Effect of cultivar, time of sowing and fungicide application on seed yield in cocksfoot (*Dactylis glomerata* L.)

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Abstract

Three New Zealand (Grasslands Wana, Grasslands Kara, Grasslands Tekapo) and two Japanese (Akimidori, Makibamidori) cocksfoot cultivars were sown in spring (23 September 1991) and again the following autumn (6 April 1992) at AgResearch Grassland's Aorangi Research Farm in the Manawatu. Seed was sown at 3 kg/ha with a 30 cm row spacing. Plot size was 1.2 x 3.0 m^2, with each plot containing 4 rows. A randomised block design was utilised with 8 replicates of each cultivar for each sowing time. For each cultivar and sowing time four of the eight replicates were sprayed with propiconazole (125 g a.i./ha) on 17 November 1992 and 8 December 1992. Spring sowings outyielded autumn sowings by 230 to 600 kg/ha depending on cultivar. Cv. Wana produced 680 kg seed/ha from the autumn sowing, and cv. Tekapo 230 kg seed/ha, but yields for the other three cultivars were less than 100 kg/ha following autumn sowing. Spring sowing produced yields of 916, 868, 625, 637 and 468 kg/ha for cv. Wana, Tekapo, Kara, Akimidori and Makibamidori respectively. Apart from cv Wana, fungicide application to autumn sown plots did not significantly increase seed yield, and similarly no differences were recorded for spring sown cv. Kara and Akimidori. However fungicide application significantly increased seed yield in cv. Wana, Tekapo and Makibamidori, the increases being 510(+72%), 573(+98%) and 315(+101%) kg/ha respectively.

Additional key words: *seed yield components, propiconazole, fungicide, sowing date, rust, eyespot, green leaf area.*

Introduction

After the ryegrasses, cocksfoot (*Dactylis glomerata* L.) is the next most important of New Zealand's certified herbage seed crops, with a total of 515 t being produced from 1001 ha in the 1993/94 season (MAF, 1994). Two cultivars, Grasslands Wana (390 t) and Grasslands Kara (97 t) made up the bulk of the seed produced, the former cultivar being bred for sheep pastures, while the latter is used for dairy pastures (Rowarth *et al.*, 1991). Although bred for New Zealand conditions, these two cultivars also have potential for use overseas, and exports of cocksfoot seed to countries such as Australia and Chile earned the New Zealand seed trade nearly $600,000 in 1990 (Rowarth *et al.*, 1991).

In the 1991/92 and 1992/93 seasons, yields of both these cultivars averaged around 500 kg/ha (MAF, 1994), although yields of over 1000 kg/ha have been recorded (eg., Rolston, 1991). Factors influencing yields are varied, but leaf diseases can be important, particularly in cool wet seasons (Welty 1989). Rolston *et al.* (1989) reported a 21% increase in cocksfoot seed yield following fungicide application to cv. Grasslands Wana.

Cocksfoot has traditionally been spring sown with the first harvest 15 or 27 months later (Batey 1981), but autumn sown cv. Grasslands Wana has produced seed yields of over 500 kg/ha 10 months after sowing (Rolston, 1991). However few comparative data exist for spring versus autumn sowing.

While the export of seed of New Zealand cocksfoot cultivars continues to increase, there is also a possibility for multiplication and re-export of seed of overseas cultivars, particularly for the Japanese market. Japan uses cocksfoot seed as a component of dairy pastures, but does not produce seed; requirements are met by imports, primarily from USA (both US cultivars and Japanese cultivars multiplied in USA, B McCloy, pers. comm.).

The work reported in this paper therefore had three different objectives:

1. to determine whether seed of two Japanese cocksfoot cultivars, Akimidori and Makibamidori could be produced in New Zealand, and to compare their yields with those of three New Zealand cultivars,

Grasslands Wana, Kara and the recently released Tekapo,
2. to compare seed yields from spring and autumn sowing and
3. to investigate the effect of fungicide application on seed yield and its components.

