

Annual cool season crops for grazing by beef cattle. A Canadian Review

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McCartney, D., Fraser, J. and Ohama, A. 2008. **Annual cool season crops for grazing by beef cattle. A Canadian Review.** *Can. J. Anim. Sci.* **88**: 517–533. With the current high feed grain costs and other economic uncertainties in the Canadian beef cattle industry, producers are trying to lower their unit costs of production. Costs can be lowered through extension of the grazing season using perennial pastures and annual crops for grazing. Oat (*Avena sativa* L.) and fall rye (*Secale cereale* L.) have traditionally been used to a nominal extent for extending the grazing season. However, there is limited information including a small number of animal grazing trials on the use of other annual cereals and annual ryegrass (*Lolium multiflorum* Lam.) for low cost grazing systems relative to feeding traditional harvested and stored forages. This review discusses annual cool season crops that show promise for supplementary grazing systems. Systems such as swath grazing of a cereal crop, grazing the regrowth from silage mixtures of spring and winter cereals, or fall grazing annual Italian ryegrass can be used to extend the grazing season. Economic considerations will ultimately determine if there will be an increased role in the future for grazing annual crops on cropping land as a means of extending the grazing season to reduce year-round costs for the beef cow calf operator.

Key words: Small grain cereals, annual ryegrass, extended grazing, forage quality

McCartney, D., Fraser, J. et Ohama, A. 2008. **Annuelles de saison fraîche pour les bovins de boucherie mis à l'herbe. Un panorama canadien.** *Can. J. Anim. Sci.* **88**: 517–533. Avec la hausse du prix des aliments du bétail et les autres incertitudes économiques associées à l'élevage des bovins de boucherie au Canada, les producteurs cherchent comment réduire leurs coûts de production unitaires. Il serait possible de le faire en prolongeant la saison de paissance avec des pâturages de vivaces et d'annuelles. On a toujours un peu recouru à l'avoine (*Avena sativa* L.) et au seigle d'automne (*Secale cereale* L.) pour prolonger la saison de paissance. Néanmoins, on ne sait pas grand-chose sur l'usage d'autres céréales annuelles et du ray-grass annuel (*Lolium multiflorum* Lam.) comme pâturages peu coûteux, comparativement à leur récolte et à leur stockage en tant que fourrage, car peu d'essais portent sur les animaux paissant de telles cultures. Les auteurs passent en revue les cultures de la saison fraîche qui promettent comme systèmes de paissance complémentaires. Ces systèmes, tels l'andainage des céréales pour la paissance, l'engraissement des animaux avec la repousse des mélanges de céréales de printemps et d'hiver destinés à l'ensilage ou les pâturages automnaux de ray-grass d'Italie, pourraient allonger la saison de paissance. Au bout du compte, ce sont des considérations d'ordre économique qui détermineront si la paissance des cultures annuelles sur les terres agricoles jouera un plus grand rôle dans l'avenir lorsqu'on voudra prolonger la saison de paissance pour réduire les coûts annuels de l'élevage des bovins.

Mots clés: Céréales secondaires, ray-grass annuel, prolongation de la saison de paissance, qualité des fourrages

HISTORICAL INTRODUCTION TO GRAZING ANNUALS

Grazing of annual cereals and annual ryegrass has been used to supplement grazing in Canada over a wide range of soil and climatic conditions for the past 100 yr (Kilcher and Heinrichs 1961; Morrison 1961). However, there are economic costs to grazing annual cereals, including the high annual initial input costs of machinery, fuel, fertilizer and seed, in addition to some environmental costs from tillage operations. With emphasis on having livestock graze rather than mechanically harvesting feed, the flexibility and productiv-

ity of grazing annual crops can be an attractive alternative. In some areas of western Canada, where perennial pasture is in short supply, there is interest from cattle producers in obtaining research information on the grazing potential of a wide variety of annual crops. In other areas of Canada, the use of annual forages for grazing is becoming more prevalent, stimulated by recurring droughts and the need to extend the grazing season to lower year-round livestock costs of production.

Baron et al. (1993a) reported that in the Aspen Parkland of Alberta, many cool season perennial

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Abbreviations: ADF, acid detergent fibre; CP, crude protein; DM, dry matter; NDF, neutral detergent fibre; TDN, total digestible nutrients

forages produced 60% of their seasonal production before Jul. 01. In contrast, annual cereals can have flexible planting dates and their peak yields occur later than perennial forages. Thus, these crops can be used to augment perennial pasture yield shortfall later in the growing season (Kilcher and Lawrence 1979).

Limited information on potential grazing annual crops has been summarized for Atlantic Canada [Nova Scotia Crop Development Institute (NSCDI) 1993] and for annual ryegrass for Alaska (Klebesadel 2000), but information has not been summarized for grazing potential elsewhere in Canada or northern United States of America. Thus, there is a need to summarize the existing information on evaluating annuals for grazing, rather than creating new research and demonstration trials.

This paper summarizes historical and current research from plot and animal grazing trials from the various eco regions of Canada and related areas in northern United States of America on the adaptability of annual cereals and ryegrass for potential grazing.

POTENTIAL OF SPRING CEREALS FOR GRAZING

Dry Matter Forage Yield of Oat

Most of the early research in Canada on cool season cereals for forage production was evaluated using oat for annual hay production. Early author Woll (1916) as well as research in western Canada (Anonymous 1924, 1936, 1940, 1946, 1952), Ontario (Anonymous 1950, 2004), and Atlantic Canada (Nass et al. 1975; NSCDI 1993) indicated that oat for forage production out-yielded other spring cereals such as barley (*Hordeum vulgare* L.), wheat (*Triticum aestivum* L.), or rye (*Secale cereale* L.). Unfortunately, much of the pre World War II research data were derived from non-replicated and non-peer-reviewed reports. These experiments were used to develop early forage and grazing management recommendations and the research results might not be entirely accurate. This review will highlight the early information on a historical basis. In addition, most of the other studies cited research from annual forage plots where the material was harvested for silage at the soft dough stage of maturity. This information could differ if the material had been harvested for grazing at the pre-boot stage of maturity.

Researchers at Indian Head, SK, harvested whole plant oat at the medium dough stage for feed for a dry matter (DM) yield of 5520 kg DM ha⁻¹ (Anonymous 1924). Although no yield data were given, MacKenzie (1948), quoted by NSCDI (1993), claimed that oat proved to be the most reliable and adaptable annual hay tested and that testing was discontinued because the results were fairly conclusive. In Ontario, oat was more palatable than wheat, barley and rye and was the preferred spring cereal for grazing (Anonymous 2004). Oat could be pastured 6–8 wk after seeding, and could be seeded anytime from spring to fall. Very little animal

grazing research results could be found for oat or other cereals in eastern Canada. Annual forage crops in eastern Canada are primarily used as a cover or nurse crop for the establishment of perennial forages and harvested as silage, or in the event of serious winterkill of perennial forages, cereals serve as an emergency forage crop.

In western Canada, the evaluation of annual cereal forages for grazing was prevalent at the Lacombe Research Centre from 1932 to 1952 (Anonymous 1936, 1946, 1952). Authors concluded that oat was superior to other cereal crops in yield and quality for both hay and pasture. Forage yield of oat was 3640 kg DM ha⁻¹, which was 43% greater than barley (Anonymous 1940). The experience from the early research indicated that oat was one of the best annual pasture crops and that late-maturing oat varieties out-yielded and produced better pasture crops than early-maturing varieties. This was reconfirmed by Kibite et al. (2002).

Grazing research is very expensive and very few actual grazing trials using annual cereals have been done. Most cereal forage studies relied on harvest DM yield from plots for their assessment. Berkenkamp and Meeres (1988a) evaluated simulated grazing plot trials on Black Chernozemic and Gray-Wooded Luvisolic soils in central Alberta. Oat had the highest yield of 3350 kg DM ha⁻¹ on Black soils and 50% more DM than barley on both sites. Oat was the most productive pasture on the Gray-Wooded soils (2110 kg DM ha⁻¹). Oat had tolerance to moderate acidity and had greater forage yield than barley on Grey-Wooded soils (Walton 1975; Berkenkamp and Meeres 1987; Kibite et al. 2002). Carr et al. (2004) reported that forage yields averaged 8000 kg DM ha⁻¹ in field experiment under relatively high soil N conditions. Even though the majority of the research has been from agronomic silage plot research, which is cut at the soft dough grain stage, oat still has a good potential to be used for grazing at a pre-boot heading stage when provided with adequate soil moisture and moderate growing temperatures.

