Effect Of Cultivar, Time Of Sowing And Fungicide Application On Seed Yield Of 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 150 to 482 kg/ha depending on cultivar. The ability of the spring sown cultivars to outproduce autumn sown cultivars was due largely to their ability to produce a greater number of fertile tillers. Autumn sown cultivars failed to produce a large number of fertile tillers which lead to a reduced potential seed yield. This was further exaserbated by the fact that the floret site utilisation (FSU) of the autumn sown cultivars was lower than that of the spring sown cultivars. Cultivar Wana was the only cultivar able to produce a reasonable number of fertile tillers following autumn sowing. It was also able to double the number of florets/tiller compared to that of spring sown cv Wana, thus allowing it to produce a reasonable seed yield. Cultivar Wana produced 557 kg seed/ha from the autumn sowing, and cv. Tekapo 244 kg seed/ha, but yields for the other three cultivars were less than 100 kg/ha following autumn sowing. Spring sowing produced pure seed yields of 707, 566, 593, 383 and 307 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 Akimidori and Makibamidori.

However fungicide application significantly increased seed yield in cv Wana, Kara and Tekapo, the increases being 521 (+ 74%), 119 (+ 21%) and 564 (+ 95%) kg/ha respectively, even though the incidences of fungal pathogens was less than 1%. These seed yield increases were due to an increase in the green area of the leaves and stem. In cv Wana and Tekapo there was also a significant increase in FSU due to the application of fungicide.

Following harvest stubble was removed and the area retained for another year and subsequent harvest. As the effects of time of sowing were considered no longer significant, the trial was run as one block of 80 plots, thus giving 16 replicates of each cultivar. For each cultivar, four replicates received one of four different fungicide (188 g ai/ha of terbuconazole) treatments; a nil application, one application at approximately 10% ear emergence, one application at approximately 10% ear emergence followed by another at early anthesis and one application at early anthesis followed by one post anthesis (10 days after full anthesis).

In the absence of fungicide pure seed yields produced were 1133, 1208, 915, 556 and 671 kg/ha for cv. Wana, Kara, Tekapo, Makibamidori and Akimidori respectively. Although once again the incidence of fungal pathogens was less than 1%, fungicide increased the seed yield of all cultivars. The best results came from two applications of fungicide, one at ear emergence and one at anthesis. The exception to this was for cv Tekapo which gained the greatest increase from one application at ear emergence. These treatments increased the pure seed yield by 29%, 15%, 23%, 43% and 19% for cv Wana, Kara, Tekapo, Makibamidori and Akimidori respectively. Different cultivars reacted differently to the application of fungicide, with fungicide significantly increasing the thousand seed

weight of cv Kara, Tekapo, Akimidori and Makibamidori, although it had no such effect on cv Wana. Fungicide application increased the FSU of cv Wana and Tekapo but did not significantly affect cv Akimidori, Makibamidori and Kara. Cultivars Wana and Makibamidori showed a significant association between green area and seed yield, but these relationships were not significant for the other three cutivars. There was a significant association between FSU and seed yield after fungicide application for all the cultivars except cv Kara. The most cost effect return for the application of fungicide was that of a single application at ear emergence.

Keywords: Cocksfoot, *Dactylis glomerata*, rust, eyespot, propiconazole, terbuconazole, fungicide, sowing date, cultivar.

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CHAPTER 1

INTRODUCTION

Cocksfoot (*Dactylis glomerata* L.) is a wind-pollinated, out-crossing perennial grass. It is densely tufted and in the vegetative state can be easily distinguished from other important forage grasses by its flattened shoots (Rumball 1994). The leaves are dull or bluish-green, with a prominent central vein but without auricles. The inflorescence is a panicle bearing spikelets crowded together in clumps, and each spikelet contains 3 - 5 florets (Langer 1990).

Cocksfoot is well adapted to moderate fertility and low soil moisture and after the ryegrasses 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 1993). Two cultivars, 'Grasslands Wana' (390 t) and 'Grasslands Kara' (97 t) made up the bulk of the seed produced, with cultivars such as Saborto and 'Grasslands Apanui' being produced in much smaller amounts. Grasslands Wana is bred for use in sheep pastures (Rowarth *et al* 1991) with its low crown and dense tiller formation (Rumball 1982b). Grasslands Kara is bred for dairy pastures with its more erect and sparsely tillered morphology (Rumball 1982a). 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 comparitive 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 imported, primarily from USA (both US cultivars and Japanese cultivars multiplied in USA, B McCloy, pers comm.).

The work reported in this thesis therefore had a number of different objectives:

Year 1

I) to determine whether seed of two Japanese cocksfoot cultivars, Akimidori and Makibamidori could be produced in New Zealand, and to compare their seed yields with those of three New Zealand cultivars, Grasslands Wana, Kara and the recently released Tekapo.

II) to compare seed yields from spring and autumn sowing.

III) to investigate the effect of fungicide application on seed yield and its components.

Year 2

I) to compare seed yields of the five cocksfoot cultivars after time of sowing effects were no longer a factor.

II) to investigate the effect of fungicide application at different times on seed yield and its components.

LITERATURE REVIEW

Growth and Reproductive Development

Temperate grasses usually consist of an apparent rosette of distichously arranged leaves arising from a short stem. The leaf comprises a long, narrow, distal lamina and a proximal leaf sheath which ensheaths younger leaves and the stem apex. Tillers arise in the axils of the leaf sheaths and for each order of tillering are arranged at right angles to the parent axis, thus giving rise to the tufted or tussocky habit of grasses (Jewiss 1966; Lampert 1972). Tillers are the basis of the grass producing system, and depending upon their position in the plant and time of appearance, they may or may not produce seed heads (Langer 1970). In temperate perennial grasses such as cocksfoot and perennial ryegrass, the majority of tiller production occurs in autumn (Langer 1980). During the autumn period when flower induction has not occurred and daylength is not adequate to cause inflorescence initiation, perennial grasses will remain vegetative. The shoot apex will continue to cut off new leaf primordia which unfold as foliage leaves at a rate depending on temperature and other environmental conditions. There is no stem elongation and new tillers will continue to be produced for as long as environmental conditions allow.

In some perennial grasses, prior to floral induction, the plant goes through a phase in which it is insensitive to environmental conditions which later promote flowering (Calder 1963). Such grasses include chewings fescue (*Festuca rubra* L.), meadow fescue (*Festuca* *pratensis* Huds.), Kentucky bluegrass(*Poa pratensis* L..) and cocksfoot (*Dactylis glomerata* L.) (Cooper and Calder 1964). In cocksfoot the juvenile stage is believed to be a period of up to six weeks when the plant is increasing in size and weight but is not making any progress towards flowering (Calder 1963). The juvenile stage, however, is not indicative of all perennial grasses, as no such stage has been confirmed in perennial ryegrass (*Lolium perenne* L.) (Cooper and Calder 1964) or tall fescue (*Festuca arundinaceae* Schreb.) (Hare 1994).

Following the juvenile stage is the floral induction stage. For floral induction to occur in a grass, specific requirements must be fulfilled. The common denominator of all inductive conditions is the ability to bring a plant to a state enabling it to respond to short photoperiods which stimulate inflorescence initiation (Calder 1966). Along with photoperiod, low temperature (vernalization) requirements must be met. These requirements vary from species to species and are generally met during winter (Langer 1972). Cocksfoot, perennial ryegrass and medow fescue (Calder 1966) and *Poa pratensis* (Calder 1966, Habjorg 1980) all require such conditions to induce the profound physiological changes which cause floral induction. Inductive conditions in Scandinavian cocksfoot occurred in short daylength at 9 - 21 ^{o}C in 8 - 10 weeks (Niemelainen 1991). At the time of floral induction no morphological or biochemical change can be detected, but tillers thus induced are now capable, when temperature becomes favourable for growth, of responding to increasing photoperiod by initiating reproductive structures.

Once a plant is fully induced, it can initiate an inflorescence when grown in an appropriate photoperiod (Calder 1966). Cocksfoot is described as a long-day plant (Calder 1963) as are practically all grasses which require vernalization (Langer 1972). This means that once full floral initiation has occurred, increased photoperiods and temperatures will promote floral induction. Wilson (1959) observed that in perennial ryegrass, cocksfoot, Italian ryegrass (*Lolium multiflorum* Lam.) and timothy (*Phleum pratense* L.), no floral initiation took place during winter, whilst the exact time and therefore conditions under which initiation occurred was different for each species. Langer (1980) described floral initiation as when the shoot apex increases rapidly in length and forms primordia which are no longer destined to become foliage leaves. Instead, the primordia develop into spikelets and each spikelet primordium differentiates further to produce individual florets, complete with lemma, palea, lodicules, anthers, stigmas and ovary. Meanwhile the internodes below the shoot apex elongate successively, pushing the developing inflorescence upwards within the encircling leaf sheaths. In cocksfoot, timothy and meadow fescue it is the tillers present in early autumn which make up the bulk of the seed crop the following year (Langer 1980). White (1990) suggested that 80% of ears present at harvest were derived from tillers which appeared up to May. These are the tillers which have been subjected to the previously described inductive requirements which result in floral initiation.

Hebblethwaite, Wright and Noble (1980) grouped the development of a grass seed crop into two stages:

1. Establishment of yield potential;
2. Utilisation of yield potential;

as explained in Table 1.

For cocksfoot the tillers produced during autumn provide the bulk of the seed crop (Langer 1980). Therefore the number of tillers produced in autumn will have a large impact on the potential yield of the crop. For example, Rolston (1991) sowed 'Grasslands Wana' cocksfoot on 3 April 1981; this crop had only 50 fertile tillers/m^2 on 26 December 1981, with a subsequent seed yield of 170 kg/ha. The period of time prior to winter was presumably

Table 1. Developmental processes determining potential and actual yield components of perennial ryegrass seed crops[1].

Yield Component	Developmental process
Establishment of the Yield Potential	
Number of fertile tillers	Tillering
Spikelets/fertile tiller	Apical development
Florets/spikelet	
Yield potential = number of florets/unit ground area at anthesis.	
Utilization of the Yield Potential	
Seeds/spikelet : % seed set	Pollination/Fertilisation
Mean weight/seed	Seed growth
Actual yield = Seed weight/unit ground area at harvest.	

[1] Hebblethwaite *et al*, (1980).

too short for the cocksfoot to produce a large number of vegetative tillers. Therefore few tillers were able to receive the inductive requirements prior to spring. However, when the same crop was harvested the following year 910 fertile tillers/m^2 were present prior to harvest with a subsequent yield of 800 kg/ha. The plants had more time in which to produce vegetative tillers prior to winter. Hampton and Hebblethwaite (1983) suggested that providing fertile tiller numbers are not limiting, then seed numbers and therefore yield depend primarily on conditions governing the number of seeds/spikelet.

It is during the period between spikelet initiation and ear emergence when the spikelets and florets are developed and their numbers determined (Ryle 1966). In cocksfoot the period between floral initiation and ear emergence varies depending on the age of the tillers. With floral initiation tending to occur in early October, the interval until ear emergence is 32 days (early-formed tillers) to 24 days (late-formed tillers) (Wilson 1959). The total number of florets in the inflorescence depends on the number of primary spikelet branches (14.5 primary branches/ear in cocksfoot). In cocksfoot basal branches develop considerably more spikelets and thus more florets than the terminal ones (Ryle 1966).

With the production of fertile tillers and apical development complete, the establishment of the yield potential may be considered to be complete at first anthesis (Hebblethwaite *et al* 1980). However the potential seed yield is much greater than the actual seed yield. Hampton *et al* (1985) found that a crop of 'Grasslands Nui' perennial ryegrass had a potential yield of 5.37 t/ha but only realised an actual yield of 0.96 t/ha. Elgersma (1985) considered that seed yield depends largely on the degree of floret site utilisation (FSU), which she defined as the percentage of florets, present at anthesis, which at harvest contain a viable seed. Seed growers are concerned about the percentage of florets present at anthesis which contribute to the harvested seed. This results from the following processes: pollination, fertilization, seed set, seed development, harvesting and cleaning. It is during these processes where substantial losses can occur, so that potential yield will be greater than actual yield. Ryle (1964) estimated the potential seed yield of cocksfoot during one trial as 1750 kg/ha of which only 280 kg/ha (16% FSU) was realised. Factors influencing this large difference in potential and actual yield included fertilization, seed set and maturation of seed. Anslow (1963) found that in perennial ryegrass the maximum percentage of all florets setting seed was about 65%. This would not be an unrealistic estimation for cocksfoot. This number can drop as low as 26% in perennial ryegrass.

Considering this and the fact that Falcinelli *et al* (1994) recorded shattering losses from 44.4 to 68.9% in cocksfoot, a 20% FSU is not unrealistic and is probably quite acceptable.

Anthesis, or opening of the floret, is the first outward sign that pollination is about to begin (Langer 1972). When the floret opens the anthers and stigmas are exposed to the pollinating agent(s) (Hill 1980). Temperature and light intensity have a positive effect by inducing and promoting anthesis. The release of pollen is also influenced by these two factors. Hampton and Hebblethwaite (1983) found that minimum screen temperature time (less than 10^{o}C) accounted for over 70% of variance in seed numbers recorded. Cocksfoot exserts anthers more slowly than perennial ryegrass and therefore tends to be influenced by weather conditions the previous day. That is, sunny weather initiates anther exsertion during the day, but as exsertion is slow the anther is not ready to release its pollen until the following morning. Night temperatures below 12.8^{o}C followed by a cloudy day inhibit pollen release (Hill 1980). This is due to a decrease in flowering intensity and a reduction in the number of florets open at peak anthesis caused by such conditions.

Pollination is the term used to describe the processes occurring from the time of anther dehiscence until the pollen tube reaches the embryo sac in the ovary. Fertilization on the other hand is the actual fusion of the male nucleus with the ovum (Hill 1980). During these processes, as well as anthesis, potential yield reductions can occur. As with other grasses, cocksfoot is wind pollinated, and therefore the distance over which the pollen must travel and the duration in relation to receptivity of the stigma is important (Fairey 1993). Although the viability of pollen may last up to 24 hours (Fairey 1993), anthesis in grasses lasts less than 20 minutes (Langer 1972). This means the open florets only have a short period of time in which to capture the available pollen. Also, pollen does not remain viable for as long in bright sunshine (Langer 1972), which leads to desiccation and subsequent failure of fertilization.

Following the successful pollination and fertilization of the florets is 'seed set'. This is a term which describes the early growth of the embryo and endosperm, 'set' being indicated by the presence of cell division following successful fertilization. Unless this cell division occurs the ovules eventually shrivel and die, even though pollination has taken place (Hill 1980). The development of seed is distinguished by three stages in ryegrasses (Hyde *et al* 1959):

Stage 1: the growth stage; duration 10 days after pollination.
Characteristics: rapid increase in seed weight, high seed moisture content and non-viability.

Stage 2: the food reserve accumulation stage; duration a further 10-14 days.
Characteristics: a threefold increase in seed dry weight. Seeds attain full viability.

Stage 3: the ripening stage; duration 3-7 days.
Characteristics: dry weight remains approximately constant, but moisture content falls from about 40% to equilibrium with the atmosphere.

A number of factors can influence the proportion of seed which is set in temperate herbage species. When a floret is not pollinated or the egg cell is not fertilised, the ovule and ovary degenerate resulting in empty florets. Poor pollination or fertilisation can be caused by lodging or minimum temperature at anthesis and during the week after anthesis (Elgersma

1991). In ryegrass, abortion may occur after fertilization up to approximately 21 days after anthesis. It has been reported that one-third of unproductive florets contained ovaries and two-thirds contained seeds at a very early stage of development. It has been shown that severe frosts during seed development can cause sterility in florets, as can extreme temperatures. However, temperatures above 40°C do not tend to be a threat in temperate climates (Hill 1980). It has also been demonstrated that there is up to 10% morphological sterility in cocksfoot florets (Hill 1980).

Anslow (1963) showed that the position of the floret on the spikelet influences its ability to set seed in perennial ryegrass. He found that only two thirds of all florets set seed, with that proportion being lower in late emerging heads. There was also a fall in floret fertility in the upper spikelets, compared with those in the middle and at the base of the spike, and a marked reduction in fertility in the outer florets of each spikelet.

During seed development seed shedding from the inflorescence is another principal source of yield loss. Heavy winds and spread in ripening time promotes shattering (Elgersma 1985). Harvest losses can occur when the seed is harvested too early and the moisture content is too high; this causes damage to the seed through mechanical crushing and internal fracturing (Hill 1980). Delaying harvest in perennial ryegrass resulted in losses due to shedding. Hence the optimum time to harvest, for maximum seed yield, depends on the balance between loss of seed by shedding from over-ripe inflorescences, and gain in yield of seed from later-maturing inflorescences (Hebblethwaite *et al* 1980). This is around the end of the ripening stage when the moisture content is at about 40%. All these factors along with seed lost during harvesting and cleaning lead to the actual yield being substantially less than the potential yield.

Effects of Time of Sowing and Sowing Rate

In relation to the environmental requirements for floral development of a temperate grass such as cocksfoot, the time at which the crop is sown is extremely important. Additionally it is the tillers produced in the autumn prior to harvest that produce the greatest quantity of seed. Ryle (1964) showed that the relationship between the size of the inflorescence in ryegrass, meadow fescue and cocksfoot and date of origin of the tiller was similar in all three species. Twice as many florets and therefore potentially twice as many seeds were recorded on tillers originating in autumn than from those which were produced in early spring. This finding confirmed the result from Wilson (1959) who found that in a trial carried out at Palmerston North the percentage of cocksfoot tillers which became reproductive was high (approx. 70%) only for those tillers originating before the end of June.

Research work on perennial ryegrass has shown that this species has the ability to produce high yields when sown in autumn for harvesting the following summer. White (1990) reported that autumn produced tillers had a higher survival rate than those formed in spring and became almost exclusively reproductive. These tillers produced larger seed heads which bore more spikelets and florets/head. Hill and Watkin (1975) found that in Ruanui perennial ryegrass, only 3% of those seed heads present at harvest could be attributed to tillers which appeared in September or later.

However, research in cocksfoot and many other grasses suggests that this ability to produce a good seed yield in the summer following a late summer/autumn sowing is not present. Van Keuren and Canode (1963) found that only relatively small yields of seed could be obtained from cocksfoot and tall fescue after autumn sowing and suggested that sowing in spring and harvesting the following year provided the best establishment for seed production in both species. Beddows (1964) obtained disappointing panicle production after a late summer/early autumn sowing of cocksfoot. Cocksfoot was sown at two week intervals during spring and summer, and the later the sowing, the further the capacity to produce panicles the following summer diminished. With three distinct developmental stages controlling flowering: juvenile, inductive and initiation, the juvenile stage, where the plant is increasing in size and weight, takes 5 - 6 weeks. Unless the plant completes all the requirements of the juvenile stage, it will not respond to environmental stimuli. Therefore the later the sowing date the less time the plant has to prepare itself for the winter inductive conditions which lead to panicle production during the warmer long days of spring and summer.