Materials and Methods

The trial was carried out at the AgResearch Grasslands lowlands research station, Aorangi, near Palmerston North (latitude 40° S), on a Holocene siliceous sandy alluvium soil (Kairanga silt loam). The five cultivars were sown by hand at a rate equivalent to 3 kg/ha on 23 October 1991 (spring sown). Plot size was 3 x 1.2 m, and row width was 30 cm. Each cultivar was replicated eight times in a randomized design. A parallel area was sown on 6 April 1992 (autumn sown), each again using a randomized design with eight replicates of each cultivar.

The trial site was cultivated from a three year old ryegrass/white clover pasture. Following ploughing and a three week fallow, the site was disced and then power-harrowed to prepare the seed bed. After the spring sowing bentazone and clopyralid were applied at a rate of 1440 g a.i./ha and 42 g a.i./ha on 18 December when the cocksfoot plants were at the 3 - 4 leaf stage. Prior to the autumn sowing, plots were sprayed with glyphosate (720 g a.i./ha) and then rotary-hoed to prepare a seedbed. Herbicides and rates were the same as for the spring sowing. On 6 April 1992 an NPKS (8:10:20:2) fertiliser (30 kg/ha) was applied to all plots, and spring sown plots were cut to approximately 5 cm. On 17 September 139 kgN/ha as urea was applied to all plots.

For both the spring and autumn sowings, four randomly selected plots of each cultivar had propiconazole (125 g a.i./ha) applied via a pressurised knapsack sprayer on 17 November 1992 (anthesis) and 8 December 1992 (during seed development). At anthesis a 50 cm length of row was cut at ground level from each row of each plot for assessment of fertile tiller number and florets per tiller. A further 25 randomly selected fertile tillers were removed from each plot for the eye assessment of rust occurrence and green leaf area of the flag leaf, leaf 2, leaf 3 and stem. A percentage key (James, 1971) was used for this purpose. However since the incidence of foliar pathogens was very low (< 5%) only green leaf area data are presented.

Seed was harvested over 26 December - 15 January (depending on cultivar) by hand cutting all seed heads from each plot when seed moisture was about 40 %. Seed heads were placed in hessian bags and ambient air dried to a seed moisture content of approximately 14% before being threshed using a belt thresher. Seed lots were initially air screen cleaned and finally cleaned using a 5.50 mm indented cylinder which separated multiple and single seeds. From the two seed fractions a 1.0 g working sample was obtained for assessment of seed purity (ISTA 1993). Pure seed and inert matter were separated by air blast (12 km/hr) using a Micro-blower type 35. The germination and thousand seed weight (ISTA, 1993) of the pure clean seed were obtained from each fraction.

Data were analysed using a protected LSD (SAS 1994).

Results

Seed yields were significantly greater ($P<0.05$) from spring than autumn sowings for all five cultivars (Table 1). Yields from spring sowings in the absence of fungicide ranged from a low of 311 kg/ha for cv. Makibamidori, to a high of 712 kg/ha for cv. Wana. Seed yield did not differ significantly for the three New Zealand cultivars, and both Japanese cultivars had lower ($P<0.05$) yields than the New Zealand cultivars.

Wana was the only cultivar able to produce a good seed yield (557 kg/ha) following autumn sowing (Table 1). Yields for cv. Kara, Akimidori and Makibamidori

Table 1. Effect of time of sowing and fungicide application on seed yield (kg/ha) of five cocksfoot cultivars.

		Time of sowing	
Cultivar	Fungicide	Spring	Autumn
Wana	-	712	557
	+	1221	807
Kara	-	564	84
	+	685	164
Tekapo	-	582	237
	+	1155	239
Akimidori	-	341	22
	+	300	34
Makibamidori	-	311	33
	+	627	130
LSD P<0.05 fungicide		116.3	124.9
LSD P<0.05 cultivar		183.8	197.6
P > F (F * Cv)		0.009	NS
LSD P<0.05 sowing date (-F)		100.9	
LSD P<0.05 sowing date (+F)		137.6	

were less than 100 kg/ha, while cv. Tekapo produced only 237 kg/ha.

