Potential of warm-season annual forages and *Brassica* crops for grazing: A Canadian Review

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McCartney, D., Fraser, J. and Ohama, A. 2009. **Potential of warm-season annual forages and *Brassica* crops for grazing: A Canadian Review.** Can. J. Anim. Sci. **89**: 431–440. Extension of the grazing season beyond the normal perennial grazing season has been identified as a potential mechanism to reduce the cost of production on Canadian cow-calf operations. This review will provide an overview of the potential use of warm-season and *Brassica* crops including corn (*Zea mays*), Golden German foxtail millet (*Setaria italica* L. Beauv.), kale (*Brassica oleracea* L.), forage rape (*B. napus* ssp. *biennis* L.) and turnip (*B. rapa* L.). These crops have a high yield potential, but the cost for grazing these crops has not been adequately compared with the cost of grazing oat (*Avena sativa* L.), barley (*Hordeum vulgare* L.), and fall rye (*Secale cereale* L.). There are very few actual animal grazing trials evaluating the economics of using these crops in grazing systems in Canada, and this requires further research.

Key words: Corn, millet, sorghum, sudan grass, fodder crops, brassicas

McCartney, D., Fraser, J. et Ohama, A. 2009**. Potentiel des annuelles fourragères de la saison chaude et des cultures du genre *Brassica* pour la paissance. Panorama au Canada.** Can. J. Anim. Sci. **89**: 431–440. Prolonger la saison de paissance au-delà de la saison normale des vivaces concourrait à réduire les coûts d'élevage des naisseurs canadiens. L'article que voici brosse un panorama de l'usage potentiel des cultures de la saison chaude et des espèces du genre *Brassica* pour la paissance, notamment le maïs (*Zea mays*), le millet des oiseaux (*Setaria italica* L. Beauv.), le chou fourrager (*Brassica oleracea* L.), le colza fourrager (*B. napus* ssp. *biennis* L.) et le navet (*B. rapa* L.). Ces cultures présentent un potentiel élevé, mais on n'a pas comparé adéquatement le coût de leur paissance à celui de l'avoine (*Avena sativa* L.), de l'orge (*Hordeum vulgare* L.) et du seigle d'automne (*Secale cereale* L.). On procède actuellement à très peu d'essais pour évaluer les paramètres économiques de l'usage de ces cultures dans les systèmes de paissance au Canada, ce qui milite en faveur de recherches plus poussées.

Mots clés: Maïs, millet, sorgho, herbe du Soudan, cultures fourragères, *Brassica*

Since the early 1900s, cow-calf producers have grazed annual crops as an alternative to deal with drought and perennial pasture shortage as a means of lowering their annual costs. Extension of the grazing season beyond the normal perennial grazing season is an alternative low-cost method. A previous review (McCartney et al. 2008) summarized the potential of annual cool season cereal crops for grazing. There has been considerable interest in evaluating the grazing potential of warm-season annual crops for their suitability in extending the grazing season in Canada because warm-season annuals tend to be seeded later and vary in days to maturity (May et al. 2007). This could be advantageous in a grazing system for extending the grazing season. This review summarizes warm-season and *Brassica* crops that show promise in grazing systems that are applicable to Canadian conditions. As limited published research on this grazing method can be found, historical information from other types of research summaries will be included as the information still has value.

GRAZING WARM-SEASON CROPS

Corn

In the moist warm regions where corn (*Zea mays*) is traditionally harvested as a grain crop, the stover or crop residue has been used as a grazing resource for late fall or winter grazing for weaned calves and dry pregnant beef cows (Ward 1978; Klopfenstein et al. 1987; Gutierrez-Ornelas and Klopfenstein 1991; Poland et al. 2003). In this type of grazing system, the quality of the ration depends upon the amount of grain left in the field after harvesting. Gutierrez-Ornelas and Klopfenstein (1991) in Nebraska found in vitro organic matter digestibility (IVOMD) concentrations from the grain, husks, leaf blades, stem and cobs were 986, 684, 420, 410 and 481 g kg^{-1} dry matter (DM), respectively, with

Abbreviations: CP, crude protein; **ADF**, acid detergent fibre; **NDF**, neutral detergent fibre; **DM**, dry matter; **TDN**, total digestible nutrients; **IVOMD**, in vitro organic matter digestibility reported live weight gains of 1 kg d^{-1} on dry beef cows grazing in corn fields after harvest.

Recently in Canada there has been interest in grazing standing corn to avoid the costs of conventional harvesting and storage. However, corn production is limited to areas receiving a minimum of 2000–2100 corn heat units (Macaulay 2004; Erickson et al. 2005; Aasen and Bjorge 2009). This limits the growing areas to the southern portion of eastern Canada and the southern area of the prairies. A research trial in New Liskard, ON, showed that ewes grazing corn recorded reasonable weight gain (154 g d^{-1}) and adequate condition score gains (Johnston et al. 2000b). Corn has been successfully grazed at Nappan, NS, during the summer. Muddy field conditions have limited adoption of standing or residue corn grazing in eastern Canada. (John Duynisveld, Agriculture and Agri-Food Canada, Nappan, NS, unpublished data).

McCaughey et al. (2002) in Brandon, MB, evaluated several varieties of corn for grazing as a standing crop, or swathed and later grazed during the winter. Swathing the corn was difficult due to the height and volume of the crop. Carrying capacity and forage quality at the time of consumption were better when corn forage was swathed than when it was left standing. Dry matter yields ranged from 4000 to 14,600 kg DM ha^{-1} with carrying capacity for dry pregnant beef cows ranging from 281 to 546 cow grazing days ha^{-1}. The high input costs of the corn seed and herbicide cost were a concern.

In Lanigan, SK, corn grazing trials showed that early-maturing silage-type corn varieties provided excellent late-season grazing either grazed as a standing crop or swath grazed during the winter (Lardner 2000, 2002). Forage quality in corn varied according to cultivar and seeding date with early-maturing cultivars such as Canamaize (Canamaize Seed Inc., Minto, MB) having higher crude protein (CP) (119–125 g kg^{-1}) than late-maturing cultivars such as Amaizing Graze 101 (Baldridge Hybrids, Cherry Fork, OH) (91–108 g kg^{-1}). The greatest number of dry cow grazing days was obtained with Canamaize and Hyland corn (Prairie Seeds Ltd., Nisku, AB) at 132 and 121 animal grazing days ha^{-1} respectively. In another study, corn that was sod seeded into old perennial pastures for fall grazing yielded 7800 kg DM ha^{-1} DM (Lardner 2000). The fields had been treated with 1.3 kg a.i. ha^{-1} of glyphosate [*N*-(phosphonomethylglycine)]; however, the corn did not compete well with volunteer grass during the first 6 wk of establishment. Adequate weed control and high fertility requirements plus high seed costs increased the cost per hectare compared with barley. Elsewhere, May et al. (2007), in plot trials in southeastern Saskatchewan, found that corn had variable yield (1.3 to 13.7 t ha^{-1}) and in some cases yielded similar to oat or barley, but often did not reach physiological maturity. May et al. (2007) also noted in their study that corn was marginal in meeting the CP requirements of pregnant beef cows.

