The suitability of cool- and warm-season annual cereal species for winter grazing in Saskatchewan

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[1]Agriculture and Agri-Food Canada, Indian Head Research Farm, P. O. Box 760, Indian Head, Saskatchewan, Canada S0G 2K0 (e-mail: mayb@agr.gc.ca); [2]Saskatchewan Agriculture and Food, P.O. Box 2003, Weyburn, Saskatchewan, Canada S4H 2Z9; [3]Saskatchewan Agriculture and Food, Box 3830 Thatcher Ave., Saskatoon, Saskatchewan, Canada S7H 2H6; and [4]Saskatchewan Agriculture and Food, 1192,102 street, North Battleford, Saskatchewan, Canada S9A 1E9. *Received 21 February 2006, accepted 5 April 2007.*

May, W. E., Klein, L.H., Lafond, G. P. McConnell, J. T. and Phelps, S. M. 2007. **The Suitability of cool-and warm-season annual cereal species for winter grazing in Saskatchewan.** Can. J. Plant Sci. **87**: 739–752. Winter grazing is a practice that can reduce feeding cost for cattle production. Current production has been utilizing traditional cool-season cereals for winter grazing. Warm-season (C_4) cereals also have the potential to be adapted to winter grazing in Saskatchewan. The objective of this study was to evaluate cool and warm season annual cereal species for adaptation, quality, and dry matter production in annual fall and winter grazing systems. Two seeding dates, nine treatments and two harvest times were used at sites across Saskatchewan over 3 yr. The crops in this trial have significant differences in maturity and dry matter yield. Seeding date did not consistently affect dry matter yield. Pearl millet [*Pennisetum glaucum* (L.) R. Br.] and sorghum-sudangrass [*Sorghum bicolor* (L.) × *S. arundinaceum* (Desv.) Stapf var. *sudanense* (Stapf) Hitchc.] had low dry matter yields and were poorly adapted to Saskatchewan. The proso millet (*Panicum miliaceum*) cultivar, Crown, and the foxtail millet (*Setaria italica* L.) cultivars, Red Siberian and Golden German, had yields similar to oat (*Avena sativa* L.) and barley (*Hordeum vulgare* L.), but lower than high-input corn (*Zea mays* L.). Corn had dry matter yield that was similar to barley and oat but yield variability across sites and years was higher for corn. Delaying the harvest lowered the protein concentration of all the crops except pearl millet and sorghum-sudangrass. There were significant changes in acid detergent fibre (ADF), neutral detergent fibre (NDF), calcium (Ca) and phosphorus (P) due to a cultivar × harvest timing interaction. Weathering in the windrow until December did not significantly reduce the quality of the forage. Golden German foxtail millet is well adapted for swath grazing in eastern Saskatchewan. More data are required to determine its adaptability in central and western Saskatchewan and the adaptability of corn in all of Saskatchewan.

Key words: *Avena sativa* L., *Hordeum vulgare* L.,*Setaria italica* L., *Panicum miliaceum*, *Zea mays* L., swath grazing

May, W. E., Klein, L. H., Lafond, G. P. McConnell, J. T. et Phelps, S. M. 2007. **Utilité des céréales annuelles de saison fraîche et de saison chaude pour la paissance hivernale en Saskatchewan**. Can. J. Plant Sci. **87**: 739–752. La paissance hivernale réduit le coût d'engraissement des bovins. Jusqu'à présent, on a surtout recouru aux céréales de saison fraîche à cette fin, cependant on pourrait adapter les céréales de saison chaude (C_4) à cette pratique, en Saskatchewan. L'étude devait évaluer les espèces annuelles de saison fraîche et de saison chaude d'après leur capacité d'adaptation, leur qualité et la production de matière sèche dans les systèmes de paissance annuels d'automne et d'hiver. Les auteurs ont utilisé deux dates de semis, neuf traitements et deux dates de récolte à divers endroits de la Saskatchewan pendant trois ans. Les espèces testées variaient sensiblement au niveau de la précocité et du rendement en matière sèche. La date des semis n'affecte pas de manière cohérente le rendement en matière sèche. Le millet à chandelle (*Pennisetum glaucum* (L.) R. Br.) et le sorgho-herbe du Soudan (*Sorghum bicolor* (L.) × *S. arundinaceum* (Desv.) Stapf var. *sudanense* (Stapf) Hitchc.) produisent peu de matière sèche et sont mal acclimatés à la Saskatchewan. Le cultivar Crown du millet commun (*Panicum miliaceum*) et les cultivars Red Siberian et Golden German du millet des oiseaux (*Setaria italica* L.) donnent un rendement similaire à l'avoine (*Avena sativa* L.) et à l'orge (*Hordeum vulgare* L.), mais inférieur à celui du maïs (*Zea mays* L.) de haute production. Le rendement en matière sèche du maïs est similaire à celui de l'avoine et de l'orge, mais il varie d'un endroit à l'autre et, certaines années, le rendement du maïs était supérieur. Retarder la récolte réduit la concentration de protéines pour toutes les cultures sauf le millet à chandelle et le sorgho-herbe du Soudan. L'interaction entre le cultivar et la date de récolte modifie sensiblement la concentration de fibres au détergent acide, de fibres au détergent neutre, de calcium et de phosphore. Le fanage en andain jusqu'en décembre n'altère pas de manière significative la qualité du fourrage. Le millet des oiseaux Golden German est bien adapté à la paissance sur andain dans l'est de la Saskatchewan. On aurait besoin de données supplémentaires pour établir la capacité d'adaptation de ce cultivar dans le centre et l'ouest de la province ainsi que la capacité d'adaptation du maïs dans l'ensemble de la Saskatchewan.

Mots clés: *Avena sativa* L., *Hordeum vulgare* L.,*Setaria italica* L., *Panicum miliaceum*, *Zea mays* L., paisssance sur andain

Abbreviations: **ADF**, acid detergent fibre; **CP**, crude protein; **GDD**, growing degree days; **NDF**, neutral detergent fibre

Grazing in the fall and winter is of interest to producers to reduce over-winter feeding costs (D'Souza et al. 1990; Johnston and Wand 1999). Swath grazing and the grazing of standing corn (*Zea mays* L.) are two production practices that are currently being used on the Canadian prairies (Baron et al. 2003; Anonymous 2004). Several studies have shown that swath grazing will reduce feeding costs for spring-calving beef cows and wintering calves (Volesky et al. 2002; McCartney et al. 2004). Spring-seeded barley (*Hordeum vulgare* L.) and oat (*Avena sativa* L.), cool-season cereals, are the most common species used for swath grazing in western Canada. Seeding date is important because the producer must balance biomass production against potential weathering. Several studies found that as seeding was delayed biomass production of oat decreased (Buglass 1955; Baron et al. 1994; Kibite et al. 2002). However, if the oat and barley are seeded in early to mid May, the crop will be swathed in early August in most of western Canada, while oat or barley seeded in early June will be swathed in early to mid-September. The earlier the crop is swathed the longer it is exposed to weathering. In addition, temperatures are higher in August then in September, allowing degradation to occur at a faster rate in August especially if significant precipitation occurs. The swath is grazed in the fall or winter. Currently, producers delay seeding to reduce the potential loss of biomass and quality from weathering; however, with delayed seeding comes the risk of reduced biomass production.

This problem led people to consider the adaptability of warm-season cereals for swath grazing on the Canadian prairies since they tend to be seeded later and vary in days to maturity. Warm-season grasses have been evaluated for use as hay and silage as early as 1902 in Saskatchewan but their use has never been widely adopted (MacKay 1903; Davidson 1949). The development of swath grazing and of newer cultivars provide a new potential use for annual warm-season cereals. Preliminary studies conducted at Brandon, MB, indicated that the winter grazing of swathed foxtail millet (*Setaria italica* L.) and standing corn was feasible and that these warm-season cereals could produce large amounts of biomass (McCaughey et al. 2002).

