EFFECT OF ROW SPACING ON SEED AND HAY PRODUCTION OF ELEVEN GRASS SPECIES UNDER A PEACE RIVER REGION MANAGEMENT SYSTEM

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The effect of row spacing on seed and hay yields of 11 perennial grass species, including crested wheatgrass (*Agropyron cristatum* L.), intermediate wheatgrass (*A. intermedium* (Host.) Beauv.), a northern biotype of bromegrass (*Bromus inermis* Leyss.), a southern biotype of bromegrass, Russian wildrye (*Elymus junceus* Fisch.), meadow fescue (*Festuca pratensis* Hudson), creeping red fescue (*F. rubra* var. *genuina* L.), chewings fescue (*F. rubra* var. *commutata* Gaud), reed canarygrass (*Phalaris arundinacea* L.), a turf-type timothy (*Phleum bertolonii* DC (*P. bulbosum* auct.)) and hexaploid timothy (*Phleum pratense* L.), was studied under a system with limited inputs of fertilizer and no weed control. The width of the row spacings ranged from 16 to 104 cm where seed yields were measured and from 27 to 93 cm where hay yields were measured. The seed yield of all grasses was greater at a row spacing of 16 cm than at row spacings of 60 cm or more. Hay yields of all grasses, averaged over four production years, were also greatest at narrow row spacings (27 cm). These yields decreased as row spacings increased to 49 through 93 cm. Row spacing had its greatest effect on hay yields during the first production year. After this period the effects of row spacing on hay yields were small.

Key words: Row spacing, perennial grasses, seed yields, hay yields

[Effets de l'espacement des rangées sur le rendement grainier et fourrager de onze espèces de graminées cultivées dans la région de Peace River.]
Titre abrégé: Effets de l'espacement des rangées sur les graminées vivaces.
Nous avons étudié les effets de l'espacement des rangées sur les rendements grainiers et fourragers de onze espèces de graminées vivaces — l'agropyre à crête (*Agropyron cristatum* L.), l'agropyre intermédiaire (*A. intermedium* (Host.) Beauv.), un biotype nordique du brome (*Bromus inermis* Leyss.), un biotype méridional du brome, l'élyme de Russie (*Elymus junceus* Fisch.), la fétuque élevée (*Festuca pratensis* Hudson), deux variétés de la fétuque rouge (*F. rubra* var *genuina* L. et *F. rubra* var *commutata* Gaud), l'alpiste roseau (*Phalaris arundinacea* L.), une fléole à gazon (*Phleum bertolonii* DC (*P. bulbosum* auct.)) et la fléole hexaploïde (*Phleum pratense* L.) — sous un système cultural caractérisé par des apports limités en engrais et l'absence de désherbage. L'espace ménagé entre les rangées variait de 16 à 104 cm pour l'évaluation du rendement grainier et de 27 à 93 cm pour l'évaluation du rendement fourrager. Le rendement grainier de toutes les graminées était meilleur avec un espacement des rangées de 16 cm qu'avec un espacement de 60 cm ou plus. Les rendements fourragers moyens de toutes les graminées, établis sur quatre saisons de production, étaient aussi meilleurs lorsque les rangs étaient moins espacés (27 cm). Ces rendements ont diminué à mesure que l'espacement des rangées augmentait de 49 à 93 cm. L'espacement des rangées a eu son effet le plus important sur les rendements fourragers pendant la première saison de production. Après cette période, les effets de l'espacement des rangées sur les rendements fourragers n'ont pas été importants.

Mots clés: Espacement des rangées, graminées vivaces, rendements grainiers, rendements fourragers

Growing perennial grasses for seed and hay production is an integral part of the economy of the Peace River region of northern Alberta and British Columbia. The grasses are grown under a range of management systems, but systems characterized by limited levels of inputs predominate.

Row spacing has been shown to have an effect on seed yields of perennial grasses (Garrison 1960) and as a management factor, requires minimum additional input. It is generally agreed that most cool-season grasses produce more seed in rows than in solid stands (Fulkerson 1959; Garrison 1960; Fulkerson and Tossell 1961; Pardee and Lowe 1963; Bolton 1985). However, the optimum reported row spacings tend to vary from study to study. This is probably due to the interaction of row spacing with many other factors such as species (Roberts 1961; Austenson and Peabody 1964), soil moisture (Stitt 1954), soil nutrients or fertilizer treatments (Roberts 1961; Canode 1968; Black and Reitz 1969; Lawrence 1980), seeding rate (Fulkerson 1959; Fulkerson and Tossell 1961), age of stand (Lawrence and Heinrichs 1968; Lawrence 1980) and weeds (Fulkerson and Tossell 1961).

