Bloat in cattle grazing alfalfa cultivars selected for a low initial rate of digestion: A review

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Berg, B. P., Majak, W., McAllister, T. A., Hall, J. W., McCartney, D., Coulman, B. E., Goplen, B. P., Acharya, S. N., Tait, R. M., and Cheng, K.-J. 2000. **Bloat in cattle grazing alfalfa cultivars selected for a low initial rate of digestion: A review.** Can. J. Plant. Sci. **80**: 493–502. The occurrence of frothy bloat limits the practice of alfalfa grazing in spite of the availability of strains bred specifically for pasture. Bloat is a chronic condition, endemic to cattle. Prophylactics and management techniques are available to reduce its incidence but they are expensive, difficult to administer, conflict with traditional grazing management regimens and do not eliminate bloat in all circumstances. A program to breed and evaluate a bloat-reduced strain of alfalfa was initiated in 1980 to overcome some of these limitations. A review of the results of grazing and feeding trials using alfalfas with low initial rates of digestion (LIRD) shows that this new strain reduces the incidence and severity of frothy bloat on pasture. Their effectiveness in controlling bloat was related to feeding or grazing management practices, the maturity of the plants and the season of use. Graziers may reduce the risk of occasional livestock losses from bloat by using LIRD cultivars, like AC Grazeland, or managing species/cultivar mixtures in ways that reduce the initial rate of digestion. Other bloat preventive strategies, including co-seeding with bloat-free legumes and using bloat-controlling prophylactics in combination with a LIRD alfalfa, are being investigated.

Key words: Bloat, alfalfa, lucerne, legume, low initial rates of digestion, cattle, grazing

Berg, B. P., Majak, W., McAllister, T. A., Hall, J. W., McCartney, D., Coulman, B. E., Goplen, B. P., Acharya, S. N., Tait, R. M. et Cheng, K.-J. 2000. **Météorisme chez les bovins pâturant des cultivars de luzerne sélectionnés pour leur faible taux initial de digestion: mise au point bibliographique**. Can. J. Plant Sci. **80**: 493–502. Le problème du météorisme spumeux restreint le pâturage de la luzerne malgré la disponibilité de souches sélectionnées spécifiquement pour cette utilisation. Le météorisme est une affection chronique, endémique chez les bovins. Il existe des techniques préventives et des méthodes de conduite qui réduisent sa fréquence, mais en plus du fait qu'elles n'éliminent pas toujours le trouble, elles coûtent cher, leur application difficile et elles ne s'insèrent pas facilement dans les régimes classiques de gestion du pâturage. Pour surmonter certaines de ces contraintes, un programme de sélection et d'évaluation d'une souche de luzerne à effet météorisant moins prononcé était mise en place en 1980. La lecture des résultats publiés des essais de pâture et de distribution en vert conduits sur des lignées de luzerne à faible taux initial de digestion (FTID) révèle que ces nouvelles lignées réduisent la fréquence d'apparition et la gravité des cas de météorisme spumeux au pâturage. Leur efficacité à cet égard dépendait des pratiques de distribution en vert ou de pâturage employées ainsi que du stade de croissance des plantes et de la saison d'utilisation. Les exploitants de pâturage peuvent diminuer les risques de pertes occasionnelles de bestiaux pour cause de météorisme en utilisant des cultivars FTID, comme AC Grazeland ou en conduisant le pâturage d'associations spécifiques ou variétales de manière à réduire le taux initial de digestion. On envisage actuellement d'autres protocoles de prévention du météorisme, notamment l'inclusion de légumineuses non météorisantes dans les mélanges à pâturage et l'emploi de substances antimétéorisme, en combinaison avec des lignées de luzerne FTID.

Mots clés: Météorisme, luzerne, légumineuse, FTID, bovin, pâture

Ruminants are nutritionally dependent on the efficiency of a continuous-flow, anaerobic fermentation system to digest their food. Changes in the animal's diet or health easily perturb the rumen ecosystem, but it normally adjusts to maintain a stable environment. The system can be destabilised if the mechanisms that compensate for the disturbance are disabled or overwhelmed, as for example when disease limits the animal's ability to prehend, swallow or regurgitate. The distress observed in an animal with a distended, bloated rumen is an obvious manifestation of a destabilised rumen ecosystem.