Little is known about the appropriate stage to swath warm-season cereals for swath grazing on the northern plains of North America. As the oat plant matures, biomass increases while the quality generally tends to decreases (Kilcher and Troelsen 1973; Kaulbars and King 2004). A balance must be struck between biomass production and quality when selecting the optimal development stage for swathing warm-season cereals. The objective of this study was to evaluate seeding date, harvest timing and annual cereal species for adaptation, feed quality, and biomass production in fall and winter grazing systems on the Canadian prairie.

MATERIALS AND METHODS

This trial was conducted from 2002 to 2004 at several locations across Saskatchewan (Table 1). The plots were seeded in a split plot design with the main plot being seeding date, the subplot consisting of nine treatments and with harvest measurements repeated over time. Four replications were used. The seeding dates were, May 15 or Jun. 10. The subplot treatments consisted of eight cultivars and one extra treatment. The cultivars and species used were Pinnacle oat, Ranger barley, Crown proso millet (*Panicum miliaceum*), Red Siberian foxtail millet, Golden German foxtail millet, Mil Hy 300 pearl millet [*Pennisetum glaucum* (L.) R. Br.] in 2002 and 2003 and Leafy Green #4 pearl millet in 2004, Mega Green sorghum-sudangrass [*Sorghum bicolor* (L.) × *S. arundinaceum* (Desv.) Stapf var. *sudanense* (Stapf) Hitchc.] in 2002 and 2003 and Forage King in 2004, and a corn hybrid, 39T71. An extra treatment with corn at a higher level of fertility and wider row width was included in the trial. Not all the subplot treatments were seeded at every site in every year. When the data were combined across locations and years, each location in each year became a site.

To determine the optimum crop stage for harvesting the warm season crops, samples for forage yield and quality were collected on two separate dates from each plot. The first samples were collected at the recommended stages for the cool season cereals: milk dough for oats and soft dough for barley (Kaulbars and King 2004). The first samples were collected for the warm season cereals at 50% milk line for corn, and 2–3 wk after heading for the proso millet, foxtail millet, pearl millet and sorghum-sudangrass. The second samples were collected 2 wk after the first sample at which time the foxtail and proso millets would have reached the grain filling stage but not sorghum-sudangrass and pearl millet. To determine the suitability of the crops for swath grazing, a third set of samples for quality analysis was collected in December. These were collected only from the mid June seeded plots that were windrowed after the second yield samples were collected except for corn which was left standing. Forage quality samples were analyzed at Norwest Labs in Lethbridge using wet chemistry FD6N package for crude protein (CP) (Association of Official Analytical Chemists 1997), ADF (Association of Official Analytical Chemists 2003a), NDF (Undersander et al. 1993), Ca and P (Association of Official Analytical Chemists 2003b). To reduce cost, the treatments in the first and second replications were combined and the third and forth replications were combined resulting in two separate analyses per treatment for forage quality.

Fertilizer was side banded during seeding at 55 kg ha^{-1} nitrogen (urea) and 22 kg ha^{-1} P (monoammonium phosphate) except at Melfort in 2003, Loon Lake in 2003, and Scott in 2004. At Melfort the fertilizer was broadcast and worked into the soil and at the other two sites the fertilizer was banded into the soil before seeding. Two plots of corn were seeded, one at the above fertilizer rate, and a second with a nitrogen rate of 135 kg ha^{-1} with the row width doubled by removing every second row. These two treatments are hereafter referred to as low- and high-input corn. The seeding rate of the corn was adjusted to maintain the same plant density. On the first seeding date glyphosate [*N*-(phosphonomethyl)glycine] was applied if weeds were present in the field. Glyphosate was always applied for weed control prior to seeding except at Melfort in 2003, which used tillage, and Scott in 2004, which used hand weeding. The

Table 1. Species and cultivars of annual forage grasses grown at 13 site-years across Saskatchewan from 2002 to 2004

	Year	2002			2003							2004		
	Location	Indian Head	Redvers	Canora	Indian Head	Redvers	Canora	Scott	Loon Lake	Swift Current	Melfort	Indian Head	Scott	Canora
Species	Cultivar													
Oat	Pinnacle[z]	x	x	x	x	x	x	x	x	x	x	x	x	x
Barley	Ranger[z]	x	x	x	x	x	x	x	x	x	x	x	x	x
Proso millet	Crown[z]	x	x	x	x	x	x	x	x	x	x	x	x	x
Foxtail millet	Red Siberian	x	x	x	x	x	x					x	x	x
	Golden German[z]	x	x	x	x	x	x	x	x	x	x	x	x	x
Pearl millet	Mil Hy 300[y]	x	x	x	x	x	x					x	x	x
Sorghum-sudangrass	Mega Green[x]	x	x	x	x	x	x				x	x	x	x
Corn - high input	39T71				x	x		x	x	x	x	x	x	x
Corn - low input	39T71				x	x		x	x	x	x	x	x	x

[z]Cultivars that were at all site years.
[y]The cultivar was leafy Green #4 in 2004.
[x]The cultivar was Forage King in 2004.

rate of glyphosate depended on the weed spectrum at the time of spraying. Plots were seeded directly into standing stubble using a low disturbance no-till plot seeder with a row spacing ranging from 20 to 30.5 cm except at Melfort, where the plots were seeded into tilled soil. The stubble was canola at Canora in 2003 and at Indian Head in 2002 and 2004, spring wheat at Indian Head in 2003, Redvers in 2002 and 2003, and Scott in 2003 and 2004, and barley at Loon Lake in 2003 and Canora in 2002 and 2004. Seeding rates were 34 kg ha^{-1} for pearl millet and 22.5 kg ha^{-1} for proso millet, foxtail millets and sorghum-sudangrass. The 22.5 kg ha^{-1} seeding rate is currently the rate recommended to Saskatchewan growers by the seed industry. A higher seeding rate was used for pearl millet due its larger seed size (Teutsch 2002). The seeding rates for oat, barely and corn were adjusted using the average seed weight and the percentage of viable seeds to achieve a target plant density of 250 plants m^{-2} for the oat and barley, and 7 plants m^{-2} for corn. Samples were hand harvested at most sites with a total harvest area between 1 and 1.3 m^2, except at Melfort in 2003 with a harvest area of 7.2 m^2, and Scott in 2004 with a harvest area of 7.5 m^2. The area of an individual plot ranged between 22.8 and 44.5 m^2. Growing degree days (GDD) were calculated by subtracting 5 from the daily mean temperature of each day and then summing the result across the desired period of time. The daily mean temperature was calculated by taking the average of the maximum and minimum temperature of the day. No maximum or minimum thresholds were used.

Statistical Analysis

Data (winter harvest data excluded) were analyzed with the PROC MIXED procedure of SAS (Littell et al. 1996) with treatments, seeding date, and harvest date as fixed effects, and block and site (location by year combinations) as random effects. With sites considered random effects, inferences regarding optimal seeding and harvest management for different forage crops can be extended to most forage oat and barley fields in the eastern Canadian prairies unless there are large differences among cultivars of a specific forage crop. Contrasts were used to make specific comparisons among the different treatment combinations. To investigate the effect on the quality of the treatments when left in the field until early December, a second analysis was carried out with the PROC MIXED procedure of SAS (Littell et al. 1996) with treatments, and harvest date (winter harvest data included) as fixed effects, and block and site as random effects. The May 15 seeding date data were excluded for this analysis. A third analysis of variance (winter harvest data excluded) was conducted with sites as a fixed effect to further investigate why treatment effects varied at the individual study sites. Statistical significance was declared at $P \le 0.05$ for all analyses. When LSD are presented in this paper missing data necessitated that the LSD were estimated by applying the average standard error of mean difference to the calculation for each effect.