Fungicide application significantly increased seed yield in spring sown cv. Wana, Kara, Tekapo and Makibamidori, but not cv. Akimidori (Table 1). These increases ranged from 21% (cv. Kara) to 102% (cv. Makibamidori). For the autumn sowing, only cv. Wana had an increased ($P<0.05$) seed yield following fungicide application. There was a significant interaction between cultivar and fungicide application for the spring sowing, but not the autumn sowing (Table 1). Sowing date interactions were not significant.

Cultivars differed in their ability to produce fertile tillers (Table 2), the range for spring sowings being from 318 to 651/m^2. Cv. Kara and Makibamidori had significantly fewer fertile tillers/m^2 than the other cultivars. Similarly there was a range in florets/tiller (532 to 817/tiller) and thousand seed weight (Table 2). Of the five cultivars Tekapo had the greatest seed yield potential (49.7 x 10^4 florets/m^2) and Makibamidori the lowest (22.8 x 10^4 florets/m^2). However floret site utilisation (percentage of florets at anthesis containing seeds) was greater ($P<0.05$) in cv. Wana and Kara (34 and 38%) than the other three cultivars (20% or less). Fungicide application appeared to increase fertile tiller number in cv. Tekapo and Akimidori, had no effect on florets/tiller, but significantly increased seed weight for all five cultivars. However, while fungicide application increased floret site utilisation only for cvs. Wana and Makibamidori (Table 2), it significantly increased the green leaf area of both the flag leaf and stem in all five cultivars. There was a significant cultivar x fungicide interaction for TSW (with the greatest response (+ 0.28g) from cv. Akimidori), and the GLA of the flagleaf (with the greatest response (74.9%) from cv. Wana) and the GLA of the stem (with the greatest response (83.8%) from cv. Akimidori).

The ability of the cultivars to produce fertile tillers (Table 3) was variable for autumn sowings, with a range from 90 to 357/m^2 (Table 3). Cv. Wana was the only cultivar capable of producing a reasonable number of fertile tillers. The number of florets/tiller varied significantly ($P<0.05$) among cultivars (559 -1225 florets/tiller) as did the thousand seed weight (Table 3). Cv. Wana achieved the greatest seed yield potential (38 x 10^4 florets/m^2) and the best floret site utilisation (24%) compared to the other four cultivars. Fungicide application had no significant effect on fertile tiller number or number of florets/tiller, but significantly increased thousand seed weight for all five cultivars and increased the floret site utilisation of cvs. Kara and Makibamidori (Table 3). Fungicide application also increased the green leaf area of the flag leaf in cvs. Wana, Tekapo and Makibamidori, while the green leaf area of the stem was increased significantly ($P<0.05$) in all cultivars except cv. Kara. There was a significant cultivar x fungicide interaction for TSW (with the greatest response (+ 0.19g) from cv. Akimidori), and the

Table 2. Effect of cultivar and fungicide treatment on yield components, floret site utilisation and green leaf area of spring sown cocksfoot.

		Seed yield components			% floret		
Cultivar	Fungicide	fertile tillers per m^2	florets per tiller	TSW[1] (g)	site utilization	% green leaf area flag leaf	stem
Wana	-	651	532	0.67	34.3	4.2	84.9
	+	593	507	0.76	56.8	79.1	98.9
Kara	-	325	615	0.81	38.4	32.0	89.9
	+	325	624	0.91	39.2	73.6	96.7
Tekapo	-	609	817	0.77	15.1	15.6	73.7
	+	851	795	0.90	19.3	70.2	98.1
Akimidori	-	440	716	0.78	16.0	0.1	6.3
	+	683	641	1.06	6.4	49.2	90.1
Makibamidori	-	318	718	0.73	20.6	3.3	22.6
	+	283	942	0.88	28.5	74.2	93.9
LSD $P<0.05$ cultivar		97.6	NS	0.03	5.4	5.37	5.00
LSD $P<0.05$ fungicide		154.4	146.5	0.05	8.6	8.49	7.90
Pr > F (Cv * F)		NS	NS	0.0035	0.012	0.0013	0.0001

[1] thousand seed weight

Table 3. Effect of cultivar and fungicide treatment on yield components, floret site utilisation and green leaf area of autumn sown cocksfoot.