Bloat is a serious problem in cattle and sheep (Howarth et al. 1991). Research on bloat is motivated by the need to

Abbreviations: **DMD**, dry matter disappearance; **LIRD**, low initial rate of digestion; **LIRD-1, 3, 4**, LIRD cultivar selection cycle 1 through 4 understand its etiology and test the efficacy of novel ideas for its control. These goals are not mutually exclusive because proving hypotheses about bloat may lead to solutions that allow ranchers to detect the condition early and reduce its severity, incidence and potential for economic loss. For the rancher, though, research aimed at preventing bloat is the priority. Effective treatments are needed to avoid economic loss, regardless of cause. This review is concerned with the prevention of bloat. It examines problems associated with the diagnosis and treatment of pasture bloat and summarises the results of recent trials to evaluate the bloat-reducing capability of alfalfa cultivars derived from a unique breeding program.

BLOAT MANAGEMENT

Diagnosis

Causes of Bloat

Bloat ensues as a chronic manifestation of disease, a dysfunction of the upper digestive tract, or from the consumption of a bloat-provoking feed (Cole et al. 1945; Johns 1954; Cole and Boda 1960; Howarth et al. 1978a; Garry 1990a). The rumen becomes tympanitic when the rate of gaseous discharge is less than the rate of gas produced from fermentation. Bloat is symptomatic of many conditions that interfere with normal eructation and rumen motility, including hypocalcaemia, vagal nerve damage, abomasal displacement, thoracic inflammation, ruminal stasis, and obstructions of the cardia or reticulo-omasal orifices. Bloat is also a symptom of diseases like pneumonia, tetanus, and reticulo-peritonitis. Plant species known to cause bloat in grazing cattle include legumes such as alfalfa (*Medicago* spp.), red, alsike, and subterranean clovers (*Trifolium* spp.) and sweet clover (*Melilotus* spp.); and grass species such as winter wheat, triticale, and the rye grasses (*Triticum* spp., *Triticosecale* spp., *Secale* spp., *Lolium* spp.). In confined feeding systems, cattle bloat when their diets contain processed cereal grains; preserved feeds such as alfalfa or clover hays, pellets and even corn silage (associated with increased digestibility or excessive cell wall destruction during processing); and on poorly processed tubers and fruits (animals choke on potatoes, turnips, apples and kiwifruit) (Cole et al. 1945; Ayre-Smith 1971; Howarth 1975; Waghorn, G. 1997 personal communication).

Cattle are more disposed to bloat than other species, such as sheep or deer, and the susceptibility of individual animals varies widely (Ayre-Smith 1971; Clarke et al. 1974; Colvin and Backus 1988). Animals with a high susceptibility to bloat maintain comparatively high volumes of fluid in the rumen (Cockrem et al. 1987b). This implies that bloat-prone animals may maintain more digesta in the rumen for longer periods and pass digesta through the rumen at a slower rate than non-bloaters (Okine et al. 1989). The condition is heritable and a function of physiological or behavioural traits (Cockrem et al. 1983; Howarth et al. 1984).

Types of Bloat

A distinction is made between frothy bloat and free-gas bloat on the respective basis of the presence of a stable foam associated with amorphous, non-layered rumen contents or the absence of a stable foam and defined, normal layering of the rumen contents (Cole and Boda 1960; Howarth 1975; Garry 1990b). Both types of bloat can occur simultaneously (Boda et al. 1956). However, they could arise from different pathological conditions that require different prophylaxes. For example, an animal that has been grazing legume pasture and has contracted pneumonia may bloat because the infection affects the animal's ability to eructate. Retention of rumen gas may lead to a free-gas bloat at the same time that the digestion of the alfalfa forage may create a non-pathological froth. Other distinctions likely reflect differences in the feed or the by-products of digestion rather than the etiology of the condition. Frothy feedlot and pasture bloat differ in some rumen parameters; viscosity is greater and pH is often lower in feedlot bloats. Thus the differences between feedlot and alfalfa pasture bloat are primarily in degree of change and indicate that a range of feeds and rumen conditions can generate stable foams (Clarke and Reid 1974; Cheng et al. 1976). Similarly, the difference between sub-acute and acute bloat is also one of degree.

SUB-ACUTE BLOAT. A state of sub-acute bloat occurs when the animal has difficulty discharging gas from the rumen. The condition is asymptomatic, so the animal shows few signs of distress, but it can stimulate behavioural and physiological adaptations in the animal. Eructation and feeding behaviours are modified as the rumen's static pressure increases, to adjust to the new gas dynamics (Cole et al. 1945). Grazing bouts are shorter, rumination times are reduced and ruminal movements increase in frequency (Hancock 1954). Production losses are primarily a result of a reduced feed intake (Johns 1954; Reid and Johns 1957; Alder et al. 1967; Hall et al. 1988). In cases of sub-acute frothy bloat on legume pasture, the rumen has normal motility and low to moderate pressure but may be fully charged with a stable, amorphous foam containing elevated chlorophyll levels, cation imbalances and an increased capacity to produce gas (Cole and Boda 1960; Reid 1960; Howarth et al. 1977, 1978b; Majak et al. 1980, 1985, 1986a, b; Ledgard et al. 1990; Majak and Hall 1990). The danger for animals with sub-acute frothy bloat is that they are predisposed to the onset of an acute bloat (Majak et al. 1983; Hall et al. 1988).