Willms et al. (1993), in southern Alberta, showed that grazing whole corn allowed cows to maintain body weight from November to February, and minimized feed inputs prior to calving. The corn did not mature, but the CP and IVOMD were 84 g kg^{-1} DM and 829 g kg^{-1} DM, respectively. Baron et al. (2003) evaluated corn varieties [Canamaize, Amaizing Graze 101 and conventional silage varieties (Pioneer 39K72, 39N03, 39T68 from Pioneer Hi-Bred Ltd., Chatham, ON)] in plot trials at Lacombe and Brooks, AB. Dry matter yield and IVOMD concentration declined, while neutral detergent fibre (NDF) concentration increased by 10% over the period from September to January. Energy and CP concentration of corn during winter exceeded minimum nutrient requirements and were adequate for non-lactating, pregnant beef cows. Grazing and short stature corn varieties were not superior to early conventional corn genotypes for winter grazing potential. They concluded that the choice of using corn for winter grazing should be made on the basis of cost of production, early maturity and long-term reliability of suitable weather for growing corn. Although corn is still not as economical to grow and graze as cereals in western Canada, it is much more economical to be grazed than as silage due to the increased harvesting costs (Aasen et al. 2005; Erickson et al. 2005). With the availability of glyphosate-resistant corn varieties, new grazing research is required to assess the economic merits of using early varieties of this type of corn compared with grazing oat, barley or fall rye in winter grazing systems (McCartney et al. 2008).

As discussed above, corn for grazing has generated variable results in yield, forage quality, response to environmental conditions and geographic adaptability. Other considerations include; high seed and herbicide costs, restrictions on herbicides that can be used for corn grazing and the requirement for adequate soil temperatures and corn heat units for maturation. Last, there are labour and management problems in trying to regulate grazing of standing corn using electric cross fencing as wide paths have to be mowed to prevent the standing corn from falling on the electric fence. The alternative would be to swath the corn prior to grazing. We conclude that the cost versus benefit of grazing whole plant corn may not be practical relative to other annual crops such as oat, barley or fall rye. Additional economic grazing research is required.

Sorghum, Sorghum-sudan

Sorghum (*Sorghum bicolor* L. Moench) is relatively new in Canada for grazing, and includes grain and forage sorghums and, sudan grass [formerly *Sorghum sudanense* (Piper) Stapf, now classified as *S. bicolor* (L.) Moench (Harlan and de Wet 1972) or *Sorghum vulgare* Pers.], and sorghum-sudangrass [*Sorghum bicolor* (L.) × *S. Arundinaceum* (Desv.) Stapf var. *sudanense* (Stapf) Hitchc.] (Undersander et al. 2000b; Undersander 2003). Sorghum is a coarse erect grass from 0.45 m to over 5 m in height with grains of different sizes, but small in comparison to corn. The structure, growth and general appearance of forage sorghums are similar to corn (Fribourg 1995; Undersander et al. 2000b, Aasen and Bjorge 2009). Grain sorghums have 25 000–60 000 seed kg^{-1}, while grass sorghums have 120 000–150 000 seed kg^{-1} (Fribourg 1995). Sudangrass is a fine-stemmed, tufted annual grass with heavy tillering, but no rhizomes (Duke 1983). Sorghum-sudangrass hybrids are taller, have larger stems and can be higher yielding than sudangrass (Undersander et al. 2000b).

The main advantage of sorghum, sudangrass and hybrids over corn is their drought tolerance. Sorghums can be grown when annual precipitation is as low as 400 mm and are thus suited to warm semiarid regions. They can also resume vegetative growth after drought-induced dormancy (Fribourg 1995). The most favourable growth temperature ranges between 25 and 30°C. These species may be used for supplemental grazing when perennial cool season forages go into a semi-dormant stage during the hot summer months (Najda 2003).

Several small plot research trials in different regions of Canada have evaluated these crops. In Nova Scotia, forage yields of sorghum, sudan grass and sorghum-sudan hybrids ranged from 6400 to 9900 kg DM ha^{-1} [Nova Scotia Crop Development Institute (NSCDI) 1993]. However, sorghum was not suitable for pasturing until it reached a height of 60–65 cm as young plants and early regrowth contained high levels of prussic acid. McKinlay and Wheeler (1998), in Ontario, found that sorghum-sudangrass hybrids were more efficient in water absorption because they had twice as much secondary root system, and only half as much leaf area as corn for evaporation loss. They also found that sorghum-sudangrass had 170 g kg^{-1} DM CP, 290 g kg^{-1} DM acid detergent fibre (ADF) and 55 g kg^{-1} DM NDF when cut at the vegetative stage. However, the quality of sorghum-sudangrass can be variable, making it more suited for grazing with low-producing cows, dry cows and heifer replacements. Wedin (1970) found CP concentrations of 184 g kg^{-1} DM and IVOMD of 701 g kg^{-1} DM for frequently harvested sudangrass and sorghum-sudangrass hybrids.

At Swift Current, SK, Holt (1993) grazed steers on sorghum-sudangrass and average daily gains were 0.97–1.18 kg d^{-1}. Hubbard and Waldern (1976) in the interior of British Columbia showed that sorghums could be planted later than corn and could be grazed about 8 wk after seeding. Undersander et al. (2000b) found that sudangrass was superior in forage yields to other sorghums in Wisconsin or Minnesota (similar to Canadian conditions), but only when used for pasture. This type of pasture could provide abundant grazing with DM yields ranging from 6720 to 13 440 kg DM ha^{-1} in mid to late summer when perennial cool-season species such as alfalfa and timothy (*Phleum pratense* L.), become dormant.

Klopfenstein (1994) showed that grain sorghum stubble provided better winter grazing than corn stalks since the grain sorghum heads were located near the top of the plants with more standing leaves available above the accumulated snow. Compared with corn, the leaves of standing grain sorghum had higher protein (60–130 g kg^{-1} DM) than corn leaves (62–75 g kg^{-1} DM), but the grain was not as well utilized as corn grain due to trampling (Klopfenstein 1994).

Seeding date can have an effect on sudangrass or sorghum-sudangrass productivity. In Illinois, which is similar in climate to southern Ontario, seeding sorghum-sudan hybrid in late June-early July rather than May resulted in an 18% decrease in seasonal carrying capacity, but 29% more grazing during late July, August and September, since the later-seeded forage remained in the vegetative state (Spahr et al. 1967). This factor could be very important if supplemental pastures are needed late in the summer and fall in areas with sufficient heat units.