Hare (1994) found that a three week delay in sowing date (15 April compared to 25 March) reduced first-summer seed yields by between 500 and 1000 kg/ha in three different tall fescue cultivars. In 1992 Hare produced similar results with 'Grasslands Roa' tall fescue. The later the sowing date the lower the seed yield. This was despite autumn sown crops initially establishing better than spring and summer sowing. By the end of winter autumn sown crops had substantially fewer tillers which produced lighter seed than those sown in spring. Hare suggested that autumn produced tillers received insufficient vernalization over the winter period. Hare (1990) also suggested that cocksfoot, fine fescue and in many cases, tall fescue are very slow to establish and must be sown in spring in order to have sufficient tiller production before going into autumn and winter.

The inability of either cocksfoot or tall fescue to produce a good seed yield after an autumn sowing is not a foregone conclusion. Cultivars are now available which do have the potential to produce a good seed yield after an autumn sowing. White (1990) suggested that autumn sowings of 'Grasslands Wana' cocksfoot have the potential to produce seed crops in the first summer, 10 months from sowing. The crop should be sown in February/early March. This is also supported by Hare (1990) for both 'Grasslands Wana' cocksfoot and 'Grasslands Roa' tall fescue. When sown early, in warm moist conditions, the plants have enough time to establish themselves and reach a substantial size prior to winter and the consequent inductive conditions (i.e. complete the juvenile stage).

The rate at which the seed crop is sown is very important, especially considering the findings of Calder and Cooper (1961) which suggest that the lower the plant density the better the floral initiation of the crop. Brown (1980) found that the optimum plant density for 'Grasslands Nui' perennial ryegrass was 300 - 400 plants/m^2 while for 'Grasslands Matua' prairie grass it was 100 - 130 plants/m^2. Hare (1990) suggested about 200 plants/m^2 for cocksfoot and tall fescue. White (1990) noted that it is common practice to sow cocksfoot in wide rows and at low rates (3 - 5 kg/ha). Brown *et al* (1983) gained maximum yields when 'Grasslands Wana' cocksfoot was sown in 30 cm row spaces at three harvests in consecutive years. Wider rows (45 and 60 cm) produced more seed heads per unit area but greater floret death resulted in lower seed yields while 15 cm rows produced fewer seed heads and lower seed yields.

Effect of Diseases on Cocksfoot Seed Yield

Plant diseases generally affect herbage seed crops more than grazed pastures, as grazing removes much of the diseased plant. In a herbage seed crop, diseased material is not removed and therefore the disease is allowed to incubate (Latch 1980, Labruyere 1980).

Plant diseases may affect the quantity and quality of seed in three ways (Latch 1980):

- Foliage and root diseases which reduce plant vigour and so may reduce the number of flowering tillers formed and quantity of nutrients available to the developing seed.
  example: Stem rust (*Puccinia graminis* f.sp. *avenae* Pers.), Eyespot (*Mastigosporium rubricosum* (Dearn. and Barth.) Nannf.)

- Some diseases destroy the developing seed.
  example: Ergot (*Claviceps purpurea* (Fr.) Tul.), Blind seed (*Gloeotinia temulenta* (Prill. and Del.) Wilson, Noble and Gray.)

- Many diseases contaminate viable seed with spores, mycelium, bacteria, viruses or nematodes within or on the seed.
  example: Barley Yellow Dwarf Virus (BYDV), *Fusarium* and *Penicillium* spp.

In this literature review only foliar diseases of cocksfoot seed crops will be discussed.

There are several leaf diseases which are considered to have a detrimental effect on the seed yield of cocksfoot. Latch *et al* (1981) noted three leaf diseases that have moderate to severe effects on cocksfoot seed yields. Stem rust (*Puccinia graminis* Pers) occurs commonly on leaves and seed heads and attacks most pasture grasses in New Zealand, including cocksfoot. Stripe rust (*Puccinia striiformis* var. *dactylidis* Westend.) is only found on cocksfoot and can seriously affect seed yield. Rolston *et al* (1989) found that fungicide application reduced stem rust on cocksfoot and produced a 600 kg/ha seed yield increase.

White (1990) stated that stripe rust can also reduce seed yield. Leaf scald (*Rhynchosporium orthosporum* Caldwell) affects both ryegrass and cocksfoot, but is only considered to be moderately severe on cocksfoot.
Labruyere (1980) described stem rust as being mainly confined to leaf sheaths, culms and rachides, which bear first the reddish-brown uredina and later the conspicuous blackish-brown telia. Latch (1980) suggested that rust infection on the stems interferes with translocation of nutrients to the developing seed, resulting in shrivelled and sometimes non-viable seed.

Stripe rust was described by Latch (1980) as being distinct with bright yellow pustules which form lines up to 10cm long on the leaves, culms and inflorescences. Ganev and Harvey (1994) reported that infected leaves turn yellow and senesce early in the season. This leaf infection can seriously reduce seed size and yield (Latch 1980). The yellow pustules turn black as the spore stages change from uredospores to teleutospores (Ganev and Harvey 1994).

Ganev and Harvey (1994) described leaf scald as initially dark water-soaked lesions on the leaves and leaf shoots. These affected areas dry out rapidly and the lesion turns grey in the centres with a very distinct dark brown margin. Severely affected leaves and leaves with lesions near the base of the leaf are weakened and often wrinkled or bent over.

Another leaf disease which Ganev and Harvey (1994) describe as the most common leaf spotting disease in cocksfoot is eyespot (*Mastigosporium rubricosum*). This disease is found on leaves all year round. This is not to be confused with Drechslera leaf spot (*Drechslera* spp.) of which there are six species present on cocksfoot in New Zealand, although these are of little significance. The first symptoms of eyespot are small elliptical water soaked spots about 1 mm in diameter on both sides of the leaf. These become dark brown and are usually surrounded by a yellow to bright orange-tan halo. Lesions enlarge up to 12 mm by 5 mm. Leaves become chlorotic and senesce prematurely. This disease can cause a reduction in green leaf area and seed yield through reduced seed numbers and thousand seed weight.

The effect of these diseases and many others on the seed yield of pasture plants can be counteracted through the use of fungicides. Welty (1989) and Rolston *et al* (1989) both reported work on the effect of fungicide application on cocksfoot seed yield. Welty found the use of fungicide to control eyespot, leaf scald and leaf streak (*Cercosporidium graminis* Fckl.) was effective and resulted in increased seed yields. The use of chlorothalonil (1754 g ai/ha), captafol (1345 g ai/ha) and propiconazole (252 g ai/ha) at heading and flowering in the first year provided a significantly higher seed yield than that of the control. Cholrothalonil was the most effect fungicide in controlling these particular leaf diseases. Rolston *et al* (1989) on the other hand used propiconazole (125 g ai/ha) and mancozeb (1.5 kg/ha) in 300 l water/ha to control eyespot in cocksfoot. Both fungicide treatments had a marked effect on maintaining the green leaf area (GLA) by delaying senescence and seed yield increases of 15 - 21% were obtained from early fungicide application where pathogen infection was low. The yield increases were attributed to maintaining GLA during seed development and maturation, resulting in increased seeds/spikelet.

Hampton and Hebblethwaite (1984) found that in perennial ryegrass, the application of fungicide increased seed yield, even when the incidence of eyespot stem lesions, powdery mildew (*Erysiphe graminis* D.C. Tul) and *Drechslera* leaf spot were low. Using Bayer

UK087 (triadimefon 6.25%, carbendazim 10%, captafol 40%) at 2 kg/ha in 250 l water applied at monthly intervals from tillering until harvest, seed yield was increased by 15% in the first year and by 43% the following year. This increase was due to an increase in seeds/spikelet as a result of increased LAD, brought about by delays in senescence of photosynthetic tissue.

Further work by Hampton (1986) looking at the effect of fungicide on the seed yield of perennial ryegrass showed once again that the application of fungicide could increase seed yield. But this result was rather dependant on the fungicide used. This trial concentrated on the effect of fungicide on stem rust, which occurred in 62% of all tillers. Once again UK087 was used as with Hampton and Hebblethwaite (1984). This time the components of UK087 were also applied individually at either ear emergence or ear emergence and just prior to anthesis, along with UK087. Triadimefon was applied at 125 g ai/ha, carbendazim 200 g ai/ha and captafol 800 g ai/ha, all with 250 l water/ha. UK087 and triadimefon provided better control of disease than carbendazim and captafol, with no significant difference between the number of fungicide applications. All fungicides except carbendazim increased the GLA of the flag leaf and penultimate leaf. UK087 and triadimefon were the only fungicides to increase seed yield. This seed yield increase resulted from an increase in seeds/spikelet and an increase in TSW related to decrease in stem rust infection and delayed leaf tissue senescence.

It appears that fungicide not only controls disease but can also be used successfully to increase the seed yield of the crop even when the incidence of disease is low. The size of this increase can depend largely on the timing of the application, as these results indicate an early application is best. Marshall (1985) suggested that the early application of fungicide maintains the photosynthetic activitiy of tillers and results in an improved assimilate supply to the developing seed. This causes a reduction in abortion and therefore provides an increase in the number of seeds/spikelet. In addition it is possible that the application of fungicide exerts a cytokinin-like action on the developing seeds. This would make the seeds a stronger sink, therefore allowing them to compete better for assimilates, and thus reducing their susceptibility to abortion. Also the fungicide used is important, with triadimefon appearing to be the most effective fungicide available. This is supported by Latch (1981) who recommended this systemic fungicide in the control of both stem and stripe rust along with leaf scald.

Cultivars used in this Trial

In 1980 two new cocksfoot cultivars were released by DSIR Grasslands, Palmerston North, to succeed 'Grasslands Apanui'. 'Grasslands Kara' is a taller more erect, and more sparsely-tillered plant than cv Apanui. The mature leaves of cv. Kara are generally longer, broader, and more bluish than those of cv Apanui. In a sward, cv Kara has wider, longer, erect leaves, and slightly lower shoot density than cv Apanui (Rumball 1982a). Cultivar Kara heads about the same time as cv Apanui, but peak flowering is a few days later (mid-December). There are slightly fewer seed heads than in cv Apanui, and seed yield may be similar or slightly lower with a similar thousand seed weight (1.0 g/1000 seed).

Cultivar Wana is distinctly different in morphology from that of its predecessor. The individual plants are low-crowned, with shorter leaves than that of cv Apanui. The leaves of cv Wana are also ligher and shinier green and the foliage is much more resistant to stem rust and stripe rust. In swards cv Wana gives a dense even cover unlike cv Apanui. Cultivar Wana inflorescences are shorter and begin to emerge a few days later than those of cv Apanui, but reach peak flowering at about the same time (mid-December). There are usually more heads per plant in cv Wana, so that although individual seed weights are slightly smaller, the total seed yield may be greater than that of cv Apanui (Rumball 1982b).

Compared with cv Kara, cv Wana is prostrate and densely-tillered, light green and rust-free. It flowers a few days earlier and yields more seed. Cultivar Wana is intended for use in sheep pasture, providing summer forage especially where soil fertility and moisture are low (Rumball 1982b). Cultivar Kara on the other hand is intended for use in dairy pastures in seed mixes with other tufted grasses such as timothy, prairie grass, and ryegrass, together with clovers (Rumball 1982a).

Cultivars Wana and Kara are two of five cultivars which were examined in this trial, the third being a newly released Grasslands cultivar, 'Grasslands Tekapo'. It is similar in its morphology to that of cv Wana, prostrate with similar leaf colour and similar tiller density at heading. The leaf of cv Tekapo is slightly shorter and narrower than that of cv Wana. Due to a slighty shorter and less branched panicle than cv Wana, cv Tekapo has a slightly lower seed yield potential. Cultivar Tekapo has little winter growth, and vigorous summer growth. Thus it is intended for use in sheep pastures in areas with low fertility and rainfall (Anon 1995).

The remaining two cultivars used in this trial were cv Makibamidori and Akimidori which come from Japan. No information was available on the morphology or seed producing ability of either of these cultivars.

CHAPTER 2

INTRODUCTION

Little research has been published on cocksfoot seed production, which after ryegrass is the species for which the second largest quantity of grass seed is produced annually in New Zealand. This trial aims to compare the seed yield of five different cultivars of cocksfoot following sowing in spring and harvesting 15 months later and sowing in autumn and harvesting 10 months later. This comparison will establish which cultivars are able to produce more seed after 15 or 10 month sowing times and what seed yield components enable these cultivars to do so. The effect of fungicide fungicide application will also be examined, with regard to its effect on seed yield and seed yield components.

MATERIALS AND METHODS

The trial site selected for this work was located at AgResearch Grasslands lowlands research station, Aorangi, near Palmerston North (latitude 40°S), on a weakly leached, slowly accumulating, poorly drained, recent gley soil, from quartzo-feldspathic alluvium (Kairanga silt loam) (Hare, 1992). The 0.1 ha site was cultivated in late August 1991 from three year old ryegrass/white clover pasture using a mould-board plough. After a three-week fallow period the site was disced, then power-harrowed, to prepare the seedbed.

The five cultivars were sown by hand at a rate equivalent to three kg/ha on 23 October 1991 (spring sown). Each cultivar was replicated eight times in a randomised block design (Fig. 1). Plot size was 3 x 1.2 m with row widths of 30 cm (i.e. four rows). Bentazone (Basagram, BASF products) was applied at a rate of 1440 g a.i./ha and clopyralid, bromoxynil and MCPA (Lontrel, Cereal, Dow Chemical Co.) were applied at a rate of 90 g a.i./ha, 300 g a.i./ha and 900 g a.i./ha respectively on 18 December 1991, (when the cocksfoot plants were at the 3 -

Figure 1. Experimental design - plot plan.

Spring sown trial

Kara (c)	Wana (tr)	Wana (tr)	Kara (tr)
Wana (tr)	Tekapo (c)	Tekapo (c)	Akimidori (c)
Akimidori (c)	Makibam (c)	Makibam (tr)	Wana (c)
Tekapo (tr)	Akimidori (tr)	Kara (tr)	Tekapo (tr)
Makibam (tr)	Kara (c)	Akimidori (tr)	Makibam (tr)
Akimidori (tr)	Tekapo (tr)	Kara (c)	Makibam (c)
Kara (tr)	Makibam (tr)	Akimidori (c)	Kara (c)
Wana (c)	Kara (tr)	Wana (c)	Tekapo (c)
Makibam (c)	Wana (c)	Makibam (c)	Akimidori (tr)
Tekapo (c)	Akimidori (c)	Tekapo (tr)	Wana (tr)

Autumn sown trial

Kara (c)	Wana (tr)	Wana (tr)	Kara (tr)
Wana (tr)	Tekapo (c)	Tekapo (c)	Akimidori (c)
Akimidori (c)	Makibam (c)	Makibam (tr)	Wana (c)
Tekapo (tr)	Akimidori (tr)	Kara (tr)	Tekapo (tr)
Makibam (tr)	Kara (c)	Akimidori (tr)	Makibam (tr)
Akimidori (tr)	Tekapo (tr)	Kara (c)	Makibam (c)
Kara (tr)	Makibam (tr)	Akimidori (c)	Kara (c)
Wana (c)	Kara (tr)	Wana (c)	Tekapo (c)
Makibam (c)	Wana (c)	Makibam (c)	Akimidori (tr)
Tekapo (c)	Akimidori (c)	Tekapo (tr)	Wana (tr)

c - control (nil fungicide)
tr - treated (fungicide)

4 leaf stage), to remove broadleaf and annual weeds. On the 27 December the first vegetative tiller count took place. A one metre length of row was randomly selected from each plot. From this, all vegetative tillers were counted and recorded. On 6 April 1992 (autumn sown) a second identical series of plots was sown in the same randomized block formation with eight replicates of each cultivar (Fig. 1). Again, each 3 x 1.2 m plot was sown by hand at a rate of 3 kg/ha. Prior to this autumn sowing the area was sprayed with glyphosate at a rate of 720 g a.i./ha then rotary hoed 3 weeks later to prepare the seedbed. The same herbicides and rates used for the spring sown plots were applied to these autumn sown plots on 29 May 1992. On 6 April vegetative tiller numbers were re-determined for the spring sown plots, using the method previously described. Following tiller counts all spring sown plots were cut to approximately 5 cm with a rotary mower, and cut vegetation removed. After the spring plots had been cut, NPKS (8:10:20:2) fertiliser was applied by hand at a rate of 30 kg/ha, to both spring and autumn sown plots.

Two vegetative tiller counts in spring sown plots were made on 19 June and 11 September 1992, and three vegetative tiller counts in autumn sown plots on 25 May, 24 June and 18 September. On 18 September a further 130 kg N/ha as urea (Petrochem of New Zealand Ltd) was applied by hand to all plots.

Visual scoring of reproductive tillers was carried out in each plot to estimate the percentage of the total tiller population which was reproductive. In spring sown plots these assessments began on 28 September 1992 (at this stage there was no head emergence in the autumn sown plots) and continued every 4 - 7 days until 6 December. Scoring in autumn sown plots started on 16 November, and continued on the same days as the spring sown plots until the final assessment which took place on 12 December.

In both spring and autumn sowings, four plots of each cultivar were randomly selected for fungicide application. On 17 November 1992 (onset of anthesis, becoming an arbitrary date for the spraying of all treated plots) and 8 December 1992 (during seed development) propoconizole (125 g a.i./ha) was applied to the selected plots with a gas pressurised knapsack sprayer which delivered 5 l water/150 m^2. The remaining four plots of each cultivar remained untreated. Spraying took place on windless days to ensure fungicide was only applied to the selected plots.

At anthesis, a 50 cm length of randomly selected row was cut at ground level from all plots. The number of fertile tillers in each sample was recorded. From each sample, 20 fertile tillers were randomly selected to determine spikelet and floret numbers. All spikelets on each of 20 heads were counted. The average number of florets per spikelet was determined by counting the number of florets in randomly selected individual spikelets from the top, middle and bottom of the head. This average multiplied by the number of spikelets gave the number of florets/head. The number of florets/head for all 20 tillers was averaged to give the number of florets/head in each plot.

On the 23 and 24 December 1992 a further 25 reproductive tillers were randomly selected from all plots. Visual scoring was used to assess the occurrence of rust (*Puccinia graminis* Pers. and *P. striiformis* Westend. var *dactylidis* Manners), and green area of the flag leaf, leaf 2, leaf 3 and stem, using a percentage key (James, 1971).

Beginning on 20 December, seed moisture content of each cultivar and fungicide treatment was determined using the constant temperature oven method (ISTA,1993). Duplicate 1 g samples of seed were taken at random by hand from each plot. For each sample, an empty container and lid was weighed (m1), then reweighed with the seed in it (m2). The containers were then placed in an oven with a constant temperature of 130°C for 1 hour. All containers were removed, placed in a desiccator for 10 - 15 minutes to cool before being re-weighed (m3). The seed moisture content was calculated as follows:

$$(m2 - m3) \times 100/m2 - m1$$

Seed harvest began on December 26 for cv. Akimidori, when its seed moisture content had reached 40%. Harvest continued up to 15 January 1993 (Table 2) as the other cultivars and fungicide treatments reached 40% seed moisture content. All plots were harvested by hand, by removal of all heads from the entire plot with hand shears. The cut heads from each plot were placed in individual hessian sacks, and the sacks labelled. The sacks were hung on a fence for three weeks to allow seed to air dry to ambient seed moisture content in the sun and wind.