ACUTE BLOAT. The development of an acute bloat can be rapid or protracted, with a sub-acute state remaining stable for extended periods (Lindahl et al. 1957). For acute bloat to occur, interactions between the animal and the feed source, the by-products of digestion or the microbial environment must escalate to a breakpoint beyond which fermentation gases begin to accumulate at a rate faster than the existing compensating mechanisms can expel them. If this point is not reached, the bloat may remain sub-acute and even abate without incident. Acute bloat often develops in conjunction with alterations in the forage quality, fluctuations in digestive conditions, when handling stress or a disease affects the animal's equilibrium, or during changes in the ambient environment (Hall et al. 1984; Garry 1990b; Hall and Majak 1991, 1995; Waghorn 1991; MacAdam et al. 1995).

The additional gas held in the rumen during an acute bloat generates high pressure, leading to severe distension and distress. Therapeutics for the treatment of acute bloat are limited by time, especially if emergency medical intervention is required to prevent asphyxiation or internal haemorrhage and the death of the animal (Garry 1990a, b). Proper diagnosis is a lesser concern when the difference between death and life is a matter of a few minutes. Consequently, many experienced ranchers and veterinary practitioners use several remedies (chasing, tubing, drenching with oils, detergents, or pluronics, trocarization, and rumenotomy), chosen sequentially or at random, no matter the cause of the bloat, to relieve the distension. Ranchers need ways to control digestion or to detect sub-acute bloats before acute bloats develop and generate a serious economic loss (Clarke and Reid 1974; Howarth 1975).

Distension is the first clinical symptom used to detect bloat but it is generally insufficient to ascertain the severity of bloat or to verify the onset of acute bloat (Lindahl et al. 1957; Garry 1990b). Other visual symptoms of distress that show severity include panting, frequent urination, stamping the hind feet, kicking at the belly, or an abnormal stance, usually with forequarters and head elevated (Boda et al. 1956; Garry 1990b). However, animals vary in their physical ability to adapt to the pressure and in their individual response to discomfort. A change in girth is not linear with respect to changing ruminal pressure (Reid 1957; Waghorn 1991). As the rumen expands it fills the abdominal cavity, stretching the muscles and exerting pressure on the internal organs. Discomfort will be more severe in animals that have small body cavities, larger internal organs, or layers of non-elastic fat, connective tissue and muscle. Thus, the only objective measure of severity is intra-ruminal pressure (Waghorn 1991) and for intact animals the recommended procedure is palpation of the left flank (Lippke et al. 1972). In ruminally cannulated animals, the pressure released when the cannula is opened yields ample evidence of bloat severity.

FROTHY AND FREE-GAS BLOAT. Visually, the distension resulting from frothy bloat is indistinguishable from free-gas bloat. In the case of frothy bloat on pasture, the clinical symptom is the presence of a stable foam that sequesters the gas products of fermentation and retains them in the rumen (Reid 1960; Moate et al. 1997). Free-gas bloat may have a different etiology, but in an animal grazing legume pasture, a bloat may be a combination of free-gas and froth. Again, for intact animals, the only reliable external diagnostic procedure is palpation of the left flank to establish whether the rumen contents are abnormally uniform, due to the presence of foam, or stratified normally as is the case in free-gas bloat (Garry 1990b). A second, more invasive protocol, gastric intubation, can be used to expel gas and some rumen contents to confirm the diagnosis. Free-gas bloat may not be as prevalent in ruminally cannulated animals because gas can be expelled through the fistula. Thus, the severity and the incidence of bloat or the degree of distension may be underestimated in cannulated animals if pasture bloats are normally a mix of free gas and froth. However, the cannula provides a ready means of distinguishing between froth and a rumen distended with forage from a recent meal.

Prevention and Control of Frothy Bloat

Generally, correct diagnoses of the causes of bloat are made with the expectation that a reliable course of action can be taken to control or eliminate it. This is certainly true of bloat caused by a medical condition (Garry 1990a), but perhaps less so for frothy bloat (Howarth 1975). Popular recipes and rules of thumb on how to suppress frothy bloat on pasture or manage bloated animals are strikingly similar in publications over a 250-yr period (Beddows 1952; Anderson 1997). Turning animals out to pasture late in the day or onto mixtures containing grasses and trefoil were important management rules in 1716, whereas drenching with some special concoction is still a common remedy even today. The ingredients for the drench have changed considerably from “terpentine in beer” but soaps, oils and other organic solvents are still recommended. All methods fail occasionally, which suggests that there are problems recognizing predisposing conditions that result in acute bloat, selecting an appropriate therapy or determining what caused a bloat (when treatment is given without diagnosis). On the other hand, the consistency of the prophylaxes demonstrates that some treatments have a high degree of efficacy.

