

## Environmental Sensitivity of Seed Production in Orchardgrass (*Dactylis glomerata* L.)

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### ABSTRACT

The environmental conditions and crop management required for seed production in grasses may differ from those required for herbage production. The environmental sensitivity of seed and herbage production of nine orchardgrass cultivars of diverse origin was compared and contrasted over two production years at three sites (55 to 58°N) in the Peace region of Canada. Two of the six site x year correlations between the residuals of seed and herbage yield of the cultivars were significant; one was negative and low while the other was positive and relatively high. The cultivars ranked consistently within site-years for their seed-producing capabilities. Seed yields differed greatly among cultivars, from 50 to 180 kg ha<sup>-1</sup> in 1989 and from 115 to 737 kg ha<sup>-1</sup> in 1990 when averaged over sites. Both seed and herbage yield rankings for the three sites, averaged over cultivars, were inconsistent among production years. Seed production of several cultivars (particularly Comet, Filippa, Mobite and Niva) was inhibited by environmental conditions, especially at two of the sites in the first production year; the cause, however, remains in doubt. Biological production efficiency can be increased by developing grass cultivars specifically for their end-use characteristics in one region and multiplying their seed in agrilimatic regions where the environmental conditions are particularly conducive to the production of seed of those cultivars. The Peace region of northwestern Canada appears to provide a suitable environment for producing seed of specific orchardgrass cultivars, particularly those developed for herbage purposes in more northerly latitudes such as Scandinavia.

*Additional index words:* cocksfoot, cultivars, herbage yield, seed yield, temperature.

### INTRODUCTION

About one-third of the herbage seed produced in Canada originates from the Peace region of the provinces of Alberta and British Columbia, the area between 50 and 60°N, and the Rocky Mountains in the west to Lesser Slave Lake in the east. About one-quarter of the eight million hectares of arable land in this region is under cultivation. At present the principal grass seeds produced in this region are those of red fescue (*Festuca rubra* L.), smooth brome grass (*Bromus inermis* Leysser), and timothy (*Phleum pratense* L.). There is an increasing awareness of the need to incorporate more soil-conserving practices into the cereal-based agriculture of this region. Herbage seed crops provide an opportunity to diversify cash-crop production while maintaining or enhancing the quality of the soil.

Since 1961, when Canada became a member of the Organisation for Economic Co-operation and Development (OECD) scheme for the varietal certification of herbage seed moving in international trade (OECD, 1970), numerous cultivars of a broad range of herbage/turf species from many countries have been evaluated for their seed-producing capabilities in the Peace region (eg see Elliott, 1969; Elliott and Howe, 1979; Fairey, 1989 and 1990). The principal objective has been to identify foreign herbage/turf cultivars that are adapted for seed multiplication in the region. Seed of adapted cultivars is normally grown on contract for subsequent export to countries of origin or end-use where they are grown for herbage and/or amenity purposes.

In order to develop and exploit the foreseeable opportunities in herbage seed production in the Peace region, an understanding of the physiological adaptation characteristics and potential of the species and their cultivars is required. This study documents some of the differential physiological sensitivity of seed and herbage production of nine orchardgrass syn. cocksfoot (*Dactylis glomerata* L.) cultivars to environmental conditions at three sites in the Peace region. Some implications of this sensitivity, for regional seed production and future cultivar development, are presented.

### MATERIALS AND METHODS

Trials were conducted at three sites in the Peace region of Alberta, viz. Beaverlodge Research Station 55° 12'N, 119° 24'W), Foster's farm near Beaverlodge (55° 10'N, 119°23'W), and Fort Vermilion Experimental Farm (58° 23'N, 116° 02'W), hereafter referred to as BRS, FOS, and FTV, respectively. The sites were selected to be representative of the range in latitude and principal soil types of the region. The soil at BRS was a Dark Gray Solod (Esher clay) to Dark Gray Luvisol (Hythe fine loam), that at FOS was an Orthic Humic Gleysol (Goose fine loam to Codner clay), and that at FTV was a Dark Gray Luvisol (Leith coarse loam). The trials were sown in late May/early June 1988, following at least one year of fallow at each site. Each experimental site was fertilised with 200 kg ha<sup>-1</sup> of 11-55-0 fertiliser prior to seedbed preparation, and nitrogen