Table 2. Harvest dates[1]

Cultivar	Spring Sown		Autumn Sown	
	Control	Fungicide	Control	Fungicide
Wana	6 Jan 1993	6 Jan 1993	14 Jan 1993	15 Jan 1993
Kara	11 Jan 1993	11 Jan 1993	15 Jan 1993	15 Jan 1993
Tekapo	5 Jan 1993	5 Jan 1993	14 Jan 1993	14 Jan 1993
Akimidori	27 Dec 1992	4 Jan 1993	4 Jan 1993	4 Jan 1993
Makibamidori	7 Jan 1993	8 Jan 1993	15 Jan 1993	15 Jan 1993

[1] date at which 40% seed moisture content was recorded.

After seed heads had dried for three weeks, two 1 g samples of seed were randomly selected from each treatment and cultivar and tested for seed moisture content using the method previously described. At this stage, seed had reached about 14% seed moisture content, and was threshed from the heads using a belt thresher, which consisted of two rubber belts, one travelling on top of the other in the same direction but at different speeds. This produces a rubbing action which removed the seed from the seedhead. The seed and some chaff collected from each plot after threshing was weighed, giving the equivalent of the field dressed seed yield. All samples were then machine cleaned on a Clipper two screen air screen cleaner, to remove unwanted leaf and stem material. Care was taken to ensure that each seed sample remained completely separate, with the cleaner being carefully cleaned and vacuumed between samples. The top screen had 5.5 mm x 20 mm elongated holes, and the bottom screen 2 mm x 5.5 mm elongated holes. After the removal of unwanted trash the seed was separated into multiple and single seed units using a Westrup indented cylinder (5.50 mm indents).

After cleaning the seed, each sample of machine dressed seed was weighed on a Mettler PE 3600 balance. Data were recorded for the weight of multiple seeds, single seeds and total machine dressed seed yield from each plot. Multiple seeds and single seeds were kept separate to evaluate any possible differences in the purity and germination between the two due to the effect of fungicide application. After the yield had been recorded the seed moisture content was again determined using the constant temperature oven method (ISTA, 1993).

After the determination of the seed moisture content, each sample (both single seed unit and multiple seed unit samples) was divided using a Gamet centrifugal precision divider to produce two identical duplicate fractions of 1 g from each main sample (a 2 g sample had been estimated to contain a minimum of 2500 seeds which fulfils seed testing requirements (ISTA, 1993)). From these duplicate working samples the analytical purity and germination of each lot was determined using internationally standardised methodology (ISTA, 1993). When these working samples were not in use they were stored in paper bags at 5°C.

To calculate the average purity of a sample, each 1 g working fraction was placed in a Micro-blower type 35 and exposed to a 12 m/sec air blast for 2 minutes. This separated inert matter from pure seed. The pure seed and inert matter were then weighed to two decimal places using a Mettler PE 3600 balance. By dividing the pure sample weight by the total weight of the working sample and multiplying by 100 the percentage pure seed in each working sample was calculated. As there were four working samples for each plot (two 1 g fractions of single seed units and two 1 g fractions of multiple seed units), the average of the four was taken as there was no significant difference between the percentage purity of multiple seed and single seed fractions. This average percentage purity was then multiplied by the total seed yield from each plot to give the pure seed yield per hectare.

The pure seed was used to determine thousand seed weight. In each sample, four lots of 100 seeds were counted and weighed to four decimal places using a Sartorius basic balance. The mean weight of the four lots of 100 seeds was then multiplied by 10 to give the weight of one thousand seeds.

Following the determination of yield components (yield (kg/ha), tillers/m^2, florets/head and thousand seed weight (g)), floret site utilisation (FSU) was calculated by dividing the number of seeds (calculated from the pure seed yield) by the number of florets present at anthesis and multiplying by 100.

Germination results were obtained by following the ISTA (1993) Rules for cocksfoot. The pure seed fractions were used for germination testing. Both single seeds and multiple seed units were germinated separately. From each working fraction (two single seed unit and two multiple seed unit) four lots of 50 seeds were counted out. Each lot was placed on top of moist paper (90 mm x 90 mm) which was then placed in a plastic container 125 mm x 225 mm x 25 mm. In each container two lots of 50 seeds were germinated. A lid was then firmly placed on top of the container to prevent moisture loss prior to prechilling at 5°C. Cvs Wana and Kara received 7 days prechilling while the remaining cultivars only received 4 days prechilling as recommended by the MAF Seed Testing Station, Palmerston North. After prechilling, the containers were placed in a Warren Sherer KY50R controlled environment germinator at alternating temperatures of 20°C for 16 hours without light and 8 hours at 30°C with light for a total test period of 21 days. Interim counts were made at 7, 10 and 14 days. During these counts normal seedlings, abnormal seedlings and mouldy seeds were removed and recorded (Fig. 2.). At the final count (21 day) all remaining seeds were assessed, including fresh ungerminated seeds and dead seeds. The classification of normal and abnormal seedlings and fresh ungerminated seeds was as described by ISTA (1993).

Following the completion of germination tests, a heating damage assessment was conducted on each sample. For each cultivar 10 seeds were randomly selected from both a control sample and a fungicide treated sample. The seeds were placed on potato dextrose agar (PDA) with 7.5% salt in 85 mm diameter x 12 mm deep petri dishes . Potato dextrose agar was made by mixing 39.0 g PDA/l of distilled water in a flask; to this 75 g NaCl was added along with 0.05 g/l of chloramphenicol to prevent bacterial growth. The flask, sealed with cotton wool and tin foil was autoclaved for 20 minutes at 121°C. Following sterilisation, approximately 10 cc of agar was poured into each sterile petri dish in a Laminar flow cabinet to prevent contamination. Once the agar had set, ten seeds were plated on each dish which were then incubated at 25°C with light for 5 days. At this time each plate was assessed for the presence of storage fungi. PDA with salt allows storage fungi to grow readily, but has a generally depressing effect on the growth of field fungi. This gives an indication if any heating damage has occurred in the seed sample following harvest, which may result in a reduction in seed quality (ie lowered germination). If such a problem had occurred, this would be seen by the development of fungi from the *Aspergillus* spp. and *Penicillium* spp..

Figure 2. Germination Test

KIND OF SEED:____________________ DATE OF TEST:________________

ANALYSTS NAME: ______________ TEST METHOD USED:________________

		REPLICATES				MOULDY SEEDS AND ABNOMAL SEEDLINGS REMOVED BEFORE FINAL COUNT	
DAY	DATE	A	B	C	D		
						TOTAL	%
TOTAL NORMAL							
ABNORMAL SEEDLINGS							
HARD SEEDS							
FRESH UNGERMINATED							
DEAD SEEDS							
	TOTAL						

After all data had been collected a statistical analysis was carried out, using a protected LSD (SAS, 1987)..

RESULTS

Vegetative Tiller Production

Vegetative tiller numbers (11 September 1992) following spring sowing in October 1991 ranged from a low of 2100 tillers/m^2 for cvs. Makibamidori and Akimidori, to a high of 4100 tillers/m^2 for cv. Wana (Fig. 3). Both cvs Makibamidori and Akimidori were slower to produce vegetative tillers over the first six months following sowing than all three New Zealand cultivars. By mid autumn (6 April 1992) cvs Akimidori and Makibamidori had produced significantly fewer vegetative tillers than cvs Wana and Tekapo, but cvs Makibamidori and Kara were similar in this respect. Over the winter (June - September, 1992) vegetative tiller production rate slowed slightly in both cvs Wana and Tekapo, but not as much as for the other three cultivars, in which there was no net gain in vegetative tiller numbers. While initially cv Kara produced significantly more tillers than cv Akimidori, over the winter period there was no significant difference in tiller numbers between the two Japanese cultivars and cv. Kara in the early spring. Cultivars Wana and Tekapo produced more vegetative tillers than the other three cultivars over the winter period, although by early spring (11 September) cv. Wana had significantly more vegetative tillers than cv. Tekapo.

Vegetative tiller numbers on 18 September 1992 following autumn sowing ranged from 690 tillers/m^2 for cv Tekapo to 1250 tillers/m^2 for cv Wana (Fig. 4). Unlike the spring sowing, all

Figure 3. Vegetative Tiller Numbers Following Spring Sowing

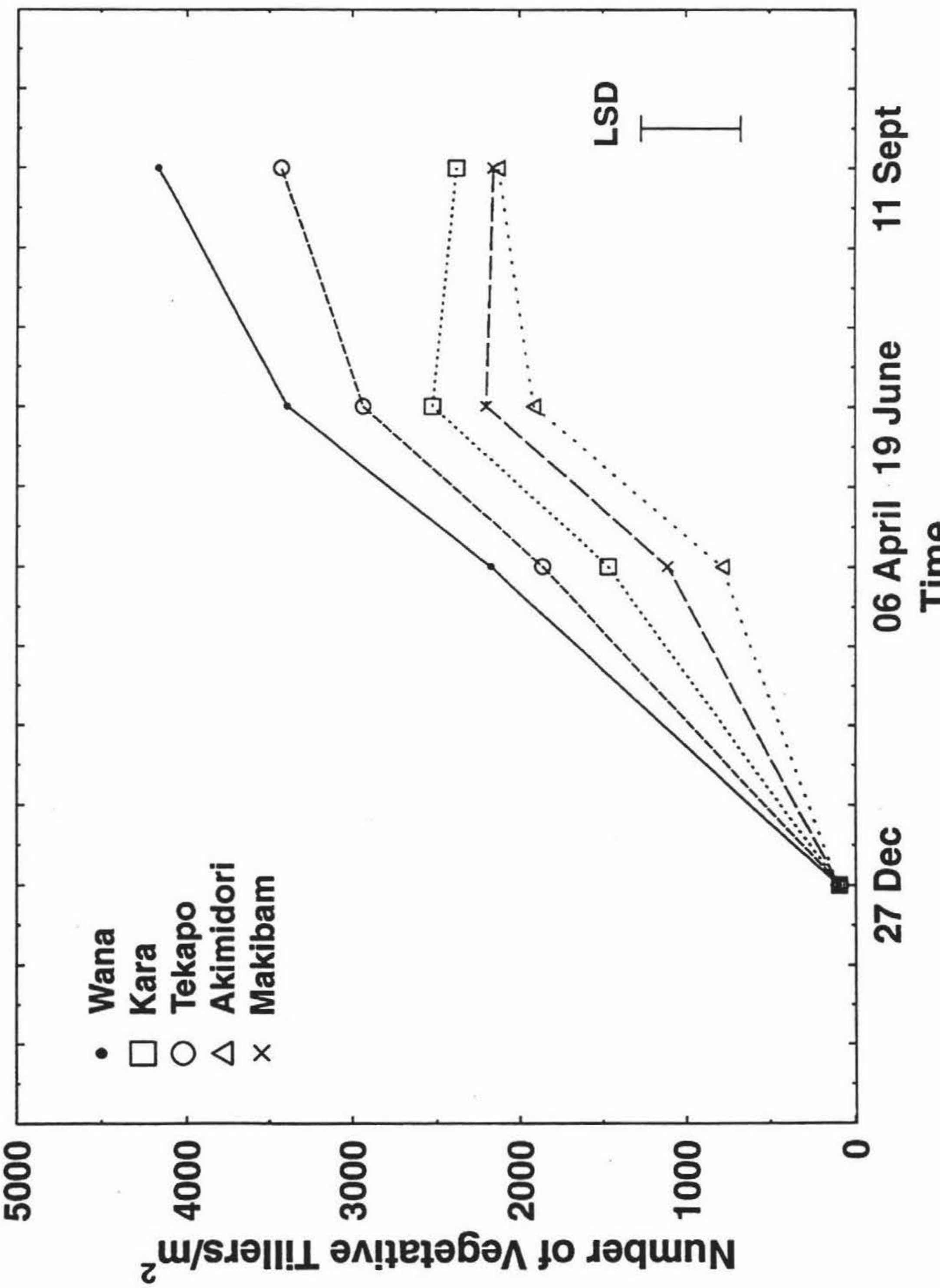
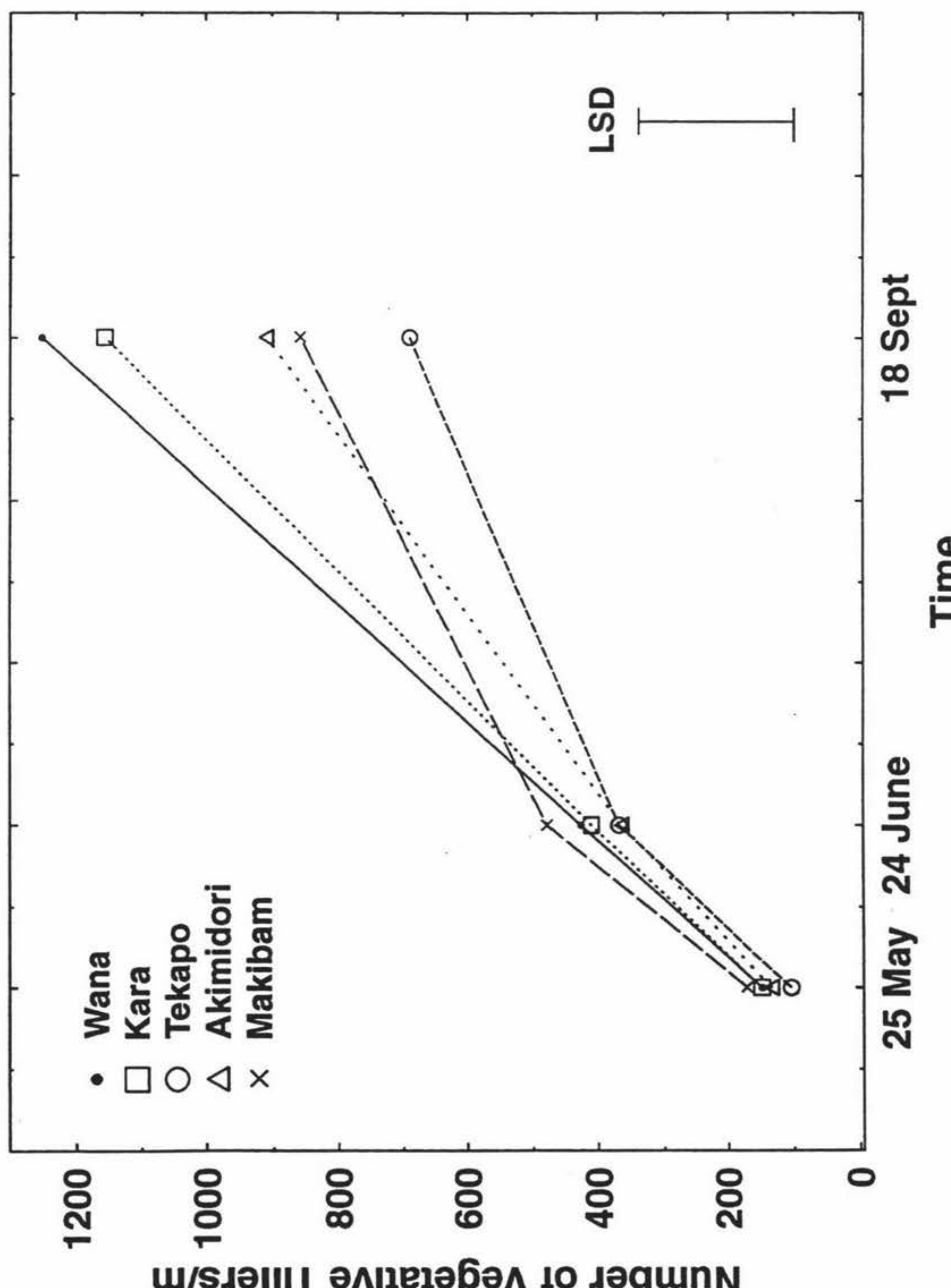


Figure 4. Vegetative Tiller Numbers Following Autumn Sowing



cultivars continued to show a net gain in total tiller number during winter (June - September). On 18 September there was no significant difference in vegetative tiller numbers between cvs Tekapo, Makibamidori and Akimidori, but all three cultivars produced significantly fewer tillers than both cvs Wana and Kara. There was no significant difference in tiller numbers between cv Wana and Kara.

In all cultivars, spring sowing produced a significantly greater number of vegetative tillers than autumn sowing (eg in September 1992, 4100 vegetative tillers/m^2 following spring sowing compared to 1250 vegetative tillers/m^2 following autumn sowing for cv. Wana (Figs. 3 and 4)).

Reproductive Tillers

In the spring sown crop, head emergence began first in cv Akimidori and by 7 and 12 November this cultivar had a significantly greater percentage of reproductive tillers than the other cultivars (Fig. 5). The percentage of reproductive tillers for cv Tekapo did not differ from that of cv. Akimidori on 16 November 1992, but at this time both cultivars had significantly greater percentages of tillers with heads than the other three cultivars. No more heads emerged in cv Akimidori after 16 November, but cv Kara continued to produce heads until 6 December. However differences in the percentage of fertile tillers were not significant among the cultivars after November 23.