		Seed yield components					
		fertile tillers	florets per	TSW[1]	% floret	% green leaf area	
Cultivar	Fungicide	per m^2	tiller	(g)	site utilization	flag leaf	stem
Wana	-	317	1198	0.70	23.8	35.6	88.2
	+	357	1225	0.74	26.0	75.3	97.3
Kara	-	95	619	0.85	16.9	32.2	87.7
	+	90	670	0.90	31.9	35.6	90.2
Tekapo	-	265	819	0.82	12.4	25.6	81.5
	+	281	752	0.88	12.6	46.6	92.7
Akimidori	-	107	559	0.60	6.2	10.0	27.9
	+	103	629	0.79	6.9	14.7	55.7
Makibamidori	-	175	701	0.69	4.2	2.1	33.4
	+	195	708	0.82	11.6	39.7	69.9
LSD P<0.05 cultivar		NS	NS	0.027	3.9	6.82	5.03
LSD P<0.05 fungicide		94.8	125.6	0.043	6.1	10.78	7.95
Pr > F (Cv * F)		NS	NS	0.0026	NS	0.0022	0.0006

[1] thousand seed weight

GLA of the flagleaf (with the greatest response (39.7%) from cv. Wana) and the GLA of the stem (with the greatest response (36.5%) from cv. Makibamidori).

Discussion

Little information as to the effects of specific plant pathogens on cocksfoot seed yield exists. Latch (1980), Labruyere (1980) and Close (1990) all reported that stem rust (*Puccinia graminis*) and stripe rust (*Puccinia striiformis*) can reduce seed yields, while Bouchet (1987) reported significant seed yield increases following the control of eyespot (*Mastigosporium rubricosum*) in France. Similarly Rolston *et al.* (1989) found that control of eyespot increased seed yield in New Zealand. However, in the 1992/93 trial, the incidence of fungal diseases was very low (< 5% rust infection and < 1% eyespot), yet spring sown cv. Wana, Kara, Tekapo and Makibamidori, and autumn sown cv. Wana and Makibamidori all produced significant seed yield increases following fungicide application.

This seed yield response to fungicide application in the apparent absence of fungal disease has been previously recorded in cocksfoot (Rolston *et al.*, 1989), perennial ryegrass (Hampton and Hebblethwaite, 1984; Hampton, 1986; Horeman, 1989) and prairie grass (Rolston *et al.*, 1989). When seed yield components were recorded, the major response was an increase in seeds per spikelet, or more accurately, better floret site utilisation because of a reduction in seed abortion (Hampton, 1986). In all these reports, fungicide application appeared to delay leaf senescence, as green leaf area was significantly increased. For spring sown cvs. Wana, Tekapo and Makibamidori there was a significant association between green leaf area (flag leaf) and seed yield (Table 4), while for cv. Wana and Tekapo, improved floret site utilisation was positively and significantly associated with the seed yield increase recorded. The association between green leaf area and seed yield was not significant for cvs. Kara and

Table 4. Regression values (R^2) for seed yield components, floret site utilisation (FSU), and green leaf area (GLA) against seed yield in five spring sown cocksfoot cultivars.

		Florets		% GLA	
Cultivar	TSW[1]	per tiller	% FSU	Flagleaf	Stem
Wana	0.043	0.268	0.665*	0.528*	0.633*
Kara	0.045	0.206	0.024	0.100	0.100
Tekapo	0.309	0.085	0.641*	0.518*	0.350
Akimidori	0.001	0.153	0.427	0.066	0.039
Makibam.	0.676*	0.589*	0.480	0.673*	0.630*

[1] thousand seed weight. * significant difference at $P < 0.05$

Akimidori, even though the application of fungicide did improve the green leaf area. This improved green leaf area also failed to have a significant impact on their floret site utilisation. This failure of the improved green leaf area to have a significant impact on the floret site utilisation was also found in cv. Tekapo. However, cv. Tekapo had a far greater number of reproductive tillers than either cv. Kara or cv. Akimidori, which led to it having a superior seed yield. The reason why cv. Akimidori did not respond to fungicide application could not be determined from the data recorded.