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(N) fertiliser (as 34-0-0) was applied just prior to soil freeze-up in autumn, 1988 and 1989 at 55 kg N ha<sup>-1</sup>. At each site, a randomised complete block design with four replications of nine orchardgrass cultivar plots was used. Each experimental plot consisted of four rows, 6.1 m long, spaced 30.5 cm apart, and was sown with 4.2 kg ha<sup>-1</sup> of viable seed. Weeds were controlled by inter-row cultivation and hand-weeding.

The nine orchardgrass cultivars (and country of origin) studied were Angelkemp (former Federal Republic of Germany), Apelsvoll (Norway), Comet (USA), Filippa (Denmark), Haka (Finland), Hattfjelldal (Norway), Kay (Canada), Mobite (Netherlands), and Niva (Czechoslovakia). Of these, only two are registered for trade and agricultural use within Canada; Kay, registered in 1970, is recommended for herbage production throughout most of the country, and Mobite, registered in 1987, is recommended for herbage production only in British Columbia (Agriculture Canada, 1990).

Seed herbage yields were recorded from designated areas (the central 5 m of two adjacent rows) of each cultivar plot for each production year, 1989 and 1990. The area sampled for herbage was cut twice each year, at ear emergence and in early September. The date of seed harvest was determined individually for each cultivar plot, in order to avoid loss of seed from shattering.

Experimental observations were analysed statistically using Release 1.3 of Genstat 5 (Lawes Agricultural Trust, 1987), using generalised linear models (McCullagh and Nelder, 1989) with error distribution appropriate for the variate undergoing analysis, and correlation procedures. Although the experiment could have been analysed as a split-plot in time, we chose to analyse the results of the two production years separately, and compare the year effects informally. We preferred this over formal statistical comparisons of year effects in a perennial crop study, where treatments cannot be randomised independently for each year of results.

The seed yield was analysed in two ways. First, a variate was derived from the seed yield for each experimental plot which was set to zero when no seed was harvested, and to unity when seed yield was greater than zero. This derived variate was considered to have a binomial distribution, and the generalised linear model used a logit link function. This analysis can therefore be considered to be of the probability of a cultivar producing seed.

Second, the seed yields themselves were analysed. Zero yield values were omitted to restrict comparisons to treatments that actually produced seed; this was necessary for some cultivars at BRS and FOS for the 1989 seed yield. Because the coefficient of variation was approximately constant regardless of the magnitude of the treatment mean for seed and herbage yields (total of two cuts), the effects of cultivar and site of production on these variates were determined by specifying a gamma error distribution with

the reciprocal link function (McCullagh and Nelder, 1989).

## RESULTS

The BRS and FOS experimental sites were only 4 km apart so the agrometeorological information recorded at the BRS weather station (Table 1) is applicable to both sites, and any differences in crop performance presumably result more from differences in the soil than the atmospheric environment. The FTV site was located 350 km north of the BRS and FOS sites, and the meteorological conditions, as well as the soil characteristics, were somewhat different; the winters were cooler, the summers were warmer, and the precipitation was received more uniformly throughout the year (Tables 1 & 2).

Two of the six site x year correlations between the residuals of seed and herbage yield of the cultivars were significant statistically; one was negative and low while the other was positive and relatively high (Table 3). Four cultivars (Comet, Filippa, Mobite and Niva) did not produce seed at BRS and FOS in 1989, and the probability of producing seed was influenced significantly by the main effects of cultivar and site but not by the cultivar x site interaction (Table 4). Using the linear model underlying the analysis in Table 4, the predicted probability ranged from 33 to 92% among sites and from 17 to 100% among cultivars (Table 5), and was in contrast to that observed for the second production year (1990), where each cultivar produced seed at each site (analysis not presented).