In the autumn sown crop, head production again occurred first in cv Akimidori, and the proportion was significantly higher than for all other cultivars on 16, 20, 23 and 27 November (Fig. 6). There was no significant difference in the rate of head emergence between cvs Makibamidori and Tekapo at any time. Although both of these cultivars reached full head

Figure 5 **Estimated Rate of Head Emergence Following Spring Sowing**

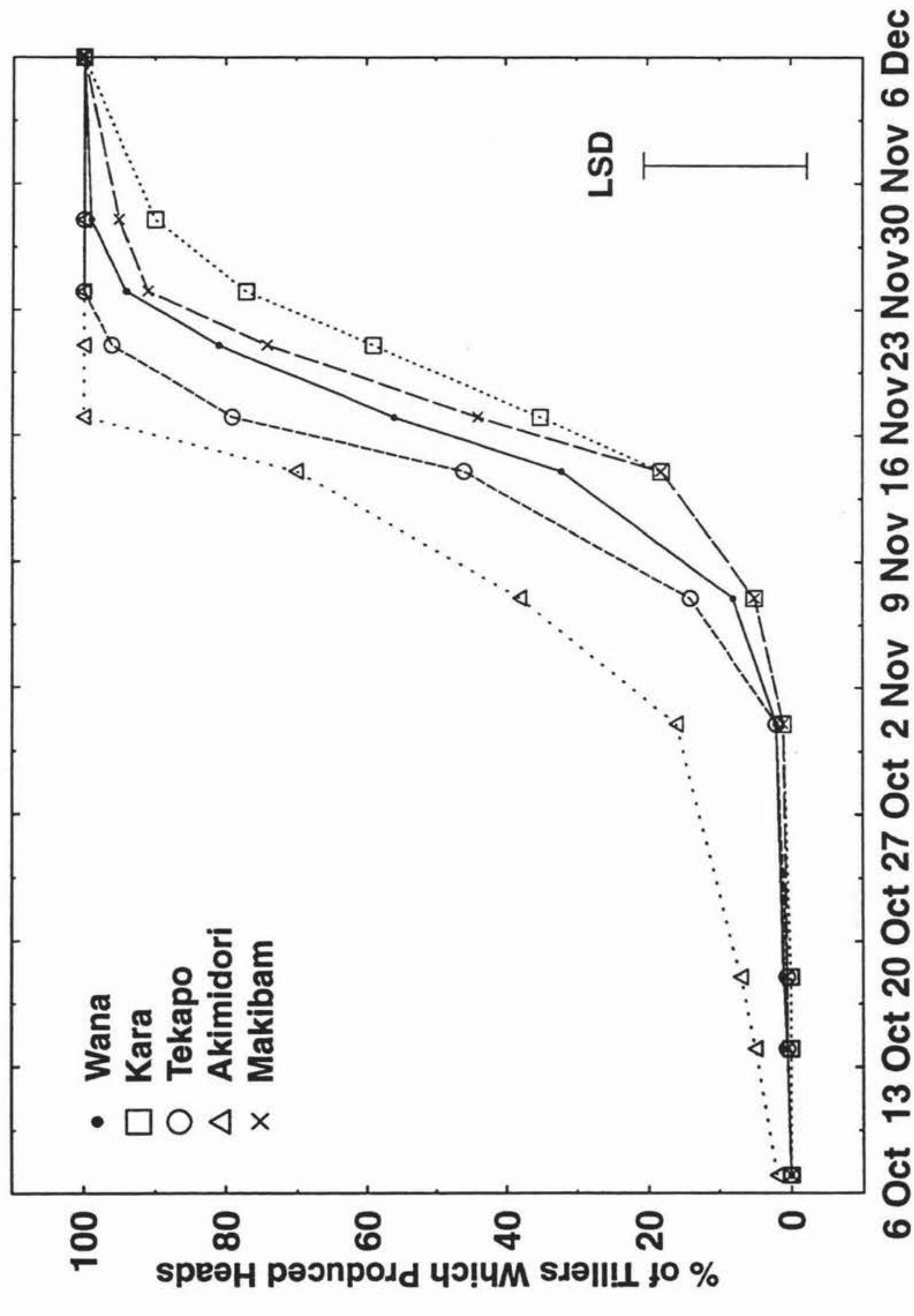
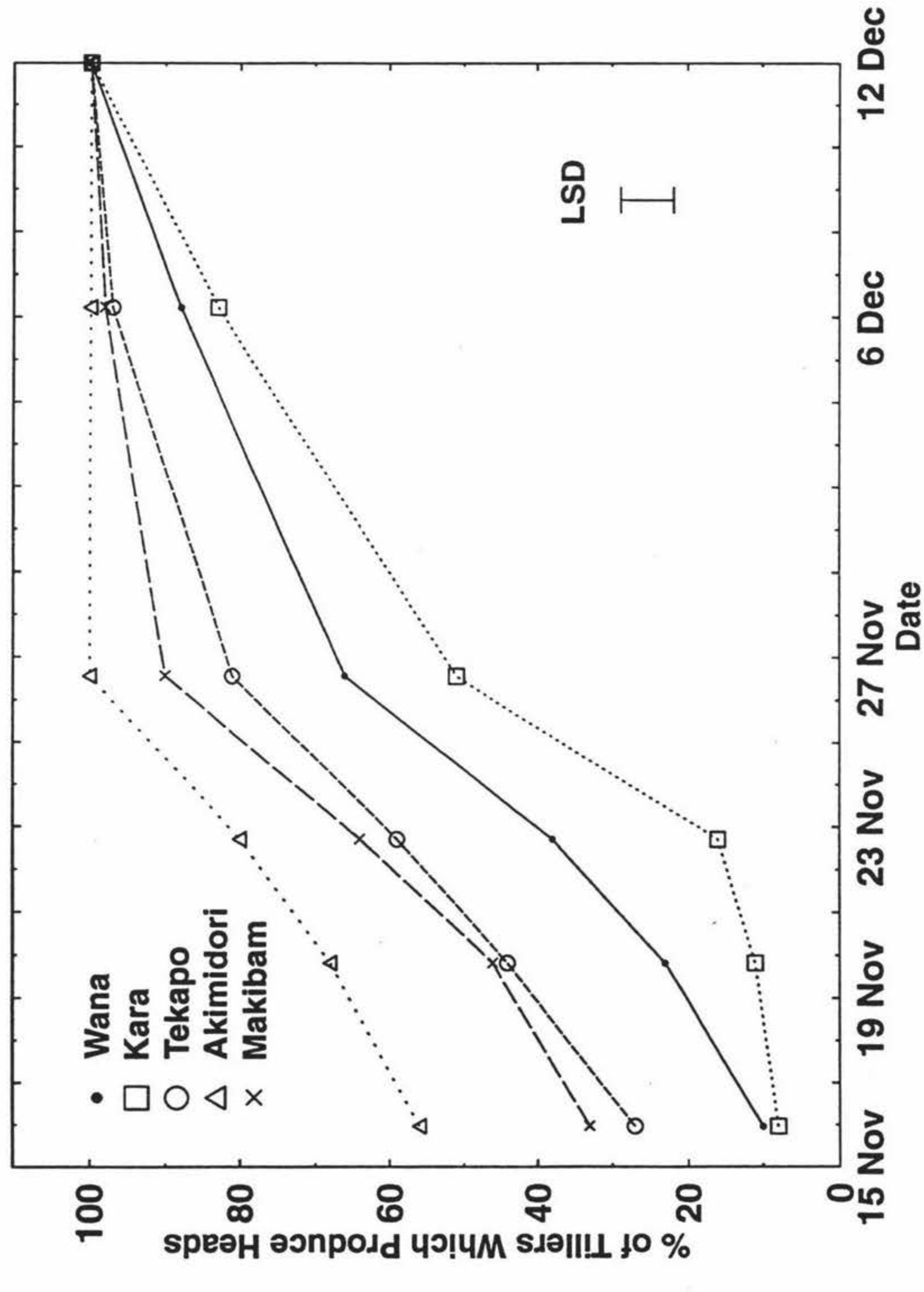


Figure 6. **Estimated Rate of Head Emergence Following Autumn Sowing**



emergence earlier than cvs Wana and Kara, the latter kept producing heads until 12 December, at which time all cultivars were assessed as having reached maximum head production. On 16 November there was no significant difference between cvs Wana and Kara; however, on 20, 23 and 27 November cv Wana had a significantly higher rate of head emergence. By 6 December there was no significant difference between the two (Fig. 6).

Green Area

Fungicide application significantly increased green area (GA) of the flag leaf, leaf 1, leaf 2 and the stem in all five cultivars (Table 3) in spring sown cocksfoot. Because leaf and stem pathogens had an incidence of less than 1%, data were not analysed and are not presented.

There was however, a significant cultivar x fungicide interaction for the GA of the flagleaf (greatest response (75%) in cv Wana), leaf 1 (greatest response (72%) in cv Wana), leaf 2 (greatest response (56%) in cv Wana) and the GA of the stem (greatest response (84%) in cv Akimidori).

In the autumn sown crop, fungicide application also increased the green area of the flag leaf and leaf 1 in cvs. Wana, Tekapo and Makibamidori (Table 4), while the green area of leaf 2 was significantly ($P<0.05$) increased in all cultivars. The GA of the stem was increased significantly ($P<0.05$) in all cultivars except cv Kara. There was a significant cultivar x fungicide interaction for the GA of the flag leaf (greatest response (40%) in cv Wana), leaf 1 (greatest response (24%) in cv Wana), leaf 2 (greatest response (18%) in cv Wana) and the GA of the stem (greatest response (37%) in cv Makibamidori).

Seed Yield Components

Cultivars differed in their ability to produce fertile tillers (Table 5), the range for the spring sowing being from 318 to 651/m^2 in the absence of fungicide. Cvs Kara and Makibamidori

Table 3. Effect of cultivar and fungicide treatment on percentage Green Area in spring sown cocksfoot.

Cultivar	Fungicide	%GA[1]			
		flag leaf	leaf 1	leaf 2	stem
Wana	-	4.2	2.13	1.50	84.9
	+	79.1	74.40	57.87	98.9
Kara	-	32.0	19.79	7.86	89.9
	+	73.6	53.69	26.54	96.7
Tekapo	-	15.6	4.93	1.35	73.7
	+	70.2	61.88	35.81	98.1
Akimidori	-	0.1	0.25	0.00	6.3
	+	49.2	54.50	37.46	90.1
Makibamidori	-	3.3	2.56	0.63	22.6
	+	74.2	65.87	51.53	93.9
LSD P<0.05 fungicide		8.49	6.61	7.86	7.90
LSD P<0.05 cultivar		5.37	NS	NS	5.00
Pr > F (Cv * F)		0.0013	0.0119	0.0357	0.0001

[1] = green area, assessed on 23/24 December 1992

produced significantly fewer fertile tillers/m^2 than other cultivars. Similarly there was a range in florets/tiller (532 to 817/tiller) and thousand seed weight (0.67 - 0.81g) (Table 5). 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 was greater (P<0.05) in cvs Wana and Kara (34 and 38%) than in the other three cultivars (21% or less). Fungicide application had no effect on fertile tillers or florets/tiller, but significantly increased

Table 4. Effect of cultivar and fungicide treatment on percentage Green Area of autumn sown cocksfoot.

Cultivar	Fungicide	%GA[1]			
		flag leaf	leaf 1	leaf 2	stem
Wana	-	35.6	35.38	16.27	88.2
	+	75.3	58.92	34.45	97.3
Kara	-	32.2	18.79	6.87	87.7
	+	35.6	23.87	16.84	90.2
Tekapo	-	25.6	21.99	15.65	81.5
	+	46.6	37.92	25.32	92.7
Akimidori	-	10.0	7.00	3.72	27.9
	+	14.7	12.42	10.65	55.7
Makibamidori	-	2.1	0.83	0.00	33.4
	+	39.7	24.12	16.53	69.9
LSD P<0.05 fungicide		10.78	7.36	6.03	7.95
LSD P<0.05 cultivar		6.82	11.64	9.53	5.03
Pr > F (Cv * F)		0.0022	NS	NS	0.0006

[1] = green area, assessed on 23/24 December 1992

seed weight in all five cultivars. Fungicide application only increased floret site utilisation in cvs Wana and Makibamidori (Table 5). There was a significant cultivar x fungicide interaction for TSW (greatest response (+ 0.28g) in cv Akimidori) and floret site utilisation (greatest response (+ 22.5%) in cv Wana).

Table 5. Effect of cultivar and fungicide treatment on yield components and floret site utilisation of spring sown cocksfoot.

Cultivar	Fungicide	Seed yield components			% FSU[1]
		fertile tillers/m²[2]	florets/ tiller[2]	TSW[3] (g)	
Wana	-	651	532	0.67	34.3
	+	593	507	0.76	56.8
Kara	-	325	615	0.81	38.4
	+	325	624	0.91	39.2
Tekapo	-	609	817	0.77	15.1
	+	851	795	0.90	19.3
Akimidori	-	440	716	0.78	16.0
	+	683	641	1.06	6.4
Makibam	-	318	718	0.73	20.6
	+	283	942	0.88	28.5
LSD P<0.05 cultivar		97.6	146.5	0.03	5.4
LSD P<0.05 fungicide		NS	NS	0.05	8.6
Pr > F (Cv * F)		NS	NS	0.003	0.012

[1] = floret site utilisation
[2] = data taken at anthesis
[3] = thousand seed weight

The ability of the cultivars to produce fertile tillers was variable in the autumn sowing, ranging from 90 to 317/m^2 (Table 6). Cv Wana was the only cultivar capable of producing an acceptable number of fertile tillers. The number of florets/tiller also varied significantly (P<0.05) among cultivars (559 -1198 florets/tiller) as did thousand seed weight (Table 6). 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 6) following autumn sowing. There was a significant cultivar x fungicide interaction for TSW (greatest response (+ 0.19g) in cv Akimidori).

Table 6. Effect of cultivar and fungicide treatment on yield components and floret site utilisation of autumn sown cocksfoot.

Cultivar	Fungicide	Seed yield components			% FSU[1]
		fertile[2] tillers/m^2	florets/[2] tiller	TSW[3] (g)	
Wana	-	317	1198	0.70	23.8
	+	357	1225	0.74	26.0
Kara	-	95	619	0.85	16.9
	+	90	670	0.90	31.9
Tekapo	-	265	819	0.82	12.4
	+	281	752	0.88	12.6
Akimidori	-	107	559	0.60	6.2
	+	103	629	0.79	6.9
Makibam	-	175	701	0.69	4.2
	+	195	708	0.82	11.6
LSD P<0.05 cultivar		94.8	125.6	0.027	3.9
LSD P<0.05 fungicide		NS	NS	0.043	6.1
Pr > F (Cv * F)		NS	NS	0.003	NS

[1] = floret site utilisation
[2] = data taken at anthesis
[3] = thousand seed weight

Field Dressed Seed Yield

In the absence of fungicide, field dressed seed yields (FDSY) from spring sown cocksfoot ranged from 638 kg/ha for cv Makibamidori to 1425 kg/ha for cv Wana (Table 7). The FDSY for cv Wana was significantly greater (P<0.05) than other cultivars, but there was no significant difference amongst the remaining four cultivars (P<0.05), except that cv Tekapo yielded significantly more than cv Makibamidori.

Table 7. Effect of cultivar and fungicide treatment on field and machine dressed seed yield, cleaning losses, purity and mutiple seed units of spring sown cocksfoot.

Cultivar	Fungicide	Yield (kg/ha) FD.[1]	Yield (kg/ha) MD.[2]	Cleaning[3] losses (%)	Purity (%)	MSU (%)[4]
Wana	-	1425	1325	7.0	53.4	34.2
	+	1702	1583	6.9	77.6	42.5
Kara	-	839	763	9.0	74.2	51.8
	+	918	850	7.4	80.6	42.4
Tekapo	-	942	845	10.3	70.2	37.3
	+	1798	1605	10.7	72.1	27.2
Akimi.	-	789	698	11.5	54.9	62.1
	+	484	418	13.6	79.2	51.0
Makib.	-	638	565	11.4	48.2	46.2
	+	888	793	10.7	71.7	46.4
LSD P<0.05 fungicide		179.4	166.9	1.49	4.68	NS
LSD P<0.05 cultivar		283.7	263.9	2.36	7.41	9.56
Pr > F (Cv * F)		0.005	0.008	NS	0.005	NS

[1] = field dressed
[2] = machine dressed
[3] = (FD - MD / FD) x 100
[4] = Multiple seed units

The field dressed seed yields of cvs Wana, Tekapo and Makibamidori were significantly ($P<0.05$) increased by the application of fungicide (Table 7). These increases ranged from 19% (cv Wana) to 91% (cv Tekapo). However fungicide application failed to significantly increase the field dressed seed yield of cv Kara and produced a significant reduction in field dressed seed yield in cv Akimidori (- 39%). There was a significant interaction between cultivar and fungicide application for field dressed seed yield, with the greatest response (+ 856kg) from cv. Tekapo.

In the absence of fungicide the field dressed seed yield of autumn sown cocksfoot ranged from 92 kg/ha (cv Akimidori) to 943 kg/ha (cv Wana) (Table 8). Cultivar Wana produced a significantly ($P<0.05$) higher field dressed seed yield than all other cultivars, but there was no significant difference among the other four cultivars. Only cv Wana produced a significant increase in field dressed seed yield following the application of fungicide (Table 8).

Machine Dressed Seed Yield

In the absence of fungicide, machine dressed seed yield (MDSY) from spring sown cocksfoot ranged from 565 kg/ha (cv Makibamidori) to 1325 kg/ha (cv Wana) (Table 7). The MDSY for cv Wana was significantly greater ($P<0.05$) than all other cultivars. There was no significant difference ($P<0.05$) among the other four cultivars, except between cv Tekapo (942 kg/ha) and cv Makibamidori (565 kg/ha).

MDSY of cvs Wana, Tekapo and Makibamidori was significantly ($P<0.05$) increased by the application of fungicide. These increases ranged from 19% (cv Wana) to 90% (cv Tekapo).

Table 8. Effect of cultivar and fungicide treatment on field and machine dressed seed yield, cleaning losses, purity and multiple seed units of autumn sown cocksfoot.

Cultivar	Fungicide	Yield (kg/ha) FD.[1]	Yield (kg/ha) MD.[2]	Cleaning losses (%)[3]	Purity (%)	MSU (%)[4]
Wana	-	943	845	10.4	65.9	37.7
	+	1228	1156	5.9	72.2	26.4
Kara	-	167	137	18.0	61.5	47.2
	+	258	224	13.2	71.0	45.2
Tekapo	-	430	355	17.4	68.9	39.9
	+	406	333	18.0	70.4	44.8
Akimid.	-	92	71	22.8	29.4	64.9
	+	84	65	22.6	48.1	53.4
Makib.	-	140	109	22.1	30.0	45.3
	+	278	216	22.3	60.6	48.7
LSD P<0.05 fungicide		190.5	175.6	3.61	3.79	NS
LSD P<0.05 cultivar		301.2	277.7	5.70	5.99	6.02
Pr > F (Cv * F)		NS	NS	NS	0.001	0.017

[1] = field dressed
[2] = machine dressed
[3] = (FD - MD / FD) x 100
[4] = Multiple seed units

The application of fungicide did not significantly affect the machine dressed seed yield for either cv Kara or Akimidori. There was a significant interaction between cultivar and fungicide application for machine dressed seed yield, with the greatest response from cv Tekapo (+ 760 kg/ha).

In the absence of fungicide the MDSY of autumn sown cocksfoot ranged from 71 kg/ha (cv Akimidori) to 845 kg/ha (cv Wana)(Table 8). There was no significant difference (P<0.05) in the machine dressed seed yield among cvs Kara, Tekapo, Akimidori and Makibamidori, but cv Wana produced significantly more seed than the other cultivars. With the application of fungicide cv Wana was the only autumn sown cultivar to produce a significant ($P<0.05$) increase in machine dressed seed yield.

Cleaning Losses and Percentage Pure Seed

In the absence of fungicide the percentage cleaning losses in spring sown cocksfoot ranged from 7.0% for cv Wana to 11.5% for cv Akimidori (Table 7.), with cv Wana losing significantly less than cvs Tekapo, Makibamidori and Akimidori ($P<0.05$). The application of fungicide resulted in a significant ($P<0.05$) reduction in cleaning loss for cv Kara and an increase for cv Akimidori, but had no significant ($P<0.05$) effect on the cleaning loss of the remaining three cultivars (Table 7). There was no significant interaction between cultivar and fungicide applicaton for cleaning losses.

In the absence of fungicide the percentage of pure seed (ISTA, 1993) ranged from 48.2% (cv Makibamidori) to 74.2% (cv Kara) in spring sown cocksfoot (Table 7). There was no significant difference ($P<0.05$) in the purity of cvs Kara and Tekapo, both of which had a significantly higher purity than other cultivars. The application of fungicide resulted in a significant ($P<0.05$) increase in the percentage of pure seed in all cultivars except cv Tekapo.