In southeastern Saskatchewan, May et al. (2007) found that sorghum-sudangrass had poor and inconsistent emergence at either seeding date of May 15 or June 10, noting that minimum recommended soil temperature was above 18°C. Forage yield tended to be highly variable, and most often vegetative yields were low due to late maturities (0.2–13.0 t ha^{-1} across harvest times, seeding date, years and locations; 4.83 t ha^{-1} using the most appropriate seeding date and harvest time). Compared with using other warm-season species such as foxtail millets (to be discussed below); corn, despite the variability exhibited, and traditional cool season crops such as oat and barley, it was concluded that current varieties of sorghum-sudangrass were not suitable for swath grazing in Saskatchewan. More-detailed grazing research evaluating the economics of growing these crops for grazing compared with cool season cereals is required in regions that have adequate heat units and moisture.

Millets

Millets includes a number of cultivated semi-arid tropical annual grasses such as proso millet (*Panicum miliaceum* L.), foxtail millet (*Setaria italica* L. Beauv.), pearl millet (*Pennisetum glaucum* L.R. Br.), and Japanese or barnyard millet (*Echinochloa frumentaceae* L.) (Wheeler 1950; Baltensperger 1996; Aasen and Bjorge 2009). Proso millet is grown primarily for birdseed and secondarily as forage in Canada. Proso millet has a panicle type seed head, awns, coarse stems and is less leafy than foxtail millet, and consequently has a lower palatability for grazing than foxtail millets (Wheeler 1950; Baltensperger 1996). Proso millet may grow from 50 to 150 cm high, is a short-season crop with a low water requirement, and grows further north (up to 54°N) than the other millets (Hinze et al. 1978; Matz 1986). Compared with foxtail millets, proso millet is quite prolific with volunteer plants, has more aggressive seedling vigour and quickly covers the ground to out-compete weeds. A disadvantage of millet is the lack of chemical weed control options. Proso millet is known for its drought tolerance and rapid maturity, and this may be advantageous in the event that it is seeded to replace an earlier seeded crop failure (Baltensperger 1996; ARECA 2006). Proso millet is tolerant of chemical residue from atrizine herbicide [6-chloro-N-ethyl-N′-(1-methylethyl)–1,3,5-triazine-2,4-diamine] used in corn crop rotations. This may be advantageous for establishment, especially when used for grazing in zones with marginal growing conditions; however, the lack of adequate chemical control measures to control volunteer proso millet in subsequent corn crops is of great concern especially in Ontario (Bough and Cavers 1987).

Very little grazing information is available on millet, and the information that is available is highly variable. In a clipping frequency test (irrigated) at Brooks, AB to simulate grazing pressure, proso millet provided only one harvest of 5920 kg DM ha^{-1} at July 15 (Riemer and Gaudiel 1984). At Lacombe, AB, proso millet produced the highest yield (5530 kg DM ha^{-1}) in 5 harvests. Proso and foxtail millets had considerable year to year yield variability, and poor seedling vigour compared to barley and oats (Riemer and Gaudiel 1984, 1986). Proso cultivars had consistently higher yields (6590 kg DM ha^{-1}) than the foxtail types (5600 kg DM ha^{-1}). These authors suggested that the yield variability in proso and foxtail millets could be used for selection under dryland conditions. At Lacombe, Berkenkamp and Meeres (1988) evaluated several lines of proso millet and foxtail millet for yield, but found that both types of millets were extremely frost sensitive and not adaptable to the Aspen Parklands' short growing season.

In studies at Swift Current, SK, Holt (1993) found that the productivity of annual crops tended to be less variable than that of perennial forages over the years. The average steer grazing days ha^{-1} were 225 for fall rye, 198 for sorghum-sudangrass, 173 for proso and foxtail millet, 173 for spring cereals of wheat or oat and 148 for spring/winter cereals of spring/fall rye and spring/winter triticale. The mean average daily gain across all treatments was 1 kg d^{-1} and was greater than the steers grazing perennial pastures in that area. Crude protein concentration of spring-seeded proso millet (pre-boot stage) at Swift Current, was 229 g kg^{-1} DM, which was higher than oat, and fall rye (211 and 209 g kg^{-1} DM), respectively (Holt 1993).

May et al. (2007) found that the proso millet cultivar, Crown, had DM yield similar to oat and barley at fertility levels of 55 kg ha^{-1} of nitrogen (6.15 T ha^{-1} DM yield), but lower than corn at 135 kg ha^{-1} of nitrogen (8.78 T ha^{-1} DM yield); however, proso millet did not yield as consistently as did Golden German foxtail millet.

Foxtail millet is also known as Italian millet, German millet or hay millet (Baltensperger 1996). It is an annual grass with slender, erect, leafy stems and grows from 50 to 150 cm high and requires soil temperature greater than 10°C. Foxtail millet is generally taller, later maturing and better suited to forage production than proso millets. The seeds are borne in a compact spike that resembles the spike of green foxtail (*Setaria viridis* L.). Low seedling vigor, poor competitiveness and limited weed control options are a disadvantage of growing foxtail millets. Unlike proso millet, foxtail millet can be seeded at a later seeding date where it rarely reaches the stage of maturity to produce viable seed. This has the advantage of no volunteer plants to control in the future. Foxtail millet is more palatable for grazing than proso millet, but cattle need to adapt to it. Preliminary research at Brandon, MB, showed that White Wonder foxtail millet was a slightly coarser, later-maturing plant more suited to arid conditions of the western Prairies, whereas Golden German foxtail millet was more suited towards higher rainfall areas with heavier darker soil (McCaughey et al. 2002). The authors suggest that millets may be a good alternative crop for fall and winter swath grazing in areas with high summer heat such as 32–35°C. The advantage of grazing Golden German foxtail millet was its ability to grow in high temperatures, and when seeded late it would not produce viable seed for volunteer growth in the future. Golden German foxtail millet was seeded in the middle of June and swathed as soon as the crop headed in order to prevent volunteer seed from causing a problem in the succeeding crop. DM yields of Golden German foxtail millet ranged from 7270 to 8860 kg DM ha^{-1} over 4 yr with carrying capacity of weaned cows ranging from 188 to 385 grazing days ha^{-1}. Golden German foxtail millet grew well in hot dry weather, whereas other cereal crops did not perform, and costs were comparable to growing cereals for swath grazing. Elsewhere, in Lanigan, SK, backgrounding newly weaned calves on swath grazed Golden German foxtail millet averaged 1.06 kg d^{-1} over a 26-d period (Lardner 2004). In another study, Lardner et al (2008) backgrounded weaned calves on swathed millet and found the cost per kilogram of weight gain was $1.90 for calves grazing millet, while calves on swathed barley cost $ 1.39 kg^{-1}, and calves in the feedlot cost $2.57 kg^{-1}. Research trials grazing millet have variable results. Helm (1988) found that foxtail millet had shallow roots and could be easily uprooted by grazing animals. The regrowth after grazing was slow, especially when there was a shortage of soil moisture, and millet was not recommended for pasture except in an emergency situation.