In the first production year (1989), herbage and seed yields (of cultivars that actually produced seed) were affected significantly only by the site; the cultivar and cultivar x site interaction had no significant effect. The highest seed yields, and the lowest herbage yields, were produced at FTV, the most northerly site (Tables 6 & 7). In the second production year (1990), the site effect was again significant for both herbage and seed yield but, in addition, the cultivar effect was significant for herbage yield, and both the cultivar x site and cultivar effects were significant for seed yield (Tables 6 & 7). The significant cultivar x site interaction for 1990 seed yield was caused by a smaller range of yields at FTV than at the other two sites; seed yields (kg ha<sup>-1</sup>) of the cultivars ranged from 165 to 980 at BRS, from 35 to 1002 at FOS, and from 134 to 345 only at FTV. Despite this, the seed yields of the nine cultivars in 1990 were ranked similarly at each of the three sites (Table 8). The most productive cultivars for both seed and herbage were Hattfjelldal and Apelsvoll (Table 7).

Herbage yield was affected by site but the ranking of sites was not consistent for the two years. Cultivars each produced similar amounts of herbage in the first production year, ranging from 4.6 to 6.2 t ha<sup>-1</sup> of dry matter, but significant differences were found in the second production year when yields ranged from 2.1 to 3.7 t ha<sup>-1</sup>; herbage yield rankings of cultivars were less consistent from year-to-year than those for seed yield (Table 7).

Table 1. Agrometeorological information for Beaverlodge Research Station.

Year	Month	Daily air temperature (°C)			Mean daily soil temperature (°C at 10cm)	Precipitation		
		Mean	Maximum	Minimum		Rain	Snow(water)	Total
1988	Jan	-12.2	-7.6	-16.9	-4.4	0.0	37.5	37.5
	Feb	-9.0	-3.7	-14.3	-3.3	0.0	29.8	29.8
	Mar	1.1	6.0	-3.8	0.1	0.3	9.3	9.6
	Apr	6.3	12.7	0.0	4.3	5.3	0.0	5.3
	May	10.9	18.1	3.6	10.0	28.1	0.0	28.1
	Jun	13.3	19.0	7.5	14.0	101.6	0.0	101.6
	Jul	14.7	21.1	8.3	15.2	64.4	0.0	64.4
	Aug	14.9	22.1	7.7	14.3	45.5	0.0	45.5
	Sep	10.4	16.9	3.8	10.8	34.1	0.3	34.4
	Oct	6.4	13.2	-0.4	6.1	3.4	0.6	4.0
	Nov	-6.2	-2.2	-10.1	-0.2	6.5	16.6	23.1
	Dec	-7.8	-3.3	-12.4	-3.6	0.0	15.8	15.8
1988	Jan-Dec	3.6	9.4	-2.2	5.3	289.2	109.9	399.1
1989	Jan	-9.2	-4.7	-13.8	-4.6	0.0	25.1	25.1
	Feb	-13.5	-7.6	-19.3	-6.1	0.0	6.2	6.2
	Mar	-11.1	-5.3	-16.9	-5.0	0.0	25.3	25.3
	Apr	5.2	12.0	-1.6	3.0	0.0	6.3	6.3
	May	9.7	16.4	3.0	9.1	57.4	1.6	59.0
	Jun	14.6	21.6	7.6	14.6	68.4	0.0	68.4
	Jul	15.6	22.1	9.2	17.4	101.4	0.0	101.4
	Aug	14.8	20.5	9.2	17.0	103.8	0.0	103.8
	Sep	10.3	16.5	4.2	11.1	62.0	0.0	62.0
	Oct	3.5	8.9	-2.1	5.2	9.4	10.6	20.0
	Nov	-3.7	1.3	-8.6	1.0	2.4	14.4	16.8
	Dec	-5.6	-0.9	-10.3	-1.2	0.4	17.3	17.7
1989	Jan-Dec	2.6	8.5	-3.2	5.2	405.2	106.8	512.0
1990	Jan	-10.4	-6.3	-14.5	-2.8	0.3	32.9	33.2
	Feb	-11.6	-5.0	-18.2	-4.4	0.0	9.6	9.6
	Mar	0.3	5.7	-5.1	-0.7	0.0	5.5	5.5
	Apr	3.4	9.4	-2.6	2.2	9.5	3.4	12.9
	May	9.7	15.9	3.5	8.8	44.2	22.7	66.9
	Jun	13.3	19.6	7.0	13.6	189.9	0.0	189.9
	Jul	16.3	23.1	9.4	17.5	58.7	0.0	58.7
	Aug	15.8	22.3	9.3	16.6	45.5	0.0	45.5
	Sep	12.3	19.2	5.4	11.8	16.6	0.0	16.6
1990	Jan-Sept	5.6	11.7	-0.5	7.1	364.7	74.1	438.8