Yield data using the site × crop mean also were fit to the combined effects of total growing season (May 01 to Sep. 01) precipitation and GDD using the PROC RSREG procedure of SAS (SAS Institute, Inc. 1999). A plotting interval finer than the interval of the actual precipitation and GDD interval was used to generate a smooth response surface over a relevant range of precipitation and GDD for the region.

RESULTS AND DISCUSSION

Environment, Emergence and Maturity

Monthly accumulated precipitation and average temperature from Apr. 01 to Aug. 31 at each site are provided in Table 2. Precipitation from April to August was below average at all sites in 2003 and at or above average in 2002 and 2004. Temperatures in 2004 tended to be much lower than in 2002 and 2003, especially in July and August.

The crops were established with direct seeding equipment into standing stubble at all sites, except Melfort in 2003. Uniform and vigorous emergence was obtained for oat and barley (data not shown). In most cases, uniform and vigorous emergence was obtained from the foxtail and proso millet cultivars, even when seeded in the middle of May. When soils were cold, emergence of the foxtail and proso millet cultivars were delayed and weed competition increased. It was difficult to achieve consistent and even emergence from the sorghum-sudangrass and pearl millet cultivars used in this test. These two crops need special attention regarding soil temperature at seeding when a grower is trying to establish them in western Canada. The recommended soil temperature at seeding for pearl millet and sorghum-sudangrass is above 18°C (Teutsch 2002). However, it should be noted that it has also been recommended that the minimum soil temperature at seeding be 18°C for foxtail millet. Corn emergence was consistent and fairly even.

The crops in this trial have important differences with respect to maturity, with crop and seeding date affecting the GDD accumulated to reach the first and second harvesting stages. The warm-season annuals seeded in mid-June require fewer GDD to reach the first harvesting stage than when seeded in mid-May ($P \leq 0.001$; crop × seeding date × harvesting stage interaction $LSD_{0.05} = 43$, data not presented). On the mid May seeding date, barley and oat require 799 and 807 GDD, respectively, to reach the first harvesting stage. The proso millet cultivar, Crown, required 970 GDD to reach the first harvesting stage, significantly more than oat or barley. The two foxtail millet cultivars required more GDD than proso millet with Red Siberian averaging 1088 GDD and Golden German averaging 1203 GDD to reach first harvest. Golden German required significantly more GDD than Red Siberian foxtail millet to reach first harvest. Barley, oat and proso millet seeded at mid-June, required a similar number of GDD, 853, 847 and 877, respectively. Red Siberian foxtail millet required 943 GDD to reach the first harvesting stage, significantly more than required by the barley, oat and proso millet. Golden German foxtail millet required 1051 GDD to reach the first harvesting stage, which was significantly more than the Red Siberian foxtail millet. Pearl millet and sorghum-sudangrass had difficulty reaching the correct stage for first harvest. They were usually harvested at the same time as the Golden German foxtail millet but at a less mature stage. The variety of corn used reached black layer or physiological maturity in 2003 but not 2004 and in 2003 the corn needed 1206 (first harvest) GDD to reach 50% milk line when seeded in mid May.

Forage Yield

Forage yield when averaged across sites was affected by crop but not by seeding date (Table 3). Harvest timing almost had a significant effect on forage yield ($P \leq 0.055$, Table 3). In addition, forage yield was affected by site, site × crop, site × crop × seeding date and site × crop × harvest timing.

The relationship between the average yield and yield variability for each crop is highlighted when the yield and the coefficient of variation (CV) averaged across all sites are plotted in Fig. 1. Barley and oat have high yield and a relatively low CV. Proso millet, Red Siberian foxtail millet and Golden German foxtail millet are grouped together with slightly lower yields and higher CVs. Both corn treatments had high yield, but greater variability in yield. The forage biomass of the corn ranged from 1.3 to 13.7 t ha^{-1} at the same location but in different years. Due to poor emergence and late maturities, sorghum-sudangrass and pearl millet tended to have low yields and high variability.

Some of the causes for this variation in yield become apparent when the environmental conditions at individual sites were examined. In 2004, a cool year (Table 2), corn yields were lower than oat or barley at both sites especially at Scott (Table 4), while in 2003 corn outyielded the oat or barley under warmer temperatures and below average rain fall at three out of five sites. In addition, since corn is grazed standing instead of placed in a swath, the portion of the biomass in the leaves and stalk above the cob may be lost due to breakage from weathering before the cattle enter the field to graze. Baron et al. (2003) reported corn losses from mid-September to January between 13 and 16% except at 1 site year when the biomass lost due to weathering was 39%. When there was a yield difference between the corn treatments at individual sites, the high input corn outyielded the low input corn at four out of seven sites (Table 4). The low input corn outyielded high input corn only at the lowest yielding site, Swift Current in 2003. All the warm-season annuals did not yield as well as oat or barley under the cool conditions that occurred in 2004. The yield of Golden German foxtail millet in 2002 and 2003 was as good as or better than the combined mean of oat and barley yield, except at Swift Current in 2003. Proso millet had lower yields than the combined yield of oat and barley at Redvers, and Indian Head in 2002 and Swift Current and Melfort in 2003. Therefore, the yield of proso millet was not as consistent as the yield of Golden German foxtail millet. The yield of sorghum-Sudangrass was very variable but tended to be quite low except at Canora in 2002 and 2003.

The effect of environment on oat, barley, proso millet and Golden German foxtail millet was further investigated by estimating the effect of total season precipitation and GDD on yield using a surface response. Barley and oat responded in a similar manner with yield increasing as GDD increase when precipitation was low (Fig. 2). As precipitation

Table 2. Precipitation (mm) and soil moisture conditions in spring and monthly mean temperatures during the study

	2002			2003						2004		
	Indian Head	Redvers	Canora	Redvers	Indian Head	Canora	Melfort	Swift Current	Scott	Indian Head	Scott	Canora
Estimated Soil moisture reserves (Spring)	Poor to Fair	Poor	Fair	Very Good	Very Good	Very Good	Very Good	Very Good	Fair	Fair	Fair	Fair
Total Precipitation from August to March before seeding (mm)	97	79	137	241	226	272	242	251	152	142	151	139
Precipitation	(mm)											
April	20	16	17	38	55	15	28	52	24	17	2	10
May	18	21	31	40	24	32	45	42	221	105	35	100
June	115	87	117	39	18	29	52	79	34	85	52	80
July	49	94	49	31	23	61	36	8	66	75	69	84
August	98	125	117	21	11	9	24	21	45	71	44	95
September	22	18	42	15	18	34	23	36	44	7	15	18
October	17	16	28	8	20	20	26	20	15	34	15	22
November	10	12	16	0	15	8	6	8	4	3	1	6
December	25	33	30	0	12	3	5	21	1	54	23	NA
Five month total (April to Aug.)	299	342	330	167	131	146	185	202	191	354	202	368
Percent of 30-yr average over 5 mo	114	131	145	64	50	66	89	86	92	134	98	166
Average temperature	(%C)											
April	-0.6	1.6	0.6	5.3	4.3	4.1	3.7	6.3	4.1	3.7	4.7	4.4
May	7.1	8.3	7.1	11.8	11.4	11.9	12.2	8.6	10.4	6.8	7.9	6.7
June	15.8	16.8	16.6	16.2	15.5	15.9	15.7	12.9	14.4	12.6	12.6	12.9
July	18.6	19.8	19.3	19.6	18.6	19.1	18.1	17.6	17.8	16.3	16.7	17.1
August	15.7	16.7	16.5	21.2	19.5	19.8	19.8	15.3	20.0	13.1	14.0	13.9
September	12.1	12.5	11.5	12.0	10.6	11.1	10.4	11.8	10.3	11.5	9.9	11.9
October	–1.5	–0.7	–1.5	6.9	6.5	5.6	5.4	8.3	5.9	3.5	1.8	3.9
November	–4.6	–4.6	–7.9	–10.2	–11.3	–12.8	–9.5	–8.6	–9.6	–1.1	–2.4	0.2
December	–8.3	–8.3	–6.0	–9.6	–10.1	NA[z]	–10.1	–7.0	–9.7	–11.2	–11.5	NA
Four month average (May to Aug.)	14.3	15.4	14.9	17.2	16.3	16.7	16.5	13.6	15.7	12.2	12.7	12.7
Percent of 30-yr average over 4 mo	90	96	99	107	103	111	109	87	106	77	86	84