While fungicide application can result in delayed leaf senescence, thus presumably allowing extended photosynthetic activity and more assimilate to support seeds, the reason why this response occurs is still not known. Hampton (1986) suggested that control of micro-organisms involved in leaf senescence may be an explanation, or that growth regulatory properties of the fungicides (i.e., hormonal changes) may be involved, but this is still to be determined. Another possibility could be the failure to recognise a pathogen associated with leaf scorching and premature senescence of cocksfoot which is being controlled by the fungicide applications. This situation has recently been reported for *Didymella* spp. in New Zealand cereals (Cromey *et al.*, 1994).

Although fungicide application improved the seed yield of four of the cultivars, the economic value of carrying out such applications should be considered. Welty (1989) noted that the cost-benefit ratios must be evaluated carefully before deciding whether fungicide applications are economic in cocksfoot. For spring sown cultivars, the two application of fungicide were cost effective for all except Akimidori, when calculations are based on a price of approximately $3.30/kg for the seed produced (J. McKay, pers. comm.) and the cost of the two fungicide applications is $92.00/ha. The greatest return came from cv. Tekapo (additional $1798/ha) and the lowest return came from cv. Kara (additional $307/ha). For autumn sown cultivars two applications of fungicide were cost effective only for cv. Wana (additional $733/ha) and despite the low yield, Makibamidori (additional $228/ha).

Cocksfoot, as with other temperate grasses such as perennial ryegrass, has specific environmental requirements for seed production (Langer 1980). Prior to winter a temperate grass will remain vegetative. During winter, under the influence of low temperatures and short days (vernalization) floral induction occurs. Once vernalization has occurred, the tillers are capable of becoming reproductive once temperature and photoperiod increase. The greater the number of tillers available for vernalization the greater the number of reproductive sites at anthesis. In this trial all spring sown cultivars outyielded the autumn sown cultivars. When cocksfoot is spring sown, it has time to produce vegetative tillers which are available for vernalization during the following winter, resulting in a greater number of reproductive tillers the second summer. However, for the autumn sowings in this trial, the time before winter was presumably too short to produce a high number of tillers for vernalization. Therefore the autumn sown cocksfoot failed to produce as much seed as the spring sown cocksfoot purely because of lack of reproductive sites. With only one autumn sowing date (6 April), it is possible that the ability of the cultivars to produce an acceptable seed yield was not fairly assessed. Hare (1994) for example recorded a 500 kg/ha reduction in seed yield of tall fescue (*Festuca arundinacea* Schreb.) following a three week delay in sowing (15 April cf. 25 March) at the same site, primarily because of lower tiller production at the later sowing. Whether this type of response also occurs in cocksfoot in New Zealand is not known, but is highly likely, especially considering the data presented by Niemelainen (1991), who showed that in Finland reproductive tillers numbers decreased as autumn sowing date was delayed. Presumably as well as time of sowing, the environment following sowing is also an important factor, as Rolston (1991) did record a seed yield of 1310 kg/ha (from 445 fertile tillers/m^2) for cv. Wana at a sowing on 3 April.

In the absence of fungicide all New Zealand cultivars yielded more seed than the Japanese cultivars when sown in spring. This was related to the failure of the Japanese cultivars to produce as many fertile tillers as two of the cultivars (Wana and Tekapo) presumably because of a poorer tillering ability, although this needs to be verified. The two New Zealand cultivars were able to produce a higher number of vegetative tillers than the other cultivars for vernalization. In contrast, cv. Kara was able to outyield both Japanese cultivars due to a superior FSU. It is important to note however that in the second harvest year, the two Japanese cultivars were able to almost double the seed yield of their first harvest, producing a yield of about 600 kg/ha (Wilson, unpublished data).

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