The cleaning losses in autumn sown cocksfoot in the absence of fungicide ranged from 10.4% (cv Wana) to 22.8% (cv Akimidori) (Table 8). Cultivar Wana had significantly ($P<0.05$) lower cleaning losses than all other cultivars, which did not differ significantly. The application of fungicide significantly reduced the cleaning losses of autumn sown cvs Wana and Kara cocksfoot.

The percentage of pure seed extracted from the machine dressed seed ranged from 29.4% (cv Akimidori) to 68.9% (cv Tekapo) for autumn sown cocksfoot in the absence of fungicide. All three New Zealand cultivars had significantly higher ($P<0.05$) purity levels than either of the two Japanese cultivars, and cv Tekapo had a significantly higher seed purity than cv Kara. There was no significant difference in the seed purity between cvs Akimidori and Makibamidori. Fungicide application produced a significant increase in seed purity in all cultivars except cv Tekapo. Both Japanese cultivars had the biggest increases in purity after fungicide application, with a 64% increase in cv Akimidori and a 102% increase in cv Makibamidori.

Multiple Seed Units

The percentage of multiple seed units (MSU) ranged from 34.2% (cv Wana) to 62.1% (cv Akimidori) in the absence of fungicide in spring sown cocksfoot (Table 7). Cultivar Akimidori had a significantly ($P<0.05$) higher percentage of multiple seed units than all other cultivars. There was no significant difference in % MSU between cvs Kara and Makibamidori or between cvs Wana and Tekapo which both had significantly fewer multiple seed units than cv Kara. The application of fungicide did not have a significant ($P<0.05$) effect on the percentage of multiple seed units present in any one cultivar.

In the absence of fungicide, the percentage of multiple seed units in autumn sown cocksfoot ranged from 64.9% (cv Akimidori) to 37.7% (cv Wana). Cultivar Akimidori had a significantly ($P<0.05$) higher percentage of multiple seed units than the remaining four cultivars. There was no significant difference in the proportion of multiple seed units between cvs Kara and Makibamidori, both of which were significantly higher than cvs Wana and Tekapo. The application of fungicide had no significant ($P<0.05$) effect on the percentage of multiple seed units in any of the cultivars.

Pure Seed Yield

Pure seed yields (MDSY x % purity) were significantly greater ($P<0.05$) in a spring than in autumn sown crop in all five cultivars (Table 9). Yields from spring sowings in the absence of fungicide ranged from 307 kg/ha for cv Makibamidori to 707 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 an "acceptable commercial" pure seed yield (557 kg/ha) following autumn sowing (Table 9). Yields for cv Kara, Akimidori and Makibamidori were all less than 100 kg/ha, while cv Tekapo produced only 237 kg/ha.

Fungicide application significantly increased pure seed yield in spring sown cv Wana, Kara and Tekapo, but not in cvs Akimidori or Makibamidori (Table 9). These increases ranged from 21% (cv Kara) to 95% (cv Tekapo). 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 9). Sowing date interactions were not significant.

Table 9. Effect of time of sowing and fungicide application on pure seed yield (kg/ha) of five cocksfoot cultivars

		Time of sowing	
Cultivar	Fungicide	Spring	Autumn
Wana	-	707	557
	+	1228	834
Kara	-	566	84
	+	685	159
Tekapo	-	593	244
	+	1157	234
Akimidori	-	383	21
	+	331	31
Makibamidori	-	307	33
	+	405	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	

Seed Quality

The germination of seeds produced from spring sown cocksfoot ranged from 80% (cv Kara) to 83% (cv Tekapo) in the absence of fungicide, with no significant (P<0.05) difference in germination among cultivars (Table 10.). The application of fungicide did not significantly affect the germinability of any cultivar or the percentage of fresh ungerminated and dead seeds. In the absence of fungicide cvs Wana and Kara had significantly (P<0.05) more fresh ungerminated seed than the other three cultivars. However, the percentage of dead seeds did not differ significantly among cultivars in the absence of fungicide.

Table 10. Effect of fungicide treatment and cultivar on the germination of seed from spring sown plots.

Cultivar	Treatment	Normal Seedlings (%)	Fresh Ungerminated Seeds (%)	Dead Seeds (%)
Wana	-	80	3	16
	+	83	3	14
Kara	-	80	3	16
	+	82	4	15
Tekapo	-	83	1	15
	+	85	2	12
Akimidori	-	82	1	17
	+	83	1	15
Makibam	-	81	1	17
	+	82	2	15
LSD P<0.05		3.6	1.6	3.4

Note: Abnormal seedling (%) not included as all results were less than 1.0%.

In the absence of fungicide, the germination of seeds produced from autumn sown cocksfoot did not differ significantly (P<0.05), ranging from 78% (cv Wana) to 80% (cv Makibamidori) (Table 11). Similarly, the application of fungicide had no significant effect on germination. In the absence of fungicide there was no significant (P<0.05) difference in the percentage of fresh ungerminated seeds among cultivars, with the exception of cv Kara (3%) and cv Makibamidori (1%). A similar result was obtained for the percentage of dead seed, the only significant difference being between cv Wana (16%) and cv Akimidori (20%). The application of fungicide did not have a significant (P<0.05) effect on the percentage of fresh ungerminated seed, except for a 2% increase in cv Wana.

Table 11. Effect of fungicide treatment and cultivar on the germination of seed from autumn sown plots.

Cultivar	Treatment	Normal Seedlings (%)	Fresh Ungerminated Seeds (%)	Dead Seeds (%)
Wana	-	78	3	16
	+	80	5	14
Kara	-	79	3	17
	+	80	3	17
Tekapo	-	79	2	17
	+	81	2	16
Akimidori	-	79	2	20
	+	82	1	17
Makibam	-	80	1	18
	+	81	2	17
LSD P<0.05		2.8	1.7	2.8

Note: Abnormal seedling (%) not included as all results were less than 1.0%.

No *Penicillium* or *Aspergillus* fungal colonies were detected on seeds plated onto PDA plus salt, indicating that no storage fungi were present in the seed lots, and therefore heating damage did not account for the dead seeds present in all lots.

DISCUSSION

Effect of Time of Sowing

A number of temperate perennial grasses have shown an inability to produce an acceptable seed yield following autumn sowing. This is true of Grasslands Matua prairie grass (Hare *et al*, 1988), tall fescue, and cocksfoot (Van Keuren and Canode, 1963). Beddows (1964) found that cocksfoot sown in late summer or early autumn and harvested 9 months later produced a disappointing seed yield. The later the sowing is left, the more the crop's capacity to produce panicles in the summer is diminished. In this trial, all spring sowing outyielded the autumn sowings.

Cocksfoot, as with other temperate grasses such as perennial ryegrass, has specific environmental requirements for seed production (Langer, 1980). Cocksfoot requires warm temperatures with minimum water stress during establishment (Hare, 1990). It is traditionally sown at a low rate (3 - 5 kg/ha) and at wide row spaces (30 cm) in the spring for harvesting 15 or 27 months later. However cultivar Wana can be sown in autumn and harvested 10 months later, provided it is sown early (February - early March) (White, 1990). The ideal conditions for vegetative growth (Hare 1990) are moderate and well-distributed rainfall during spring and early summer.

Prior to winter a temperate grass will remain vegetative. During winter, under the influence of temperatures below 10^{o}C (vernalization) and short days, floral induction occurs. Calder (1965) suggested that darkness is also an essential environmental factor for completion of induction, since cocksfoot fails to head when grown from germination in continuous light.

Unlike perennial ryegrass, cocksfoot has a juvenile stage prior to floral induction. During this stage the plant is insensitive to environmental conditions which later promote flowering. The length of this period (up to 6 weeks) may be controlled by a minimal leaf area, apical volume, number of plastochrome cycles or by the accumulation of carbohydrates within the plant (Calder, 1965). Once vernalization has occurred, the tillers are capable of becoming reproductive once temperature increases, along with photoperiod. The greater the number of tillers available for vernalization the greater the number of reproductive sites at anthesis. 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 following summer. Wilson (1959) found that cocksfoot produced relatively few seed heads from tillers formed after mid July. In this trial, compared to autumn sowing, spring sowing produced up to four times more vegetative tillers by mid July (Fig. 3 and 4).

Following winter the crop requires a fine spell of weather at the time of pollination followed by gentle rain during seed fill and a dry sunny period for ripening (Hare 1990). Pollen dispersal is restricted to several brief periods during the day (Langer, 1972). Anthesis and subsequent pollen dispersal is positively affected by temperature and light intensity. Cocksfoot exerts anthers slowly and this is therefore influenced by weather conditions the previous day. That is, warm sunny weather during one day initiates the exertion of the anthers which are slowly released over the period of that day and night. By the following morning the anthers are exerted and are therefore able to release pollen. Temperatures below 12.8°C at night followed by a cloudy day inhibit pollen release, but high day temperatures due to lack of cloud give normal pollen release (Hill, 1980). Subsequent seed development is greatly enhanced by warm temperatures and good light intensity with a good supply of water.

Cocksfoot establishes more slowly than other temperate grasses such as perennial ryegrass (Langer 1990). When autumn sown in this trial, the time before winter was too short to enable the plants to produce a large number of tillers which had passed through the juvenile stage prior to vernalization. The autumn sown cocksfoot effectively had only three months in which to establish a high number of vegetative tillers. Therefore the autumn sown cocksfoot failed to produce as much seed as the spring sown cocksfoot purely because of a 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 when sown in autumn was not fairly assessed. Hare (1994) for example recorded a 500 kg/ha reduction in seed yield of tall fescue 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 is not known, but is highly likely, especially considering data presented by Niemelainen (1991). Although his data are from trials conducted in Finland, Niemelainen observed fewer reproductive tillers the later the sowing date in the autumn. 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 following the post emergence treatment of seedling cocksfoot with 1.5 kg ai/ha of ethofumesate (to control *Poa annua*) at a sowing at this same site on 3 April.

Although head emergence began at a similar rate in both spring and autumn sown cultivars, the spring sown cultivars reach 100% head emergence about one week earlier than autumn sown cultivars. This suggests that in addition to a reduced number of reproductive tillers, head emergence was less uniform, possibly leading to a wider range of head maturity at harvest and thus more light seed at harvest. The greater cleaning losses obtained from all autumn sown cultivars when compared to spring sown cultivars certainly supports this suggestion.

The number of florets/tiller did not differ greatly between the two sowing dates, with the exception of cv Wana. Cultivar Wana showed the ability to improve its seed yield by producing more florets/tiller following autumn sowing than when sown in spring. Although autumn sown cv Wana had half the number of fertile tillers than its spring sown counterpart, it produced twice as many florets/tiller, thus giving it a similar potential seed yield. However, as with all autumn sown cultivars, the FSU was much lower than for the spring sown cultivars and therefore the autumn sown plants were unable to recognise this potential. Seed that was produced following autumn sowing was heavier than that of spring sown cocksfoot, with the exception of cv. Akimidori. This, in conjunction with higher cleaning losses, lead to all autumn sown cultivars having lower pure seed yields than the spring sown cultivars. When considering the purity of cocksfoot it has been demonstrated that up to 10% of cocksfoot florets are morphologically sterile (Hill, 1980). Thus, cocksfoot is incapable of reaching 100% FSU or purity. This also adds to the cleaning losses of both spring and autumn sown cocksfoot.

Sowing date did not affect the percentage of MSU present in the seed lot or the germanability of the seed. The germination results gained in this trial are comparable to results received for the New Zealand cultivars from MAF Seed Testing Station (Appendix 1.)

Effect of Cultivar

The ability of cocksfoot plants to produce seed can vary from cultivar to cultivar. This has been observed in different cultivars in Finland, where the seed yield per hectare was significantly higher in cv Haka than in cvs Hera Daehnfeldt, Fala, Frode and Tatu (Niemelainen, 1991). These differences were attributed largely to differences in panicle density among cultivars. Nittler *et al* (1963) went so far as to suggest the use of vegetative tiller number as a method of detecting differences among cultivars of cocksfoot, as they found that cultivar differences in respect to tillering appeared to be relatively large. Following spring sowing cvs Wana and Tekapo were capable of producing significantly more vegetative tillers than the other three cultivars. In fact these two cultivars were the only cultivars to have a net gain of tiller numbers during winter, suggesting better winter survival or less winter dormancy. A little winter growth is expected from both these cultivars (Anon 1995). These greater numbers of vegetative tillers, when exposed to winter vernalization conditions, lead to both these cultivars having a significantly greater number of fertile tillers at anthesis. It is these fertile tillers which are the most important contributing component to final seed yield (Langer 1980). Following an autumn sowing cvs Wana and Kara also produced significantly more vegetative tillers than the other three cultivars. This was reflected in the significantly higher number of fertile tillers these two cultivars produced during the following summer.

Cultivar Tekapo produced significantly more vegetative tillers than cv Kara following spring sowing, yet after an autumn sowing the reverse effect occurred. These results suggest that cv Tekapo has a greater ability to produce vegetative tillers after a spring sowing than cv Kara. However, after autumn sowing cv Kara is capable of producing greater numbers of vegetative tillers. Plant variety studies (Anon 1995) show that cv Tekapo has a similar reproductive tiller density to that of cv Wana.

This ability of cv Kara to produce more tillers than cv Tekapo appears to be an anomaly. AgResearch Grasslands trials (Anon 1995) show that cv Tekapo produces more tillers in the ten weeks following sowing than both cv Wana and Kara. With some ability to grow over winter it should be able to produce more tillers than cv Kara following an autumn sowing. The reason this anomaly occurred is unknown.

Following spring sowing cv Wana and Tekapo produced more fertile tillers than the other cultivars. This, in conjunction with a large number of florets/tiller, gave these two cultivars a greater yield potential than the other cultivars. After spring sowing, the plant has plenty of time in which to produce tillers. This particular component becomes non limiting, as has been found in ryegrass (Hampton and Hebblethwaite 1983). This is reflected in the fact that there was no significant association between the pure seed yield and tiller number (Appendix 2), with the exception of cv Tekapo, which obviously relied heavily on tiller number to provide the bulk of the pure seed yield.

Wana was the only cultivar able to produce a reasonable seed yield following autumn sowing. The next best was cv Tekapo, with less than half the seed yield of cv Wana. Cultivar Wana was able to produce more seeds largely because it was able to produce a relatively large quantity of vegetative tillers in a short period of time, thus enabling a good number to be vernalized over the winter period. It follows that cv Wana had the largest number of fertile tillers at anthesis. The ability of cv Wana to produce a good seed yield under this sowing regime has also been recorded by White (1990) and Rolston (1991). The ability of cv Wana to produce a large number of tillers, even after a short period of time, can be largely attributed to its morphology, as it is a more densely tillered cultivar compared to cv Kara and its predecessor cv Grasslands Apanui (Rumball 1982b). Also contributing to cv Wana's ability to produce a good seed yield following an autumn sowing was the plant's ability to double the number of florets produced per tiller compared to spring sown cv Wana. This relationship between spikelet number and fertile tiller number was noted in ryegrass by Hampton and Hebblethwaite (1983). Ryle (1964) found that the ear size of cocksfoot decreased in size the later the date of origin. The later the origin of the ear the fewer primary branches in the ear and fewer florets on each branch. Those ears which arise early in the autumn have a greater period of time to accumulate unexpanded leaf primordia which subsequently provide more spikelets/ear. Langer (1972) noted that it is generally tillers produced early in autumn which form the bulk of the fertile tillers. For example, in cocksfoot over 70% of inflorescences may be contributed by tillers which were present in the previous autumn. In this trial, the time before winter was so short following the autumn sowing that those early formed tillers were the only ones with the time to go through the juvenile phase, be vernalised, and thus have time to accumulate primordia and ultimately giving a large number of spikelets/head. In the spring sown plants there was a greater collection of tillers which varied in age and position on the plant, resulting in a mean lower number of spikelets/head.

An important observation noted during anthesis was the period over which seed heads flowered. In this trial there were still heads flowering just prior to harvest. Meijer (1985) suggested that uneven ripening was a major factor contributing to the poor utilization of yield potential in perennial ryegrass. Because cocksfoot has such a long flowering period, this produces a large difference in seedhead maturity. When harvest date is determined, the moisture content is measured from a range of seedheads which are going to have a range of maturities. Harvest will therefore tend to take place at the time when the majority of seedheads are ready. However, by this time some seed would have started shattering and other seed will be immature. Both spring and autumn sown cv Wana and Kara had better FSU than the remaining cultivars. It is possible that a more compact ripening period reduced the amount of seed lost due to shedding and immaturity. However data were not recorded for this possibility.

Due to its greater yield potential, cv Wana produced significantly higher FDSY and MDSY than the other cultivars. This, in association with lower cleaning losses and higher FSU, lead to cv Wana having a significantly higher pure seed yield than the remaining cultivars. All three New Zealand cultivars were able to produce more seed than the Japanese cultivars. The New Zealand cultivars showed a better ability to utilise potential floret sites. Cultivars Wana and Tekapo showed a significant association between FSU and pure seed yield (Appendix 2.), as did cv Kara, which had a smaller potential yield than the Japanese cultivars, yet still produced a higher FDSY and MDSY than the two Japanese cultivars. This, in conjunction with lower cleaning losses and a higher purity gave a significantly higher pure seed yield. The seed that the Japanese cultivars did produce was significantly bigger than all three of the New Zealand cultivars, and cv Makibamidori had a significant association between TSW and pure seed yield (Appendix 2.).

Frequencies at which different percentages of multiple seed units occur in different seedlot were supplied by the Official Seed Testing Station, Palmerston North (Appendix 6). This information gave a range of multiple seed unit frequencies which occur in certified cocksfoot seed lots in New Zealand. In comparing these ranges with the percentage of multiple seed units in this trial after threshing and cleaning, all five cultivars produced a higher percentage of multiple seed units than those supplied by the Seed Testing Station. This is possibly due to the threshing method used in this trial, which may not have been vigourous enough to split up multiple seed units which under conventional harvesting may have been reduced to a single seed.

Effect of Fungicide Application

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 and Tekapo and autumn sown cv Wana all produced significant pure 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 individual seed yield components were recorded, fungicide application was found to have different effects on different yield components. It is also important to note that over the period of reproductive tiller development and seed development, weather conditions were not conducive to high disease infection (Appendix 5), but were good for reproductive development. Plant pathogens tend to require warm temperatures and the presence of moisture to become active following winter and early spring (Agrios 1969). A pathogen will tend to have an optimum temperature and moisture availability, which if not met or exceded will prevent the fungus from establishing. Latch (pers comm) believes the climate during spring is the most important factor for the growth of fungi such as rust. The rust needs to be able to build-up a large amount of inoculum following winter, thus allowing it to establish itself during the summer. The climate during the spring and summer of 1992 (Appendix 5) had warm temperatures in conjunction with very low rainfall. Moisture is important in the transport of fungal spores (Agrios 1969). On the other hand the dry warm conditions during November were ideal for anthesis and pollination/fertilization. Also, slightly more rain during seed development and seed fill in December, followed by dry condtions at harvest in January provided almost the ideal conditions for seed production as described by Hare (1990).