Table 2. Agrometeorological information for Fort Vermilion Experimental Farm.

Year	Month	Daily air temperature (°C)			Mean daily soil temperature (°C at 10cm)		Precipitation	
		Mean	Maximum	Minimum	Rain	Snow(water)	Total	
1988	Jan	-19.5	-15.5	-24.1	-2.4	0.0	31.6	31.6
	Feb	-14.2	-9.5	-18.8	-1.9	0.0	14.6	14.6
	Mar	-4.3	1.9	-9.6	-0.9	0.0	27.2	27.2
	Apr	3.5	9.7	-2.5	0.2	4.2	4.2	8.4
	May	9.3	15.1	3.4	6.8	36.0	0.3	36.3
	Jun	15.5	21.1	9.8	14.0	67.6	0.0	67.6
	Jul	16.1	21.7	11.4	14.0	59.0	0.0	59.0
	Aug	15.7	22.1	9.8	15.4	87.2	0.0	87.2
	Sep	8.6	14.7	2.7	9.9	22.2	0.0	22.2
	Oct	-1.9	2.8	-6.9	4.5	35.1	2.5	37.6
	Nov	-12.4	-9.1	-16.4	-1.0	48.5	5.0	53.5
	Dec	-15.7	-11.7	-20.6	-3.4	11.7	1.5	13.2
1988	Jan-Dec	0.1	5.3	-5.2	4.8	371.5	86.9	458.4
1989	Jan	-21.0	-15.7	-26.4	-1.6	0.0	17.4	17.4
	Feb	-14.9	-8.9	-21.6	-2.8	0.0	2.0	2.0
	Mar	-14.9	-8.1	-21.5	-2.6	0.0	13.7	13.7
	Apr	1.9	8.6	-5.2	-0.3	0.0	9.2	9.2
	May	10.8	17.3	3.8	6.9	60.2	1.0	61.2
	Jun	16.0	22.4	10.1	14.6	30.2	3.6	33.8
	Jul	18.5	25.0	11.9	17.2	40.8	0.0	40.8
	Aug	17.3	23.1	12.1	16.3	59.0	4.6	63.6
	Sep	8.8	15.2	2.8	10.0	13.6	9.0	22.6
	Oct	1.4	6.1	2.9	4.3	18.4	13.2	31.6
	Nov	-15.4	-11.0	-20.2	1.1	1.6	39.7	41.3
	Dec	-17.6	-13.0	-22.1	-0.8	0.6	9.2	9.8
1989	Jan-Dec	-0.8	5.1	-6.1	5.3	224.4	122.6	347.0
1990	Jan	-16.9	-12.2	-21.6	-1.9	0.0	*	*
	Feb	-21.1	-15.0	-27.1	-2.6	0.0	*	*
	Mar	-4.6	2.9	-12.0	-1.2	0.0	*	*
	Apr	2.3	8.5	-3.8	7.2	0.0	*	*
	May	11.8	18.7	5.1	13.9	19.0	0.0	19.0
	Jun	15.8	22.8	8.7	16.6	31.2	0.0	31.2
	Jul	18.9	25.6	12.0	14.3	12.4	0.0	12.4
	Aug	14.9	21.3	8.3	10.2	35.4	0.0	35.4
	Sep	10.2	17.0	3.5	8.5	33.6	0.0	33.6
1990	Jan-Sept	3.5	10.0	-3.0	7.2	131.6	*	*

\* Values not available.