Row spacing has also been shown to influence herbage yields of perennial grasses (Lorenz and Rogler 1959; Lawrence and Heinrichs 1968; Black and Reitz 1969; McGinnies 1970; Kilcher et al. 1976; Leyshon et al. 1981). However, as with seed yields a number of factors interact with row spacing to influence herbage yields. These factors include fertilizer treatment (Lorenz and Rogler 1959; Black and Reitz 1969), weeds (Kilcher 1961) and age of stand (Kilcher 1961; Lawrence and Heinrichs 1968; Kilcher et al. 1976; Leyshon et al. 1981). Interaction of age of stand with row spacing has been shown to be complex in the southern Prairies (McGinnies 1970; Leyshon et al. 1981). In these studies, herbage production from crested wheatgrass and Russian wildrye was greatest from narrow row spacings (30 cm) during the first year of production. However, as the stands aged there was a transition of maximum yields from these narrow row spacings to wider row spacings. Thus, both studies concluded that when stands are kept in production for extended periods of time wide row spacings produce the greatest yields. The interaction of row spacing and seeding rate has been shown to have no significant effect on herbage production (McGinnies 1970; Leyshon et al. 1981).

Since little or no information exists on the effect of row spacing on the seed and hay production of perennial grasses when grown under the limited-input management systems of the Peace River region, the need for such studies is evident. However, the magnitude of the effort required to define the optimum row spacing for each of the numerous perennial species grown in the region makes the use of conventional experimental designs impractical. Gross (1972), using systematic designs from Nelder (1962), has developed a method for evaluating the effects of row spacing on the productivity of forage crops which requires less effort than methods using conventional designs. With Gross's (1972) method, grasses are seeded in rows which form the radii of a circle. Measurements can be made regarding interactions due to row spacing as one proceeds from the circumference to the center of the circle. Although seeding rate effects are confounded with row spacing effects, the method does have the potential to provide practical guidelines to producers, as well as for future research.

The purpose of this study was to evaluate, under a management system commonly used in the Peace River region, the effects of row spacing on the seed and hay yields of 11 common perennial grass species, using an adaptation of the method developed by Gross (1972).

MATERIALS AND METHODS

The experiments were conducted at the Research Station, Beaverlodge, Alberta on a Dark Gray Luvisolic soil. Crested wheatgrass cv. Fairway, intermediate wheatgrass cv. Chief, bromegrass (northern biotype) cv. Carlton, bromegrass (southern biotype) cv. Red Patch, Russian wildrye cv. Sawki, meadow fescue cv. Mimer, creeping

Table 1. Precipitation (mm) at Beaverlodge, Alberta 1971–1977

Date	Year							Long-term average
	1971	1972	1973	1974	1975	1976	1977	
1 Jan. - 25 Mar.	93.2	101.5	71.0	140.1	47.1	65.8	44.0	80.0
26 Mar. - 22 Apr.	18.6	14.7	2.8	5.6	32.0	10.5	2.1	20.0
23 Apr. - 20 May	2.3	1.6	5.8	51.0	14.5	14.1	93.4	25.4
21 May - 17 June	114.1	43.7	52.9	10.5	24.7	48.6	90.4	48.6
18 June - 15 July	110.5	50.7	15.2	68.9	57.2	106.1	105.5	60.8
16 July - 12 Aug.	23.7	43.9	15.0	32.4	28.9	129.7	70.0	49.2
13 Aug. - 9 Sept.	38.1	43.7	89.0	82.1	55.3	70.4	47.1	46.2
10 Sept. - 7 Oct.	87.9	68.5	39.6	23.4	24.0	46.5	66.1	37.5
8 Oct. - 4 Nov.	15.1	52.0	39.5	1.8	47.3	4.5	4.8	23.8
5 Nov. - 31 Dec.	46.5	73.6	51.0	61.7	81.0	50.6	-	56.2

red fescue cv. Boreal, chewings fescue cv. Oasis, reed canarygrass cv. Frontier, turf-type timothy cv. Aberystwyth S50 and hexaploid timothy cv. Climax were seeded in seven-row plots. Each row was 9 m long. The rows in each plot were arranged in a systematic fan-shaped design adapted from systematic designs described by Gross (1972). The row spacing at one end of each plot was 10 cm and increased to 110 cm at the other end. The plots were arranged in a randomized block design with four blocks. The above grasses were seeded at rates of 115, 105, 66, 66, 85, 82, 115, 115, 115, 131 and 131 seeds per meter of row, respectively. Only seed with high germinability (90% or greater) was used. The experiment was conducted twice with seedings on 26 May 1972 and on 2 June 1973.

