997) suggested that this may result from seeds having a longer growth duration. However Horeman (1989) found that seed ripening in perennial ryegrass (*Lolium perenne* L.) was not affected by fungicide application, and in the present cocksfoot trial, the time difference between achieving 40% SMC for the control and fungicide treated plots was only 24 h (Wilson, 1995).

Warringa (1997) also suggested that the effects of fungicides in such situations could be attributable to a slight increase in

**Table 3. Effect of fungicide application on pure seed yield, cleaning losses, thousand seed weight (TSW) and floret site utilisation (FSU) of five cocksfoot cultivars.**

| Cultivar | Fungicide[1] | Pure Seed yield (kg ha$^{-1}$) | Cleaning losses[2] (%) | TSW (g) | FSU (%) |
|---|---|---|---|---|---|
| G Wana | nil | 1133 | 29 | 0.61 | 20.8 |
| | ear | 1337 | 26 | 0.61 | 25.5 |
| | ear/anth | 1462 | 26 | 0.63 | 25.5 |
| G. Kara | nil | 1208 | 21 | 0.76 | 22.3 |
| | ear | 1203 | 21 | 0.78 | 22.2 |
| | ear/anth | 1383 | 20 | 0.85 | 19.3 |
| G. Tekapo | nil | 915 | 23 | 0.73 | 15.6 |
| | ear | 1125 | 23 | 0.77 | 20.0 |
| | ear/anth | 979 | 23 | 0.78 | 18.8 |
| Akimidori | nil | 556 | 34 | 0.79 | 11.9 |
| | ear | 645 | 41 | 0.81 | 14.4 |
| | ear/anth | 669 | 44 | 0.86 | 12.6 |
| Makibamidori | nil | 671 | 7 | 0.71 | 14.2 |
| | ear | 858 | 9 | 0.79 | 16.5 |
| | ear/anth | 958 | 6 | 0.80 | 16.6 |
| LSD P<0.05 | cultivar | 125 | 7.3 | 0.03 | 2.09 |
| LSD P<0.05 | fungicide | 111 | 8.6 | 0.03 | 1.87 |
| Pr>F | (cv. x fung) | NS | NS | NS | 0.13 |

[1] *For treatments see Table 1. Data for the anthesis/post anthesis application not included as seed yield, TSW and FSU did not differ from the control for all cultivars.*

[2] *Material harvested but removed during air blast cleaning.*

the dry weight of many seeds that would otherwise have been too light and therefore lost during seed cleaning ie. a small increase in assimilate partititioning could have a more than proportional effect on seed yield. Whether this is what occurred in this trial is difficult to determine. Fungicide treatments certainly did not reduce the cleaning losses, and in one cultivar actually increased them. Cleaning losses in the context of this experiment refer to the material (inert matter and immature ("light") seeds) removed from the pure seed after blowing at an internationally agreed pressure for 3 minutes (ISTA, 1996). Thousand seed weight was increased by the ear emergence and/or ear emergence plus anthesis fungicide application in all cultivars except G. Wana, which supports the suggestion of Warringa (1997). However, the relationship between TSW and seed yield was significant only for cv. G. Kara ($R^2 = 0.474^*$) and Makibamidori ($R^2 = 0.315^*$), and only for the former cultivar was the yield increase fully accounted for by the increase in TSW.

The seed yield increases in cv. G. Wana, G. Tekapo and Makibamidori were more strongly associated with better FSU ($R^2 = 0.730^*$, $0.821^*$, $0.583^*$ respectively), there being no significant relationship for the other two cultivars. This again implies that at least for three of the cultivars, the response to fungicide application was because more seeds were able to achieve a size by which they passed successfully through the cleaning process and therefore contributed to pure seed yield.

These results have presented more questions than answers. While leaf senescence was significantly delayed by fungicide application, the relationships between green leaf area and seed yield, and green leaf area and FSU were either not significant (cv. G. Tekapo and Akimidori) or not strong ($R^2$ ranging from $0.303^*$ to $0.509^*$). Seed yield increases were mostly accounted for by increased TSW in cv. G. Kara, by better FSU in cv. G. Wana and G. Tekapo and by a combination of both in the two Japanese cultivars. Warringa (1997) concluded that assimilate supply does not limit seed yield, but the partitioning of assimilates to the seed does, and that seed yield could be increased by an increased rate and/or duration of carbon assimilate partioning to the seeds. For cocksfoot the evidence suggests that an increased seed growth duration did not occur, although this would need to be confirmed by a detailed seed development study. A greater seed growth rate following fungicide application has been reported for barley (Cochrane, 1996) and suggested for perennial ryegrass (Warringa, 1997). It is probable that this also occurred in cocksfoot and was expressed either by increased TSW and/or improved FSU.