**Table 3. The correlation between the residuals of seed and herbage yield of nine orchardgrass cultivars at three sites in two production years.**

Site	Production year	df	Correlation coefficient
BRS	1989	17	0.101 NS
	1990	35	
FOS	1989	10	0.149 NS
	1990	35	
FTV	1989	32	-0.332 *
	1990	35	
			0.712 ***
			0.140 NS

\*, \*\*\* Significant at  $P < 0.05$  and  $P < 0.001$ , respectively.  
 NS Not significant.

**Table 4. Analysis of deviance of the probability of producing seed in the first production year (1989) for nine orchardgrass cultivars grown at three sites.**

Source of deviance	df	Change in deviance
Site	2	
Cultivar	8	30.32 ***
Cultivar x Site	16	78.62 ***
Residual	81	2.08 NS
		35.69

\*\*\* Significant at  $P < 0.001$  using Chi-square statistic.  
 NS Not significant.

**Table 5. Predicted probabilities (%), obtained from the linear model, link function and binomial distribution used in Table 4, of producing seed in the first production year (1989).**

Effect	Probability (SE)	
Site	BRS	
	FOS	50 (2.7)
	FTV	33 (5.2)
Cultivar	92 (3.7)	
	Angelkamp	58 (11.0)
	Apelsvoll	83 (8.3)
	Comet	33 (0.1)
	Filippa	17 (8.3)
	Haka	92 (7.2)
	Hattfjelldal	100 (0.2)
	Kay	83 (8.3)
	Mobite	33 (0.1)
Niva	25 (7.2)	

Table 6. Analysis of deviance of seed and herbage yields of nine orchardgrass cultivars grown at three sites for two production years (1989 and 1990).

Source of Deviance	Seed yield				Herbage yield			
	1989		1990		1989		1990	
	df	Change in deviance	df	Change in deviance	df	Change in deviance	df	Change in deviance
Site	2	40.2 ***	2	11.8 ***	2	7.5 ***	2	2.1 ***
Cultivar	8	11.9 NS	8	39.6 ***	8	0.8 NS	8	4.1 ***
Cultivar x Site	8 <sup>1</sup>	14.3 NS	16	8.9 ***	16	2.3 NS	16	1.4 NS
Residual	44 <sup>1</sup>	37.6	81	11.5	81	17.4	81	5.4

\*\*\* Significant at  $P < 0.001$  (F-probability on mean deviance ratio).

<sup>1</sup> The reduction in df, compared to the other three analyses, was caused by omitting plots where seed yield was zero to facilitate comparisons among the seed-producing plots.

### DISCUSSION

The lack of any consistent negative association between seed and herbage yield of the orchardgrass cultivars is in agreement with Andersen (1981). The present results confirm the variable nature of this association both among sites within years, and between successive years of production at the same site. Andersen (1981) considered that the

sign and magnitude of the correlation was probably influenced by restrictions emanating from evaluating the association using cultivars with proven herbage-production capabilities, the only cultivars accepted for certification and distribution. However, these conditions do not apply to this study because the cultivars were from diverse origins and were not developed locally for herbage.

Table 7. Predicted mean yield, obtained from the linear model, link function and gamma distribution used in Table 6, of seed and herbage of orchardgrass in two production years.

Effect	Seed yield (kg ha <sup>-1</sup> )				Herbage yield (t ha <sup>-1</sup> )			
	1989 <sup>1</sup>	(SE)	1990	(SE)	1989	(SE)	1990	(SE)
<b>Site:</b>								
BRS	21	(5.1)	532	(38.8)	5.0	(0.4)	3.5	(0.2)
FOS	43	(17.1)	393	(31.4)	6.9	(0.5)	2.8	(0.1)
FTV	186	(38.9)	234	(15.3)	3.6	(0.3)	2.6	(0.1)
<b>Cultivar:</b>								
Angelkamp	82	(35.4)	358	(40.3)	5.2	(0.7)	2.8	(0.2)
Apelsvoll	129	(47.0)	687	(81.6)	4.9	(0.7)	3.4	(0.3)
Comet	76	(35.3)	268	(29.6)	5.5	(0.8)	3.4	(0.3)
Filippa	70	(46.0)	115	(13.9)	5.6	(0.8)	2.1	(0.2)
Haka	126	(55.0)	551	(64.4)	5.0	(0.7)	3.0	(0.2)
Hattfjeldal	180	(75.2)	737	(88.5)	4.6	(0.6)	3.7	(0.3)
Kay	102	(44.7)	447	(51.0)	6.2	(0.9)	3.2	(0.2)
Mobite	50	(23.2)	184	(20.1)	4.6	(0.6)	2.5	(0.2)
Niva	64	(33.9)	131	(15.2)	5.2	(0.7)	2.1	(0.2)
<b>Significance of effect:</b>								
Site	***		***		***		***	
Cultivar	NS		***		NS		***	
Cultivar x Site	NS		***		NS		NS	