With the application of fungicide, the major response was an increase in seeds per spikelet, or more accurately, better floret site utilisation, most likely because of a reduction in seed abortion (Hampton, 1986). As in other reports, fungicide application appeared to delay leaf senescence, as GA was significantly increased. Marshall (1985) found that fungicide treatment maintained the photosynthetic activity of tillers and resulted in an improved supply of assimilate to developing perennial ryegrass seeds at a time when they are normally prone to abort, therefore improving FSU. For spring sown cvs Wana, Tekapo and Makibamidori there was a significant association between GA (flag leaf) and seed yield (Appendix 3). Cultivars Tekapo and Makibamidori showed a positive association between the GA (leaf 1 and 2) and seed yield. There was also a significant association between the GA of the stem and seed yield for cvs Wana and Makibamidori, which may suggest stem reserve utilisation. This has recently been found in perennial ryegrass where 14 -51% of stored stem reserves went to the developing seed (Roy and Rolston 1994). Improved seed yields in cocksfoot were obtained by Welty (1989) who implied that fungicide treated plants were able to partition more photosynthate to the seed heads. Improved GLA duration allowing the production of photosynthates for a longer period appear to have improved the seed yield. Fungicide application increased the TSW of all cultivars in both autumn and spring sown cultivars. Hampton (1986) gained improved TSW with the application of fungicide to perennial ryegrass.

For cv Wana and Tekapo, improved floret site utilisation was positively and significantly associated with the seed yield increase recorded. The association between GA and seed yield (Appendix 3) was not significant for cvs Kara and Akimidori, even though the application of fungicide did improve the GA. This improved GA failed to have a significant impact on the floret site utilisation of cvs Kara, Tekapo and Makibamidori, but it did result in a significant association between GA and floret site utilisation of cv Wana (Flag leaf, leaf 1 and stem) and cv Akimidori (Flag leaf and leaf 2) (Appendix 4). 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 Kara and Akimidori did not respond to fungicide application could not be determined from the data recorded. The application of fungicide significantly reduced the cleaning losses only from spring and autumn sown cv Kara and autumn sown cv Wana. Although these losses weren't reduced in the remaining cultivars, the percentage of pure seed was significantly increased by fungicide application in all cultivars except spring and autumn sown cv Tekapo. This is probably a consequence of the improved FSU. As previously discussed (Marshall 1985), the application of fungicide has the ability to reduce abortion of seed, and this improves the FSU of the plant. This improved FSU leads to an increased percentage of pure seed.

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 (ie 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 significantly improved the seed yield of the three New Zealand 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 cv Akimidori, when calculations are based on a price of approximately $3.30/kg for the pure 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 $1769/ha) and the lowest return came from cv Makibamidori (additional $231/ha). For autumn sown cultivars two applications of fungicide were cost effective only for cv Wana (additional $822/ha) and despite the low yield, cv Makibamidori (additional $228/ha).

CHAPTER 3

INTRODUCTION

Following the first year's harvest the trial was continued, to enable the examination of the same five cultivars once establishment effects had been removed. The second harvest seed yields of each of the five cultivars were compared, and these differences analysed through the examination of their seed yield components. Also a further fungicide trial was carried out to investigate the effects of time of application. The fungicide used was changed from propiconazole to terbuconazole, because the latter was thought to give better control of eyespot. Once again the effects of fungicide on seed yield and seed yield components were analysed.

MATERIALS AND METHODS

At the end of January 1993, following the first season harvest, all plots were cut to a height of approximately 5 cm using a rotary mower and the cut vegetation was removed. On March 25 1993, 50 kg N/ha in the form of Urea (Petrochem of New Zealand Ltd) was applied to all 80 plots. Because all plots were cut back to 5 cm, and all debris was removed, all treatment effects of the previous year were condsidered to be no longer effective, and therefore the two blocks (spring sown block and autumn sown block) were treated as one large block. This allowed a more expansive fungicide trial to be conducted in the second year.

Following the application of urea, the area around each plot was sprayed with glufosinate-ammonium (Buster) at a rate of 1500 g a.i./ha to kill broadleaf and annual weeds and undesirable grasses, including volunteer cocksfoot seedlings. Care was taken to ensure cocksfoot plants in the plots were not sprayed by spraying on a windless day and by using a plastic spray guard around the nozzle. Weeds within each plot were removed by hand. Over the winter period the plots were not touched, but on 3 August all plots were cut back to approximately 10 cm using a rotary mower, and the cut vegetation was removed.

A second application of urea (75 kg N/ha) was applied on 28 September 1993. Also on this day, the first visual scoring of reproductive tillers took place as previously described in the materials and methods section in Chapter 2. These assessments continued every 4 - 7 days thereafter until 25 November 1993.

Using all 80 plots, a new set of fungicide treatments using terbuconazole at 188 g ai/ha was set up. Four plots of each cultivar were randomly selected to receive four different fungicide treatments (Fig. 7.). The fungicide was applied using a pressurised knapsack sprayer as described in Chapter 2. The treatments were as follows:

- nil fungicide application,
- one fungicide application at ear emergence (approximately 10% ear emergence),
- two fungicide applications at ear emergence and anthesis (approximately 10% of the plot flowering),
- two fungicide applications at anthesis and post anthesis (10 days following full anthesis).

The timing of each of these applications differed slightly between cultivars as each cultivar headed and flowered at different times (Table 12).

Figure 7. Experimental design - plot plan.

Kara (eea)	Wana (apa)	Wana (apa)	Kara (ee)
Wana (ee)	Tekapo (c)	Tekapo (eea)	Akimidori (ee)
Akimidori (c)	Makibam (ee)	Makibam (eea)	Wana (c)
Tekapo (apa)	Akimidori (ee)	Kara (ee)	Tekapo (eea)
Makibam (eea)	Kara (apa)	Akimidori (ee)	Makibam (ee)
Akimidori (eea)	Tekapo (eea)	Kara (apa)	Makibam (c)
Kara (c)	Makibam (c)	Akimidori (apa)	Kara (eea)
Wana (apa)	Kara (c)	Wana (c)	Tekapo (apa)
Makibam (apa)	Wana (ee)	Makibam (c)	Akimidori (apa)
Tekapo (ee)	Akimidori (eea)	Tekapo (ee)	Wana (eea)
Kara (ee)	Wana (eea)	Wana (ee)	Kara (apa)
Wana (c)	Tekapo (apa)	Tekapo (apa)	Akimidori (c)
Akimidori (apa)	Makibam (apa)	Makibam (apa)	Wana (apa)
Tekapo (c)	Akimidori (c)	Kara (c)	Tekapo (ee)
Makibam (ee)	Kara (eea)	Akimidori (eea)	Makibam (apa)
Akimidori (ee)	Tekapo (ee)	Kara (eea)	Makibam (eea)
Kara (apa)	Makibam (eea)	Akimidori (c)	Kara (c)
Wana (eea)	Kara (ee)	Wana (eea)	Tekapo (c)
Makibam (c)	Wana (c)	Makibam (ee)	Akimidori (eea)
Tekapo (eea)	Akimidori (apa)	Tekapo (c)	Wana (ee)

c - control (nil fungicide)
ee - ear emergence (one fungicide application)
eea - ear emergence and anthesis (two fungicide applications)
apa - anthesis and post anthesis (two fungicide applications)

On 5 December a 50 cm length of a randomly selected row was chosen in each plot. The number of fertile tillers in each 50 cm length was counted and recorded without being removed. Then from each plot 20 tillers were randomly selected and removed to determine spikelet and floret numbers as described in Chapter 2. These tillers were also used to determine disease incidence and green area, also as described in Chapter 2.

Table 12. Dates on which fungicide was applied during ear emergence, anthesis and post anthesis in 1993.

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

Beginning on 20 December, seed moisture content of each cultivar and fungicide treatment was determined using the same method as described in Chapter 2. Seed harvest began on December 23 for cv Akimidori, when its seed moisture content had reached 40%. Harvest continued up to 6 January 1994 (Table 13) as each of the other cultivars and fungicide treatments reached 40% seed moisture content. The method of harvest was as described in Chapter 2.

The threshing and cleaning of seed following harvest and drying was as described in Chapter 2. Following cleaning the yield and purity of each sample was determined in the same manner as in Chapter 2, with the exception that single seed units and multiple seed units were not kept separate due to the fact that no significant difference between the two were found in the previous year's results.

The determination of yield components, germination testing and health testing were all carried out using identical techniques to those described in Chapter 2. The only exception was in the case of the health testing, where an extra lot of 10 seeds from each treatment was placed on PDA which did not contain chloramphenicol, to check whether seed borne bacteria were present.

After all data had been collected a statistical analysis was carried out, using a protected LSD (SAS 1987).

Table 13. Harvest dates[1]

Cultivar	Fungicide Treatment			
	Control	Ear	Ear/An	An/Post
Wana	5 Jan 1994	6 Jan 1994	6 Jan 1994	6 Jan 1994
Kara	5 Jan 1994	6 Jan 1994	6 Jan 1994	6 Jan 1994
Tekapo	1 Jan 1994	1 Jan 1994	1 Jan 1994	1 Jan 1994
Akimidori	23 Dec 1993	23 Dec 1993	23 Dec 1993	23 Dec 1993
Makibamidori	5 Jan 1994	6 Jan 1994	6 Jan 1994	6 Jan 1994

[1] dates at which the cultivar/treatment reached 40% seed moisture content.

RESULTS

Reproductive Tillers

Head emergence was first observed on 28 September 1993 for cv Akimidori, 7 October 1993 for cv Tekapo, and 20 October for the other three cultivars (Fig. 8). Akimidori had reached full head emergence (2 Nov) at a stage when the other cultivars had only 20% or less head emergence. Emergence rates were similar for all cultivars (Fig. 8). The percentage of tillers which had produced heads was significantly greater for cv Tekapo than that of cvs Wana, Kara and Makibamidori from 2 November through until 23 November when all four cultivars had reached 100% head emergence.

Green Area

The early application of fungicide (single application at ear emergence) significantly increased the GA of the flag leaf, leaf 1, and leaf 2 in all five cultivars, with the exception of leaf 1 in cv. Kara (Table 14). This early single fungicide application also significantly increased the GA of the stem in cv Wana, Kara and Akimidori. The application of fungicide at ear emergence followed by another at anthesis produced a significant increases in GA in the flag leaf, leaf 1, leaf 2 and the stem of all five cultivars. Because the leaf and stem pathogens (eyespot and stripe rust) present on the plant had an incidence of less than 1 %, data were not analysed and are not presented.

The late application (anthesis and post anthesis) of fungicide failed to have a significant effect on the GA of cvs Wana and Kara or on the GA of the stem of cv's Tekapo and

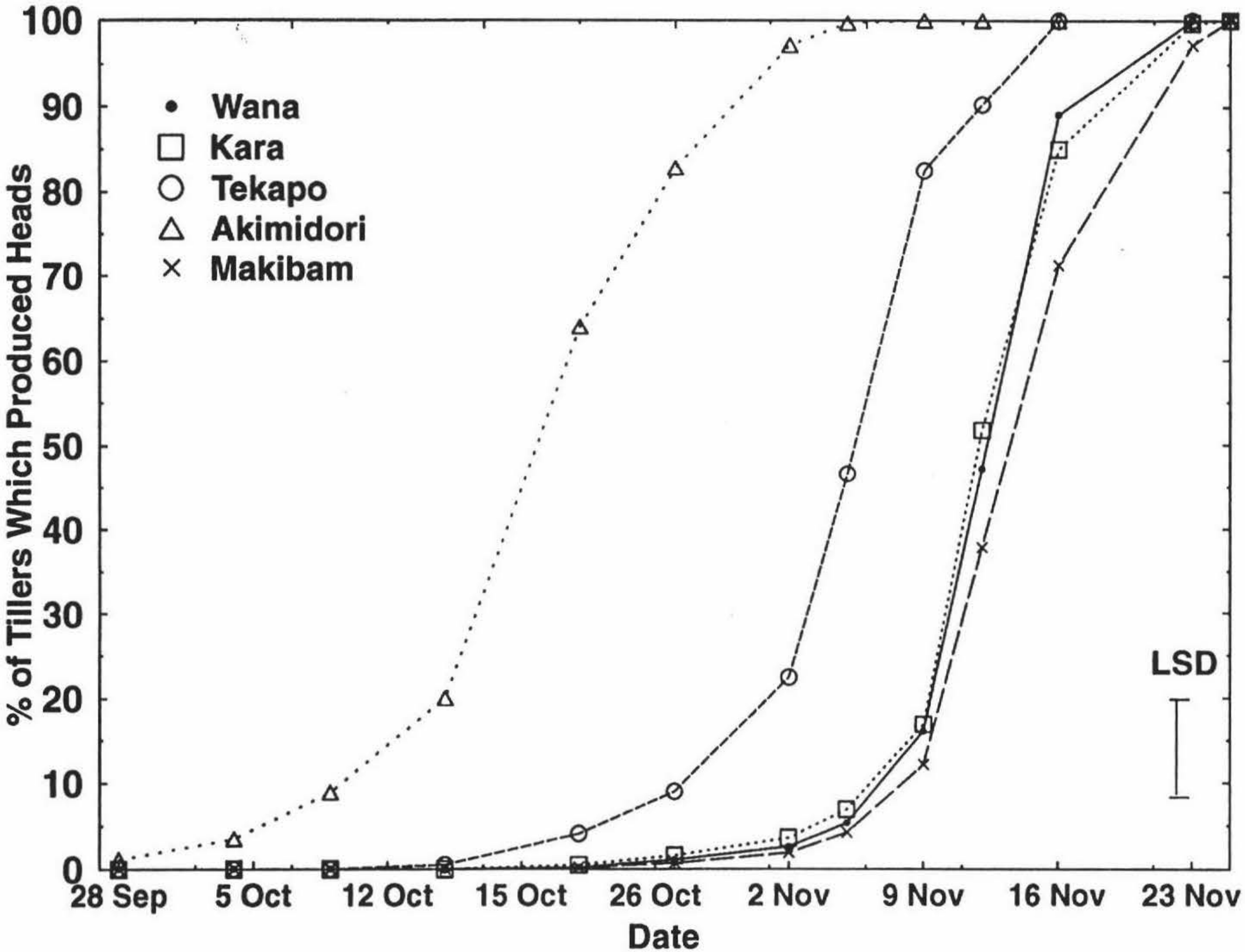


Figure 8. Estimated Rate of Head Emergence

Makibamidori (Table 14), but did significantly increase the GA of the flag leaf, leaf 1 and leaf 2 of cv Tekapo, Makibamidori and Akimidori as well as the GA of the stem in cv Akimidori.

A second application of fungicide following that at ear emergence significantly increased the GA of the flag leaf, leaf 1and leaf 2 of all five cultivars over that of the single early application (Table 14). However this was the case for the GA of the stem only in cv Kara and Makibamidori. There was a significant cultivar x fungicide interaction for GA of the flag leaf (with the greatest response (48%) in cv Akimidori), leaf 1 (with the greatest response (28%) in cv. Akimidori), leaf 2 (with the greatest response (48%) in cv. Makibamidori) and the GA of the stem (with the greatest response (63%) in cv Akimidori).

Seed Yield Components

The number of fertile tillers (Table 15) ranged from 809 to 1242/m^2. Cultivars Wana and Tekapo produced significantly more fertile tillers/m^2 than the other three cultivars. There was also a range in florets/tiller (611 to 949). In the absence of fungicide there was also a range in thousand seed weight (0.61 to 0.79 g). Of the five cultivars, cv Wana had the greatest yield potential (89.5 x 10^4 florets/m^2) and cv Makibamidori the lowest (52.5 x 10^4 florets/m^2). Cultivar Wana along with cv Kara had a significantly ($P<0.05$) greater FSU than the remaining three cultivars. Although cv Makibamidori had the lowest yield potential, it had a significantly ($P<0.05$) greater FSU than cv Akimidori.

The application of fungicide had no significant effect on the TSW of cv Wana (Table 15). However the TSW of cv Kara, Tekapo and Makibamidori after a fungicide application at ear

Table 14. Effect of cultivar and fungicide treatment on percentage Green Area[1]

Cultivar	Fungicide	Green Area (%)			
		Flag Leaf	Leaf 1	Leaf 2	Stem
Wana	Nil	63.0	59.3	40.8	91.7
	Ear	78.0	69.6	57.6	96.7
	Ear/An	85.3	83.0	77.8	98.3
	An/Post	68.8	50.5	44.4	94.1
Kara	Nil	61.1	51.3	35.8	91.5
	Ear	71.5	52.3	42.6	94.7
	Ear/An	78.8	64.5	62.7	97.4
	An/Post	60.9	48.0	39.4	92.6
Tekapo	Nil	42.2	32.0	10.6	93.4
	Ear	58.8	49.2	34.8	96.0
	Ear/An	69.1	54.9	40.2	97.6
	An/Post	48.4	41.3	30.1	95.4
Makib.	Nil	23.7	15.2	6.1	92.6
	Ear	55.9	32.6	15.0	92.1
	Ear/An	66.7	59.4	54.3	97.4
	An/Post	40.1	30.5	15.9	87.6
Akim.	Nil	7.0	6.9	2.5	27.8
	Ear	48.5	16.3	6.4	90.7
	Ear/An	55.0	34.7	22.8	91.2
	An/Post	35.0	26.5	15.0	89.0
LSD P<0.05 cultivar		3.56	3.28	3.75	2.62
LSD P<0.05 fungicide		3.19	2.94	3.36	2.37
Pr > F (Cv * F)		0.001	0.001	0.001	0.001

[1] assessed on December 5 1993

Table 15. Effect of cultivar and fungicide treatment on yield components and FSU.

Cultivar	Fungicide	Seed yield components			% FSU[2]
		fertile tillers/m^2	florets/ tiller	TSW[1] (g)	
Wana	Nil	1127	794	0.6082	21.0
	Ear	1110	770	0.6125	25.1
	Ear/An	1162	787	0.6265	25.7
	An/Post	1163	648	0.6218	21.0
Kara	Nil	957	738	0.7643	22.5
	Ear	910	761	0.7812	22.7
	Ear/An	897	949	0.8452	19.3
	An/Post	1009	785	0.7527	18.3
Tekapo	Nil	1190	677	0.7276	15.7
	Ear	1123	652	0.7649	20.2
	Ear/An	1242	541	0.7802	18.8
	An/Post	1050	604	0.7566	20.9
Makib.	Nil	809	649	0.7867	17.0
	Ear	887	623	0.8120	19.7
	Ear/An	995	611	0.8621	18.4
	An/Post	862	678	0.8111	14.7
Akim.	Nil	893	740	0.7107	12.1
	Ear	923	716	0.7884	12.7
	Ear/An	945	767	0.7995	11.3
	An/Post	880	752	0.7733	9.8
LSD P<0.05 cultivar		87.52	51.64	0.029	2.09
LSD P<0.05 fungicide		NS	NS	0.026	1.87
Pr > F (Cv * F)		NS	NS	NS	0.133

[1] = Thousand seed weight, [2] = Floret site utilisation

emergence and anthesis was significantly greater than in other treatments. Fungicide application failed to significantly ($P<0.05$) increase the FSU of cv Kara and Akimidori. Both early fungicide treatments increased the FSU of cv Wana and Tekapo. There was a significant cultivar x fungicide interaction for FSU (with the greatest response (+ 52%) in cv Tekapo).