The plot areas were fallowed for 2 yr prior to seeding. The level of inputs was similar to that used by many local producers and was, therefore, limited. Nitrogen fertilizer applied annually in late October at 25 kg N ha^{-1} was the only fertilizer applied. Inter-row tillage was not used and no weed control was attempted. Dandelion (*Taraxacum officinale* L.), along with red clover (*Trifolium pratense* L.) and alsike clover (*T. hybridum* L.), infested the study areas. Details on weed populations and their interaction with grass species and row spacing are described elsewhere (Darwent and Elliott 1979).

Effect of Row Spacing on Seed Yields

The effect of row spacing on the seed yield of each of the grasses was determined by harvesting samples from the five middle rows of each plot. Samples, 1 m in length, were obtained from each of these rows at the following intervals: 0-1, 2-3, 4-5, 6-7 and 8-9 m. The average row spacing for each of these intervals was 16, 38, 60, 82 and 104 cm, respectively. Harvests were made when the seed of each grass species reached maturity. After harvest the samples were air-dried, threshed and the seed weighed. Harvests were made in three consecutive years of production after each year of seeding.

Effect of Row Spacing on Hay Yields

The effect of row spacing on hay yields was determined in a similar manner to that of seed yields. Samples, 1 m in length, were harvested from the five middle rows at the following intervals: 1-2, 3-4, 5-6 and 7-8 m. The average row spacing for each of these intervals was 27, 49, 71 and 93 cm. Samples were harvested from each plot when the grass in that plot reached the heading stage. The grasses were clipped approximately 5 cm above ground level. Plant material from each area sampled was bagged, dried at 60°C and weighed. Harvests were made in four consecutive years of production after each year of seeding.

Analysis of the Data

Seed and hay yield data from each plot were converted to kilograms per hectare prior to any statistical analysis. The data were analyzed using Genstat (Alvey et al. 1982). Terminology used to describe the analyses and methods used to calculate missing values are from this source. Variances of means for both the seed and hay yields were observed to be nonhomogeneous. To overcome this problem, prior to analysis of variance the seed yield data were transformed using Naperian logarithms while the hay yield data were transformed by using square roots. These transformations produced homogeneous variances (Dr. L.P. Lefkovitch, pers. commun.) and permitted least squares analysis. Zero yields were treated as missing values when the transformed data were analyzed.

Table 2. Percent of total sum of squares of selected sources of variation of an analysis of variance on seed yield data transformed using Naperian logarithms

Source of variation	DF	Percent of total sum of squares
Year of production (YP)/year of seeding (YS) stratum		
YS	1	0.25**
Residual	4	0.02
Total	5	0.27
Block/YS stratum	7	3.29
Block/YP/YS stratum	11	0.09
Block/YP/YS "units" stratum		
Grass species (GS)	10	48.22**
GS/YS	10	2.82**
GS/YP/YS	40	0.42
Spacing (SP)	4	2.12**
Linear	1	2.10**
Residual	3	0.02
SP × GS	40	1.27
SP/YP × YS	20	0.63
Residual	1112	44.92
Total	1236	101.41
Grand total	1259	104.06

**Significant at the 0.01 level of probability. The grand total sum of squares = 2348.26.

RESULTS

Precipitation records for the duration of the study are shown in Table 1. These records show above-average rainfall for both of the years of seeding. As a result, growth and development of the grasses during the year of establishment was excellent. Grasses seeded in 1972 continued to grow and develop adequately throughout the life of the stands. However, in the winter of 1973-1974 considerable winter injury occurred among grasses seeded in 1973. Recovery was rapid in all species, except the turf-type timothy, chewings fescue and reed canarygrass. Russian wildrye also tended to recover more slowly than other grasses.