Three strategies have been taken to control frothy pasture bloat: suppression of foam in the rumen, grazing management that constrains forage intake or digestibility, and pasture management designed to limit the availability of bloat-causing plants. The first strategy, suppressing stable foams, has the greatest potential for yield improvements because bloat is managed independent of forage and animal productivity. The other strategies may control bloat but often adversely affect the potential productivity.

A common management practice for suppressing foam formation is to treat all animals as if they are predisposed to frothy bloat. Bloat incidents are regarded as unpredictable, random events. Animals are provided with a daily dose of a specific prophylactic to prevent bloating. Prophylactics are given in several ways including feeding them in a customised mineral supplement, dissolving them in drinking water, spraying them on pasture, “drenching” animals before or after feeding or grazing, or by inserting a mechanical, time-release bolus containing the agent into the rumen. Invariably, the efficacy of an agent is dosage dependent, so any reduction in the number of incidents and the severity of bloat is a function of the concentration of the agent in the rumen. Concentration, in turn, is dependent on the amount and frequency of administration of the agent, its rate of degradation and passage through the rumen. Thus, the ability of an agent to control bloat may be strongly influenced by a stockman’s herd management program, by the adaptation of the microbial populations to the agent or by a change in the rumen environment, and by extraneous confounding factors, like weather or palatability, that are beyond the working range of the prophylactic’s management protocol.

Many materials have been used to control the foam in bloat (Reid and Johns 1957; Ayre-Smith 1971; Clarke and Reid 1974). Prohibitive costs, administrative difficulties or regulatory barriers for an effective bloat preventative often result in the substitution of less expensive products of low efficacy (Hall and Majak 1992; Hall et al. 1994b). Pluronic detergents such as poloxalene have been proven effective but are too expensive and difficult to administer for general use in North America (Bartley et al. 1965; Acord et al. 1968, 1969; Dougherty et al. 1992; Popp et al. 1997). Sodium bicarbonate and commercial laundry soaps are substituted in spite of their proven ineffectiveness (Reid and Johns 1957). Rumour supports the practice because ranchers report their subjective observations, attributing low bloat incidents to an unmeasured difference between using the product and not using it, when the effect could be equally attributed to livestock genetics, behaviour or management (Cole and Boda 1960; Acord et al. 1968; Dougherty et al. 1989a, b; Warner 1997). Alcohol ethoxylates in a pluronic detergent carrier, have been used in New Zealand and Australia for nearly 40 yr, yet regulatory restrictions may prevent their use in North America. Similarly, monensin, an ionophore, is currently registered for use in Canada, New Zealand and Australia, but not the United States (Bergen and Bates 1984). The situation with ionophores is not likely to improve because gaining approvals to use antibiotics to enhance feed digestibility or digestive characteristics will be increasingly problematic in the future.

Critically, in this context foam cannot be eliminated, only managed. Any strategy that promises to eliminate bloat foam is contradictory because foam is created during an otherwise normal digestion process while bloat originates from many different predisposing conditions (Majak et al. 1995). Regardless of its immediate outcome, eliminating froth will not eliminate bloat; free-gas bloats will still occur. Since bloat is apparently endemic to domesticated cattle (Cockrem et al. 1987a, b), the management of the animals and the feeding regime probably hold more promise than selecting non-bloating strains of livestock (Clarke and Reid 1974; Majak et al. 1995). Consequently, strategies that reduce the risk of bloat in most circumstances, rather than elimination, will be the easiest to adopt.

The second strategy aimed at controlling frothy bloat, grazing management, uses traditional techniques, such as fencing, herding or rotational grazing, to manipulate rates of intake, passage and fermentation in the rumen. Input and output from the rumen can be indirectly affected by adopting grazing and feeding regimens that increase rumen clearance, or reduce gas and foam production. Control is a function of the rancher's skill at managing the interaction between availability and digestibility of pastured forage and the grazing behaviour of the animals (Hancock 1954; Allison 1985; Hall et al. 1994b; Majak et al. 1995).

Pasture management, a third strategy for controlling frothy bloat, is also a traditional approach to the problem. Pastures may be seeded with low amounts of bloat-causing legumes, bloat-free legumes such as sainfoin (*Onobrychis viciifolia*) or no legumes. Fertilisation and herbicides can be used to limit the amount a bloat-causing legume contributes to the available forage, thereby reducing the risk of bloat, albeit at some cost.