Field Dressed Seed Yield

In the absence of fungicide, field dressed seed yields ranged from 879 kg/ha for cv Makibamidori to 1670 kg/ha for cv Wana (Table 16). The field dressed seed yield for both cv Wana and Kara was significantly ($P<0.05$) higher than the other three cultivars. There was no significant difference between cv Tekapo and Akimidori, although cv Makibamidori was significantly lower in field dressed yield than cv Tekapo.

Both the single ear emergence and ear emergence and anthesis fungicide treatments produced a significantly ($P<0.05$) greater field dressed yield than the nil treatment and the late fungicide treatment in cv Wana (Table 16). The application of fungicide at both ear emergence and anthesis resulted in significantly more field dressed seed than the later double fungicide treatment in cv Kara. All three fungicide applications produced significantly more field dressed seed than the nil treatment in both cv Tekapo and Makibamidori. There was a significant cultivar x fungicide effect for field dressed seed yield (with the greatest response (+ 369 kg/ha) in cv Makibamidori).

Machine Dressed Seed Yield

In the absence of fungicide, machine dressed seed yield ranged from 836 kg/ha (cv Makibamidori) to 1602 kg/ha (cv Wana) (Table 16). The machine dressed seed yields for cv Wana and Kara were both significantly ($P<0.05$) higher than the other three cultivars. The machine dressed seed yield of cv Makibamidori (836 kg/ha) was significantly lower than for cv Akimidori (1000 kg/ha) which was in turn significantly lower than for cv Tekapo (1191 kg/ha).

The single application of fungicide at ear emergence gave a significant ($P<0.05$) increase in the machine dressed seed yield of cv Wana, Tekapo and Makibamidori (Table 16). A subsequent application of fungicide at anthesis failed to produce a further significant increase in the machine dressed seed yield of any of the cultivars. A double fungicide application at anthesis and post anthesis produced significantly ($P<0.05$) less machine dressed seed than the early double fungicide treatement in cv Wana, Kara and Akimidori. Compared with a single early fungicide application at ear emergence, fungicide application at anthesis and post anthesis produced significantly less machine dressed seed in cv Wana. There was no cultivar for which a double application of fungicide at anthesis and post anthesis produced a significantly higher machine dressed seed yield than a nil fungicide treatment.

Table 16. Effect of cultivar and fungicide treatment on field and machine dressed seed yield, cleaning losses, purity and pure seed yield.

Cultivar	Fungicide	Yield (kg/ha) FD[1]	Yield (kg/ha) MD[2]	Cleaning losses (%)	Purity (%)	Pure seed yield (kg/ha)
Wana	Nil	1670	1602	4.0	71.7	1133
	Ear	1909	1816	4.9	74.1	1337
	Ear/An	1949	1969	4.1	74.2	1462
	An/Post	1389	1318	5.1	74.1	977
Kara	Nil	1603	1540	3.9	78.4	1208
	Ear	1590	1525	4.1	79.0	1203
	Ear/An	1791	1717	4.2	80.6	1383
	An/Post	1397	1336	4.4	80.1	1069
Tekapo	Nil	1274	1191	6.6	77.3	915
	Ear	1531	1459	4.7	76.9	1125
	Ear/An	1377	1279	7.1	76.7	979
	An/Post	1379	1293	6.2	75.9	982
Makib.	Nil	879	836	5.1	80.3	556
	Ear	1159	1099	5.1	77.9	645
	Ear/An	1248	1187	5.1	81.0	662
	An/Post	1067	995	6.5	71.0	490
Akim.	Nil	1064	1000	5.9	56.1	671
	Ear	968	924	4.5	69.8	858
	Ear/An	1108	1049	5.2	63.8	958
	An/Post	799	745	6.9	65.9	701
LSD P<0.05 cultivar		225.5	208.8	0.68	4.95	125.0
LSD P<0.05 fungicide		201.7	186.7	0.61	4.43	111.8
Pr > F (Cv * F)		0.005	NS	NS	NS	NS

[1] Field Dressed
[2] Machine Dressed

Cleaning Losses and Percentage Pure Seed

In the absence of fungicide the percentage cleaning losses ranged from 3.9% in cv Kara to 6.6% in cv Tekapo (Table 16). Cultivars Wana and Kara had significantly ($P<0.05$) lower cleaning losses than the other three cultivars. The cleaning losses of cv Makibamidori (5.1%) were significantly lower than cv Akimidori (5.9%), which was significantly lower than cv Tekapo (6.6%).

The application of fungicide had no significant effect on the cleaning losses in cv Kara (Table 16). There was a significant ($P<0.05$) increase in cleaning losses in cv Wana, Makibamidori and Akimidori, as a result of the anthesis/post anthesis fungicide treatment compared to the nil fungicide treatment. In cv Tekapo a single fungicide application at ear emergence produced significantly lower cleaning losses than all the other treatments.

In the absence of fungicide the percentage of pure seed ranged from 56.1% (cv Akimidori) to 80.3% (cv Makibamidori) (Table 16). The latter had a significantly higher seed purity than the other cultivars. There was no significant difference between cv Kara and Tekapo, which were significantly higher than cv Wana. In the case of the three New Zealand cultivars, none of the fungicide treatments had a significant effect on the percentage of pure seed. The anthesis/post anthesis treatment caused a significant reduction in the percentage pure seed in cv Makibamidori, while all three fungicide treatments gave a significant increase in the percentage pure seed in cv Akimidori.

Pure Seed Yield

In the absence of fungicide the pure seed yield ranged from 556 kg/ha (cv Makibamidori) to 1208 kg/ha (cv Kara) (Table 16) There was no significant difference in pure seed yield between cv Wana and Kara, both of which were significantly higher than the three remaining cultivars. Cultivar Tekapo (915 kg/ha) produced significantly more pure seed than cv Akimidori (671 kg/ha) which produced significantly more seed than cv Makibamidori (556 kg/ha).

The application of fungicide at ear emergence produced a significant ($P<0.05$) increase in the pure seed yield in cv Wana, Tekapo and Akimidori. Two applications, one at ear emergence and another at anthesis produced a significant increase in the pure seed yield of cv Wana, Kara and Akimidori. The application of fungicide at anthesis and post anthesis failed to improve the pure seed yield in any of the cultivars.

Seed Quality

The germination of the seed produced ranged from 83% (cv Akimidori) to 90% (cv Tekapo) (Table 17). Cultivar Tekapo had a significantly higher germination than cv Wana, while cv Akimidori had a significantly ($P<0.05$) lower germination than the remaining four cultivars. The application of fungicide had no significant effect on the germination of cv's Kara and Tekapo. All fungicide treatments significantly improved the germination of cv Makibamidori, while only a double fungicide application at ear emergence and anthesis significantly improved the germination of cvs Wana and Akimidori.

Table 17. Effect of fungicide treatment and cultivar on the germination of seed.

Cultivar	Fungicide	Normal seedlings (%)	Dead seeds (%)
Wana	Nil	87	12
	Ear	89	8
	Ear/An	91	8
	An/Post	89	9
Kara	Nil	89	10
	Ear	89	10
	Ear/An	90	9
	An/Post	88	11
Tekapo	Nil	90	8
	Ear	89	10
	Ear/An	90	9
	An/Post	90	9
Makibidori	Nil	88	11
	Ear	92	7
	Ear/An	93	6
	An/Post	91	8
Akimidori	Nil	83	15
	Ear	85	13
	Ear/An	86	13
	An/Post	83	16
LSD P<0.05 cultivar		2.22	2.06
LSD P<0.05 fungicide		1.98	1.84

abnormal seedlings and fresh ungerminated seeds not included as all < 1%.

In the absence of fungicide the percentage of dead seeds ranged from 8% in cv Tekapo to 15% in cv Akimidori (Table 17). Cultivar Akimidori had significantly ($P<0.05$) more dead seeds than the other four cultivars. None of the fungicide treatments had a significant effect on the percentage of dead seeds in cv Kara and Tekapo, while in cv Wana and Makibamidori all three fungicide treatments reduced the percentage of dead seed. In cv Akimidori only the two early fungicide applications (ear emergence and ear emergence/anthesis) caused a significant reduction in the percentage of dead seed.

No storage fungi were found on the PDA + salt + chloramphenicol plates. However, plates where chloramphenicol was absent produced colonies of unidentified yellow bacteria in both fungicide treated and untreated seed lots.

DISCUSSION

Effect of Cultivar

As all plots were harvested in their first year, the effect of time of sowing was removed. The time between the first and second harvest gave all cultivars time to develop into large plants with a greater number of vegetative tillers. Cultivar Wana and Tekapo both produced significantly more fertile tillers (Table 14) than the other cultivars. The similar tiller number is indicative of the two cultivars (Anon 1995) both of which are capable of producing more tillers than cv Kara.

Cultivar Tekapo, however failed to produce as many florets/tiller as cv Kara. This is a reflection of cv Tekapo's inability to produce as many panicle branches as cv Kara (Anon

1995), therefore providing fewer sites for florets. Cultivar Kara has fewer panicle branches than cv Wana, hence cv Wana's ability to produce more florets/tiller. Cultivars Wana and Kara are the only two cultivars which showed a significant association between the number of florets/tiller and seed yield (Appendix 7).

The two Japanese cultivars produced similar numbers of florets/tiller to both cv Kara and Tekapo, which would indicate that these four have a similar panicle morphology. The number of tillers produced by cv Akimidori was similar to that of cv Kara while cv Makibamidori was incapable of producing as many tillers as any of the other New Zealand cultivars. However cv Makibamidori was the only cultivar to show a significant association between tiller number and seed yield (Appendix 7). Hampton and Hebblethwaite (1983b) considered that fertile tiller numbers are not usually limiting unless there is poor establishment or moisture stress. However in this case it was more likely to be a morphological effect, considering all five cultivars received the same treatment throughout the trial (i.e. fertiliser, climate). The size of the seed produced also reflected this, in the fact that there is no significant difference in the TSW of cv Kara, Makibamidori and Akimidori (Table 14). However cv Tekapo produced smaller seed than cv Kara and Makibamidori.

The TSW of cv Wana was lower than all other cultivars. This is a typical trait of cv Wana which tends to produce smaller seed than cv Kara (Rumball 1982b) and cv Tekapo (Anon 1995). However, this seed was produced in such large quantities that cv Wana was still able to out produce all cultivars except cv Kara. For cv Wana TSW was not a major factor in the final seed yield, and only cv Kara and Makibamidori showed a significant association between TSW and seed yield (Appendix 7).

The production of higher FDSY and MDSY by the three New Zealand cultivars than the two Japanese cultivars was a reflection of their ability to produce greater number of potential reproductive sites (fertile tillers x florets/tiller). Cultivar Wana produced the greatest number of sites of the three New Zealand cultivars. However, when considering the pure seed yield, there was no significant difference between cv Wana and Kara, both of which produced more pure seed than the remaining cultivars. These two cultivars had lower cleaning losses and a greater FSU than the other cultivars. In fact there was no significant difference between the FDSY, MDSY, cleaning losses and FSU of cv Wana and Kara. Considering this, cv Wana should have produced a greater seed yield than that of cv Kara. However, cv Kara had a significantly higher percentage of pure seed than cv Wana, and more importantly it produced larger seed. It is this significant association between TSW and seed yield which enables cv Kara to equal the seed yield of cv Wana. This association is made even more significant considering the fact that even with a high FSU, it was the only cultivar not to have a significant association between FSU and seed yield.

Although cv Tekapo had a greater number of potential reproductive sites than cv Kara, it was unable to utilise them, with a significantly lower FSU than both cv Wana and Kara. Cultivar Tekapo was unable to produce the FDSY that the other two New Zealand cultivars did and lost significantly more seed during the cleaning process as well. However, only cv Tekapo and Akimidori had a significant association between FSU and seed yield (Appendix 7). The two Japanese cultivars produced a much lower pure seed yield than the New Zealand cultivars, firstly because of lack of reproductive sites, but also and their inability to utilise what sites there were.

Effect of Fungicide

As discussed in chapter 2, the weather conditions in the early spring have a very important effect on the presence of pathogens later during seed development. Once again the presence of such pathogens was low, which is likely to be a reflection of the low rainfall during September and October of 1993 (Appendix 10).

Hampton (1986) suggested increases due to the application of fungicide could be obtained with application before ear emergence or in some cases following ear emergence. The first application of fungicide was in October/early November (Table 13). In the Manawatu, stem elongation begins in mid September in cocksfoot (White 1990). About a month later terbuconazole was applied to control stem rust, stripe rust and eyespot. This early application of fungicide increased the GA duration of the leaves and stem in all five cultivars. An additional application at early anthesis increases the GA further (Table 14). Hampton and Hebblethwaite (1984) considered that the developing ear faces strong competition from both the stem and vegetative tillers for assimilate. In improving the GA, there is presumably more photosynthetic tissue available to meet the demands of elongating stems and the developing ear.

The application of fungicide at the beginning of anthesis tended to improve the GA of the three leaves over and above that of the single application at ear emergence. Hampton and Hebblethwaite (1984) suggested that assimilates formed around this time may have an important role in seed filling.

Although there was an improvement of GA in all five cultivars, not all of them showed an improvement in pure seed yield. Cultivars Kara and Makibamidori showed no significant increase in pure seed yield following the application of fungicide. An early application of fungicide improved the pure seed yield of the other cultivars, while the application of fungicide at anthesis/post anthesis failed to improve the seed yield in any of the cultivars. This result supports the suggestion that the improved duration of photosynthetically active tissue during stem elongation (fungicide application at ear emergence) and seed head development (fungicide application at anthesis) is important in allowing the plant to supply assimilates to all the areas which demand them. The late application of fungicide did not provide the GA at a time when the demand for assimilate was at its highest.

Marshall (1985) suggested that fungicide treatment maintained the photosynthetic activity of tillers and resulted in improved supply of assimilate to developing seed. Cultivars Wana and Makibamidori showed a significant association between GA (Flag leaf, leaf 1 and leaf 2) and seed yield (Appendix 8). However, cv Makibamidori was unable to reflect this association with a significant increase in pure seed yield (Table 16). Cultivar Wana, however, had an improved pure seed yield following the early application (ear emergence and ear emergence/anthesis) of fungicide. Unlike cv Makibamidori, cv Wana showed a very high association between the GA of the stem and seed yield (Appendix 8). It is this association which has more than likely lead to cv Wana being able to increase seed yield following fungicide application. The stem is a sink for assimilate, but also a source of assimilate. The longer the period of time that the stem remains green, presumably more assimilate can be supplied. It is also possible that cv Wana was able to supply the seed head with stored stem reserves. Roy and Rolston (1994) noted that in ryegrass 14 - 51% of stored stem reserves were utilised by the developing seed head, especially during stress periods.

Marshall (1985) suggested that the improved assimilate supply lead to reduced seed abortion. This would tend to be reflected in the FSU of the plant. In this case only cv. Wana and Tekapo showed a significant increase in FSU following the early application of fungicide. Only cv Wana showed a significant association between GA and FSU (Flag leaf, leaf 1, leaf 2 and stem) (Appendix 9). This would suggest that fungicide may be having a different effect on the seed yield. The application of fungicide may cause a cytokinin-like effect which would make the seed head a stronger sink (Marshall 1985). This would make the seed head more capable of competing for assimilate. This idea provides an explanation as to why cv Tekapo could improve its FSU after an application of fungicide at ear emergence, yet the improved GA did not have a significant association with FSU.

Cultivar Tekapo (ear emergence application) and cv Akimidori (ear emergence and ear emergence/anthesis) were the only cultivars to have significant reductions in cleaning losses. This suggests that fewer small immature seeds were harvested. For cv Akimidori, however, the purity of the seed was very low compared to other cultivars. For cv Tekapo on the other hand, the reduction in cleaning losses would indicate less small seed, and along with the improved FSU, the possibility of a hormone effect is likely. The application of fungicide (ear emergence/anthesis) did significantly increase the TSW of cv Kara, Tekapo, Makibamidori and Akmidori (Table 15) while the single application at ear emergence only improved TSW of cv Tekapo and Akimidori. This also indicates that because the GA was improved, the developing seed was able to take up more assimilate, thus providing bigger seed.

The germination of the seed was not affected by the application of fungicide. However, the health test showed the presence of a yellow bacterium. The presence of this bacterium in the crop appeared to cause the death of the stem and flag leaf in the later stages of seed development (mid December). This senescence of the flag leaf would reduce available assimilate, while the dead stem would restrict the movement of assimilates to the seed head. The presence of such a bacterium could have altered the outcome of this field trial as the fungicide applied would not have killed the bacterium, therefore allowing it to have a detrimental effect on the plant. However, it appears that if this bacterium did have an effect on the seed yield of the plants, it possibly affected some cultivars more than others. This will be discussed further in the conclusions.

The bacterium was initially suspected to be *Corynebacterium rathayi* , the cause of Rathays disease (Zahid pers. comm). Latch (1980) considered that this disease did not affect seed yield. This is in contrast with Johnston (1956) who found that this bacterium caused the loss of a proportion of spikelets from which seed may have formed, although she could not determine the effect of this disease on seed yield. However it is now known that the species of bacterium is not *C. rathayi*, and it has been tentatively identified as a *Pseudomonas* spp (Zahid pers. comm). Work on this problem is still in progress.

The economic value of fungicide application varied between each cultivar and the timing of the application. For all cultivars, the two late applications of fungicide (anthesis and post anthesis) failed to provide significant increases in pure seed yield, and were therefore not cost effect when calculations are based on a seed price of approximately $3.30/kg and the cost of a single fungicide application is $70.50/ha. For cv Tekapo and Makibamidori a single application of fungicide at ear emergence provided the only significant return, an additional $622.50/ha and $223.20/ha respectively. This single application of fungicide also provided the best return for cv Wana (additional $602.70/ha) and cv Akimidori (additional

$546.60/ha), as after the cost of a second application at anthesis was deducted, the gain was only $342.00/ha (cv Wana) and $259.50/ha (cv Akimidori). This second application of fungicide was therefore not cost effective. Cultivar Kara was the only cultivar which failed to achieve a significant return following a single application of fungicide at ear emergence, but with two applications of fungicide (ear emergence and anthesis) a $507.00/ha return was gained.

CHAPTER 4

CONCLUSION

The pure seed yield produced from the 1993/94 season was almost double that of the spring sown cocksfoot from the 1992/93 season. Cocksfoot usually produces a greater yield in the second year's harvest compared to that of the first year (Niemelainen 1991), although yield tends to fall during the subsequent harvests. This has also been observed in perennial ryegrass, with decreased seed yields being associated with increased age of the stand (Hebblethwaite *et al* 1980).