<sup>1</sup> Omitting plots where seed yield was zero to facilitate comparisons among the seed-producing plots.

\*\*\* Significant at  $P < 0.001$  (F-probability on mean deviance ratio).

NS Not significant.

**Table 8. Predicted mean seed yield (kg ha<sup>-1</sup>), obtained from the linear model, link function and gamma distribution used in Table 6, of orchardgrass cultivars at three sites in the second production year (1990).**

Cultivar	BRS			Site FOS			FTV		
	Yield	(SE)	Rank <sup>1</sup>	Yield	(SE)	Rank <sup>1</sup>	Yield	(SE)	Rank <sup>1</sup>
Angelkamp	487	(91.8)	5	314	(59.3)	5	273	(51.5)	4
Apelsvoll	980	(184.7)	1	806	(152.0)	2	276	(52.1)	3
Comet	335	(63.2)	6	225	(42.4)	6	244	(46.0)	6
Filippa	165	(31.3)	9	35	(6.6)	9	43	(27.0)	8
Haka	849	(160.0)	3	458	(86.4)	3	345	(65.1)	1
Hattfjelldal	958	(180.6)	2	1002	(189.0)	1	251	(47.3)	5
Kay	624	(117.5)	4	435	(81.9)	4	283	(53.3)	2
Mobite	199	(37.5)	7	194	(36.5)	7	159	(30.0)	7
Niva	187	(35.7)	8	71	(13.4)	8	134	(25.3)	9

<sup>1</sup> Within-site rank for seed yield of cultivars.

The cultivars were ranked consistently for seed yield within each of the three sites, and from one production year to the next. The four cultivars with low probabilities (17 to 33%) for seed production in the first production year, viz. Filippa, Niva, Comet, and Mobite, also had the four lowest seed yields in the second year, only 30 to 69% of the average seed yield of the nine cultivars (386 kg ha<sup>-1</sup>). With the exception of Comet, three of these same four cultivars also produced low yields of herbage in the second production year, although the previous year's herbage yields had not differed among cultivars. The cultivars Hattfjelldal and Apelsvoll were well adapted for both seed and herbage production in the study region. Kay, the only cultivar in the trials recommended currently for herbage production in the study region (Alberta Agriculture, 1991), was intermediate among the cultivars for both herbage and seed production.

The absence of seed production in the first production year in the same four cultivars at BRS and at FOS, was presumably a result of their response to the prevailing environmental conditions. Niemelainen (1989), reported a greater effect of frost occurrence (-3 to -10°C) on seed than on herbage production for Haka orchardgrass, one of the cultivars included in the present study; the difference was greater at lower temperatures and, to a less extent, at later stages of panicle development. He recommended that orchardgrass seed fields in Finland be those with a low risk of early summer frost. An examination of the meteorological records from the Beaverlodge Research Station, located about 1 and 3 km from BRS and FOS, showed that minimum air temperatures (in-screen sensor height of 1.2 m) dropped below 0°C on six occasions during May in each production year; temperatures of -1.0 to -2.5°C occurred from 2nd to 28th May, 1989, and of -0.5 to -4.5°C from 7th to 16th May, 1990. At FTV, frosts occurred in May on five occasions in

1989 (-0.4 to -3.5°C from 22nd to 28th May), and on at least three occasions in 1990 (from -0.1 to -2.3°C from 8th to 13th May). The remainder of each growing season was frost-free at each site. The differences among years and sites in frost incidence are probably not great enough to explain the observed depression in seed production of the four cultivars at BRS and FOS in 1989 relative to those in 1990, unless these cultivars are considerably more sensitive to the timing and severity of frost than that reported for Haka by Niemelainen (1989).