Examination of the components of plants that may cause bloat is part of the pasture management strategy because plant breeding holds the promise of eliminating or counteracting the trait responsible for causing bloat while retaining the plant's inherent level of productivity. Picking a character for selection is difficult because its expression may not be universal, it may vary with the physiological status of the plant or the environment and, though the character may be associated with bloat, it may not be directly responsible for the development of bloat in a grazing animal. Canadian researchers have investigated protein fractions in plants, chloroplast membranes, leaf tissue disruption, and leaf and stem digestibility, comparing some of these characters with those found in bloat-safe forages (Miltmore et al. 1970; Howarth et al. 1977, 1978a, b, 1979, 1982; Majak et al. 1995). Frothy bloat in cattle was related to many of these traits, so breeding a plant with a reduced potential to cause bloat when used in a pasture management program remains a valid approach to bloat control (Howarth et al. 1982, 1991).

ALFALFA FOR GRAZING

Since the turn of the 20th century, alfalfa has been bred to improve its quality, productivity and adaptation to the agronomic conditions in North America. It was primarily selected for its value in stored feed, and most cultivars were selected under a mechanical harvest protocol. Alfalfa was rarely grazed in Canada, so it was never subjected to sufficient grazing pressure to induce grazing tolerance. The demand for grazing alfalfas has risen with the demand for improved productivity and reduced cost of pastured forage.

Three criteria need to be met before an alfalfa strain can be called a grazing type. First, it must tolerate the environmental conditions. In western Canada, these conditions include harsh limitations like summer drought, severe winters, short growing seasons, and marginally productive soils. Second, it must tolerate grazing, including intermittent but severe defoliation and trampling. Third, and most important, it must possess a nutritional quality that enhances its suitability for grazing and reduces the incidence of bloat. The screening of genotypes for each criterion has been independent, the only area of crossover being that breeders of new strains have relied on previously screened genetic material.

Precursors of a Grazing Alfalfa

Canadian researchers have successfully met the first criterion, environmental tolerance, releasing several alfalfa cultivars that are industry standards for dryland pasture and rangeland seedings. Some early alfalfa cultivars were called grazing-types although they were never specifically bred for grazing (Heinrichs 1963). Recently released varieties are hardy plants with traits that include persistence, fall-dormancy, drought and winter-hardiness, low-set crowns, creeping roots, and disease and pest resistance. There were tradeoffs, yield in particular, for survival in cold regions (Lorenz et al. 1982; Berdahl et al. 1989; Caddel 1997).

Dryland alfalfa cultivars have a degree of grazing tolerance because a few traits, such as low-set crowns and creeping roots, enhance their survival in pasture. Although some cultivars have been tested in grazing trials (Berdahl et al. 1986), they were never selected for grazing tolerance. A grazing-tolerant alfalfa must persist under a regimen of severe defoliation and animal impact. Grazing-tolerant cultivars have decumbent growth habits, more crown buds and greater residual leaf cover after grazing, which may help maintain higher levels of total nonstructural carbohydrates in their root systems (Smith et al. 1989; Brummer and Bouton 1991, 1992).

The high feed quality of alfalfa may make it less than ideal for grazing because some factors responsible for its quality, such as digestibility and protein content, are implicated in bloat (Miltmore et al. 1970; Howarth et al. 1977). Breeding for lower quality is antithetical; alfalfa breeding programs rarely maintain lower quality lines except to evaluate traits for selecting lines of higher quality (Allinson et al. 1969; Shenk and Elliot 1970, 1971). However, species such as sainfoin or trefoil (*Lotus* spp.) seldom cause bloat. A reasonable approach would consider these differences in developing a bloat-resistant strain of alfalfa (Howarth et al. 1978a, 1979, 1982; Fay et al. 1980, 1981; Goplen et al. 1980, 1985; Kudo et al. 1985).

Thick plant cell walls are a characteristic of bloat-free legumes. Rumen bacteria take more time to invade and rupture cells in these species than in alfalfa (Howarth et al. 1979; Lees 1984), so alfalfa strains selected for low leaf tissue disruption could be bloat resistant (Howarth et al. 1982). The breeding program undertaken by Agriculture and Agri-Food Canada selected individual alfalfa genotypes for dry matter disappearance (DMD) when fresh clippings from the tops (15 cm) of vegetative leaders were incubated in vivo in nylon bags for 4 h. Plants with a low initial rate of disappearance (LIRD), defined as a low DMD, were screened and intercrossed through four cycles of selection. The final cultivar, LIRD-4 (released as AC Grazeland B[r]) has thick cell walls and a DMD 15% lower than a parental standard cultivar, Beaver, after 4 h in vivo incubation (Goplen et al. 1993).