Effect of Row Spacing on Seed Yields

Row spacing had a significant effect on the seed yields of the 11 grass species (Table 2). The mean yield of all grasses, averaged over the 3 yr of production and 2 yr of seeding, was greatest where the rows were spaced 16 cm apart and declined linearly as row spacing widths increased (Table 3). There was no significant row spacing × grass species interaction, although, seed yields of intermediate wheatgrass, southern bromegrass and hexaploid timothy tended to be similar when grown in row spacings up to 60 cm apart. Year of seeding, grass species within year of seeding and grass species also had significant effects on seed yields (Table 2). The overall mean seed yield for all grass species seeded in 1972 was significantly, although marginally, higher than that for grasses seeded in 1973 (Table 4). However, the seed yields of all grass species did not follow this pattern. Seed yields of some grass species were higher when seeded in 1973 than when seeded in 1972 while seed yields of other grass species where either the same for the 2 yr of seeding or followed the opposite trend to the above three species. As expected, there were significant differences in the seed yields of the 11 grass species when these yields were averaged for all row spacings, years of production and years of seeding.

Effect of Row Spacing on Hay Yields

Row spacing had a significant effect on the hay yields of the grass species (Table 5). The

Table 3. Mean seed yield of 11 grass species, averaged across 3 yr of production, seeded at row spacings between 16 and 104 cm in 1972 or 1973. Means in parentheses are those calculated when the data were transformed and analyzed using Naperian logarithms

Row spacing (cm)	Year of seeding		Mean
	1972	1973	
16	412 (5.43)	466 (5.59)	439 (5.51)
38	419 (5.40)	389 (5.40)	404 (5.40)
60	395 (5.35)	316 (5.15)	356 (5.25)
82	339 (5.25)	267 (4.98)	303 (5.12)
104	304 (5.14)	232 (4.82)	268 (4.98)
Mean	374 (5.32)	334 (5.19)	
	SE†	(0.95)	
	SED† year of seeding	(0.02)	
	SED row spacing	(0.08)	

†SE, SED Standard error and standard error of the difference, respectively.

Table 4. Seed yields (kg ha^{-1}), averaged over 3 yr of production and five row spacings, for 11 grass species. Means in parantheses are those calculated when the data were transformed and analyzed using Naperian logarithms

Grass species	Year of seeding		Mean
	1972	1973	
Crested wheatgrass	521 (5.89)	615 (6.16)	568 (6.02)
Intermediate wheatgrass	501 (6.03)	594 (6.21)	548 (6.12)
Northern bromegrass	553 (6.25)	490 (5.90)	521 (6.07)
Southern bromegrass	401 (5.76)	352 (5.52)	376 (5.64)
Russian wildrye	126 (4.22)	128 (4.62)	127 (4.42)
Meadow fescue	614 (5.88)	505 (5.82)	559 (5.85)
Creeping red fescue	552 (5.82)	450 (5.89)	501 (5.85)
Chewings fescue	64 (3.62)	50 (3.92)	57 (3.77)
Reed canarygrass	142 (4.20)	44 (3.40)	93 (3.80)
Turf-type timothy	210 (4.88)	61 (3.80)	136 (4.34)
Hexaploid timothy	430 (5.91)	388 (5.81)	409 (5.86)
Mean	374 (5.32)	334 (5.19)	
	SE†	(0.95)	
	SED† year of seeding	(0.02)	
	SED† grass species	(0.12)	

†SE, SED Standard error and standard error of the difference, respectively.

nean hay yield for all grasses averaged over he 2 yr of seeding and 4 yr of production, leclined in a linear fashion from 596 kg ha^{-1} at a row spacing of 27 cm to 946 kg ha^{-1} at a row spacing of 93 cm Table 6). All grass species reacted to the effect of row spacing in the same manner, i.e. he row spacing × grass species interaction vas not significant (Table 5). However, there vas a significant row spacing within year of eeding × year of production interaction. Average yields from grasses seeded in either 972 or 1973 showed a clear trend of decrease n the first year of production as row spacings increased from 27 to 93 cm (Table 6). However, in the second, third and fourth years of production row spacing had little effect on hay yields.