With the increased interest in grazing warm-season annuals, May et al. (2007) evaluated in plot trials, cool (oat and barley) and warm-season annuals (proso Crown millet; Red Siberian foxtail millet, Golden German foxtail millet, pearl millet, sorghum-sudangrass, and corn) seeded in mid May and mid June at six locations in Saskatchewan to evaluate seeding date, harvest times, adaptation, feed quality and DM yield. May et al. (2007) found that unless the soil temperatures were cold, there was uniform and vigorous emergence of both proso and foxtail millets both in May and June. First harvesting date for millets was 2–3 wk after heading, and 2 wk after the first harvest, which resulted in the foxtail and proso millets having reached the grain-filling stage. The foxtail millets required more growing degree days than the proso millet, where Red Siberian foxtail millet required fewer growing degree days than Golden German foxtail millet. Overall Golden German foxtail millet had the most significant and consistent characteristics for swath grazing. The warm-season annuals seeded in mid June required fewer days to heading, than when seeded in mid May, although overall the authors found that forage yield was most affected by crop and its response to the environment and not by seeding date. For the oat and barley, when precipitation was abundant, these cool-season crops made best use of the available water, and when the temperatures were lower, these crops had the highest yields under conditions of high rainfall and low growing degree days (6.48 t ha^{-1} averaged across seeding dates). Proso, Crown millet DM yields were maximized with higher growing degree days and moderate rainfall (6.18 t ha^{-1}), whereas Golden German foxtail millet maximized yield as both growing degree days and rainfall increased (6.35 t ha^{-1}). Under these conditions, oat and barley yields were low. May et al. (2007) suggested that the difference between the millets' response to environmental condition may be explained by species differences between the millets or to the later maturity of Golden German foxtail millet. The authors go on to suggest that since the yields of oat and barley were low when Golden German foxtail millet yield was high, using fields of oat or barley in combination with fields of Golden German foxtail millet may provide the most stable yield over time. The CP concentration of proso, Crown and Golden German foxtail millet (93–97 g kg^{-1} DM) was sufficient to meet nutritional requirements for cattle winter grazing and weathering in the swath did not reduce feed quality. Last, harvest date did not have a large effect on yield or quality of the warm-season annual cereals; however, this study did not determine the best development stage for swathing foxtail millet for swath grazing. This study should be followed up with a grazing study comparing the economics of grazing these different crops.

Pearl millet is a tall, erect annual grass which can grow to 4.5 m. (Wheeler 1950). The inflorescence is a dense spike-like panicle. Pearl millet can be grown where annual precipitation is as low as 250 mm (Baltensperger 2002), and can resume vegetative growth after drought-induced dormancy (Fribourg 1995). It is adapted to poor, droughty and infertile soils because it will produce more reliably under these conditions than other grain crops (Baltensperger 2002). Compared with sudan grass, pearl millet is coarser, slightly less palatable to livestock and is less tolerant of severe drought.

Hubbard and Waldern (1976) used pearl millet for temporary summer pasture in British Columbia, and found that pearl millet should not be grazed until it was 45–55 cm high, and regrowth was 50 cm before being regrazed. Very little grazing research has been done in eastern Canada with pearl millet. However, in plot trials, DM yields of 12 000 kg ha^{-1} were similar to sudangrass while Japanese millet was 6000 kg ha^{-1} (Banks and Stewart 1998). Pearl millet had slightly higher CP concentration of 180 g kg^{-1} DM than sudangrass, Japanese millet or corn. The TDN concentration of pearl millet was 690 g kg^{-1} DM. Pearl millet was very sensitive to frost and was not recommended for early seeding. Unlike sorghums, pearl millet does not produce prussic acid. Palatability has occasionally been found to be a problem in livestock grazing pearl millet, especially when plants were drought stressed. This was due to the presence of alkaloids (Rouquette et al. 1980). Since corn appears to have higher yields it is questionable if pearl millet is an economical supplementary grazing alternative in Canada. Likewise, May et al. (2007) found that pearl millet had low DM yields and was poorly adapted to Saskatchewan.

Japanese millet is coarser and grows more rapidly under cool conditions than foxtail millet (Muldoon 1983). Seedlings establish quickly and tiller profusely, and it could be grown on waterlogged soils and survived short periods of submersion (Koch and Mitchell 1988). Forage dry matter yields of 6200 kg DM ha^{-1} for Japanese millet were reported in Atlantic Canada (NSCDI 1993). Koch and Mitchell (1988) seeded Japanese millet into herbicide-treated sod as a means of renovating pastures. This concept could be used in the moist warm areas of Canada as a possible pasture rejuvenation system. However, research on grazing Japanese millet is minimal, and it does not show characteristics that are suitable for extending the grazing season in the prairies.

In general, there has been renewed interest by cow-calf producers in growing warm-season crops for supplemental pastures in Canada. Higher nitrogen levels will produce considerably higher yield, but severe lodging and the risk of nitrate accumulation in the forage might offset any gains (ARECA 2006). When used to extend the grazing season for swath grazing, millet will resist some weathering in the swath due to a thick waxy coating over its leaves and stems (ARECA 2006). Based on the limited research findings, it appears that using millets for supplementary grazing is best where there is adequate heat units (growing degree days) and moisture on an annual basis. In Canada, this would be considered traditional silage corn-growing areas of southern Canada. Early silage varieties of corn and Golden German foxtail millet appear to have grazing potential; however, control of grassy weeds such as *Setaria viridis* (green foxtail) is a major limiting factor in these crops. The millets, especially proso millet, need to be managed in order that seed is not produced resulting in volunteer plants. New research is required to evaluate the economic benefits and risks of growing warm-season crops for supplementary grazing in comparison with grazing oats, barley or fall rye for supplemental pastures in various ecoregions of Canada.

Brassica crops

Brassica crop can also be used for grazing, and include kale (*Brassica oleracea* L.), forage rape (*B. napus* ssp. *biennis* L.), swedes or rutabagas [*B. napus* L. var. *napobrassica* (L.) Rchb.], stubble (white) turnips (*B. rapa* L.) and their hybrids such as tyfon (*B. campestris* ssp. *sensulato* × *B. rapa* L.), radish (*Raphanus sativus* L.), mangels and sugar beets (*Beta vulgaris*) (Aasen and Bjorge 2009). Annual forage *Brassica* crops have been used extensively in Europe for livestock feed for at least 600 yr (Fitzgerald and Black 1984; Najda 1991). The agronomic practices and the potential of root and other crops for grazing use has been reviewed by Woll (1916) and Morrison (1961). Woll (1916) concluded that fodder corn would produce about 50% more DM and 20% more digestible DM per hectare than root crops at one-half the cost of, harvested and stored root crops. In an early grazing trial at Ottawa, ON, forage rape was a valuable forage crop grown as supplementary summer and fall pasture, but due to its high moisture content and low CP concentration, supplementation was required. Early reports from the Hay and Pasture Improvement Committee (1940) evaluated marrow stem kale, thousand-headed kale, and dwarf Essex rape for extending grazing in the fall in Ontario. Unfortunately, all of these early experiments were derived from non-replicated and non-peer-reviewed reports and were used to develop early forage and grazing management recommendations; thus, the research results might not be entirely accurate.