Bloat in LIRD Alfalfa

The progressive development of LIRD cultivars and measurement of their effect on bloat was accomplished in feeding and partial grazing trials using both sheep and cattle. Comparative trials were complicated because there are no cultivars with a known bloat potential to compare against, even among the older, dryland alfalfa varieties (Ashford and Heinrichs 1967). Thus the grazing trials were valuable because the tests established a standard for future comparisons of bloat reduction. Beaver, a parental cultivar of the LIRD line, is widely grown in western Canada, has a record of bloat, and was therefore used as a standard for comparison.

Feeding trials were used to assess the effect of reducing DMD in the first LIRD alfalfa strain. Kudo et al. (1985) did not mention bloat incidents in any of the trials in which LIRD-1 was fed to sheep. However, the differences in the rumen fluid between animals fed LIRD-1 and those fed Beaver were consistent with other bloat research. Higher levels of chlorophyll, soluble proteins and carbohydrates, and a lower pH are found in the rumen fluid of animals that subsequently bloat (Majak et al. 1986b). Rumen fluid from LIRD-1 fed sheep had lower levels of chlorophyll, protein and carbohydrates, and a higher pH (Kudo et al. 1985), which indicated that progress had been made in the direction of bloat resistance. However, an interaction with the timing of harvests was also reported. The first two feeding trials were conducted after the alfalfa had more than 40 d of growth, whereas the last trial had less than 25 d regrowth. Rumen fluid from this latter harvest contained higher levels of chlorophyll and other components and a lower pH than the earlier harvests, irrespective of the strain of alfalfa fed.

Goplen et al. (1993) felt that the LIRD character was affected by environmental conditions and management, and considered that variations in plant maturity would affect its capability to reduce bloat. Partial (4 h) DMD of alfalfa obtained at several sites illustrate the confounding effects of management (cutting and regrowth periods, irrigation and dryland) and environment (soil type, climate and location) on LIRD (Goplen et al. 1993). In 1992, alfalfa plots at Kamloops, BC, and Lethbridge, AB, were clipped, irrigated and allowed to regrow for 27 d and 46 d, respectively, after the first DMD trials, and 26 d and 58 d, respectively, after the second trials (Hall et al. 1994a). The different periods between trials in the same year were due to differences in the environment and in some management practices (time allocated for rest and regrowth) between the two locations. Overall, partial DMD was lower at Lethbridge compared to Kamloops, perhaps because the management (rest) periods were longer at Lethbridge and the plant material was more mature. The proportional reduction in DMD between Beaver and LIRD-3 at Kamloops averaged 5.6%, with a range of 4 to 7%. In the same year at Lethbridge, the reduction averaged 9.6% and ranged between 4 and 19%. At Saskatoon, SK 6 yr earlier, the reduction in DMD in the original LIRD-3 selection trials on dryland averaged 14.5%, and ranged from 8 to 21% (Goplen et al. 1993). Thus, field management and the environment may significantly affect the outcome of subsequent bloat trials.

The first trials designed to measure the effect of LIRD on bloat were feedlot trials. Ruminally cannulated cattle were held in pens and fed green-chopped alfalfa once per day, a method that induces bloat incidents, which is useful for testing the efficacy of anti-bloat products (Hall and Majak 1992). Bloat was reported as a visual distension on one or both sides, 2 h after feeding, in three separate trials (Hall et al. 1994a). The incidence of bloat was 46.5% of 372 animal-days on feed. The overall bloat incidence was 20% less in cattle fed the LIRD-3 cultivar than in those fed Beaver, but the LIRD character was only effective in reducing bloat in one of the three trials.

Grazing trials to evaluate the LIRD-3 cultivar were also equivocal (Hall et al. 1994a). Restricted grazing allowances were used to mimic the feed availability in the feedlot trials and to reduce labour costs. Bloat was induced by allowing animals 6-h (morning) grazing periods on pasture followed by fasting for the remainder of the day. The incidence of bloat was much higher than in the feedlot trials, occurring on 60.6% of the 330 animal-days of grazing. The LIRD character showed no measurable effect in any trial, and overall the bloat incidence was only 2% less in cattle grazing the LIRD-3 cultivar.