In Finland, low yields from the first seed crop of Haka orchardgrass have been attributed to factors such as seeding with a cover crop (where crop competition may preclude floral induction), winter damage from ice cover and/or low temperatures without snow cover (where herbage yield was reduced as well), and late spring/early summer frosts of < -4°C (Niemelainen, 1991). In addition, cold winter temperatures and an extended period of snow cover under Finnish conditions reduced orchardgrass panicle production more than herbage production (Niemelainen, 1990). Further research is required to elucidate the specific causes for the low first-year seed yields found in the present study, particularly with respect to the interaction effects of photoperiod and temperature.

Both the site and the year of production affected seed and herbage production of orchardgrass, even though the relative rankings of the nine cultivars remained consistent within sites for each production year. The ranking of the three sites for seed production in the second production year was the reverse of that in the first year. For herbage production, the least herbage was produced at FTV in each year while at BRS and FOS, the ranking was reversed in the two production years; this reversal is most likely to have been caused by differences in soil characteristics because

the sites were only 4 km apart. Andersen (1981) commented that seed yield in grasses depends on the prevailing climate and crop management, and suggested that an interaction between cultivar and growth conditions is to be expected. In studying the genetic variation of perennial ryegrass (*Lolium perenne* L.), Elgersma (1990) reported that the seed yield of the highest-yielding cultivar was consistently superior over a wide range of environments, a finding similar to the present results. The same author and others (Griffiths, Lewis and Bean, 1966; Andersen, 1981) concluded that it is feasible to develop grass cultivars with both high seed and high herbage yields. The selection for high seed yield, however, should be under environmental conditions where the seed is likely to be multiplied, and not where the cultivar is to be recommended for herbage/amenity use (Godshalk, Shenk and Rincker, 1984; Luedtke, 1984; Stratton and Ohm, 1989). Furthermore, Andersen (1981) cautioned that selection for improved seed yield in grasses could lead to enhanced intra-plant competition between tillers and inflorescences, thereby resulting in lower herbage yields. The large differences in seed yield observed among cultivars of a single grass species, in both this and other field trials (Elliott and Howe, 1979), emphasise the importance of matching grass cultivars to specific production environments for efficient seed production, an approach similar to that advocated for herbage legumes by Hampton (1990).

### CONCLUSIONS

Environmental conditions had a profound effect on the association between seed and herbage production of orchardgrass cultivars. Despite acceptable vegetative growth, seed production differed widely among sites and among cultivars, even though the rankings of cultivars were consistent over two production years and three study sites. High seed yields were produced by Hattfjelldal and Apelsvoll from Norway, and by Haka from Finland; intermediate seed yields were produced by Kay from Canada and Angelkamp from Germany; and low seed yields were produced by Filippa from Denmark, Niva from Czechoslovakia, Comet from the USA, and Mobite from The Netherlands. This limited evidence suggests the existence of a positive association between seed yield and latitude or origin for orchardgrass cultivars grown in the Peace region, possibly associated with the photoperiod, temperature or their interaction. Hattfjelldal and Apelsvoll were well adapted for both seed and herbage production. It may be possible to increase the biological efficiency of crop production by developing grass cultivars specifically for their end-use characteristics in one region, but multiplying their seed in a region in which the environmental conditions are particularly conducive to that process. The Peace region of northwestern Canada appears to provide a suitable environment for producing seed of specific orchardgrass cultivars, particularly those developed for herbage purposes

at more northerly latitudes. Seed production of some orchardgrass cultivars, however, should not be attempted in this region because their reproductive development is seriously inhibited by as yet undetermined factors. The lack of seedhead production from specific cultivars might be exploited to grow more nutritious herbage, provided productivity can be maintained and a negative association between feeding value and seedhead numbers per unit land area can be confirmed.

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