Dry Matter Forage Yield of Barley, Wheat, Rye, and Triticale

Woll (1916) claimed that barley was adapted for pasture, and other early research on barley for annual hay was conducted at Rosthern, SK (Anonymous 1924). Barley suffered more severely in the dry weather and produced lower forage yields than oat (Anonymous 1924). As well, Robertson (1980), under grazing conditions, and May et al. (2007) under single cut conditions, had barley yields equivalent to or greater than oat. May et al. (2007) looked at seeding date and harvest date at various locations, and although the differences were small, when averaged over locations, barley out-yielded oat at either seeding and harvest date and again when averaged across seeding and harvest date (6790 vs. 6280 kg DM ha⁻¹). According to Cherney and Marten (1982), barley forage yield was equal or superior to

forage yield of oat in subhumid regions (MN), but was inconsistent and often lower when compared with in the Northern Great Plains (ND) (Carr et al. 2004). Therefore, only under certain conditions, such as dry weather, in the Brown soil zone and low seeding rates, will barley out-ield oat as an annual forage.

Early results (Anonymous 1936, 1940, 1954) indicated that wheat was not adequate in forage yield to be recommended as an annual pasture crop. However, wheat had shown greater drought resistance than barley or oat and was recommended for use as an annual in the drought area of the short grass prairie (Anonymous 1940). Walton (1975) found that wheat gave consistently low yields compared with oat and barley and wheat gave the lowest yield at all the seeding rates tested. Berkenkamp and Meeres (1987) claimed that wheat gave poor forage yields; however, wheat slightly out yielded barley at both Black and Grey Wooded soil sites. In simulated grazing, wheat did not yield as well as barley. If given a choice of spring cereal for forage production, wheat generally would not be recommended (Berkenkamp and Meeres 1987).

Spring rye was identified as adapted for pasture and having value as a very early hay crop in Brandon, MB (975 kg DM ha⁻¹) (Woll 1916). At Scott, SK, spring rye yielded 2940 kg DM ha⁻¹ in the bloom stage and having benefitted from late July rains produced a second cut hay crop having total yield production of 3540 kg DM ha⁻¹ (Anonymous 1924). At Lacombe, AB, spring rye was similar to barley or wheat in productivity but it was suggested that it was more suitable to drier portions of the province (Anonymous 1936). Like wheat, it was recommended as an annual for the dry short grass prairie. At 2060 kg DM ha⁻¹, spring rye yielded less than barley but more than wheat (2085 and 1660 kg DM ha⁻¹) in other studies (Anonymous 1940). Berkenkamp and Meeres (1988b) found under simulated grazing, spring rye yielded less than oat only in Grey Wooded soils and spring rye was more adapted to acidic soils than barley. However, rye yielded more than triticale (*Triticosecale* Wittmack L.) in Black soils.

Triticale, a hybrid between wheat and rye, was developed to have the grain quality and productivity of wheat, and the vigor and hardiness of rye (Oelke et al. 1989). Berkenkamp and Meeres (1987, 1988b) reported low forage yield values for spring triticale and wheat on both Black and Grey Wooded soil under both grazing and single cut management. Little information is available on spring rye and triticale as an annual forage for grazing. More research needs to be done on validating whether or not these spring cereals have a role in grazing.

Seeding Date of Annual Cereals for Forage Production

Many questions have been raised in regards to seeding date and the effect on forage yield. Kibite et al. (2002) in central Alberta evaluated the effect of seeding date

(May vs. June) and harvest stage and concluded that on average, DM yield of early-seeded cereals produced nearly 5000 kg DM ha⁻¹ or 35% more forage yield than late-seeded cereals, most notably on Black soils. For both early and late planting, yield maximized at either 2 or 3 wk after heading (approximately early milk stage). Planting date had no consistent effect on nutritive value at time of harvest. May et al. (2007) in Saskatchewan also found DM yield decrease in oat and barley with later seeding dates (mid-May vs. mid-June). The major implication was late planting reduced yield and increased the cost of digestible DM production. These studies did not address the potential of weathering losses when the early-seeded cereal crops were swathed early in the fall and left on the ground for winter swath grazing, nor did they look at the palatability issues and wastage of the straw portion of the early-seeded cereal when swathed grazed. These issues need to be addressed by further research.

Nutritive Value of Spring Cereals

There is very little research information available on the forage quality of annual cereals as it relates to actual grazing trials. Most data were from silage or cereal hay crops. Some early data on annual pasture crop nutritive value were given by Anonymous (1940). Protein values seem unusually high, and no growth stage was given. However, forage yields were comparable with the simulated grazing of Berkenkamp and Meeres (1988b) and it is not unreasonable to assume that the high crude protein (CP) concentration values reported were a reflection of repeated grazing of these cereals. Unfortunately, Berkenkamp and Meeres (1988b) and Robertson (1980) had no CP concentration reported to complement their grazing data. Under silage situations, Berkenkamp and Meeres (1988b) reported that barley was the highest followed by wheat, triticale, oat, and rye for CP concentration. However, Holt (1993) found CP concentrations of spring-seeded fall rye, spring rye, and oat to range from 196 g kg⁻¹ DM to 211 kg⁻¹ DM and in vitro organic matter digestibility of 720 kg⁻¹ DM when grazed at the pre-boot stage (Table 1).

In silage trials, barley consistently had higher CP concentration than oat except in one instance in Grey Wooded soils (Kibite et al. 2002). It is notable that wheat and triticale had higher for CP concentration than barley on Grey Wooded soil, but were comparable with barley for CP concentration in Black soils as reported by Berkenkamp and Meeres (1987).

Several factors have been identified that do not affect CP concentrations in cool season cereals. Increased seeding rates (Walton 1975), DM yield (Berkenkamp and Meeres 1987), and effect of seeding date (May et al. 2007) had no effect on CP concentration. Delayed harvest decreased CP yield ha⁻¹ by 34% from heading to 2 wk after heading (Kibite et al. 2002), and by 22% 2 wk after the milk dough stage (May et al. 2007). However, increased seeding rates reduced fibre contents

Table 1. Forage quality in spring seeded annual cereals for grazing

Crop/cultivar	Location	Seeding date (s)	Sample date(s)	g kg ⁻¹ DM			CP (kg ha ⁻¹)	References
				CP	NDF	ADF		
Annual ryegrass								
Aubade	Kamloops, AB	Apr. 19-May 19		136–155	500–515	303–399		Quinton (personal communication)
Marshall	ON (3 locations)		55–95 d after seeding	140–174	526–549	313–374		Johnston and Bowman (1998)
Lemtal	Charlottetown, PEI	May 14	July 14-Oct/ 06	147–207				Burgess and Kunelius (1982)
Lemtal	Charlottetown, PEI	May 26	July 11-Nov. 07	190–310			261–327	Kunelius and Boswall (2002)
Aubade	Melfort, SK		Oct 13-Nov. 09	172–232		207–298		Foster et al. (1996)
Aubade	Melfort, SK		Sep. 05-Nov. 09	145–240	458–469	209–271		McCartney (2000)
Maris Ledger	Melfort, SK		Sep. 05-Nov. 21	144–274	440–654	223–374		McCartney (2000)
NA ^z	Charlottetown, PEI			160				Narashimalu et al. (2000)
Barley								
Conquest	St. Augustin, QC	May 12–22	4–12 wk after seeding	72–241				McElroy and Gervais (1983a, b)
Ranger	SK (3 locations)	May 17, Jun. 17	64–84 d after seeding	65–135			384–1030	Klein (2002)
Oat								
Triple Crown	Lanigan, SK	May 25 2000	Oct. 10	129		347	889	Lardner (2000)
Dorval	St. Augustin, QC	May 12–22	4–12 wk after seeding	74–249				McElroy and Gervais (1983a, b)
Pinnacle	SK (3 locations)	May 17, Jun. 17	64–85 d after seeding	64–114			482–619	Klein (2002)
Calaber	Melfort, SK	Spring	Sep. 20 regrowth	99	472	238		McCartney, unpublished data
NA	Swift Current, SK	Spring	Pre-boot	211				Holt (1993)
Fall rye								
NA	Camrose, AB	Jul. 09	Oct. 22	264	488	184		Hosford and Yoder (1996)
Prima	Melfort, SK.		Sep.. 20	207	472	238		McCartney, unpublished data
Prima	Lanigan, SK	May 13	Jul. 10-Nov. 09	279–307		193–251	1884	Lardner (1998a, 1999)
NA	Swift Current, SK	Spring	Pre-boot	209				Holt (1993)
NA	Melfort, SK		Oct. 05-Nov. 03	239–270				Foster et al. (1996)
NA	Lanigan, SK	May-first week	Jul. 09, Sep. 14	285–118		246–350		Cohen et al. (1988)
Winter triticale								
Banjo/Copia	Camrose, AB	Jul. 09	Nov. 21–25	137	623	362		Hosford and Yoder (1996)
Sandrow	SK (3 locations)	May 14- June 17	64–84 d after seeding	68–107			344–566	Klein (2002)
Pika	Melfort, SK		Sep. 20	194	422	219		McCartney, unpublished data
Winter wheat								
Norstar	Stavelly, AB	mid May-mid June	September	86–112				Willms et al. (1993)
NA	Melfort, SK		Oct. 05–Oct 20	161–217				Foster et al. (1996)
NA	Lanigan, SK	May-first week	Jul. 09, Sep. 14	266–117		276–381		Cohen et al. (1988)
Opal	St. Augustin, QC	May 12, 21	Jointing	138				McElroy and Gervais (1983b)