Approximately 25% of the total variation in the experiment was attributable to the year of production within year of seeding stratum (Table 5). Two factors are responsible for this variation: year of seeding and year of production within year of seeding. The overall mean yield for the four production years of all grass species seeded in 1972 was 2704 kg ha^{-1} while the same mean for grass species seeded in 1973 was only 1726 kg ha^{-1}. The

Table 5. Percent of total sum of squares of selected sources of variation of an analysis of variance on hay yield data transformed using the square root transformation

Source of variation	DF	Percent of total sum of squares
Year of production (YP)/year of seeding (YS) stratum		
YS	1	11.17
Residual	6	20.70
Total	7	31.87
Block/YS stratum	7	2.26
Block/YP/YS stratum	17	2.00
Block/YP/YS "units" stratum		
Grass species (GS)	10	31.28**
GS/YS	10	1.46**
GS/YP/YS	60	9.25**
Spacing (SP)	3	2.52**
Linear	1	2.51**
Residual	2	0.01
SP × GS	30	0.41
SP/YP × YS	21	1.88**
Residual	1217	19.57
Total	1351	66.37
Grand total	1382	102.50

** Significant at the 0.01 level of probability. The grand total sum of squares = 372 369.

Table 6. Mean annual hay yield of 11 grass species for 4 yr of production following seeding in 1972 or 1973 a four different row spacings. Means in parentheses are those calculated when the data were transformed and analyzed using the square root transformation

Year of production	Row spacing (cm) 27	49	71	93	Mean
		Seeded in 1972			
1973	4080 (56.1)	3503 (51.6)	2971 (47.3)	2559 (42.8)	3278 (55.0
1974	4108 (51.0)	3895 (49.3)	3994 (49.7)	3722 (47.8)	3932 (61.5
1975	1680 (51.7)	1392 (48.1)	1394 (48.6)	1463 (49.4)	1482 (36.6
1976	2388 (51.9)	2036 (48.2)	2041 (48.6)	2031 (48.9)	2124 (44.7
		Seeded in 1973			
1974	2801 (48.9)	2080 (40.9)	1626 (35.0)	1214 (30.1)	1967 (40.0
1975	1649 (42.5)	1433 (39.5)	1285 (37.7)	1130 (35.2)	1374 (35.8
1976	2398 (41.9)	2082 (38.4)	2021 (37.9)	1929 (36.7)	2108 (44.9
1977	1663 (40.6)	1417 (38.1)	1364 (37.7)	1518 (38.5)	1505 (36.4
Mean	2596 (48.1)	2230 (44.3)	2087 (42.8)	1946 (41.2)	
	SE†				(7.6)
	SED† Spacing				(0.6)
	SED† Spacing/year of production × year of seeding				(6.2)

†SE, SED Standard error and standard error of the difference, respectively.

remaining approximate 15% of the variation in the year of production within year of seeding stratum can be attributed to the effects of year of production on hay yield. Yields varied from one year of production to the next in all species, but there were no apparent consistent trends, i.e. yields of grasses seeded i 1972, averaged over all spacings were 3278 3932, 1482 and 2124 kg ha^{-1} for years c production 1 to 4, respectively, while simila yields of grasses seeded in 1973 were 1967 1374, 2108 and 1505 kg ha^{-1} for years c

Table 7. Hay yields (kg ha^{-1}), averaged over five row spacings and 4 yr of production, for 11 grass species seeded in either 1972 or 1973. Means in parentheses are those calculated when the data were transformed and analyzed using the square root transformation

Grass species	Year of seeding: 1972	Year of seeding: 1973	Mean
Crested wheatgrass	2585 (49.1)	2035 (43.8)	2310 (46.5)
Intermediate wheatgrass	4087 (62.6)	2874 (52.7)	3480 (57.7)
Northern bromegrass	3315 (56.4)	1905 (42.0)	2610 (49.2)
Southern bromegrass	3525 (58.3)	2338 (47.3)	2931 (52.8)
Russian wildrye	1696 (39.5)	830 (26.3)	1263 (32.9)
Meadow fescue	2251 (44.4)	1317 (33.5)	1784 (39.0)
Creeping red fescue	2364 (46.8)	1715 (40.3)	2040 (43.6)
Chewings fescue	1034 (30.8)	854 (26.6)	944 (28.7)
Reed canarygrass	3229 (54.6)	1624 (38.9)	2427 (46.7)
Turf-type timothy	1926 (42.2)	899 (26.1)	1412 (34.2)
Hexaploid timothy	3731 (59.4)	2483 (48.6)	3107 (54.0)
Mean	2702 (49.4)	1744 (39.1)	
	SE†	(7.6)	
	SED† year of seeding	(6.0)	
	SED† grass species	(1.0)	

†SE, SED Standard error and standard error of the difference, respectively.

production 1–4, respectively (Table 6).