All feedlot and restricted grazing trials were conducted during periods when the reported differences in DMD between Beaver and LIRD-3 in the same location were less than 11% (Hall et al. 1994a). The plant material used for

Table 1. Bloat incidents (number of bloat-postitive days) in cattle grazing two alfalfa cultivars (cv. AC Grazeland and Beaver) at three locations over three years (adapted from Berg et al. 1997)

Grazing trial	Location & period[z]	AC Grazeland	Beaver	Reduction (%)
Spring				
Trial 1	Kamloops, 10 – 29 May 1995	1	8	
Trial 2	Lethbridge, 21 June – 7 July 1995	6	4	
Trial 3	Melfort, 23 June – 13 July 1995	0	2	
Overall		7	14	50.0%
Summer				
Trial 1	Kamloops, 17 Aug. – 1 Sept. 1995	7*a*	23*b*	
Trial 2	Lethbridge, 8 – 24 Aug. 1995	18	20	
Trial 3	Melfort, 23 July – 8 Aug. 1996	1	0	
Overall		26	43	39.5%
Fall				
Trial 1	Kamloops, 15 – 26 Sept. 1994	5*a*	30*b*	
Trial 2	Lethbridge, 15 Sept. – 1 Oct. 1995	9*a*	20*b*	
Overall		14	50	72.0%
Total		47	107	56.1%

[z]No bloats during trials at Lethbridge from 21 May – 10 June 1996, 7 July – 30 July 1996 and 17 Aug. – 5 Sept. 1996 or Melfort from 3 Aug. – 18 Aug. 1995, 11 June – 28 June 1996 or 5 Sept. – 19 Sept. 1996.
a,b One tail probability test of AC Grazeland < Beaver at $P = 0.05$. Within a row, values followed by different letters differ ($P < 0.05$).

DMD determination was the tip of pre-bloom alfalfa leaders. This material is very palatable and likely the first selected by grazing livestock (Dougherty et al 1989b). In feedlot situations, cattle have less choice and eat more of the whole plant than would normally be consumed in grazing trials. Overall bloat incidence in feedlot trials would therefore be expected to be lower than in grazing trials, but all trials together would be unlikely to show significant differences between treatments if the difference in DMD was insignificant. Perhaps differences between treatments are masked when bloating conditions are extreme, as in the grazing trials, especially if the magnitude of bloat reduction is based on small variations in the initial digestion kinetics.

BLOAT IN CATTLE GRAZING AC GRAZELAND ALFALFA

The inconclusive bloat results from trials with early LIRD cultivars were discouraging. There had also been a lack of sufficient seed for feeding and grazing trials through much of the program. When a limited amount of seed of LIRD-4 (AC Grazeland B[r]), the fourth, and last, cycle of selection became available, the research team decided to conduct a full series of grazing trials in western Canada (Berg et al. 1996, 1997). The objective was to measure bloat occurrence and severity in steers grazing AC Grazeland compared to Beaver using an unrestricted grazing regimen.

Location and Seasonal Effects of AC Grazeland on Bloat

Trials were conducted at three sites – the Agriculture and Agri-Food Canada Research Centres near Lethbridge, AB (49°42′ N; 110°47′ W), Kamloops, BC, (50°42′ N; 120°24′ W) and Melfort, SK (52°65′ N; 104°45′ W). Beaver and AC Grazeland were seeded on adjacent 1-ha fields at each location, under irrigation at Lethbridge and Kamloops and on dryland at Melfort. The soil at the Lethbridge site is a slightly alkaline clay loam, a Dark Brown Chernozem that receives an average annual precipitation of 414 mm. The Kamloops soil is also an alkaline clay loam, a Humic Gleysol that receives 256 mm of precipitation. Melfort's soil is a silty clay loam, a Black Chernozem that receives 380 mm of precipitation.

Project managers at each location replicated the trial protocols as closely as possible to accommodate differences in agronomy and livestock handling between sites. Pastures at Lethbridge and Kamloops were irrigated as required, while unstocked. Paddocks were purposely understocked to permit a high degree of diet selection. All animals were ruminally cannulated and managed according to the guidelines of the Canadian Council on Animal Care. At Lethbridge, the herds were predominantly Jersey steers (body weight 480 ± 30 kg) ranging in maturity from 1 to 3 yr of age. The Kamloops Jersey herd was older (>3 yr). The herd at Melfort was mixed, including both beef and dairy breeds with a wider range of maturity (1 to 7 yr).

At each location, either 8 or 10 steers, depending on animal health and forage availability, were randomly allocated to one of two grazing groups. The four or five animals in each group were considered replicate grazers and were assigned to graze one or other of the alfalfa cultivars for the first of two periods in each grazing trial (Berg et al. 1996). The length of each grazing period in a grazing trial was limited by the cumulative bloat score following the protocol of Hall et al. (1994a). Grazing periods were not fixed except that after 7 to 10 d of grazing, forage availability often declined to such a degree that no more bloats could be expected. When either the cumulative number of bloats or reduced forage availability ended the first grazing period, each group was moved to the ungrazed paddock of the other cultivar for the second crossover period.