^zNA, not available.

and thus increased the nutritive value (Walton 1975). Kibite et al. (2002) found a general decline in digestibilities with delayed harvest date. When harvested at the same stage of development, barley tended to have greater digestibility and CP concentration than oat regardless of sites and seeding dates. Barley frequently had higher neutral detergent fibre (NDF) concentrations than oat, but was not consistent enough to make a generalization (Kibite et al. 2002). Carr et al. (2004) reported lower acid detergent fibre (ADF) and NDF concentrations and higher total digestible nutrients (TDN) values for barley in the Northern Great Plains and concluded that like in the sub-humid regions, barley produces higher quality forage than oat (Cherney and Marten 1982). However, Helsel and Thomas (1987) reported that in general, wheat, oat, and barley forages at similar maturities had similar DM digestibilities. Reported quality factors such as TDN and DM digestibilities, seem to be variable, and Carr et al. (2004) quote Brink and Marten (1986) who emphasized that environmental factors could affect relative quality differences between barley and oat forage. The results of Carr et al. (2004) suggest that crop species and cultivar selection could impact TDN concentrations of small grain forages. However, environmental factors and presence or absence of awns or spikelets in barley could also impact quality traits (Carr et al. 2004). Unfortunately, the majority of the nutritional quality data on annual forages were taken in a silage system after heading and not under actual grazing conditions, which

would be in the pre-boot stage. Thus stage of maturity at sample harvesting could influence the quality of forage for grazing.

On a DM basis, a gestating beef cow requires 70, 80–90, and 100–110 g kg⁻¹ DM CP concentration and 500, 550, and 600 g kg⁻¹ DM TDN for 2nd and 3rd trimesters and post-calving, respectively (NRC 1996). Grazing spring cereals under most circumstances meet the nutrient requirements of beef cows (Tables 1 and 2). Berkenkamp and Meeres (1987) suggested that for oat, if not fertilized, or if harvested later than the soft dough stage, protein content could be below that required for grazing beef cows. However, these quality samples were taken in a silage system and not a grazing system and stage of development could have an effect on grazing. Wheat, triticale, and rye have DM forage and CP yields comparable with those of barley, and may be used for grazing, though further actual grazing research is required to support this (Tables 1 and 2).

Since the majority of nutritional quality research on cool season cereals has been done on silage crops, future research is required to evaluate the nutritional quality of a wide range of annual cereals in grazing trials.

POTENTIAL OF WINTER CEREALS FOR GRAZING

Winter cereals, unlike spring cereals, need a period of vernalization before meristems initiate reproductive growth. Growth prior to seed set is vegetative, and after winter vernalization, growth is early and rapid. Fall rye, which is seeded in late summer, has an advantage over

Table 2. Average daily gain and live weight gains by grazing annual forages

Crop(s)	Location	Animal(s)	Grazing period (d)	ADG (kg d ⁻¹)	Livewt. gain (kg ha ⁻¹)	Reference(s)
Annual ryegrass	Charlottetown, PEI	Cows	116	0.21		Burgess and Kunelius (1982)
Annual ryegrass	Charlottetown, PEI	Steers	78	0.9		Narasimhalu et al. (1994)
Annual ryegrass	Charlottetown, PEI	Steers	57	0.54		Narasimhalu et al. (2000)
Annual ryegrass	New Liskeard, ON	Calves	28	0.68	157	Johnston (2000)
Annual ryegrass	Melfort, SK	Calves	22–70	0.44–0.97	362–535	McCartney (2000)
Barley	Melfort, SK	Lambs, ewes	82	0.16–0.20	305	Beacom (1991)
Barley	Swift Current, SK	Steers	7	1.36		Holt (1993)
Fall rye + oat	New Liskeard, ON	Calves	28	0.68	73	Johnston (2000)
Oat	Swift Current, SK	Steers	35–38	0.95–1.61	200–278	Holt (1993)
Oat	Melfort, SK	Lambs, ewes	88	0.14–0.19	328	Beacom (1991)
Oat + winter triticale + fall rye	Lacombe, AB	Heifers	56	1.53	132	Aasen and Baron (1992)
Fall rye (spring seeded)	Swift Current, SK	Steers	21–29	0.77–1.09	169	Holt (1993)
Fall rye (fall seeded)	Swift Current, SK	Steers	33–39	1.02–1.18	214–286	Holt (1993)
Fall rye (fall seeded)	Swift Current, SK	Cows calves	32–62	0.97–1.51	84–191	Kilcher and Lawrence (1979)
Fall rye (fall seeded)	New Liskeard, ON	Calves	28	0.68	73	Johnston (2000)
Fall rye (spring seeded)	Lanigan, SK	Steers	39	0.86		Lardner (1999)
Fall rye (spring seeded)	Lanigan, SK	Heifers	69	0.82	244	Cohen et al. (1988)
Winter triticale	Swift Current, SK	Steers	25–30	0.78–1.36	146	Holt (1993)
Winter triticale + oat	New Liskeard, ON	Calves	28	0.68	76	Johnston (2000)
Winter triticale + spring barley	Lacombe, AB	Steers	115	0.95	236	Baron et al. (1991)
Wheat (spring)	Swift Current, SK	Steers	22	0.91	123	Holt (1993)
Winter wheat	Stavelly, AB	Cows	30	0.07		Willms et al. (1993)
Winter wheat	Melfort, SK	Heifers	69	0.85	252	Cohen et al. (1988)
Wheat (spring)	Swift Current, SK	Steers	21	1.55	260	Holt (1993)

spring cereal crops. Fall rye can be grazed later in the fall and, unless grazed too close to the ground, it will live through the winter, and the second year's growth can be used for pasture, green feed, or grain production. Consequently, fall or winter rye has been recommended as a pasture crop for the short grass and marginal prairie regions and the Aspen Parkland to provide forage production late and/or early in the grazing seasons (Anonymous 1936, 1940, 1954). Forage yields of winter wheat and fall rye were low in dry years, but gave good yields of DM and protein in years of favorable moisture. These crops were quite frost resistant, and well suited to late fall grazing. In simulated grazing trials, the fall rye and winter wheat produced less DM, but more protein than oats (269 vs. 227 g kg⁻¹ DM) (Anonymous 1940, 1952). Later, under similar multiple cut conditions, Berkenkamp and Meeres (1988b) found that winter cereals produced good pasture yields. Unlike spring cereals, which showed more rapid growth in the spring and were ready for pasture earlier, winter cereals, when spring seeded, grew most rapidly in mid-summer and continued to produce into fall when moisture was adequate (Anonymous 1954). Spring-seeded winter triticale could also be grazed, although it has not been used as extensively as winter rye and winter wheat. Spring-seeded winter cereals were ready for grazing 8 wk after planting, whereas spring cereals were ready for grazing in about 6 wk (Foster 2004). Spring-seeded fall rye was about 2 to 3 wk earlier for grazing than winter wheat (Aasen and Baron 2001), and could be used to provide excellent mid- to late-season pasture in the establishment year and in the following year. Winter cereals, when fall seeded, provide more spring grazing than perennial species (Riemer and Gaudiol 1986).