Following the first harvest, the cocksfoot plants are well established, with a good number of leaves and tillers along with a good root system. Prior to the second winter, the established plant has time to develop more tillers capable of reaching the size and weight necessary to fulfil the juvenile phase requirements (Calder 1963). This means that a larger number of vegetative tillers can be induced during the winter months (Langer 1972). The presence of more vegetative tillers is reflected in the fact that the second year crop had asmost twice as many tillers as that of the sping sown first year crop in all five cultivars. The number of florets/tiller did not increase as significantly, and in the case of cv Tekapo, Akimidori and Makibamidori there was no change. Hampton and Hebblethwaite (1983b) found that spikelets per tiller decreased significantly with increasing fertile tiller numbers. Although this did not exactly occur in this trial, the second year crop did not show any improved ability to produce more florets/tiller. The number of florets/tiller is dependant on the number of leaf primordia accumulated during the vegetative phase (Hebblethwaite *et al* 1980). With a bigger plant to maintain during the vegetative phase fewer of these leaf primordia can accumulate.

The FSU of the second year crop was lower than that of the first year crop. This was not a reflection of components such as cleaning losses or purity. In fact the cleaning losses were lower in the second year than in the first, and the purity was higher. The seed in the first year harvest was however, bigger than that harvested in the second year. Clemence and Hebblethwaite (1984) found that the stem dominates assimilate resource until is has finished elongating, after which the ear becomes a net importer. The longer the stem remains green and healthy the longer assimilate can be supplied. In this trial, a number of things could have occurred which resulted in reduced FSU. One possibility is that the increased number of tillers in the second year crop placed increased pressure on assimilate supply, thus leaving less for the developing panicle. This would have resulted in seeds not receiving enough assimilate to develop, and consequently they aborted. This would also explain the lower TSW. Another possibility, is that the stem did not remain green and therefore photosynthesising for a long period of time. This however, was not shown by the data collected in this trial.

Another reason the FSU may not have been as good in the second year, is the environmental conditions during anthesis. During the month of November 1993 (Appendix 10), there was a very high rainfall. Hill (1980) stated that grass florets generally do not open unless the weather is warm and dry, and that pollen is rapidly washed out of the air by rain. Also the duration of anthesis can be significantly prolonged during wet weather. This could mean that in the case of the second year crop, a lot of florets were not pollinated due to rain, thus reducing FSU. It could also mean that the prolonged period over which anthesis occurred leads to uneven ripening of the seed crop. Meijer (1985) suggested that uneven ripening is a major contributing factor to poor floret site utilization.

The effect of fungicide on the green area of the leaves and stem of the cocksfoot plant cannot be compared between seasons as the assessment dates were different. However, even with the refinement of the timing of fungicide application and the change in fungicide used, the increases in pure seed yield were not as great in the second year as they were in the first year. This may be due to the fact that although the incidence of fungal pathogens was low, there was possibly a bacterial pathogen (*Pseudomonas* spp) present on the crop. Even in the fungicide treated plots the flag leaf and stem had senesced by mid-December. This presumably reduced the supply of assimilate to the seed head regardless of whether fungicide had been applied or not. In the first year crop the stem GA was almost as high at 23 December as it was at 5 December in the second year. It is this reduction in stem GA which could have possibly lead to the reduced seed yield increase. Work is being carried out at the moment to look more closely at the effects of this particular bacterium on cocksfoot.

In the second year cv Wana and Kara produced a similar amount of seed, indicating that once the seed crop has established cv Kara has the same potential as cv Wana. Cultivar Tekapo, which has a similar yield potential did not utilize it as well and failed to produce as much seed as the other two New Zealand cultivars. However, all three New Zealand cultivars out-produced the Japanese cultivars.

Of the two Japanese cultivars examined in this trial, neither had sufficient pure seed yield to consider sowing in autumn and harvesting 10 months later. However, in the second year they both showed a reasonable seed yield potential, with cv Akimidori being the better of the two. As cv Akimidori develops earlier than the New Zealand cultivars it may of more use than cv Makibamidori, in that it can be put in a crop rotation for early harvest, thus giving a greater spread in the harvest season. Cultivar Akimidori was also able to produce more seed than cv Makibamidori. It should be noted that these two cultivars may produce more seed if sown in Canterbury where the climate is better noted for herbage seed production.

Only cv Wana showed any ability to produce seed following an autumn sowing and harvesting 10 months later. The other cultivars appear to be unable to produce the vegetative mass required to fulfil the juvenile stage and the subsequent inductive requirements during the winter.

Fungicide application was shown to be a cost effective way of increasing seed yield, even in the absence of fungal pathogens. In the second year the early applications (ear emergence and anthesis) of fungicide provided the greatest increase in seed yield. Although it was shown that a single application of fungicide at ear emergence provided the most cost effective return.

Other work that needs to be looked at more closely is the ability of cocksfoot, in particular cv Wana, to utilise its stem reserves. Data for cv Wana suggested that this may have been a factor in this trial. Roy and Rolston (1994) suggested that in ryegrass, 14 - 51% of stored stem reserves are utilised by the seed head, but similar data are not available for cocksfoot as a species, let alone any individual cultivars.

In cocksfoot, breeding had attempted to improve the seed retention of the plant, thus reducing shedding losses (Falcinelli *et al* 1994). The duration of anthesis is another area that could be examined in consideration for the long term improvement of cocksfoot seed yields. Cocksfoot appears to have a long period of anthesis, and subsequently a long period for seed maturity. As Miejer (1985) found in perennial ryegrass, uneven ripening of the seed crop contributes to poor floret site utilization. A reduction in this flowering time could be carried out through site selection (climate) or maybe through breeding programs.

Work is still required with regard to the effect of fungicide on seed production in the absence of disease. Is the seed yield being improved by delays in the senescence of photosynthetic tissue (Hampton and Hebblethwaite 1984), or by the applied fungicide exerting a cytokinin-like action on the seed head making it a stronger sink for assimilates (Marshall 1985)? Is it a combination of both of these things or is there another factor involved? This requires further investigation.

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APPENDICES

Appendix 1. Germination results from 1993 season from samples of cv Wana and Kara from MAF Seed Testing Station.

Range (% Germination)	Wana	Kara
	(% of seed lots within each germination range)	
60 - 69%	3	1
70 - 79%	7	3
80 - 89%	31	11
90 - 100%	34	7

Appendix 2. Regression values (R^2) for tillers/m^2, thousand seed weight, florets/tiller and floret site utilisation against pure seed yield in five spring sown cocksfoot cultivars.

Cultivar	Tillers/m^2	TSW[1]	Florets/tiller	% FSU[2]
Wana	0.379	0.043	0.268	0.665*
Kara	0.267	0.045	0.206	0.024
Tekapo	0.733*	0.309	0.085	0.641*
Akimidori	0.259	0.001	0.153	0.427
Makibamidori	0.200	0.676*	0.589*	0.480

[1] = thousand seed weight, [2] = floret site utilisation.

* = significant at $P < 0.05$

Appendix 3. Regression values (R^2) for green area against seed yield in five spring sown cocksfoot cultivars.

	% GA[1]			
Cultivar	Flag leaf	Leaf 1	Leaf 2	Stem
Wana	0.528*	0.444	0.219	0.633*
Kara	0.100	0.077	0.003	0.100
Tekapo	0.518*	0.612*	0.570*	0.350
Akimidori	0.066	0.067	0.088	0.039
Makibam.	0.673*	0.746*	0.784*	0.630*

[1] = green area.

* = significant at P < 0.05

Appendix 4. Regression values (R^2) for green area against floret site utilisation in five spring sown cocksfoot cultivars.

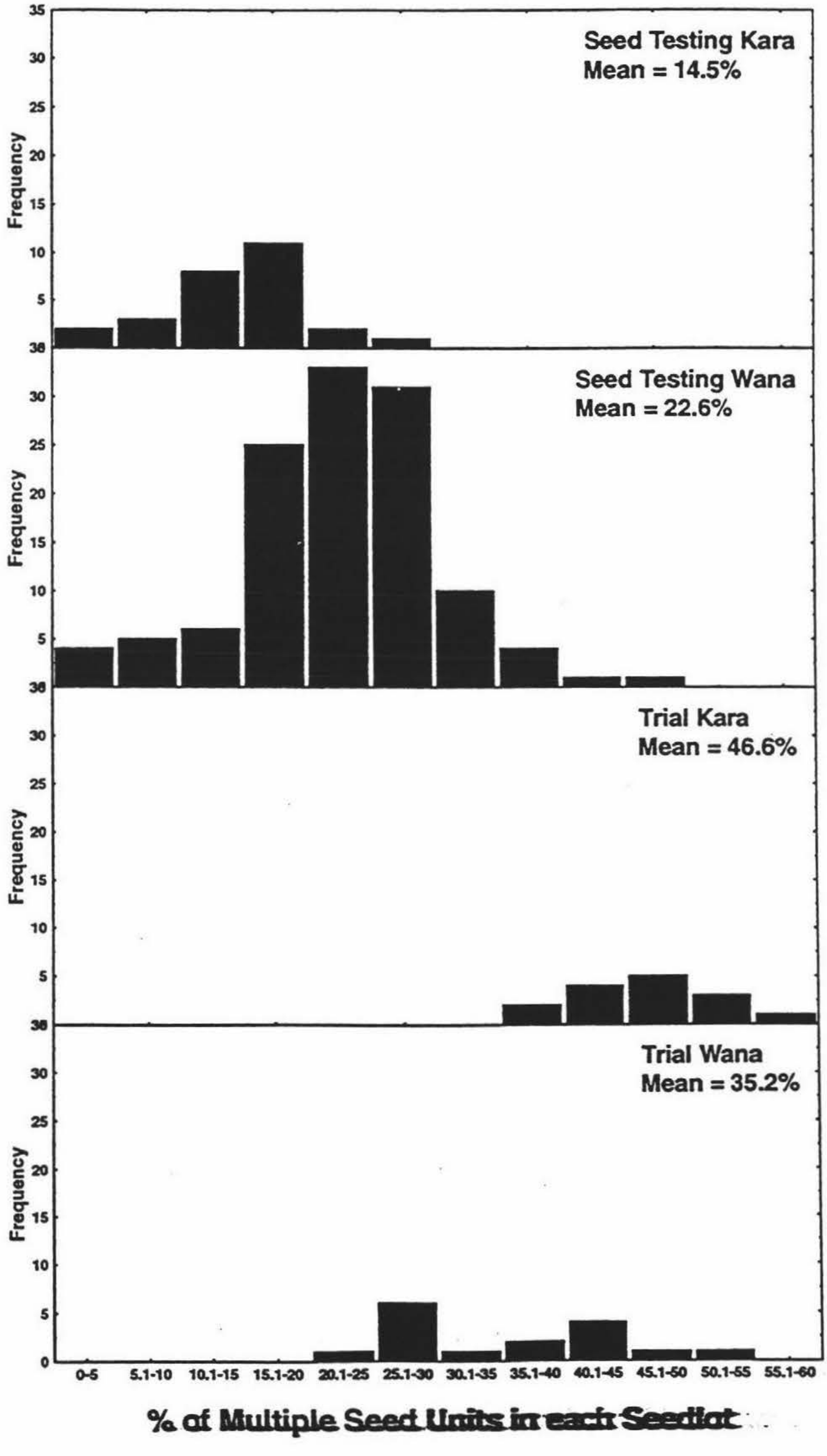
Cultivar	Flag leaf	Leaf 1	Leaf 2	Stem
Wana	0.554*	0.510*	0.433	0.864*
Kara	0.027	0.048	0.066	0.001
Tekapo	0.320	0.385	0.367	0.210
Akimidori	0.531*	0.528*	0.484	0.458
Makibamidori	0.126	0.122	0.145	0.145

* = significant at P < 0.05

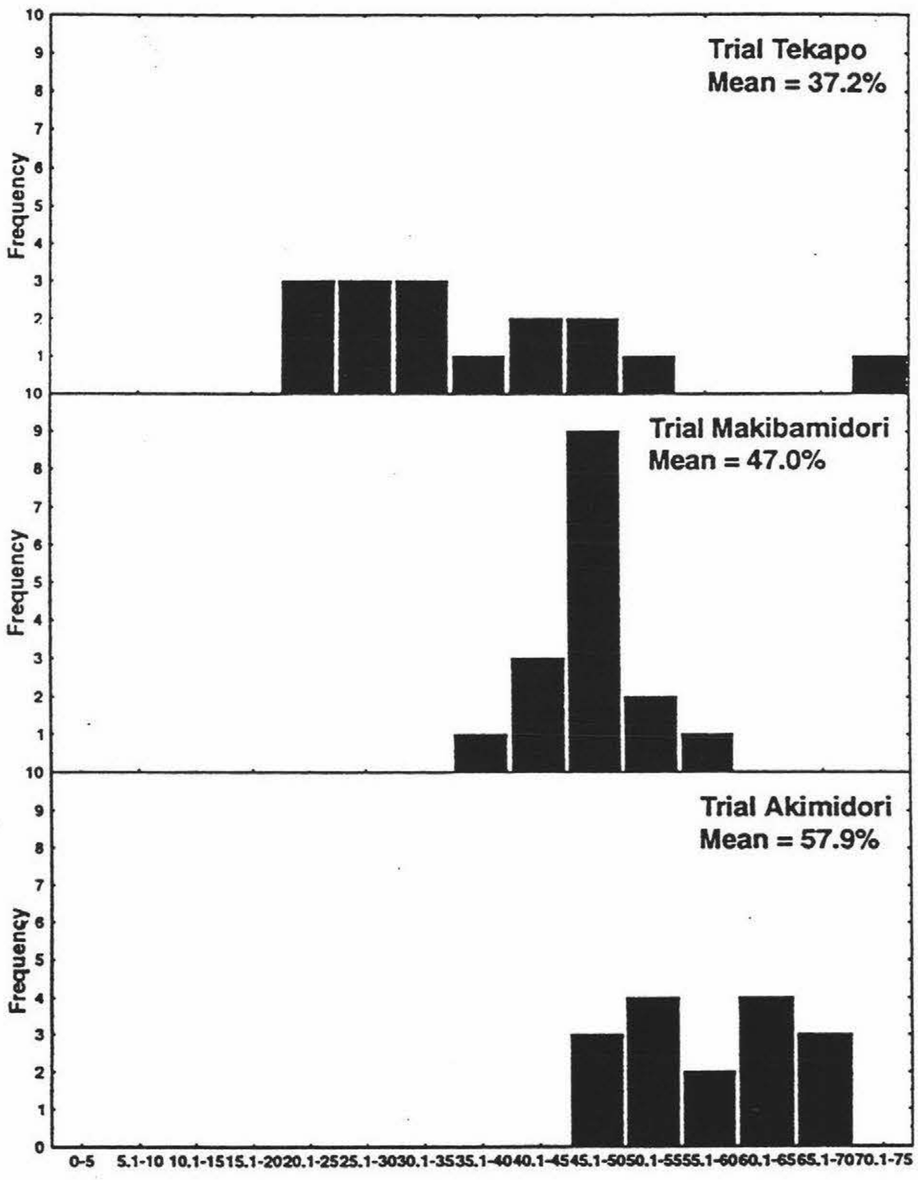
Appendix 5. Meterological data 1992, Aorangi Lowland Research Station.

		Aug	Sept	Oct	Nov	Dec	Jan
Rainfall (mm)	Maximum daily	11.4	18.0	21.4	13.2	38.4	11.2
	20 year average	79.7	78.9	78.9	59.5	69.3	59.6
	Total monthly	92.4	85.8	81.6	52.2	197.2	55.6
Max. Air Temp (°C)	Maximum	15.3	15.8	20.3	23.2	24.5	21.8
	Minimum	8.7	10.5	10.6	14.9	14.4	15.6
	Mean	11.8	12.7	15.3	18.0	19.2	19.3
	20 year average	13.5	15.1	15.1	18.7	20.8	22.6
Min. Air Temp (°C)	Maximum	-	-	-	13.6	16.2	16.2
	Minimum	-2.6	-2.1	-0.8	4.8	1.2	3.6
	Mean	4.0	5.6	6.7	10.2	10.3	11.0
	20 year average	4.5	6.7	6.7	9.5	11.2	12.4
Radiation (MJ)	Maximum	17.1	25.7	28.6	36.5	36.6	37.0
	Minimum	2.7	5.8	4.4	10.7	12.1	15.0
	Mean	10.2	15.1	18.5	23.1	22.8	28.2

Appendix 6.1 Frequencies at which different percentages of multiple seed units occur in different seedlots.



Appendix 6.2 Frequencies at which different percentages of multiple seed units occur in different seedlots.



Appendix 7. Regression values (R^2) for seed yield components against seed yield in five cocksfoot cultivars.

Cultivar	Fertile tillers	TSW	Florets/tiller	FSU
Wana	0.001	0.155	0.357*	0.730*
Kara	0.030	0.474*	0.305*	0.139
Tekapo	0.001	0.032	0.211	0.321*
Makibamidori	0.305*	0.315*	0.034	0.583*
Akimidori	0.002	0.005	0.046	0.250*

Appendix 8. Regression values (R^2) for green area against seed yield in five cocksfoot cultivars.

Cultivar	Flag leaf	leaf 1	leaf 2	Stem
Wana	0.320*	0.397*	0.304*	0.730*
Kara	0.207	0.138	0.509*	0.135
Tekapo	0.058	0.040	0.092	0.145
Makibamidori	0.353*	0.303*	0.262*	0.230
Akimidori	0.039	0.001	0.022	0.029

Appendix 9. Regression values (R^2) for green area against floret site utilisation in five cocksfoot cultivars.

Cultivar	Flag leaf	leaf 1	leaf 2	Stem
Wana	0.354*	0.328*	0.314*	0.319*
Kara	0.004	0.054	0.010	0.047
Tekapo	0.068	0.111	0.330*	0.130
Makibamidori	0.123	0.052	0.024	0.011
Akimidori	0.014	0.064	0.039	0.231

Appendix 10. Meterological Data 1993, Aorangi Lowland Research Station.

		Aug	Sep	Oct	Nov	Dec	Jan
Rainfall (mm)	Max. (daily)	17.6	14.8	16.8	43.0	25.4	13.0
	20 year average	79.7	78.9	75.7	59.5	69.0	-
	Monthly	53.0	75.2	59.4	124.4	81.8	30.8
Max. Air Temp. (°C)	Maximum	14.6	15.6	20.8	21.1	24.4	26.7
	Minimum	9.1	9.1	13.5	12.7	15.8	17.0
	Mean	12.4	12.7	16.4	16.4	18.8	21.2
	20 year average	13.5	15.1	16.7	18.7	20.8	-
Min. Air Temp. (°C)	Maximum	8.3	10.4	13.5	12.2	15.7	16.8
	Minimum	-3.7	-2.6	1.2	0.1	2.0	5.1
	Mean	2.8	4.8	7.4	6.5	10.4	12.1
	20 year average	4.5	6.7	8.0	9.5	11.2	-
Radiation (MJ)	Maximum	19.8	26.3	35.2	37.8	39.1	39.3
	Minimum	3.0	4.1	10.7	5.5	11.4	18.3
	Mean	12.8	15.5	23.4	25.2	26.9	29.2