[z]Not available

Table 3. Analysis of variance for the dry mater yield and quality data of annual grass forages collected in Saskatchewan at Indian Head and Canora in 2002, 2003 and 2004, Redvers in 2002 and 2003, Scott in 2003 and 2004, Swift Current in 2003 and Melfort in 2003

Effect[z]	Yield	CP	ADF	NDF	Ca	P
			(P value)			
Crop (C)	**< 0.001**	**< 0.001**	**< 0.001**	**< 0.001**	**< 0.001**	**0.021**
Seeding date (D)	0.609	**0.011**	0.420	0.220	0.091	0.777
C × D	0.899	0.620	0.217	0.913	0.085	0.402
Harvest timing (H)	0.055	**< 0.001**	0.737	0.428	0.473	0.093
C × H	0.539	**< 0.001**	**< 0.001**	**< 0.001**	**0.001**	**< 0.001**
D × H	0.909	0.478	0.274	0.955	0.380	0.554
C × D × H	0.203	0.268	0.822	0.952	0.243	0.982
			Variance estimate[y]			
Site (S)	4.46*	4.21*	5.92	7.68	0.00080	0.00339*
S × C	3.18**	1.75**	2.97**	5.69**	0.00207**	0.00088**
S × D	0.14	0.00	1.73*	1.00	0.00000	0.00002
S × C × D	1.18**	0.54**	0.24	0.00	0.00042*	0.00015**
S × H	0.19	0.15	2.73*	7.47*	0.00048	0.00012
S × C × H	0.56**	0.17	0.00	0.00	0.00000	0.00011**
S × F × H	0.22	0.10	0.14	1.27	0.00005	0.00003
S × C × D × H	0.01	0.09	2.50**	5.43**	0.00000	0.00000
			% total variance[x]			
S	45	60	36	27	21	72
S × C	32	25	18	20	54	19
S × D	1	0	11	4	0	0
S × C × D	12	8	2	0	11	3
S × H	2	2	17	26	12	3
S × C × H	6	2	0	0	0	2
S × F × H	2	1	1	4	1	1
S × C × D × H	0	1	15	19	0	0

[z]Data collected for the winter harvest date were omitted.
[y]The statistical significance of variance component are indicated as follows: '*' = 0.05 ≥ *P* value ≥ 0.01; and '**' = *P* value < 0.01.
[x]The variance for a given effect, divided by the sum of the variance estimates for the effects associated with site, and multiplied by 100.

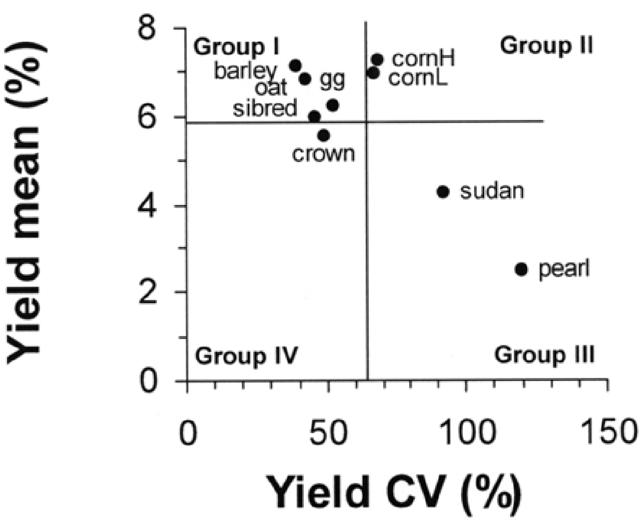

Fig 1. Yield and coefficient of variation for cultivars of annual grass forage species averaged across sites (location by year combinations: Indian Head, Redvers, Canora, Melfort, and Swift Current from 2002 to 2004) and treatments. Group I: high yield, low variability (optimal); Group II: high yield, high variability; Group III: low yield, high variability (poor); and Group IV: low yield, low variability. Crop abbreviations are as follows: cornH: corn high input; cornL: corn low input; crown: Crown proso millet; gg: Golden German foxtail millet ; pearl: pearl millet; sibred: Red Siberian foxtail millet; and sudan: sorghum-Sudangrass.

increased, GDD had to decrease to increase biomass yields. The highest yields were obtained under conditions with high rainfall and low GDD. The reason that high rainfall and low GDD was the best combination may be due to the fact that oat and barley development is accelerated as the temperature increases and evapotranspiration also increases as temperature increases. Therefore, when there is an abundance of water, oat and barley can make the best use of it for the longest time when temperatures are lower. The lowest yields were obtained when rainfall and GDD were both low or when rainfall and GDD were both high. Proso millet yield was lowest under low GDD and precipitation. As GDD increased yield increased and then leveled off. There was a quadratic relationship between yield and precipitation with the highest yield occurring in the mid range of precipitation. Proso millet yields seemed to be maximized with higher GDD and moderate rainfall. Golden German foxtail millet was similar to proso millet in that the lowest yields occurred when both GDD and precipitation were low; however, unlike proso millet, Golden German foxtail millet maximized yield as both rainfall and GDD increased. This difference between proso millet and Golden German foxtail millet may be due to the later maturity of the Golden German foxtail millet or to species differences between proso millet and foxtail millet. Since the yields of oat and barley were low when Golden German foxtail millet yields were high, using fields of Golden German foxtail millet in

Table 4. Forage yield of annual grass species and cultivars grown at 11 sites[z] when averaged across harvest timing and seeding date

		2002			2003						2004	
Species	Cultivar	Indian Head	Redvers	Canora	Indian Head	Redvers	Canora	Scott	Swift Current	Melfort	Indian Head	Scott
		(t ha^{-1})										
Barley	Ranger	7.0	6.7	6.5	5.6	6.6	9.5	5.9	3.9	9.5	8.8	4.9
Oat	Pinnacle	6.4	7.7	5.8	4.8	5.9	7.0	5.4	4.3	8.7	8.3	4.9
Proso millet	Crown		5.5	5.7	3.4	5.6	11.1	6.3	2.5	7.3	3.8	2.4
Foxtail millet	Red Siberian				4.9						3.8	3.2
	Golden German		7.1	9.4	5.1	6.9	11.6	5.2	3.0	8.9	3.8	2.6
Pearl millet					1.4		5.0				0.4	0.1
Sorghum-sudangrass			7.5	13.0	3.3	4.5	9.4	2.9	1.2	4.5	1.2	0.2
Corn - high[y]	39T71				5.6	8.8		13.7	1.3	12.1	5.6	1.7
Corn - low[x]	39T71				5.0	9.3		11.4	2.1	9.5	4.7	1.9
	$LSD_{0.05}$	0.9	1.0	1.2	0.6	0.9	2.3	1.6	0.4	1	0.8	0.4
Contrast		(P value)										
cereal vs. crown			< 0.001	0.416	< 0.001	0.064	0.006	0.354	< 0.001	< 0.001	< 0.001	< 0.001
cereal vs. siberian					0.151						< 0.001	< 0.001
cereal vs. ggm			0.745	< 0.001	0.63	0.107	0.002	0.451	< 0.001	0.715	< 0.001	< 0.001
cereal vs. pearl					< 0.001						< 0.001	< 0.001
cereal vs. sudan			0.536	< 0.001	< 0.001	< 0.001	0.279	< 0.001	< 0.001	0.001	< 0.001	< 0.001
cereal vs. corn h/l[w]					0.683	< 0.001		< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
corn - low vs. corn - high					0.019	0.280		0.005	0.001	< 0.001	0.040	0.486