Dual Purpose Winter Cereals

Hard red winter wheat is a dual purpose crop and is a major component of livestock systems in the US Great Plains (Redmon et al. 1995) as income is derived from both the grazing of growing cattle and grain harvesting. A review by Redmon et al. (1995) for the southern Great Plains, indicated that grazing winter wheat during fall, winter and spring generally increased wheat grain yields under favorable growing conditions compared with non grazed wheat.

Baron et al. (1999) and Salmon et al. (1996) have determined that the use of winter cereals in western Canada is not as extensive as in the United States of America, because of a much shorter growing season. Winter cereals in western Canada are dormant during November to March, unlike the Southern Great Plains where temperatures permit growth during the winter period. Thus, cattle producers are limited by our climate for the utilization of fall and spring growth of winter cereals for grazing. There are a limited number of varieties available having adequate winter hardiness and suitable agronomic characteristics for grain production. Fall rye is the hardiest of all the winter cereals, and

the most resistant to diseases that may injure or kill the crop in the winter and early spring (Berkenkamp and Meeres 1988b; Baron et al. 1999). Although limited work has been done with winter cereals as a dual purpose crop in Canada, Kilcher (1982) in Swift Current, SK, found that fall grazing of fall rye reduced subsequent grain yields by 17%, whereas spring grazing reduced yields by only 10% and grazing both in fall and spring reduced grain yields by 25% in this region of the semi-arid mixed grass prairie, unlike the results of Redmon et al. (1995). Winter cereal adaptability and suitability for both grazing and grain production has yet to be conclusively evaluated for Canada.

Spring-seeded Winter Cereals

Berkenkamp and Meeres (1988b) evaluated winter wheat and fall rye, seeded in May and managed under simulated grazing conditions. When seeded in the spring, both winter wheat and fall rye produced more pasture than when seeded the previous fall. Winter wheat seeded in the spring produced 32% more forage yield than spring-seeded fall rye. Spring-seeded fall rye tended to tiller and stay close to the ground, which helped form a weed-suppressing carpet of vegetation. In central Saskatchewan, Cohen et al. (1988) found similar liveweight gains of heifers grazing spring-seeded fall rye or winter wheat pastures. Total DM forage production for fall rye was 4340 kg ha⁻¹ compared with 3600 kg ha⁻¹ for the winter wheat pastures. The grazing period lasted from Jul. 09 to Sep. 14 and CP concentration at the start of the grazing period was 285 and 266 g kg⁻¹ DM for fall rye and winter wheat and averaged 117 g kg⁻¹ DM at the end of the grazing period. The TDN concentration was 688 and 656 g kg⁻¹ DM for fall rye and winter wheat at the beginning of the grazing period and 588 and 566 g kg⁻¹ DM at the end of the grazing period. The fall rye pastures produced 244 kg ha⁻¹ of beef, while the winter wheat pasture yielded 252 kg DM ha⁻¹. In a later grazing trial from Jul. 09 to Aug. 28 at the same location, spring-seeded fall rye produced 6410 kg DM ha⁻¹, CP concentration of 294 g kg⁻¹ DM, and TDN of 72.5 g kg⁻¹ DM. Liveweight gains of 325-kg steers averaged 0.86 kg d⁻¹ (Lardner 1999) (Table 2).

Berkenkamp and Meeres (1988b) found that yields were significantly greater when plants were harvested for hay versus simulated pasture for winter wheat and fall rye when spring or fall seeded. When seeded in mid-May, neither crop was ready for pasture until the second week of July. Forage yield reduction from simulated grazing of spring-seeded winter wheat and fall rye was 13% compared with hay yield. Spring-seeded winter cereals averaged 51% more forage DM yield under simulated grazing and 76% more forage yield under hay cut than fall-seeded winter cereals. Berkenkamp and Meeres (1988b) concluded that the only advantage to a fall seeding would be to provide a very early spring pasture, with the possibility of a reduced grain harvest (Kilcher 1982).

Fall-seeded Winter Cereals

Baron et al. (1999) found that irrespective of fall seeding dates (Aug. 15 or Sep 15), fall rye tended to produce spring pasture earlier than winter wheat and triticale. In this study, winter wheat yielded better than fall rye under late seeding conditions and triticale yielded better than wheat under early conditions. Dry matter yields were higher when seeded in late August than in late September (Berkenkamp and Meeres 1988b; Baron et al. 1999). Delayed seeding (Sep. 15) resulted in later forage production, smaller plants and decreased DM, and did not produce sufficient DM for early spring grazing the next spring. Baron et al. (1999) did not determine the effect of grazing or clipping in the fall on time or yield of spring grazing. Berkenkamp and Meeres (1988b) found that a fall pasture cutting regime reduced overwintered fall-seeded winter wheat and fall rye pasture yield by 47 and 35%, respectively, compared with hay yield. The average date of the first pasture harvest of overwintered fall rye was late May, which was a week earlier than the winter wheat. When averaged over harvest systems, seeding dates and years, winter wheat yielded significantly more than fall rye (5110 vs. 4320 kg DM ha⁻¹). However, Maloney et al. (1999) found that 80 to 90% of the total fall and spring forage yield of winter wheat and fall rye came from the spring harvest. Winter wheat tended to out-yield fall rye when spring seeded, but was inferior when overwintered. Fall-seeded and overwintered fall rye had higher forage yield than winter wheat most likely because of its greater winter hardiness and disease resistance.

At Swift Current, SK, the perennial Altai wild ryegrass (*Elymus angustus* Trin.) and Russian wild ryegrass (*E. junceus* Fisch.) pastures provided twice as many grazing days as did fall-seeded fall rye (Kilcher and Lawrence 1979). Average daily liveweight gains were highest for fall rye, but Altai wild ryegrass produced 50% more total liveweight gain ha⁻¹ (286 kg ha⁻¹) than Russian wild ryegrass (191 kg ha⁻¹) and nearly twice as much more than fall rye (134 kg ha⁻¹).

At Melfort, SK, McCartney (unpublished) showed that mid-August seeding of fall rye following a silage harvest provided insufficient DM yield for October grazing, while in the spring, fall rye quickly set seed and produced limited DM for early spring grazing. By the time there was sufficient available grazing yield in the spring and the cow calf pairs were able to complete the spring grazing, it was too late to seed a silage crop in that field.

POTENTIAL OF ANNUAL RYEGRASS FOR GRAZING

Annual ryegrass species were identified as early as 1936 in western Canada as a grass for late fall pasture. The herbage was not damaged by fall frosts; however, it was not winter hardy (Anonymous 1936). Annual ryegrass could be used as a summer annual from mid-summer to late fall to help extend the grazing season in western

Canada, (Berkenkamp and Meeres 1988a; Thompson and Stout 1992; Stout et al. 1997; McCartney 2003), in Alaska (Brundage and Branton 1967; Klebesadel 2000) and in eastern Canada (Kunelius 1980, 1991; Narasimhalu et al. 1992; Carter and Kunelius 1993; NSCDI 1993; Johnston and Bowman 1998; Kunelius and Boswall 2002).

Italian and Westerwolds ryegrasses are collectively called annual ryegrasses (Narasimhalu et al. 1992). Italian ryegrass is a biennial originating from northern Italy. It is leafy and tillers readily, which makes it suitable for pasture and green manure. This crop does not usually set seed, and will not overwinter in western Canada. Westerwolds ryegrass is an annual that was developed from Italian ryegrass in the Netherlands in the 1900s by selecting plants that produced seed in the year of seeding. Westerwolds ryegrass with its stemmy, upright growth habit and seed production may be grown for silage, grazing and green manure. Westerwolds ryegrass will produce seed in the year of seeding and needs to be cut for silage or heavily grazed at various times to prevent seed set as volunteer seed can be a problem the next year (Kunelius 1991; McCartney 2003). Thus, Italian ryegrass is the preferred type for grazing and only Italian ryegrass data are presented and discussed.

At Lacombe, AB, Italian ryegrass consistently gave the highest simulated pasture yields, 5010 kg DM ha⁻¹, as compared with oat, barley, spring-seeded winter wheat, fall rye and triticale (Berkenkamp and Meeres 1988a). Spring cereals showed more rapid growth in the spring and were ready for grazing earlier than Italian ryegrass in simulated grazing trials. Italian ryegrass grew more than cereals in mid-summer and into the fall provided moisture was adequate. However adequate moisture and early weed control was required for the Italian ryegrass.