Research on root crops began as early as 1910 in Atlantic Canada and in the 1930s root crops were extremely popular as livestock feed because they were well suited to the Maritime climatic and soil conditions (NSCDI 1993). Despite root crops being well suited to the Atlantic conditions, interest in them as livestock feed dramatically decreased by late 1940s. The decrease was attributed to the high cost of labour and the damage caused by club root (*Plasmodiophora brassicae*). Results at that time showed that it cost approximately twice as much to produce a tonne of digestible nutrients from a root crop as from a hay crop. However, some farmers still found swede crops profitable as a forage crop and from 1953 to 1957 swede hybrids were evaluated for disease resistance. Interest in grazing fodder crops was renewed in the 1980s as these crops were frost tolerant, and provide late-season grazing in the Atlantic provinces (NSCDI 1993). Forage rape, turnip and forage radish under simulated grazing provided 4350 and 5690 kg DM ha^{-1} averaged over three harvest dates. September harvest of forage rape resulted in a yield of 5540 kg DM ha^{-1} and 138 g kg^{-1} DM for CP concentration. Yield of DM yield increased to 7900 kg DM ha^{-1} by late October and CP concentration decreased to 98 g kg^{-1} DM. Yield of DM and CP concentration then remained unchanged until early December (Kunelius and Sanderson 1989, 1990). Narasimhalu et al. (2000) found a similar increase in kale from 8700 kg DM ha^{-1} in October to 11 400 kg DM ha^{-1} in November and having a CP concentration of 130 g kg^{-1} DM. The DM yield of kale declined as seeding dates were delayed and it was concluded that kale should be seeded by mid-June (Kunelius et al. 1987). Primary yield of forage rape, radish and turnip hybrid remained the same from May to July seeding dates and regrowth yields were maximized with the earlier seeding (Kunelius et al. 1987). The IVOMD concentration ranged from 920 g kg^{-1} DM for kale to 855 g kg^{-1} DM for radish,k while CP concentration averaged 181 g kg^{-1} DM.

Western Canadian research on root crop was first reported in 1924 (Anonymous 1924). Morden, MB, reported that the cool, wet July, August and September proved favourable for the growth of turnips, but excessive rains in September caused roots to develop in the swedes. However, they reported 72 000 kg ha^{-1} (wet weight) yield from mangels. Indian Head, SK, claimed to have very low root yields on low fertility grain land and Swift Current, SK, reported yields for mangels and turnips at 28 100 and 25 270 kg ha^{-1} (wet weight), respectively. After 10 yr of working with root crops it was doubtful if these crops would be used for forage crops because of the high hand labour inputs to grow and harvest the crop (Anonymous 1924, 1936, 1946). Mangel and sugar beet were susceptible to late spring frosts, soil drifting, cutworms and other biting insects. Turnips were not as susceptible to these hazards, but yields were often reduced by maggots. Forage rape was found to be a good annual late fall pasture, despite its high moisture content and was not injured by early fall frosts (Anonymous 1940).

Berkenkamp and Meeres (1988) at Lacombe, AB, evaluated several species of *Brassica* crops including kale, forage rape, grazing turnip, fodder and oilseed radish and canola (*B. napus* L.) for pasture yield under a simulated pasture study. They found that under a single cut system, depending on the year, kale produced 6320 DM ha^{-1} to 16780 kg DM ha^{-1}, but under simulated grazing yielded between 2260 and 3000 kg DM ha^{-1}. This was 33 to 50% of the DM yield of oilseed and fodder radish, forage rape and grazing turnip under simulated grazing. Oilseed radish produced the highest pasture yields of over 6200 kg DM ha^{-1}.

Najda (1991) found that forage rape grew faster than kale and produced a leafy crop that was ready to graze about 8 wk after seeding. There are two kinds of forage rape, the giant type and the dwarf type. The DM yields of the giant type of rape under irrigation in Alberta were over 10 000 kg DM ha^{-1} (Najda 1991).

Hybrids

Rape, rape × Chinese cabbage, turnip × Chinese cabbage and rape × swede hybrids have been evaluated under frequent cutting and yield was least under frequent cutting (30 and 60 d), but also had the lowest total yield (7000 vs. 9200 kg DM ha^{-1}) (Jung et al. 1988). The hybrids were either more suited to a single cut or frequent cutting. Compared with the check forage rape variety yield at 180 d (9460 kg DM ha^{-1}) the rape × swede hybrid yielded 94% of the check, while the other hybrids yielded less than one-half to one-third. Under frequent harvest, the turnip × Chinese cabbage and rape × swede hybrids yielded 66% of the check and the rape × Chinese cabbage hybrids yielded 93% of the check. It was noted that the early maturity and disease susceptibility of the rape or turnip × Chinese cabbage hybrids limited their usefulness to harvest schedules with frequent crop removal. Therefore, these crops were less suited for stockpiling forage than some cultivars of forage rape. Similarly, Wiedenhoeft (1993) found turnip × Chinese cabbage hybrids to have a high potential for top production under frequent harvesting when compared with rape and stubble turnip in Maine. Jung et al. (1988) found CP concentration in hybrids ranges from 174 to 277 g kg^{-1} DM, equivalent to 2860 to 6400 kg CP ha^{-1}. The regrowth had a lower fibre and higher protein concentration than early growth (Wiedenhoeft and Barton 1994).

Turnips and Other Root Crops

Both the root and leaf portion of a turnip are palatable and nutritious for grazing animals (Rook 1998). Some varieties of turnips, swedes and their hybrids are ready for grazing within 60 to 90 d after seeding (Jung et al. 1986; Bartholomew and Underwood 2002). At New Liskeard, ON, ewes grazed stubble turnips between 42 and 58 d, with liveweight gains ranging from 113 to 166 kg ha^{-1} (Johnston et al. 2000a). A study at Scott and Loon Lake, SK, indicated that turnips had potential to extend the grazing season in western Canada with tops having higher CP concentration than roots (Phelps et al. 2003), but lower TDN concentration (Rook 1998). Turnip tops survived temperatures between −6 and −9°C, while the roots were a few degrees hardier (Bartholomew and Underwood 2002). Plants were both cold hardy and drought tolerant and were ready for grazing when plants were 30 cm tall, 150–180 d after seeding (Undersander et al. 2000a). Koch et al. (2002) found CP concentration in turnip roots under irrigation averaged 100 g kg^{-1} DM, radish tops 119 g kg^{-1} DM and sugar beet tops averaged 88 g kg^{-1} DM. The CP concentration varied more between years than between crops. Koch et al. (2002) observed that sheep consumed between 85 and 90% of the turnip and radish tops. About half of the turnip roots were utilized even though the roots were not removed, and very few of the radish roots were consumed by the sheep. Heinemann and Hanks (1980) and Heinemann (1984) also had high utilization when grazing lambs consumed an average of 92, 82 and 75% of purple top turnip, cow turnip and radish, respectively. One of the limitations of turnips and other *Brassica*s is the fact that they are hosts of the sugar-beet cyst nematode *(Heterodera schachtii* Schm.), which is detrimental to the sugar beet industry (Koch et al. 2002).