[z]Site was considered a fixed effect.
[y]Corn grown in 60 cm rows with 135 kg ha^{-1} of applied nitrogen fertilizer.
[x]Corn grown in 30 cm rows with 55 kg ha^{-1} of applied nitrogen fertilizer.
[w]Low and high input corn combined.

combination with fields of oat or barley for swath grazing may provide the most stable yield over time for producers. The surface responses in Fig. 2 illustrate the effect of GDD and precipitation on biomass yield observed in this study. Since the surface response were generated using the crop × site means (n = 13), more data will increase the robustness of any prediction of future yields from precipitation and GDD data.

It was expected that as seeding was delayed the forage biomass would decrease for oat, barley and corn and increase for the other cultivars creating a significant crop × seeding date interaction. Corn was thought to differ from the other warm-season crops in this study due to reports of greater tolerance to low soil temperatures, approximately 10°C during emergence and higher forage yields when seeded early in the spring (Manitoba Corn Growers Association 2004). A significant crop × seeding date interaction did not occur, however, there was a significant site × crop × seeding date interaction (Table 3). It is difficult to pick out clear trends that consistently occurred at some sites (Table 6), but oat and barley forage yields did not consistently decrease with delayed seeding as several studies have reported for oat (Buglass 1955; Baron et al. 1994; Kibite et al. 2002). Environmental and biological conditions appear to have an overriding effect over the expected trend. For example at Indian Head in 2002, heavy competition from wild oat (*Avena fatua* L.) occurred for the first seeding date, completely overwhelming the proso and foxtail millet cultivars and reducing the biomass of the oat and barley. The Jun. 10 seeding date allowed most of the wild oat to be controlled with a pre-seeding application of glyphosate. Interestingly, there was a trend for Golden German foxtail millet to have higher yields on the earlier seeding date when not overwhelmed by weeds as it was at Indian Head in 2002. Seeding Golden German foxtail millet earlier than Jun. 10 may be advantageous in the long term if weed control can be maintained.

It was expected that as harvest was delayed, biomass of all crops would increase as found by Kibite et al. (2002) for oat and barley. This trend occurred in our study ($P < 0.06$) (Table 3). With Red Siberian foxtail millet, Golden German foxtail millet and corn, the later seeding date tended to reach the first harvesting stage in early September and environmental conditions may have limited biomass accumulation for the next 2 wk until the second harvest. The site × crop × harvest timing interaction for yield was significant; however, it represented less than 10% of the total variance and was therefore not examined.

Pre-planned contrasts were used to compare the treatments perceived to be ideal when the study was initiated. Oat and barley seeded in mid-May were compared with corn seeded in mid-May and the other cultivars seeded in June. In addition, the current agronomic practice, oat and barley seeded in June, was compared with the other species and cultivars seeded in June except corn, and early-seeded corn was compared with late-seeded corn. The harvest timing in these pre-planned contrasts were first harvest for oat and barley and second harvest for all the other cultivars (Kilcher and Troelsen 1973; Kaulbars and King 2004). The first harvest stage was used for oat and barley since previous research indicated that quality can significantly decrease after this stage while the quality of the warm-season grasses did not appear to decrease as quickly . Both early- and late-seeded oat and barley outyielded pearl millet seeded in June

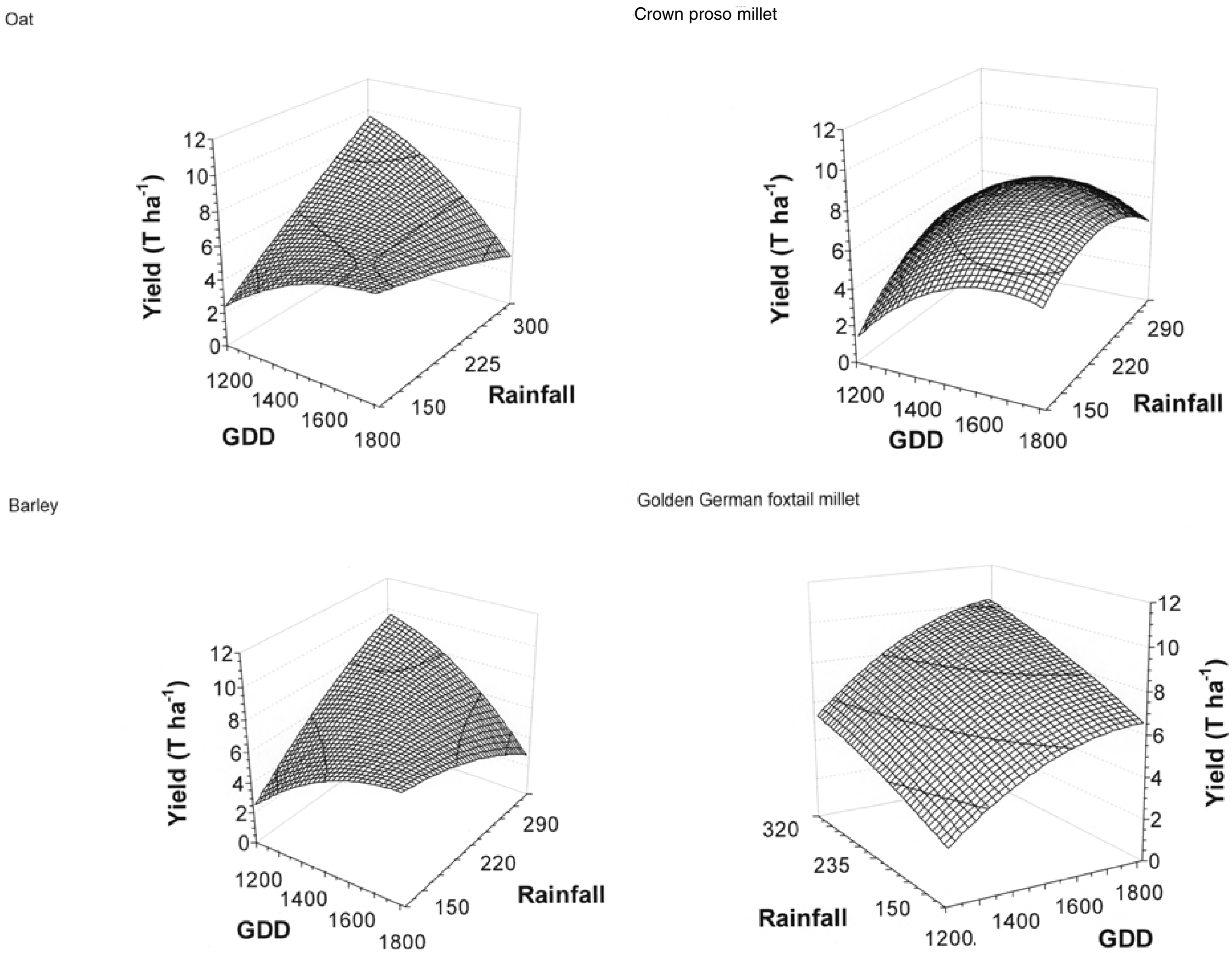

Fig 2. Estimated surface response for yield of several annual grass species to precipitation and growing and degree days (GDD). For each response surface *n* = 13.

and early-seeded oat and barley outyielded sorghum seeded in June (Table 5). Forage yield of the Golden German foxtail millet, Siberian Red foxtail millet and proso millet did not differ from early- or late-seeded oat or barley. Early-seeded corn outyielded early-seeded oat and barley. The early-seeded high input corn did not outyield early-seeded low input corn.