In north central Saskatchewan, Italian ryegrass produces the highest DM yield for fall grazing compared with spring-seeded fall rye, winter wheat, or winter triticale (McCartney et al. 2004b). Fall grazing of Italian ryegrass was an economical alternative to backgrounding beef calves in a feed lot on stored feed (McCartney et al. 2008).

Coulman (2002) evaluated Italian ryegrass at Saskatoon, SK, and Lacombe, AB, under simulated grazing conditions. At Saskatoon, only two cuts were taken and DM yields were not as high as at Lacombe (three cuts), where rainfall was higher. Coulman (2002) had seedlings from a dormant seeding study successfully emerge in the early spring that had vernalized and produced seed heads. This is a very important finding as there is the possibility of seed production for Italian ryegrass in Canada by dormant seeding. Currently, Italian ryegrass seed has to be imported into Canada.

Klebesadel (2000) has summarized extensive research on the use of ryegrass in Alaska and cited early reports from 1919 indicating that annual ryegrass seeded

without fertilizer made "fair growth". Klebesadel (2000) found in a simulated grazing trial, that total two-cut forage for Aug. 02 harvest date was 32% higher than the Jul. 21 date and CP concentrations were in the range of 177 g kg⁻¹ DM. Today, very few farmers grow annual ryegrass in Alaska and, judging from Klebesadel (2000), the types and cultivars that they do grow set seed in the year of seeding. It is speculated that many annual cultivars go to seed very early in Alaska due to the extremely long day length. As a result, annual ryegrass is difficult to manage and farmers prefer to graze traditional perennial grasses.

Annual ryegrasses are important summer annual forages in the Atlantic provinces where they are well adapted to the soil and climatic conditions (NSCDI 1993; Kunelius and Boswall 2002). A grazing study with cross-bred steers in Prince Edward Island showed that regrowth from annual ryegrass extended grazing by about 60 d from mid-October to mid-December (Narashimhalu et al. 2000). The regrowth of annual ryegrass was 2000 to 3500 kg DM ha⁻¹ during the grazing period with 160 g CP kg⁻¹ DM in an area that received 325 mm precipitation between September and November (Narashimhalu et al. 2000). Dairy farmers were also able to maintain satisfactory levels of milk production with ryegrass pasture when there was adequate rainfall. Burgess and Kunelius (1982) showed that dairy cows grazing annual ryegrass pastures had 255 cow grazing days more than native pastures, but annual ryegrass needed intensive management with high levels of fertilization.

Research has demonstrated the benefits of using Italian ryegrass in a rotational grazing system with adequate moisture. However, adoption of this new species for grazing in western Canada has been slow due to the high cost and low availability of seed.

POTENTIAL OF MIXTURES OF ANNUAL CEREALS FOR GRAZING

Clark and Poincelot (1996) reported that in the late 1800s in Ontario, there was considerable knowledge about pasture species, adaptation, and utilization. The dominant focus in forage research in the 1880 to 1930 era was evaluation of forage species and mixtures for yield distribution, persistence, and palatability. Mixture recommendations were complex, typically involving 6 to 13 species. One of the early approaches to dealing with the seasonality of pasture yield involved the use of mixtures of annual and biennial forages, such as oat, sorghum (*Sorghum bicolor* L.), sweet clover (*Melilotus alba* L.), and red clover (*Trifolium pratense* L.) for annual pastures, with annual yields averaging 3000 kg DM ha⁻¹ (Zavitz and Squirrell 1919). Little reference was made to other aspects of pasture management, including responses to fertilization, grazing practices, or weed control.

Carleton (1919) reported that at the turn of the century, winter and spring wheat or barley were sown

for spring and summer grazing in the western United States. Early work on mixtures in western Canada (Anonymous 1924, 1940) and in the Atlantic from 1927 to 1941 (NSCDI 1993) found that oat and pea mixtures gave the best yields (2060 to 8035 kg DM ha⁻¹), higher than or comparable with spring cereal monocrops (Anonymous 1924, 1940). Pea and oat mixtures always out yielded oat at Scott, SK (Anonymous 1924). The conclusions from the 1950s in regard to the value of mixtures are somewhat contradictory. Anonymous (1950) stated that there was no advantage to seeding most annual crops in mixtures or with other crops unless it was for the sake of better palatability or quality of feed. Anonymous (1954) found winter wheat, fall rye, and forage rape in mixtures with oat provided a balanced diet and a better distribution of forage throughout the grazing period by supplying late fall pasture and some early spring grazing.

More current work on mixtures has confirmed many of the previously found benefits. Spring-seeded mixtures of spring and winter cereals provide earlier grazing than winter cereals in monoculture due to the early growth of the spring cereal (Baron et al. 1993a,b). Mixtures continued to accumulate DM later in the season so that forage distribution could be increased during the traditional grazing period and into the fall (Carr et al. 1998, 2004; Baron et al. 1999; McCartney et al. 2004b). However, current work has also found that adequate fall regrowth is contingent upon the time of the first harvest of the spring cereal component, and that adequate moisture is required in the fall (Baron et al. 1995).

The biggest advantage to livestock producers of spring and winter cereal mixtures is the ability to harvest a silage crop and later graze the regrowth all on the same land base. In a grazing trial at Lacombe, AB, the winter cereal regrowth (oat underseeded with winter triticale and fall rye) after being cut for silage provided 56 d of grazing for bred heifers with 132.5 kg ha⁻¹ gain, while the perennial pasture provided 28 d of grazing and 64 kg ha⁻¹ gain (Aasen and Baron 1992). The annual pasture had a CP concentration of 182 g kg⁻¹ DM and ADF concentration of 237 g kg⁻¹ DM on the last sampling date of Oct. 26 while the perennial pasture had a final CP concentration of 152 g kg⁻¹ DM and an ADF concentration of 279 g kg⁻¹ DM.

Jedel and Salmon (1995) at Lacombe, AB, evaluated forage yield and quality for two simulated forage regimes: (1) a soft-dough cut for silage, followed by a fall clipping, (2) annual pasture with up to five clippings during the growing season. Spring cereal monocrops of spring triticale and barley and binary mixtures of the spring cereals with winter triticale or winter rye were evaluated. On average, the mixture annual pasture system produced 4850 kg DM ha⁻¹ or only 58% of the silage and pasture forage yield (8325 kg DM ha⁻¹). The spring monocrop yields averaged 8710 kg DM ha⁻¹ or 5% more than the cereal mixture silage and pasture and 31% less (3350 kg DM ha⁻¹) than the mixtures

under grazing. Winter triticale with a spring cereal yielded more when managed under simulated grazing, and fall rye with a spring cereal yielded more under a silage and pasture system. Monocrop yields declined over the growing season, while yields from the mixtures increased to mid-summer and then declined. The nutritional quality of all treatments for the early clippings of the pasture were similar. The mixtures had higher CP (266 vs. 129 g kg⁻¹ DM) and lower ADF (181 vs. 496 g kg⁻¹ DM) concentrations than the spring cereal monocrops by late summer and fall.

In a later study, Juskiw et al. (1999) evaluated spring-seeded winter triticale, fall rye, and mixtures of these cereals with spring barley at different ratios. Mean DM yields for triticale were generally as high as the fall rye treatments (5900 kg DM ha⁻¹), but the spring regrowth after overwintering for triticale harvested at the pre boot stage was only 600 kg DM ha⁻¹ compared with 1000 kg DM ha⁻¹ for fall rye. They concluded that as little as 25% spring barley in a mixture provided good early-season biomass yields for grazing but more than 50% reduced late-season forage yields. All treatments produced good-quality forage with CP concentrations > 200 g kg⁻¹ DM, NDF < 450 g kg⁻¹ DM, and ADF < 300 g kg⁻¹ DM. Thus the seeding ratio of spring crop to fall crop should be based on the relative need for fall pasture.