Wiedenhoeft and Barton (1994) found that forage rape, turnip and turnip hybrids produced CP concentration (195 g kg^{-1} DM), ADF concentration of (110 to 360 g kg^{-1} DM) and NDF concentration of (140 to 420 g kg^{-1} DM) late into the fall, thus providing a fresh forage alternative to stored forage or purchased feed. All of the fodder crops reviewed had CP concentrations that were between 70 g kg^{-1} DM (Yun et al. 1999) and 280 g kg^{-1} DM under frequent cutting (Jung et al. 1988) and Kunelius et al. (1987) reported organic matter digestibilities of 850 to 920 g kg^{-1} DM. These crops could maintain dry pregnant cows. Although DM yield tended to be highly variable under single cut conditions, yield was consistent and productive under a grazing harvest system (Berkenkamp and Meeres 1988). In contrast, beets, particularly mangels and to some degree sugar beets, were once a popular livestock feed, but their susceptibility to disease limited their current use (Anonymous 1924, 1936, 1946; NSCDI 1993). The low fibre and DM concentration of *Brassica*s may negatively affect livestock performance unless roughage (hay) is provided (Guillard and Allinson 1988).

With the more recent interest in re-evaluating non-traditional varieties of annual forages for supplementary grazing, demonstration plots at the Lacombe Research Centre, AB, in 2004–2006, revealed information that concurred with much of the above mentioned earlier research (Woll 1916; Arvid Aasen, Western Forage Beef Group, Alberta Agriculture, Lacombe, AB, unpublished data).

The cereal crops (barley, oat and triticale) tended to have more stable forage yields from year to year. Triticale and oat had similar DM yields and barley tended to yield approximately 15% less than the oat or triticale. Golden German foxtail millet, Siberian foxtail millet, proso millet and red proso were evaluated and golden German millet had yields similar to barley in the 3 yr it was grown. The other millets tested had much lower yields than the golden German millet. Two turnip varieties were tested and the tops were harvested and allowed to regrow until fall when the tops were cut and the tubers were harvested. When only the top growth was considered, the forage yields were much lower than those of the cereals, but when tubers were included, the yields were similar to oat and triticale. The tubers increased the total yields by about 30%. Turnips had the lowest fiber levels and the highest moisture content at around 90%. This high moisture level can cause poor preservation of the material when used for winter grazing or for stored feed. The millets were all considerably higher in fiber than the three cereals tested, but this may have been affected by stage of maturity. Barley had the lowest fiber level of the three cereals tested. The yield results obtained with the millets in relation to the cereals were consistent with earlier work carried out by Reimer and Gaudiel (1984, 1986).

Very few studies evaluating the economics of grazing *Brassica* crops have been done. Lardner (2003) showed that the grazing costs of turnip per AU d^{-1} were greater than $1.00 per day compared with $0.80 per AU d^{-1} for swath grazed barley. Additional replicated grazing research trials are required to examine the overall cost of grazing these warm-season and *Brasica* crops compared with grazing oat, barley or fall rye (McCartney et al. 2008).

Animal Health Concerns when Grazing Warm-season and *Brassica* Crops

Prussic acid poisoning is a concern in feeding sorghum, sudangrass, or sorghum-sudangrass hybrids (Radostits et al. 2000). These species contain varying amounts of dhurrin, a glucoside that is converted in the rumen into hydrocyanic or prussic acid (hydrogen cyanide) and readily absorbed into the blood. This interferes with respiration, and cattle can die from respiratory paralysis. A sudden disruption of growth such as frost, drought or cutting can cause prussic acid to be released inside the plant at a more rapid rate. However, prussic acid will break down 1 to 2 wk later. Sudangrass contains less than half as much prussic acid as most sorghums, while sorghum-sudan grasses are intermediate. Some species and varieties such as Piper sudangrass contain low levels of prussic acid (Undersander et al. 2000b; Undersander 2003). Dhurrin content is highest in young plants, in regrowth, and plants heavily fertilized with nitrogen or manure. In order to reduce risk of prussic acid poisoning, sudangrass should not be grazed or cut until the plants are 45 cm and greater than 55–65 cm for sorghum and sorghum sudangrass hybrids (McKinlay and Wheeler 1998). In addition, they recommend not grazing this type of forage for 7–10 d after a killing frost (McKinlay and Wheeler 1998; Radostits et al. 2000; Undersander 2003).

Nitrate poisoning can be also a problem where the above-mentioned plants accumulate high levels of nitrates (Radostits et al. 2000; Lardner 2003). This can occur when there is a prolonged drought followed by rain, or heavy applications of fertilizer or manure. When the animals eat these plants, the nitrates are converted rapidly to nitrites, which are absorbed into the blood. This alters the way the blood carries oxygen and causes rapid breathing, fast and weak heartbeat, muscle tremors, staggering and death. The same precautions for prussic acid poisoning will help prevent nitrate poisoning while grazing these crops (McKinlay and Wheeler 1998; Radostits et al. 2000).

Brassica crops can cause animal health disorders if not grazed properly. *Brassica* forages contain a number of inhibitory compounds, such as glucosinolates and S-methyl cysteine sulphoxides (SMCO) (kale anemia factor) that interfere with thyroid function or cause anaemia and goitre (Gustine and Jung 1985). Other disorders are bloat, atypical pneumonia, nitrate poisoning, hypothyroidism and polioencephalomalcia (Wilkse et al. 1987; Undersander 1996). These disorders can be avoided by dilution of the forage by introducing the grazing animals slowly (over 3 to 4 d) to *Brassica* pastures or supplemeningt with hay or other grass pasture if continually grazing *Brassica* crops (Kunelius 1992; Undersander 1996).

Research Challenges in the Future

We have been able to locate and summarize the majority of the research information on DM yield and quality of warm-season annual cereal and *Brassica* crops that could have application for supplementary grazing in Canada. This complements the review of grazing potential of cool season crops (McCartney et al. 2008). From the above discussion, several annual crops, including corn, golden German foxtail millet, kale, forage rape and turnip show promise for use in grazing systems. These crops have a high yield potential, but the cost of grazing these crops has not been adequately compared with the cost of grazing oat, barley or fall rye. There are very few actual animal grazing trial evaluating the economics of using these crops in grazing systems in Canada. Thus, the economic use of these crops compared with oat, barley and fall rye in different types of supplementary grazing systems requires further research efforts in various eco regions of Canada.

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Aasen, A., Erickson, L. and Baron, V. 2005. Corn and how to use it. Western Forage/Beef Group Newsletter Vol. 9, Issue 2, Nov. 2005. Agriculture and Agri Food Canada, Lacombe, AB.

Aasen, A. and Bjorge, M. 2009. Alberta forage manual. Alberta Agriculture and Rural Development, Edmonton, AB. pp 348.

Anonymous. 1924. Branch Experimental Farms Reports Western. 1924 Dept. of Agriculture, Ottawa ON.

Anonymous. 1936. Progress report 1932 to 1936. Experimental Station, Lacombe, AB.

Anonymous. 1940. Improved pasture crops and pasture practices for central Alberta. Dominion of Canada, Department of Agriculture, Ottawa, ON. Farmers = Bulletin 93.