Other sources of variation which had a significant effect on hay yields were grass species, grass species within year of seeding and grass species within year of production within year of seeding (Table 5). Hay yields, averaged over all row spacings, years of production and years of seeding, varied from 944 kg ha^{-1} for chewings fescue to 3480 kg ha^{-1} for intermediate wheatgrass (Table 7). This variation accounts for the effect of grass species. There was also a large amount of variation in the mean yields of the grass species within each year of seeding. However, when these yields were ranked within each of the two years of seeding, the ranking pattern for grasses seeded in 1972 was different than that for grasses seeded in 1973. This accounts for a significant grass species within year of seeding effect. There were also differences in the relative size of mean hay yields within each year of production and year of seeding.

DISCUSSION

Results of this study must be interpreted in light of the conditions under which they were obtained. Throughout the study a system of management with limited inputs was employed. Low levels of fertilizer were applied, inter-row tillage and other weed control procedures, as well as any other crop protection procedures, were not employed and no irrigation was used. Despite the low level of inputs, the conditions of this study are representative of those currently employed by the majority of forage seed and hay producers in the Peace River region.

The type of experimental design used in this study must also be considered when discussing the influence of row spacing on seed and hay yields. Row spacing and rates of seeding were confounded by the design used here; i.e. rates on a per unit area basis increased as row spacing decreased. However, this effect may not be important. Leyshon et al. (1981) have found that seeding rates have an effect on herbage yields only during the first year of production while others (Fulkerson 1972; Fulkerson and Tossell 1961) have observed no important effect of seeding rates on seed yields.

Our results do not agree entirely with recommendations provided by Bolton (1985) for maximum seed production from grasses. Bolton (1985) recommended row spacings of 60–90 cm for maximum seed production from grasses such as crested wheatgrass, bromegrass (both northern and southern biotypes), Russian wildrye and reed canarygrass. In our studies maximum seed yields from all of these grasses occurred from row spacing of less than 60 cm. The lack of inter-row tillage and subsequent increase in weed populations with increases in row spacings probably had a major influence on seed yields. Weed populations were greater between row spacings of more than 60 cm than between row spacings of less than 60 cm (Darwent and Elliott 1979). The effects of inter-row tillage on soil characteristics, such as moisture and aeration, could also have been factors improving yields had they been employed. Adaptation of the grass species to the site of the study may also have contributed to the observed responses. For example, Russian wildrye has been shown to develop slowly and produce poorly, relative to some other grass species, under northern Alberta conditions (S.G. Bonin, pers. commun.). Under these conditions, the effect of row spacing on the seed yield of Russian wildrye could be expected to be different to the effect of row spacing in regions where it is well adapted.

Row spacings of 30 cm or less are recommended for hay production from all grasses except Russian wildrye and crested wheatgrass (Alberta Agriculture 1981). Row spacings of 30–90 cm are recommended for Russian wildrye and 30–60 cm for crested wheatgrass. Thus, our results are in agreement with the recommendations, except for the latter two species.

The interaction between the age of the stand and the effect of row spacing on hay yields (Table 6) is similar to the phenomenon observed by Leyshon et al. (1981). They observed that the yields of crested wheatgrass and Russian wildrye in the first production year were higher when grown in rows spaced 30 cm apart than when grown in rows spaced 60 or 90 cm apart. However, by the fifth year of production there had been a transition in yield advantage from the 30-cm row spacings through the 60-cm row spacings to the 90-cm row spacings. In our studies, row spacing had a major effect on herbage yields in the first year of production but only a minor effect in subsequent years. Had yields been taken for more than 4 yr of production the transition observed by Leyshon et al. (1981) might have occurred.

Several features regarding row spacing and the production of seed and hay by forage grasses in the Peace River region are apparent from this study. Narrow row spacings (i.e. 16 cm) appeared to provide optimum production of seed. Such spacings also provide several advantages in addition to seed yield. In narrow rows, invasion of weeds is suppressed (Darwent and Elliott 1979) and the threat of soil erosion is reduced. Narrow row spacings are also more conducive to swathing, a practice commonly used prior to harvesting the seed. With regard to hay production, optimum row spacing appears to depend on the length of time that the stand will be grown. When stands are grown for relatively short periods of time (i.e. 2 or 3 yr) narrow row spacings (i.e. 27 cm) provided better yields than wider row spacings. However, for stands grown for longer periods of time, row spacings greater than 27 cm may be equally productive.

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