In a study of cropping systems for silage and pasture in northeastern Saskatchewan, McCartney et al. (2004b) evaluated herbage yield of spring cereals (barley or oat) in mixtures with a fall cereal (fall rye, winter wheat, and winter triticale) under a silage cut and as fall pasture. The average spring cereal silage yield (7870 kg DM ha⁻¹) was greater than the average mixture silage yield (7350 kg DM ha⁻¹). Silage cut oat as a monocrop and oat in mixtures out-yielded silage cut barley monocrop and barley mixtures. Crude protein concentration was 14% to 35% higher in the mixture system than in the corresponding spring cereal monocrop system. The NDF and ADF concentrations of barley based systems was 15 and 22% lower than those with oat. McCartney et al. (2004b) also noted that when fall cereals were seeded as a monocrop specifically for fall pasture, the DM yield was 2.4-fold higher than with mixtures of spring and fall cereals.

In another trial, McCartney et al. (2005) spring-seeded binary mixtures of a spring cereal (barley or oat) and a fall crop (fall rye). The total crop yield was often maximized with seeding ratios of 60% spring:fall crop component. Fall regrowth yields were maximized by seeding 100% fall crop component. The spring crop component yield, especially for oat mixtures contributed very little to fall regrowth yields. Seeding rates (150, 275, and 400 seeds m⁻²) frequently affected spring crop component and total crop yield, but not fall crop yield. Forage swards with greater than 60% of the spring crop component along with higher than normal total seeding

rates of 400 seeds m⁻² represent a possible integrated weed management strategy in a mixed farming system.

Elsewhere in North Dakota, Poland et al. (2003) found that DM yields of winter and spring cereals were lower, with yield reductions of up to 20%, in the mixtures compared with the spring cereals seeded alone. Diseases such as leaf rust (*Puccinia graminis* L.) and other pathogens infected both winter triticale and wheat when spring seeded, eliminating the ability of these cereals to produce forage for fall grazing. Seeding either spring barley, oat, or triticale with winter rye, triticale, or wheat produced about 3360 kg DM ha⁻¹ by mid July, with regrowth of the winter cereal component contributing an additional 504 kg DM ha⁻¹ in the fall (Poland et al. 2003). Fall rye regrowth was sufficient to provide limited amounts of forage for grazing the following spring.

Walton (1975) in central Alberta evaluated several annual forage mixtures and found that the presence of a non-cereal in the mixture reduced yield, but the pea in the mixture with oat increased the yield of CP. Pea with oat yielded more than forage rape with oat, while forage rape with barley yielded more than pea with barley. Carr et al. (2004) found that mixtures with pea increased forage and N yield. The authors concluded that forage yield was reduced but quality was enhanced when oat was replaced with barley in low-soil-N environments, but the yield and quality could be enhanced by seeding mixtures of barley or oat with pea.

Italian ryegrass and barley mixtures had high productivity in Prince Edward Island (Kunelius 1991) and under irrigation in British Columbia (Thompson et al. 1992a,b). In barley-annual ryegrass mixtures in interior BC, barley provided high energy silage for the first harvest, annual ryegrass provided hay or silage in the second harvest and the regrowth was used for silage or fall pasture (Stout et al. 1997). Mixtures of Italian ryegrass with winter cereals responded similarly to those with winter-spring cereal mixtures (Thompson et al. 1992b). Thompson et al. (1992b) showed that DM yields of fall pasture (cuts 3 and 4) were similar among annual ryegrass cultivars, and all cultivars had similar quality by late fall. When Italian ryegrass was seeded as a monocrop, it produced 91% as much DM in the silage cuts as annual ryegrass and barley mixture, but produced 105% as much pasture regrowth (Thompson and Stout 1992). Seeding rates of 15 kg ha⁻¹ of ryegrass and 50 kg ha⁻¹ of barley could be reduced from the previously higher recommended rates of 25 kg ha⁻¹ and 100 kg ha⁻¹ without reducing yield. The total DM yield of ryegrass pasture regrowth after silage harvest was not affected by ryegrass seeding rate as the annual ryegrass tillered profusely at low populations when growing conditions were favorable. McCartney et al. (2004b) found Italian ryegrass mixtures had the greatest yields, with the other spring and winter cereal mixtures yielding 68% of the spring cereal and Italian ryegrass pasture mixtures.

GRAZING MANAGEMENT STRATEGIES FOR COOL SEASON CEREALS AND ANNUAL RYEGRASS

Perennial pastures are still the most cost effective grazing system since they do not have to be seeded every year. In addition, perennial grasses tend to have a more sod forming nature than annuals, and can withstand trampling by grazing livestock better than annual pastures resulting in better utilization (Beacom 1991). However, annual pasture can provide an alternative when perennial pastures are not available or as part of a rotational grazing system with perennial forages (Table 2). King and Cohen (1988) in central Saskatchewan grazed crested wheatgrass (*Agropyron cristatum* L.) during May and June and then rotated the cattle through three spring-seeded winter wheat pastures and later back to the crested wheatgrass regrowth through to the end of the grazing season for a total of 180 and 205 animal grazing days ha⁻¹. In other studies, overwintered fall rye was used for grazing in May and June, and spring-seeded spring cereals were ready to graze in the early boot stage, by mid-June as part of a rotational grazing system (Holt 1993).

Robertson (1980) showed that the quality of oat pasture could partially be controlled by rotational grazing, and spacing the dates of seeding 2–3 wk apart starting in early May provided a longer grazing season. The delayed seeding system prevented all the crop from being at the same stage of maturity and reduced wastage through trampling when intensively grazed.

Initial grazing height was extremely important when grazing spring or winter cereals (Holt 1993). Holt (1993) recommended to begin grazing at the early flag leaf stage of the annual cereal (20–25 cm) and remove one-half of the forage with each grazing cycle until all harvestable forage was removed. As spring and winter cereals matured, grazing palatability declined. When cereals were allowed to grow to stem elongation before initial grazing, severe crop loss through animal trampling resulted and little regrowth occurred (Kilcher and Troelson 1973; Robertson 1980; Holt 1993).

The promotion of tillering of cereals was advantageous for extended grazing in research trials at Swift Current, SK (G. McLeod, personal communication, Agriculture and Agri-Food Research Centre, Swift Current, SK). Triticale had lower tillering capabilities than other cereals but grazing before the boot stage promoted tillering especially with forage types. Early grazing promoted tillering and kept late developing tillers alive. The spring-seeded fall rye and winter triticale produced 2000 kg DM ha⁻¹ by late summer before the lower leaves in the canopy began to die back. Grazing commenced when the lower leaves began to yellow. When water and fertility were adequate, regrowth was significant as first growth but depended on the time of first grazing.

Holt (1993) found that palatability was not a problem when grazing cereal forages at the vegetative stage,

although heads of mature spring wheat and oat were grazed, but bearded heads of triticale, spring and fall rye were avoided. By keeping the growth of annual cereals in the vegetative or regrowth stage, the nutritional quality of the forage will more than meet the nutrient requirements of the grazing animal.

Robertson (1980) at Melfort, SK, used sheep to compare oat and barley pastures with brome-alfalfa (*Bromus inermis* L., *Medicago sativa* L.) pastures. Grazing the annual cereals began 2 to 3 wk after grazing of the perennial pasture. Average gains per hectare during the experiment were similar for oats and brome-alfalfa (328 and 330 kg ha⁻¹) followed by barley (305 kg ha⁻¹). Annual DM yields were not different between oats and barley, averaging 5885 kg DM ha⁻¹, but were lower with 5385 kg DM ha⁻¹ for brome-alfalfa. Robertson (1980) concluded that oat could provide an alternative summer grazing system, produce equal gains to those obtained on perennial grass-legume mixtures and could be available for grazing within 6–7 wk of seeding.

Beacom (1991) summarized results from several studies at Melfort, SK, and showed that supplementary oat pastures yielded 3800 to 6000 kg DM ha⁻¹, provided 100 to 150 steer days of grazing ha⁻¹ and extended the grazing season by as much as 40 d. The forage regrowth from winter wheat and fall rye in mixtures with oat for silage supported rates of gain ranging from 0.5 to 1.5 kg head⁻¹ d⁻¹ for lactating beef cows prior to weaning.

McCartney (2000, 2003) and McCartney et al. (2008) found that Italian ryegrass could be heavily grazed once the stand was established in early summer and the regrowth, which remained vegetative, could be heavily grazed starting in the early fall (Table 2). Since the plants did not over winter, heavy grazing in the fall was advisable. Weaned calf gains could be as high as 718 kg ha⁻¹ on Maris Ledger Italian ryegrass pasture from late August to mid November and average daily gain was 0.68 to 1.13 kg d⁻¹. Backgrounding calves on high-quality Italian ryegrass pasture was more economical than backgrounding in a feedlot system.