Crude Protein

Crude protein (CP) was affected by crop, seeding date, harvest timing, crop × harvest timing, site, site × crop and site × crop × harvest timing (Table 3). As seeding was delayed there was an increase in the percentage of CP in the forage from 99 to 105 g kg^{-1}. Pre-planned contrasts revealed that pearl millet had a higher CP than the average of the oat and barley when seeded early or late (Table 5). Early-seeded corn had a lower percentage of CP than the average of early-seeded cool-season cereals, barley and oat. The late-seeded proso millet, Golden German foxtail millet, and Siberian millet all had lower percentages of CP then the average of the late-seeded oat and barley. When the harvest was delayed the CP decreased for all cultivars except pearl millet and sorghum-sudangrass (Table 7). Pearl millet and sorghum-sudangrass had the longest maturities and tended to be vegetative when harvested under the prevailing environmental conditions at the study sites.

There was a significant site × crop interaction for CP, which indicates that the overall trends among the crops for CP did not occur at every site, and corn was the major cause of this interaction. At all the sites in 2003 the corn reached physiological maturity and the protein level was 15 to 25% below the CP of oat and barley. In 2004 when the corn did not reach physiological maturity, the CP of the corn was between 23 and 28% above the average CP of the oat and barley. The site × crop × seeding date interaction for CP was significant; however, it represented less than 10% of the total variance and was therefore not examined.

Table 5. Comparison of forage yield and quality of annual grass species and cultivars obtained using the most appropriate seeding date and harvest timing

Treatment	Yield (T ha^{-1})	CP[z] (g kg^{-1})	ADF[y] (g kg^{-1})	NDF[x] (g kg^{-1})	Ca (g kg^{-1})	P (g kg^{-1})
Cereal e-f[w]	6.62	103	323	574	2.90	2.10
cereal l-f	6.33	110	330	565	2.78	2.06
Crown l-s[v]	6.18	93	320	597	2.74	1.57
Red Siberian l-s	6.53	88	348	607	3.16	1.52
Golden German l-s	6.35	97	332	595	3.69	1.58
Pearl millet l-s	1.99	147	297	599	6.83	2.16
Sorghum-sudangrass l-s	4.83	106	321	607	4.35	1.86
corn l/h e-s[u]	8.78	80	300	557	3.12	1.65
Contrast			(*P* value)			
cereal e-f vs. crown l-s	0.616	0.159	0.793	0.231	0.547	**0.002**
cereal e-f vs. ggm l-s	0.761	0.378	0.511	0.273	**0.005**	**0.002**
cereal e-f vs. siberian l-s	0.932	0.053	0.100	0.121	0.438	**0.005**
cereal e-f vs. pearl l-s	**< 0.001**	**< 0.001**	0.103	0.258	**< 0.001**	0.775
cereal e-f vs. sudan l-s	**0.043**	0.702	0.854	0.089	**< 0.001**	0.145
cereal e-f vs. corn h/l e-s	**0.009**	**< 0.001**	0.059	0.380	0.359	**0.002**
orn l e-s[t] vs. corn h e-s[s]	0.593	0.746	0.515	0.988	0.719	0.879
cereal l-f vs. crown l-s	0.858	**0.011**	0.619	0.087	0.870	**0.003**
cereal l-f vs. siberian l-s	0.84	**0.004**	0.110	**0.043**	0.251	**0.007**
cereal l-f vs. ggm l-s	0.981	**0.044**	0.605	0.107	**0.001**	**0.004**
cereal l-f vs. pearl l-s	**< 0.001**	**< 0.001**	0.056	0.116	**< 0.001**	0.612
cereal l-f vs. sudan l-s	0.081	0.464	0.682	**0.027**	**< 0.001**	0.215

[z]CP = crude protein.
[y]ADF = acid detergent fibre.
[x]NDF = neutral detergent fibre.
[w]e-f - early seeding date and first harvest.
[v]l-s - late seeding date and second harvest.
[u]l/h e-s - low and high input corn early seeding date and second harvest.
[t]l e-s - low input (30 cm seed row with 55 kg ha^{-1} N), early seeding date.
[s]h e-s - high input (60 cm seed row with 135 kg ha^{-1} N), early seeding date.

The protein requirements for beef cows, on a dry matter basis are 7% in second trimester, 8–9% in third trimester and 10–11% post calving (National Research Council 1996). Excluding Swift Current in 2003, all of the crops had a CP percentage of 8 or greater, with the exception of corn. Corn tends to be marginal for protein and it may need to be supplemented, especially as cows are getting closer to calving.

Neutral Detergent Fibre

Neutral detergent fibre (NDF) was affected by crop, crop × harvest timing, site × crop, site × harvest timing and site × crop × seeding date × harvest timing (Table 3). The pre-planned contrasts found that late-seeded, second-harvested Red Siberian foxtail millet and sorghum-sudangrass had a higher NDF than late-seeded, first-harvest cool-season cereals (Table 5). Seeding date had no effect on NDF. The NDF increased as the harvest of the Ranger barley was delayed; however, harvest timing did not affect the NDF of the other cultivars (Table 7).

The significant site × crop interaction for NDF indicates that the cultivar ranking varied among sites. When the means for the interaction are examined it appears that the ranking at one site could not predict the ranking at another site, except that oat and corn both tended to be among the cultivars with the lowest NDF at each site (data not shown). The significant site × crop × seeding date × harvest timing interaction indicate that the trends in NDF noted above for crop, seeding date and harvest time did not occur at every site

Acid Detergent Fibre

Acid detergent fibre (ADF) was affected by crop, crop × harvest timing, site × crop, site × harvest timing and site × crop × seeding date × harvest timing (Table 3). Seeding date had no effect on ADF. The pre-planned contrasts did not find any differences between the cool-season cereals and the warm-season cereals (Table 5). The ADF of barley increased and oat decreased as harvest was delayed, while the ADF of the other cultivars did not change by harvest timing (Table 7).

The significant site × crop interaction for ADF indicates that the cultivar ranking varied among sites. When the means for the interaction are examined it appears that the ranking at one site could not predict the ranking at another site, except that the foxtail millet cultivars Red Siberian foxtail millet and Golden German foxtail millet tended to be among the cultivars with the highest ADF and corn tended to be among the lowest cultivars at each site (data not shown). The significant site × crop × seeding date × harvest timing interaction indicate that the trends in ADF noted above for crop, seeding date and harvest time did not occur at every site.

Calcium

Calcium concentration was affected by crop, crop × harvest timing, site × crop, and site × crop × seeding date (Table 3).