Anonymous. 1946. Progress report 1937 to 1946. Experimental Station, Lacombe, AB.

ARECA. 2006. Year round grazing 365 days. Agricultural Research and Extension Council of Alberta, Sherwood Park, AB. 42 pp.

Baltensperger, D. D. 1996. Foxtail and proso millet. Pages 182–190 *in* J. Janick, ed. Progress in new crops. ASHS Press, Alexandria, VA.

Baltensperger, D. D. 2002. Progress with proso, pearl and other millets. Pages 100–103 *in* J. Janick and A. Whipkey, eds. Trends in new crops and new uses. ASHS Press, Alexandria, VA.

Banks, S. and Stewart, T. 1998. Forage pearl millet. Ontario Ministry of Agriculture and Food Guelph, ON. Agdex 126.

Baron, V. S., Najda. H. G., McCartney, D. H., Bjorge, M. and Lastiwka, G.W. 2003. Winter weathering effects on corn grown for grazing in a short-season area. Can. J. Plant Sci. **83**: 333–341.

Bartholomew, H. M. and Underwood, J. F. 2002. Brassicas for forage. AGF-020-92. Dept. of Agronomy, Ohio State University, Columbus, OH.

Berkenkamp, B. and Meeres, J. 1988. Annual crops for forage in the Alberta parklands. Research Branch, Agriculture Canada Tech. Bull. 1988–1E.

Bough, N. and Cavers, P. B. 1987. Proso Millet. Ontario Ministry of Agriculture and Food, Toronto, ON. Agdex 640.

Duke, J. A. 1983. *Sorghum sudanense* (Piper) Stapf. Handbook of Energy Crops. Centre for New Crops and Plant Products, Purdue University, Lafayette, IN.

Erickson, L., Aasen, A. and Baron, V. 2005. Forage corn: Silage or winter grazing? Western Forage/Beef Group Newsletter Vol. 9, Issue 2**.** May 2005. Agriculture and Agri Food Canada, Lacombe, AB.

Fitzgerald, J. J. and Black, W. J. M. 1984. Finishing store lambs on green forage crops. I. A comparison of rape, kale and fodder radish as sources of feed for finishing store lambs in autumn. Ir. J. Agric. Res. **23**: 127–136.

Fribourg, H. A. 1995. Summer annual grasses. Pages 463–472 *in* Forages Vol. 1: An introduction to grassland agriculture. 5th ed. R. F. Barnes, D. A. Miller, and C. J. Nelson, eds. Iowa State University Press, Ames, IA.

Guillard, K. and Allinson, D. W. 1988. Yield and nutrient content of summer and fall-grown forage *Brassica* crops**.** Can. J. Plant Sci. **68**: 721–731.

Gustine, D. L. and Jung, G. A. 1985. Influence of some management parameters on glucosinolate levels in *Brassica* forage. Agron. J. **77**: 593–597.

Gutierrez-Ornelas, E. and Klopfenstein, T. J. 1991. Changes in availability and nutritive value of different corn residue parts as affected by early and late grazing seasons. J. Anim. Sci. **69**: 1741–1750.

Harlan, J. R. and de Wet, J. M. 1972. A simplified classification of cultivated sorghum. Crop Sci. **12**: 172–176.

Hay and Pasture Improvement Committee. 1940. Hay and pasture improvement – Experimental data and reference material. Agricultural Representative Branch, Ontario Department of Agriculture, Toronto, ON. 41 pp.

Heinemann, W. W. 1984. Grazing supplements and management variables for steers grazing turnips. J. Anim. Sci. **35**: 168–171.

Heinemann, W. W. and Hanks, E. N. 1980. Turnips (*Brassica rapa*) and radishes (*Raphanus sativus*) as forage crops. J. Anim. Sc. **31**: 151–154.

Helm, J. L. 1988. Foxtail (hay) millet. NDSU Extension Service Bull. R635. North Dakota State University, Fargo, ND.

Hinze, G., Mann, H. O., Langin, E. J. and Fisher, A. 1978. Registration of Cope proso millet cultivars. Crop Sci. **18**: 1093.

Holt, N. W. 1993. Pasture production of annual crops. Summary report for 1987–1992. Agriculture Development Fund. Dem. Proj. D89-05-0719. Southwest Forage Association, Swift Current, SK.

Hubbard, W. A. and Waldern, D. E. 1976. Annual forage crops for the southern interior of British Columbia. Information Division, Canada Department of Agriculture, Ottawa, ON.

Johnston, J., Lenover, M., Burnett, S., Slaght, S. and Garner, B. 2000a. Performance of ewes grazing stubble turnips. Northern Stations Research Updates, New Liskeard Agricultural Research Station, New Liskeard, ON.

Johnston, J., Lenover, M., Burnett, S., Slaght, S. and Garner, B. 2000b. Grazing standing corn with sheep. Northern Stations Research Updates, New Liskeard Agricultural Research Station, New Liskeard, ON.

Jung, G. A., Byers, R. A., Panciera, M. T. and Shaffer, J. A. 1986. Forage dry matter accumulation and quality of turnip, swede, rape, Chinese cabbage hybrids and kale in the eastern USA. Agron. J. **78**: 245–253.

Jung, G. A., Shaffer, J. A., Stout, W. L. and Panciera, M. T. 1988. Harvest frequency effects on forage yield and quality of rapes and rape hybrids. Grass Forage Sci. **43**: 395–404.

Klopfenstein, T., Roth, L., Fernandez-Rivera, S. and Lewis, M. 1987. Corn residues in beef production systems. J. Anim. Sci. **65**: 1139–1148.

Klopfenstein, T. J. 1994. Crop residue used as animal feed in managing agricultural residues. P. W. Unger, ed. CRC Press, Boca Raton, FL.

Koch, D. W. and Mitchell, J. R. 1988. Potential of Japanese millet as an initial crop in a no-till forage renovation program. Agron. J. **80**: 471–474.

Koch, D. W., Kercher, C. and Jones, R. 2002. Fall and winter grazing of Brassicas – a value-added opportunity for lamb producers. Sheep Goat Res. J. **17**: 1–13.

Kunelius, H. T. 1992. Supplementary green forage crops. Agri-Info Factsheet: 92–23. Agdex 128.

Kunelius, H. T. and Sanderson, J. B. 1989. Effect of harvest dates on yield and quality of forage rape. Crop Res. **29**: 19–25.

Kunelius, H. T. and Sanderson, J. B. 1990. Effect of harvest dates on yield and composition of forage rape, stubble turnip and forage radish. Appl. Agric. Res. **5**: 159–163.

Kunelius, H. T., Sanderson, J. B. and Narasimhalu, P. R. 1987. Effect of seeding date on yield and quality of green forage crops. Can. J. Plant Sci. **67**: 1045–1050.

Lardner, H. A. 1999. Grazing fall rye pasture. Annual Tech. Report. Western Beef Development Centre, University of Saskatchewan, Saskatoon, SK.