In New Liskeard, ON, over 28 d of grazing, calves on oat-annual ryegrass pastures produced 157 kg ha⁻¹ liveweight gain compared with 75 kg ha⁻¹ on oat-fall rye or oat-winter triticale (Johnston 2000).

Swath Grazing of Cereals

Swath grazing of cereals is a low-cost system used for late fall and winter grazing for pregnant beef cows. Swath grazing is gaining popularity in western Canada (Entz et al. 2002; Baron et al. 2004; McCartney et al. 2004a). Oat or barley is seeded in late May, swathed at the soft dough stage and later grazed in the swaths in the late fall and winter. This system takes advantage of the high yield potential of the spring cereal and consolidates the forage so that the cows can graze through the snow (Aasen et al. 2004). Access to the swaths is limited by

electric fencing. Delayed seeding of this crop delays maturity and cutting at the soft dough stage can be near the date of the first frost thus reducing swath deterioration due to weather. Cool weather then maintains the nutritive value of forage for fall and winter grazing. The late seeding also allows time to control spring weeds (Schoofs and Entz 2000). However, the later the crop is seeded the lower the yields (Kibite et al. 2002; May et al. 2007). To maximize DM yield under normal conditions in south east Saskatchewan, May et al. (2007) found that oat and barley needed to be seeded May 20–25 to take advantage of spring moisture and cool temperatures. When seeded this early, the cereals were swathed in early August in the soft dough stage. Swaths left in the field from early August to freeze-up were subject to significant weathering due to rain. However, it may be possible to take advantage of the high yields of early seeded spring cereals swathed in August at the soft dough stage, by grazing these swaths in August and September and utilizing other perennial forage regrowth later in the fall and winter.

Research in Alberta found that pregnant beef cows could be successfully wintered on swath grazed barley or oat and that savings of about 50% could be made through reduced feed harvesting, handling and feeding costs, reduced costs of manure removal and labor (McCartney et al. 2004a). Cows and calves grazed the swath residue after the fields dried the following spring and the cows were provided with energy supplements (2.7 kg DM rolled barley head⁻¹). Winter and spring swath grazing has potential to be part of an extended grazing system. Early spring swath grazing with supplementation prior to grazing of perennial grass pasture would allow perennial pastures to grow in the spring to at least the three-leaf stage before summer grazing commenced.

Some research has evaluated the use of mixtures for swath grazing. In plot studies at Lacombe, AB, Aasen et al. (2004) found similar swath grazing DM yields for barley, oat, and field pea monocrops, and mixtures did not out-yield monocrops. Yield of barley/oat mixture was more stable from year to year than the respective monocrops. The added costs of growing mixtures rather than monocrops were not offset by superior yield, nutritive value, or resistance to weathering.

ANNUAL CEREALS FOR PASTURE RENOVATION AND OTHER USES

Pasture rejuvenation offers another possibility for the use of grazing annual crops in Canada. In a roughland bush pasture study, McCartney et al. (1999) seeded oat as a companion crop with perennial Russian wild rye and rotationally grazed with the other perennial pastures. This treatment provided early summer grazing of the oat in the year of establishment and reduced the need to lower the overall stocking rates on the entire pasture. Sod seeding annual cereals into depleted perennial pastures with limited use of glyphosate

herbicide rather than cultivation offered another option to provide high-quality forage for grazing and improve land use efficiency (Wilkinson and Stuedemann 1983; Moyer et al. 1995; McCartney et al. 1999; Coffey et al. 2002). However, little research has been done on this concept.

Annual crops can be used for supplementary grazing and increasing the carrying capacity of the land. In addition, there is the direct spread of manure by the animals. Grazing annual pastures when perennial pasture are unavailable can keep livestock out of confinement pens and reduce disease and lameness. Growing annuals for supplementary pastures is more expensive than grazing perennial pastures because of the annual seeding costs. However, the cost of feeding stored feed in winter is much greater than grazing (McCartney et al. 2004a). Thus, the main role of annual pastures in Canada is to extend the grazing season on cropping land as part of a perennial pasture system.

ANIMAL HEALTH CONCERNS

A number of animal health issues may arise while grazing annual cereals. Nitrate poisoning from annual cereal crops including oat can be a problem (Bradley et al. 1940; Osweiler et al. 1985; Radostits et al. 2000). This can occur in a cereal crop when there is a prolonged drought followed by rain, following heavy applications of fertilizer or manure, or if crops have been drought stressed or damaged by hail or frost. When the animals consume these plants, the nitrates are converted rapidly to nitrites, which are absorbed into the blood reducing the ability of the blood to carry oxygen. Nitrate concentrations of plant material greater than 0.5% are considered harmful, with levels greater than 2.5% being potentially fatal (Bradley et al. 1940; Crawford et al. 1966). Juskiw et al. (1999) found that nitrate concentrations were frequently > 0.5%, especially in treatments with spring barley. There have been very few reported cases of nitrate poisoning in western Canada (Dr. Barry Blakley, Prairie Diagnostic Services, Western College of Veterinary Medicine, University of Saskatchewan, Saskatoon, SK, personal communication). McCartney (unpublished data) was able to successfully swath graze oat with nitrate values of 2.3% DM. Cows were adapted to the high nitrate levels by having access to meadow brome (*Bromus biebersteinii* Roem & Schuit) hay for 3 to 4 d at the start of the swath grazing. This tended to dilute the nitrates in their daily ration. There is a need to re-assess the nitrate levels that are considered harmful to the grazing animal as there is considerable confusion in the grazing industry. It appears that the recommendations originated with Bradley et al. (1940) and further research is required.

Winter tetany or wheat pasture poisoning is a metabolic disease caused by lower than average blood magnesium levels and it can occur when cattle graze on winter wheat, straw or other cereal grains (Bohman et al. 1983; Grunes et al. 1984; Undersander et al. 1986;

Radostits et al. 2000). It is often seen in cows in late pregnancy or in the early stages of lactation. High producing cows are particularly susceptible. Dry growing conditions and acidic soils can contribute to the accumulation of potassium in feeds which in turn reduces the amount of magnesium absorbed from the ration. Prevention is through supplementation of the ration with magnesium oxide and limestone.

Bloat has been reported when cattle grazed succulent and rapidly growing winter wheat pastures (Howarth and Horn 1984). Another health concern is atypical interstitial pneumonia, also known as pulmonary emphysema or fog fever and can become a problem when livestock are shifted from dry grazing areas to lush pastures of winter annual cereals (Radostits et al. 2000; Foster 2004).

With the high moisture content and low fibre in annual ryegrass pasture, Burgess and Kunelius (1982) advised feeding adequate amounts of hay in addition to the ryegrass pasture to prevent milk fat depression in high producing dairy cows. The high moisture and low fibre content resulted in cattle becoming dirty with very loose manure. Feeding old hay or straw has been shown to increase the fibre intake and slow the rate of passage in the digestive tract. However, this high rate of passage did not cause any animal performance problems (McCartney 2003).

Ryegrass staggers is a possible disease caused by grazing annual ryegrass (Radostits et al. 2000). The incidence is extremely variable depending on climatic conditions and resembles many other functional diseases of the nervous system, such as winter tetany.

ECONOMICS OF GRAZING ANNUAL PASTURES

The input costs of growing annuals for pasture are considerably higher than perennials, but their grazing potential may be of benefit to overcome shortages of perennial pasture in years of below-average precipitation or when pasture availability is in short supply. Kilcher and Heinrichs (1961) showed that perennial forage mixtures gave the highest hay yields in years with favorable precipitation, while cereals such as oat gave the highest DM forage yields during very dry seasons. They concluded that grazing perennial pastures should be the main source of feed, and grazing cereal crops should be used in conjunction as insurance for providing extra grazing. Perennial pasture management ultimately determines perennial pasture productivity. Annual cropping input costs have increased significantly, which may limit their adoption. Growing annuals for grazing on cropping land may or may not be part of the management strategy. Walton (1975) in central Alberta evaluated oat, barley, and winter wheat and found that while high yields of forage could be obtained from these annual crops, with the exception of oat, the most favorable yields would not justify the additional expense of cultivation and establishment when compared with perennial forage yields.