Table 6. Forage yield of annual grass species and cultivars grown at 11 sites[z] when averaged across harvest timing

			2002			2003						2004	
Species	Cultivar	Seeding date	Indian Head	Redvers	Canora	Indian Head	Redvers	Canora	Scott	Swift Current	Melfort	Indian Head	Scott
			($T\ ha^{-1}$)										
Barley	Ranger	early	6.3	7.2	5.3	6.1	6.5	8.4	5.5	5.4	11.0	8.8	5.7
		late	7.7	6.2	7.8	5.2	6.7	10.7	6.4	2.5	8.0	8.9	4.1
Oat	Pinnacle	early	5.6	8.2	5.6	5.4	5.9	6.0	5.0	6.1	9.9	8.5	6.0
		late	7.3	7.3	6.1	4.2	5.9	8.0	5.9	2.6	7.4	8.2	3.8
Proso millet	Crown	early		5.0	5.3	3.5	5.2	10.8	6.6	1.9	7.1	3.4	2.4
		late	5.7	6.1	6.2	3.3	6.0	11.5	6.1	3.1	7.5	4.2	2.3
Foxtail millet	Red Siberian	early		5.4		4.8	6.2	11.7				3.2	3.6
		late	6.0	6.0	6.3	5.0		9.2				4.5	2.7
	Golden German	early		7.5	11.1	5.4	7.2	13.0	5.2	2.7	9.7	3.8	2.7
		late	7.2	6.7	7.8	4.8	6.6	10.1	5.1	3.3	8.1	3.9	2.5
Pearl millet		early			7.3	1.1	2.2	8.6				0.0	0.0
		late	4.7		7.8	1.7	3.5	1.5				0.7	0.1
Sorghum-sudangrass		early		6.3	12.8	3.7	3.7	12.9	3.4	1.1	5.0	0.8	0.1
		late	7.1	8.7	13.2	2.8	5.3	5.8	2.4	1.4	4.0	1.6	0.4
Corn - high[y]	39T71	early				7.0	8.4		12.1	1.2	14.2	5.0	2.0
		late				4.2	9.2		15.2	1.5	10.0	6.1	1.5
Corn - low[x]	39T71	early				5.4	8.7		9.6	1.8	10.5	5.0	2.3
		late				4.5	9.9		13.2	2.4	8.5	4.5	1.5
	$LSD_{0.05}$		1.0	1.5	1.8	0.8	1.4	3.1	2.3	0.6	1.4	1.3	0.6

[z]Site was considered a fixed effect.
[y]Corn grown in 60 cm rows with 135 kg ha^{-1} of applied nitrogen fertilizer.
[x]Corn grown in 30 cm rows with 55 kg ha^{-1} of applied nitrogen fertilizer.

The pre-planned contrasts found that late-seeded second-harvest Golden German foxtail millet, pearl millet and sorghum-sudangrass had higher levels of Ca then the combined average of oat and barley at first harvest when seeded early or late (Table 5). Seeding date did not have a consistent effect on Ca (Table 3). Calcium decreased in oat and increased in pearl millet as harvest was delayed (Table 7). Harvest timing did not affect the other cultivars. Pearl millet and sorghum-sudangrass had Ca levels that were higher than the other cultivars. The significant site × crop interaction indicates the ranking of the cultivars for Ca content was not consistent from site to site. The significant site × crop × seeding date indicates that there were significant crop × seeding date interactions; however, these interactions were not consistent across enough sites for the crop × seeding date interaction to be significant.

Phosphorus

Phosphorus (P) concentration was affected by crop, crop × harvest timing, site, and site × crop, (Table 3). Seeding date had no effect on P concentration (Table 3). The pre-planned contrasts indicated that the average P concentration of first-harvest oat and barley, seeded late or early, was higher than late-seeded second-harvest proso millet, Red Siberian foxtail millet, Golden German foxtail millet and both high and low input corn (Table 5). Pearl millet and sorghum-sudangrass had similar concentration of P as oat and barley. The P concentration of oat, barley and proso millet decreased as harvest was delayed, while the P concentration of the other treatments was not affected (Table 7). Site was significant indicating that the concentration of P in the tissue varied among the sites. The significant site × crop interaction indicates that the ranking of cultivars for P concentration was not consistent among the sites. The Ca to P ratios were within the guidelines for feeding cattle established by the National Research Council (1996).

Quality Changes from Weathering in the Swath

After the second harvest, the late-seeded plots were swathed, except the corn, which was left standing, and the plots were sampled again in early December to determine quality changes from the early fall to early winter period. The swaths usually became snow covered between the middle of November and early December at most sites. All the quality parameters measured had significant crop × harvest and site × crop × harvest interactions, except P, which had significant crop × harvest and site × crop interactions (Table 8). All quality parameters were analysed with site considered a random effect. As previously noted, the protein concentration of barley, oat, proso millet, and Red Siberian foxtail millet decreased from the first harvest to the second harvest, but the protein concentration of all the cultivars did not change in the swath or when standing in the case of corn from second harvest to early winter (Table 9). The stability of crude protein in the swath is supported by Aasen et al. (2004), who observed very little change in the CP of swathed barley and oat over winter and Baron et al. (2003) in standing corn during winter. Lamm and Ward (1981) found that with corn, a small decrease in crude protein from 88 to 82 g kg^{-1} was observed over the entire winter in Nebraska. The ADF and NDF concentration of oat and proso millet increased in the swath from second harvest to early winter. Aasen et al. (2004) found that the NDF concentrations of both barley and oat increased in the swath

Table 7. Quality of annual grass species and cultivar at two harvest times when average over seeding date and sites

Treatment	Cultivar	Harvest timing: First	Harvest timing: Second	*P* value[z]	Harvest timing: First	Harvest timing: Second	*P* value[z]
		CP (g kg^{-1})			ADF (g kg^{-1})		
Barley	Ranger	104	81	**< 0.001**	316	338	**0.018**
Oat	Pinnacle	110	88	**< 0.001**	333	309	**0.03**
Proso millet	Crown	112	92	**0.000**	321	320	0.922
Foxtail millet	Red Siberian	104	89	**0.001**	351	351	0.959
	Golden German	101	92	**0.014**	344	341	0.740
Pearl millet		144	140	0.393	310	308	0.814
Sorghum-sudangrass		111	104	**0.054**	324	332	0.409
Corn - high[y]	39T71	97	88	**0.042**	311	294	0.120
Corn - low[x]	39T71	92	81	**0.010**	307	301	0.569
	LSD 0.05	8			21		
		NDF (g kg^{-1})			Ca (g kg^{-1})		
Barley	Ranger	568	593	**0.005**	3.38	2.92	0.440
Oat	Pinnacle	569	522	0.110	2.30	2.18	**0.006**
Proso millet	Crown	613	595	0.261	2.82	2.64	0.259
Foxtail millet	Red Siberian	614	617	0.893	2.97	3.10	0.513
	Golden German	610	604	0.700	3.69	3.61	0.583
Pearl millet		608	606	0.916	5.77	6.28	**0.014**
Sorghum-sudangrass		622	615	0.646	4.54	4.26	0.092
Corn - high	39T71	572	551	0.207	3.23	3.13	0.558
Corn - low	39T71	573	553	0.235	3.22	3.03	0.267
	LSD $_{0.05}$	33			0.34		
		P (g kg^{-1})					
Barley	Ranger	2.01	1.64	**< 0.001**			
Oat	Pinnacle	2.15	1.71	**< 0.001**			
Proso millet	Crown	1.76	1.57	**0.047**			
Foxtail millet	Red Siberian	1.63	1.52	0.335			
	Golden German	1.55	1.54	0.885			
Pearl millet		2.14	2.26	0.279			
Sorghum-sudangrass		1.78	1.83	0.579			
Corn - high	39T71	1.68	1.70	0.836			
Corn - low	39T71	1.74	1.63	0.259			
	LSD $_{0.05}$	0.2					

[z]*P* value assessing for the effect of harvest date for each crop.
[y]Corn grown in 60 cm rows with 135 kg ha^{-1} of applied nitrogen fertilizer.
[x]Corn grown in 30 cm rows with 55 kg ha^{-1} of applied nitrogen fertilizer.