Lardner, H. A. 2000. Grazing corn to extend the grazing season. WBDC Fact Sheet #2002-01. Western Beef Development Centre, University of Saskatchewan, Saskatoon, SK.

Lardner, H. A. 2002. Comparison of grazing corn varieties. WBDC Fact Sheet #2002-02. Western Beef Development Centre, University of Saskatchewan, Saskatoon, SK.

Lardner, H. A. 2003. Extending the grazing season with turnips. WBDC Fact Sheet #2003-03. Western Beef Development Centre, University of Saskatchewan, Saskatoon, SK.

Lardner, H. A. 2004. Backgrounding calves on Golden German millet swaths.. WBDC Fact Sheet #2004-01. Western Beef Development Centre, University of Saskatchewan, Saskatoon, SK.

Lardner, H. A. Kumar, R. and McKinnon, J. 2008. Backgrounding calves on annual forages. WBDC Fact Sheet #2008-02. Western Beef Development Centre, University of Saskatchewan, Saskatoon, SK.

Macaulay, A. 2004. Silage manual. Alberta Agriculture Food and Rural Development, Edmonton, AB.
Matz, S. A. 1986. Millet, wild rice, adlay, and rice grass. Pages 225–229 *In* Cereal science. AVI Press, Westport, CT.
May, W. E., Klein, L., 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.
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.
McCaughey, P., Small, J., Scott, S. and Irvine, B. 2002. Foxtail millet and corn: New crops to extend grazing season and cut feeding costs. Brandon Research Centre, Brandon, MB. Publ. 227.
McKinlay, J. and Wheeler, B. 1998. Forage sorghum-sudan grass. Ontario Ministry of Agriculture Food. Toronto, ON. Agdex 126.
Morrison, F. B. (ed.) 1961. Feeds and feeding. The Morrison Publ. Co., Clinton, IA. 696 pp.
Muldoon, D. K. 1983. Growth and development of two *Echinochloa* millet species in a warm temperate climate. Pages 244–247 *in* J. A. Smith and V. W. Hays eds. Proc. 14th Int. Grassland. Congress, Lexington, KY.
Najda, H. 1991. Forage *Brassicas*. Agdex 128/20–1. Alberta Agriculture, Food and Rural Development, Edmonton, AB.
Najda, H. 2003. Sorghum, sudangrass, and sorghum-sudangrass hybrids for forage. Alberta Agriculture, Food and Rural Development. Edmonton, AB. Agdex 126–20–1.
Narashimhalu, P., Kunelius, H. T., Dickson, B. A. and Scharko, P. 2000. Late-season grazing of kale or annual ryegrass by cross-bred beef steers. Agricultura and Agri-Food Canada, Ottawa, ON. Agdex: 420.62.
Nova Scotia Crop Development Institute. 1993. Atlantic Canada forage research review. Nova Scotia Agricultural College, Truro, NS. 241 pp.
Phelps, S. M., Jorgenson, T. and Nielsen, L. P. 2003. Annual forages – suitability for NW Saskatchewan, Saskatchewan Ministry of Agriculture, Regina, SK.
Poland, W., Carr, P., Nelson, J., Sedivec, K., Hyren, P., Manske, L. and Miller, W. 2003. Making extended grazing work in North Dakota. *In* NCRA 225. Improved grazing systems for animal production. North Dakota State University, Dickinson Research Extension Center, Dickenson, ND.
Radostits, O., Gay, C., Blood, D. and Hinchcliff, K. 2000. Veterinary medicine. A textbook of the diseases of cattle, sheep, pigs and horses. 9th ed. W.B. Saunders Ltd., Oxford, UK 1134 pp.
Riemer, G. and Gaudiel, R. 1984. Progress report on trials involving annual forages 1979–1983 AHRC Pamphlet 84–6. Alberta Horticultural Research Center, Brooks, AB.
Riemer, G. and Gaudiel, R. 1986. Annual forage crops (southern Alberta). Farming for the Future Proj. # 83-0201. Alberta Horticultural Research Center, Brooks, AB.
Rook, J. S. 1998. Cool season forages – are we missing an opportunity to reduce costs? The Shepherd **48**: 19–22.
Rouquette, F. M., Jr., Keisling, T.C., Camp, B. J. and Smith, K. L. 1980. Characteristics of the occurrence and some factors associated with reduced palatability of pearl millet. Agron. J. **72**: 173–174.
Spahr, S. L., Ormiston, E. E. and Peterson, R. G. 1967. Sorghum-sudan hybrid SX-11, Piper sudan grass, and alfalfa-orchardgrass for dairy pastures. J. Dairy Sci. **50**: 1925–1934.
Undersander, D. 1996. Use of *Brassica* crops in grazing systems. FC 15.4.1. Dept of Agronomy, University of Wisconsin, Madison, WI.
Undersander, D. 2003. Sorghums, sudangrasses, and sorghum sudangrass hybrids. Focus on Forage Vol. 5: No. 5. Dept of Agronomy, University of Wisconsin, Madison, WI.
Undersander, D., Kaminski, A. R., Oelke, E. A., Doll, J. D., Schulte, E. E. and Oplinger, E. S. 2000a. Rutabaga. *In* Alternative field crops manual. University of Wisconsin-Extension, Cooperative Extension, Madison, WI.
Undersander, D., Smith, L. H., Kaminiski, A. R., Kelling, K. A. and Doll, J. D. 2000b. Sorghum – Forage. *In* Alternative field crops manual. University of Wisconsin-Extension, Cooperative Extension, Madison, WI.
Ward, J. K. 1978. Utilization of corn and grain sorghum residues in beef cow forage systems. J. Anim. Sci. **46**: 831–840.
Wedin, W. F. 1970. Digestible dry matter, crude protein, and dry matter yields of grazing-type sorghum cultivars as affected by harvest frequency. Agron. J. **62:** 359–363.
Wheeler, W. A. 1950. Millets. Pages 662–671. *in* Forage and pasture crops. D. Van Nostrand Co., Inc., Toronto, ON.
Wiedenhoeft, M. H. 1993. Management and environment effects on dry matter yields of three *Brassica* species. Agron. J. **85**: 549–553.
Wiedenhoeft, M. H. and Barton, B. A. 1994. Management and environment effects on *Brassica* forage quality. Agron. J. **86**: 227–232.
Wilkse, S. E., Leathers, C. W. and Parish, S. M. 1987. Diseases of cattle that graze trunips. Compendium Food Animal **9**: F112–F121.
Willms, W. D., Rode, L. M. and Freeze, B. S. 1993. Winter performance of herford cows on fescue prairie and in drylot as influenced by fall grazing. Can. J. Anim. Sci. **73**: 881–889.
Woll, F. W. 1916. Productive feeding of farm animals. J.B. Lippincott Co., Philadelphia, PA. 342 pp.
Yun, L., Koch, D. W., Gray, F. A., Sanson, D W. and Means, W. J. 1999. Potential of trap-crop radish for fall lamb grazing. J. Prod. Agric. **12**: 559–563.