Willms et al. (1993) concluded that increasing animal condition by grazing annual forages prior to winter grazing prairie fescue was more economical than feeding preserved forage later in March to recover lost body condition.

Using annual cereals grown for extending the grazing season by winter swath grazing can have the biggest impact in lowering winter feed costs (McCartney et al. 2004a). Baron et al. (2004) found that consumption of 11.0 kg DM cow⁻¹ d⁻¹ swathed whole-plant barley was in excess of the levels predicted by NRC (1996) required to provide the energy needs of the pregnant beef cow. The cost of grazing the forage was approximately one-half as much for the swath grazing system compared with a silage system. Further savings in yardage costs of \$0.29 to \$0.52 head⁻¹ d⁻¹ were realized by swath grazing compared with the baled feed and silage systems (McCartney et al. 2004a).

The fall grazing of Italian ryegrass by backgrounding calves was more economical than backgrounding in a feedlot (McCartney et al. 2008). It has been shown that the production cost of mixtures of annual ryegrass with oat for pasture was much lower than fall rye and winter triticale due to higher DM yield (Johnston 2000), and this more than offset the higher seed costs of annual ryegrass compared with the cereals. Johnston (2000) indicated that an oat-annual ryegrass mixture had the lowest grazing cost per head per day (\$0.91 d⁻¹) compared with oat-fall rye and oat-winter triticale mixtures (\$1.48 d⁻¹ and \$1.51 d⁻¹, respectively). The annual ryegrass had the lowest cost of gain at 54 cents per pound which Johnston (2000) claims would be competitive with costs of gain, including overhead costs, in drylot.

Much emphasis in this review has been placed on using annuals as a tool or an option to extend the grazing season as a cost savings grazing option as opposed to the high cost of feeding conserved forage. However, very few studies have evaluated the economics of these systems. An analysis of the net return per hectare or per kilogram of gain is beyond the scope of this review; however, the variation and volatility in the markets for agricultural land prices, input costs and commodity values including the price of beef (and milk) are dependent on producer circumstance and management strategy. With the current high cost of grain for finishing beef cattle, producers are looking for methods of keeping feeder cattle on pasture longer and shortening the time that the cattle are being fed high grain rations in a feedlot. Annual pastures could be used as a means of extending the grazing season and more economic research is required to evaluate and develop these systems.

Benefits of Using Annual Crops –Past, Present, and Future Considerations

It is not surprising that many basic premises of grazing annuals that were discovered 75 yr ago or more, are still

relevant today. With input costs at record highs and profit margins based on feeding stored feed at record lows, increasing the length of time that beef cattle can graze is a lower cost strategy. Cultivar development and refined production and management methods have increased yields of many crops, but the following trends over the years have remained universal: (1) under most conditions, oat is very adaptable and remains the highest yielding of the annual cereal crops and; (2) of the cereals, barley has the highest nutritive value with satisfactory, if not competitive yields to oat, although oat can generally satisfy the maintenance requirements of beef cattle; (3) under grazing conditions, rotational grazing at an early phenological growth stage of the crop is the most effective method of harvesting by the animal, since trampling and wastage can be significant if the crop gets too tall.

There is considerable focus on increasing the acceptance of swath grazing in the parkland areas of western Canada. While there are many early adopters, the question still remains as to why additional producers are not switching to this winter cow management system. Agricultural economists are speculating that the cow-calf producer's fear of risk of losing their feed resource needs to be overcome before they will adapt this new winter management system. Grazing damage from water fowl, elk and deer could possibly be one of the localized reasons for not adopting swath grazing. Excessive snow might be a problem, but supplemental hay could be fed during these times and the remaining swath material could then be grazed in the spring. However, the lack of infrastructure in the form of fields suitable for planting cereals, adequate fencing, water source and shelter could be the most limiting reason for the lack of adoption of this grazing system.

With the current economic downturn in the beef industry, and the high feed grain prices, many producers are evaluating the use of extended grazing as a means of lowering cost. Grazing strategies will likely consider the benefits of using annual crops. Backgrounding beef cattle in the late summer and fall on predominately annual pasture prior to entry into a feedlot can be a means of providing an alternative to the feedlot system at a lower cost than stored feed. Other grazing management systems include the regrowth from a silage mixture with fall cereals or Italian ryegrass to provide high-quality forage for this purpose.

There is a big advantage for extending the grazing season in the fall for receiver calves coming from auction markets or assembly yards. Respiratory health problems can be substantially reduced by fall grazing receiver calves rather than moving these animals directly into a high density feedlot where the incidence of respiratory disease can occur (McCartney 2000; McCartney et al. 2008). By having the calves in a fall grazing system the incidence of respiratory disease was greatly reduced. Annual forages can be used to provide the required pasture.

Pasture finishing of beef cattle may be another option for some producers. Annual crops could become part of this grazing system. Dairy products from pasture-fed cattle and pasture-finished beef may have a role in niche markets for a health-conscious and aging society in North America. According to Mir et al. (2004), depending on the type and relative maturity of the pasture, beef from pasture-fed cattle may have a higher content of a beneficial conjugated linoleic acid than silage/grain fed beef. The conjugated linoleic acid is potentially capable of providing health benefits in humans, such as anti-carcinogenic effects, decreased blood cholesterol and obesity and enhancement of immunity to name a few (Mir et al. 2004). Research is required to assess the role of annual cereal pastures in enhancing the bio-lipid profile in the grazing animal.

Prior to this review, the production and yield data have been isolated and difficult to consolidate. No additional animal grazing or nutritional related studies have been located. In the past, producers have grown oat and fall rye for pasture use because seed was readily available, stands were more productive and easier to grow. Grazing annual pastures are becoming more popular because drought has decreased perennial pasture productivity and grazing has occurred on annual crops that have failed for commercial production. However, in the future, grazing of annual crops may have a role in conservation farming systems to immobilize nutrient flow by providing a ground cover crop that will use up the soluble nitrogen to prevent the nutrients from moving down into the water table.

We are now seeing the development of a new generation of forage and livestock producers who are recognizing the potential of innovative grazing systems, as illustrated by the large interest in the Grazing Schools and Grazing Conferences in western Canada. Using cropping land for annual pasture can provide high-quality forages for growing livestock and may provide the greatest economic return to the land base. The drought in recent years in Manitoba, Saskatchewan and parts of Alberta, has caused producers to re-evaluate the role of grazing annual crops as an alternative. Hay and pasture rental costs have escalated in some regions to a point where they are no longer considered economical. Thus annual cropping systems that integrate silage mixtures and fall grazing are a viable option.

Research Challenges in the Future

We have been able to locate and summarize the majority of the research information on the yield and quality potential of cool season annual cereals crops for possible use in grazing systems in Canada. Forage silage yield of annual cereals is the main information available. In some cases only research reports exist and this important information has been included to present the total research efforts by many research groups on the subject. In many regions of Canada, oat appears to have the highest yield potential for grazing. Thus the use of other

possible annual crops must be evaluated in relationship to the costs of grazing oat. Unfortunately, many of the studies involving winter cereals and Italian ryegrass did not involve oat. In the future, research studies should include oat in the comparisons. In addition, the oat forage breeding program in Canada and North America has been drastically reduced. This area of research needs to be readdressed. The further selection and registration of current lines originally selected for forage use needs to be completed before these plant breeding materials are lost.

Recent trends in agriculture point to developing and accessing markets geared towards local consumers who are demanding safe, high-quality, natural products that are produced in an environmentally sustainable manner. Using grazing techniques such as silage mixtures for silage and fall grazing to background or pasture finish beef or produce dairy products is a natural way to develop local healthful products. In addition, annual crops for grazing can be used in a holistic approach for crop rotation, natural or organic farming.

More research is required on validating the role of annual cool season crops other than oat and barley for grazing potential. Actual animal grazing trials are required with a full economic analysis compared with feeding stored feed in a feed yard. The added value of pasture-finished beef needs further economic evaluation.

With the current economic crisis facing the beef industry due to high feed grain costs, alternatives must be found. Research is needed to develop management systems that producers can use to produce consumer-acceptable meat products with limited grain used for finishing feedlot animals. Extended grazing of calves on high-quality perennial and annual cereals pastures rather than feeding them for long periods of time on high priced grain in a feedlot could be a method of lowering the overall cost of production and preventing economic collapse of the Canadian beef industry.

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