Table 8. Analysis of variance for the quality of annual grass forages collected in the summer and early winter in Saskatchewan at Indian Head and Canora in 2002, 2003 and 2004, Redvers in 2002 and 2003, Scott in 2003 and 2004, Swift Current and Melfort in 2003

Effect[z]	CP	ADF	NDF	Ca	P
			(*P* value)		
Crop (C)	**< 0.001**	**< 0.001**	**< 0.001**	**< 0.001**	0.111
Harvest timing (H)	**0.004**	0.155	0.149	0.921	0.271
C × H	**0.009**	**0.003**	**0.021**	**< 0.001**	**0.002**
			Variance estimate[y]		
Site (S)[x]	2.79*	4.60	2.62	0.00091	0.00327*
S × C	1.68**	3.14**	4.12**	0.00201**	0.00067**
S × H	0.52*	3.64**	8.94**	0.00031	0.00017*
S × C × H	0.79**	4.99**	9.39**	0.00079**	0.00030**
			% total variance[w]		
S	48	28	10	23	74
S × C	29	19	16	50	15
S × H	9	22	36	8	4
S × C × H	14	31	37	20	7

[z]Data collected for the winter harvest date was included and early seeding date excluded.
[y]The statistical significance of variance component are indicated as follows: '*' = 0.05 ≥ *P* value ≥ 0.01; and '**' = *P* value < 0.01.
[x]Site was a considered a random effect in this analysis.
[w]The variance for a given effect, divided by the sum of the variance estimates for the effects associated with site, and multiplied by 100.

Table 9. Changes in quality of annual grass forages when left until early winter in the field when average over sites

		Harvest timing[z]			Harvest timing effect		
	Variable / Crop	First	Second	Winter	Overall	1 vs. 2	2 vs. winter
CP (g kg^{-1})					(*P* value[y])		
Barley	Ranger	109	87	91	**0.001**	**< 0.001**	0.513
Oat	Pinnacle	114	92	86	**< 0.001**	**< 0.001**	0.285
Proso millet	Crown	113	95	90	**0.001**	**0.002**	0.489
Foxtail millet	Red Siberian	108	89	105	**0.019**	**0.006**	0.094
	Golden German	107	97	104	0.193	0.077	0.213
Pearl millet		144	150	137	0.641	0.434	0.445
Sorghum-sudangrass		114	105	103	0.153	0.117	0.797
Corn - high[x]	39T71	104	95	96	0.352	0.202	0.944
Corn - low[w]	39T71	95	84	89	0.312	0.130	0.525
	LSD $_{0.05}$		14				
ADF (g kg^{-1})							
Barley	Ranger	317	338	348	0.116	0.152	0.503
Oat	Pinnacle	333	310	363	**0.003**	0.102	**0.001**
Proso millet	Crown	320	320	357	**0.024**	0.984	**0.017**
Foxtail millet	Red Siberian	343	351	352	0.853	0.623	0.975
	Golden German	345	334	340	0.756	0.456	0.695
Pearl millet		307	296	373	0.119	0.585	**0.039**
Sorghum-sudangrass		312	322	340	0.196	0.498	0.25
Corn - high	39T71	309	292	283	0.280	0.317	0.583
Corn - low	39T71	306	296	287	0.486	0.516	0.597
	LSD $_{0.05}$		35				
NDF (g kg^{-1})							
Barley	Ranger	567	595	605	0.178	0.170	0.639
Oat	Pinnacle	560	522	597	**0.003**	0.063	**0.001**
Proso millet	Crown	607	599	659	**0.015**	0.704	**0.007**
Foxtail millet	Red Siberian	607	612	647	0.407	0.832	0.271
	Golden German	608	599	617	0.704	0.685	0.404
Pearl millet		604	599	654	0.530	0.856	0.267
Sorghum-sudangrass		608	608	640	0.258	0.985	0.152
Corn - high	39T71	567	545	548	0.588	0.348	0.9
Corn - low	39T71	569	549	543	0.490	0.388	0.795
	LSD $_{0.05}$		49				
Ca (g kg^{-1})							
Barley	Ranger	3.19	2.92	3.07	0.498	0.240	0.516
Oat	Pinnacle	2.37	2.14	2.48	0.329	0.331	0.143
Proso millet	Crown	2.72	2.73	3.31	**0.021**	0.952	**0.019**
Foxtail millet	Red Siberian	3.07	3.12	3.66	0.249	0.871	0.179
	Golden German	3.72	3.66	4.06	0.190	0.796	0.098
Pearl millet		6.11	6.98	6.64	**0.034**	**0.011**	0.625
Sorghum-sudangrass		4.63	4.48	4.67	0.744	0.565	0.468
Corn - high	39T71	3.26	3.13	2.41	**0.002**	0.592	**0.006**
Corn - low	39T71	3.21	3.03	2.38	**0.004**	0.484	**0.013**
	LSD $_{0.05}$		0.58				
P (g kg^{-1})							
Barley	Ranger	2.03	1.67	1.89	**0.016**	**0.005**	**0.07**
Oat	Pinnacle	2.09	1.69	1.56	**< 0.001**	**0.002**	0.324
Proso millet	Crown	1.79	1.54	1.45	**0.03**	0.062	0.506
Foxtail millet	Red Siberian	1.64	1.51	1.63	0.726	0.445	0.555
	Golden German	1.58	1.54	1.64	0.720	0.743	0.424
Pearl millet		2.08	2.27	1.95	0.474	0.271	0.366
Sorghum-sudangrass		1.80	1.78	1.76	0.962	0.914	0.866
Corn - high	39T71	1.79	1.77	1.90	0.589	0.918	0.354
Corn - low	39T71	1.71	1.64	1.90	0.147	0.603	0.06
	LSD $_{0.05}$		0.31				

[z]First harvest, forage harvested at optimum stage of development; Second harvest, occurred two weeks after first harvest; winter, samples were collected in early December.
[y]*P* value assessing for the effect of harvest timing for each crop.
[x]Corn grown in 60 cm rows with 135 kg ha^{-1} of applied nitrogen fertilizer.
[w]Corn grown in 30 cm rows with 55 kg ha^{-1} of applied nitrogen fertilizer.

during winter as well as the ADF concentration in oat. The NDF concentration of corn in this study did not change, which does not agree with Lamm and Ward (1981) and Baron et al. (2003), who found that NDF increased as the corn was left out in the field during winter. The concentration of Ca decreased in both corn treatments and increased in proso millet from second harvest to early winter. As previously noted, the concentration of Ca in pearl millet increased from the first to second harvest. There were no significant changes in P concentration from the second harvest until early winter. Therefore, the Ca to P ratios were not negatively affected by weathering during the winter.

CONCLUSIONS

The warm-season species tested varied in their suitability for swath grazing in Saskatchewan. Current pearl millet and sorghum-sudangrass cultivars are not suitable for use in swath grazing in Saskatchewan. Corn produced high yields but also the largest variations in yield in response to changes in environmental conditions. Unless cattle producers have the ability to adjust for this variation in corn biomass production in their feeding system, they should avoid using corn for winter grazing. Further studies are required to determine if there are geographic areas and/or refined production practices that can reduce this variation in corn biomass. Golden German foxtail millet produced similar biomass to oat and barley except under very cool conditions where production was less. Golden German foxtail millet tended to outyield oat and barley when both precipitation and average temperature were high. Therefore, Golden German foxtail millet can replace a portion of a producer's oat or barley crop for swath grazing but not all. Although seeding date did not have a large effect on yield or quality, the appropriate seeding date for the warm-season cereals should be later rather than earlier to facilitate weed control prior to seeding. Harvest timing did not have a large effect on the yield and quality of the warm-season cereals in this study. However, further research is required to determine the best development stage for swathing foxtail millet for swath grazing. The quality of the warm-season cereals in this study would meet the nutrient requirements for cattle in a winter grazing system and weathering in the swath did not reduce feed quality. In conclusion, using fields of Golden German foxtail millet in combination with fields of oat or barley for swath grazing may provide the most stable yield over time for producers, since the yield of oat and barley were low when Golden German foxtail millet yields were high.

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