However, this requires confirmation. What is clear is that this response only occurred when fungicide was applied at ear emergence or ear emergence plus anthesis. Delaying fungicide application until anthesis followed by a further application 10 days later did not increase seed yield, TSW or FSU.

Warringa (1997) found that in perennial ryegrass the main factor determining seed growth rate and hence size, was the dry weight of the ovule at anthesis. If there is competition between the elongating stem and developing ear (Ryle, 1970; Warringa, 1997) then it is possible that helping the plant to extend its photosynthetic activity by delaying senescence (or controlling leaf pathogens) at this time may increase resources for the developing ear and allow ovules to achieve a greater dry weight at anthesis. This hypothesis should be considered in future research.

Welty (1989) noted that cost-benefit ratios must be evaluated carefully before deciding whether fungicide applications are economic in cocksfoot. In the first year seed crop Wilson *et al.* (1994) reported that fungicide (propiconazole) application at anthesis plus post anthesis was cost effective for all cultivars except Akimidori. In the second season, with a seed price of approximately NZ\$3.0 $kg^{-1}$ and single fungicide application cost of NZ\$70.50 $ha^{-1}$, a single application at ear emergence increased returns by over \$500 $ha^{-1}$ in cv. G. Wana, G. Tekapo and Makibamidori, and by \$200 $ha^{-1}$ for Akimidori, but there was a net loss for cv. G. Kara. The double application (ear emergence plus anthesis) increased returns for all five cultivars (from \$50 $ha^{-1}$ for cv. G. Tekapo to \$850 $ha^{-1}$ for cv. G. Wana). For three of the cultivars (G. Wana, G. Kara and Makibamidori) the double application provided a greater financial return than the single application, but there was no advantage for G. Tekapo and Akimidori.

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## REFERENCES

1. Cochrane, M.P. 1996. Effects of foliar applications of fungicides during plant growth on grain development and grain germinability in spring barley. *Annals of Applied Biology* 128: 21-55.

2. Hampton, J.G. 1986. Fungicidal effects on stem rust, green leaf area, and seed yield in 'Grasslands Nui' perennial ryegrass. *New Zealand Journal of Experimental Agriculture* 14: 1-12.

3. Hampton, J.G., and Hebblethwaite, P.D. 1984. The effect of fungicide application on seed yield in perennial ryegrass cv. S24. *Annals of Applied Biology* 104: 231-239.

4. Horeman, G.H. 1989. Effects of fungicides on perennial ryegrass seed production. *Proceedings of the XVII International Grassland Congress:* 667-668.

5. ISTA, 1996. International rules for seed testing. Supplement to *Seed Science and Technology* 24: 1-331.

6. Latch, G.C.M. 1980. Importance of diseases in herbage seed production. In: Herbage Seed Production (ed. J.A. Lancashire), 36-40, Grassland Research and Practice Series 1, New Zealand Grassland Association, Palmerston North.

7. Niemelainen, O. 1991. Factors affecting panicle production of cocksfoot (*Dactylis glomerata* L.) in Finland. II. Effect of juvenile phase, sowing date and tillering. *Annals Agricuae Fenniae* 29: 231-239.

8. Rolston, M.P., Hampton, J.G., Hare, M.D., and Falloon, R.E. 1989. Fungicide effect on seed yield of temperate forage grasses. *Proceedings of the XVII International Grassland Congress:* 669-670.

9. Ryle, G.J.A. 1970. Distribution patterns of assimilated $^{14}C$ in vegetative and reproductive shoots of *Lolium perenne* and *Lolium temulentum. Annals of Applied Biology* 66: 155-167.

10. Skipp, R.A., and Hampton, J.G. 1996. Fungal and bacterial diseases of pasture plants in New Zealand. In: Pasture and Forage Crop Pathology, (ed. S. Chakraborty *et al.*), 213-236, ASA, CSSA, SSA, Madison, Wisconsin.

11. Warringa, J.W. 1997. Physiological constraints to seed growth in perennial ryegrass (*Lolium perenne* L.). Unpublished PhD Thesis, Landbouwuniveriteit, Wageningen, The Netherlands.

12. Welty, R.E. 1989. The effect of fungicide application on seed yield of *Dactylis glomerata. Proceedings of the XVII International Grassland Congress:* 671-672.

13. Wilson, S.M. 1995. Effect of cultivar, time of sowing and fungicide application on seed yield of cocksfoot (*Dactylis glomerata* L.). Unpublished MApplSc thesis, Massey University, Palmerston North, New Zealand.

14. Wilson, S.M., Hampton, J.G., Hill, M.J., and Rolston, M.P. 1994. Effect of cultivar, time of sowing and fungicide application on seed yield in cocksfoot (*Dactylis glomerata* L.). *Proceedings of the Agronomy Society of New Zealand* 24: 103-108.