No bloat preventatives were used. Grazing cattle were observed every 1 to 2 h, from 0530 to 2300 h daily, and scored for bloat against a 5-point index (Majak et al. 1983; Berg et al. 1996). Obvious distension was the first condition used to report bloat. Animals in the field with a distension score of 3, 4 or 5 were removed from the pasture, vented by opening the cannula to release the pressure, and returned to the paddock.

Fourteen grazing trials were conducted over 3 yr, comprising six trials at Lethbridge, five trials at Melfort, and three at Kamloops (Table 1) (Berg et al. 1997). The number of trials at each location depended on the availability of labour and the purity and amount of regrowth in the alfalfa stands.

In 8 of the 14 grazing trials, the total number of bloats was two or less and in six of these trials, all conducted at Lethbridge and Melfort, no distension warranted intervention, although conditions were subjectively similar to those trials where bloat did occur (Table 1). For example, at Lethbridge there were no distensions above a score of 2 for the three trials conducted in 1996, although foamy rumen conditions were regularly observed during routine management (cleaning and inspection of the cannula) of the animals. The Melfort trials had insufficient bloats to make any comparisons, a result that is consistent with other bloat studies in Saskatchewan on dryland alfalfa (Ashford and Heinrichs 1967).

At all three locations, most bloat cases occurred in the 1995 grazing season (Table 1). No bloats were recorded in the spring 1996 trials, and the incidence of bloat was too low in all other spring trials to evaluate treatment differences by location. The late summer of 1995 was a period of high bloat incidence at Lethbridge and Kamloops but no bloats were recorded at Melfort. Technicians reported only one bloat at Melfort and none at Lethbridge in the summer, 1996 trials. A scheduled irrigation between grazing periods in the 1996 summer trial at Lethbridge had no apparent effect on bloat. The 1996 fall trials at Melfort and Lethbridge were also bloat-free. However, the fall is a period of high bloat risk (Hall and Majak, 1991) and in two autumns of the 3 yr of trials, bloat incidents exceeded 25 during 2 wk of grazing at the irrigated sites.

The bloat frequency at Kamloops was 19.6% (74 cases of distension in 376 animal-days of grazing). At Lethbridge the frequency was similar, 20.7% (136 cases of distension recorded in 656 animal-days of grazing during the first grazing season) (Table 2). Furthermore, over half the cases of distension at Lethbridge were classified as severe bloat (Berg et al. 1996). Of these severe bloats, 3.5% had progressed to the point where death was imminent.

Bloat is a rare event but it did not occur at random (Berg et al. 1996). For a rare event, bloat happened more frequently than expected when compared against a random distribution. Thus, bloat incidents were not independent of one another. Coefficients of dispersion indicate clumping (CD> 1) (Table 2), which corroborates producer observations that bloat occurs in clusters, also known as “bloat storms”, where little or no bloat occurs most of the time, but under certain conditions the incidence will be high and can be extreme.

In a bloat storm, many animals may bloat at once, with a few having multiple bloats in a 24-h period. At Kamloops there were no multiple bloats (>1 bloat case per head per day) reported when animals were grazing AC Grazeland. At Lethbridge, the group of animals grazing AC Grazeland had three multiple bloat cases on 2 separate days. In contrast, during the same grazing periods there were 17 cases of multiple bloats on 10 different days in the animals grazing the standard cultivar, Beaver. Thus, the incidence of multiple bloats was 82% lower in cattle grazing AC Grazeland.

Table 2. Occurence and coefficients of dispersion (CD) of bloat incidents in cattle grazing two alfalfa cultivars (cv. AC Grazeland and Beaver) at Lethbridge, AB (from Berg et al. 1996)

Cultivar	Occurrence[z]	CD[y]
AC Grazeland	0.095	2.75
Beaver	0.113	2.86
Overall	0.207	4.83

[z]Frequency: animal days of bloat/animal days of grazing
[y]Coefficient of dispersion = s^2/mean. CD = 1 indicates random distribution of incidents, CD > 1 indicates clumping, CD < 1 indcates dispersion (Sokal and Rohlf 1995).

None of the animals used in the trials could be considered a chronic bloater. All cattle at Lethbridge bloated at least once and 11 of the 17 used in these trials bloated more than five times during the first grazing season. Two animals at Lethbridge showed a propensity (P = 0.05) to become distended more frequently on the standard cultivar, Beaver, than on AC Grazeland. The overall coefficient of dispersion on the frequency of bloats in individual animals was 1.9, suggesting a degree of non-random clustering of bloat incidents (Berg et al. 1996). In other words, if one animal bloated there was a likelihood that others would be found in the same condition.

Effect of Cultivar and Plant Maturity on Bloat

AC Grazeland had a significant (P = 0.05) effect on bloat incidence (Table 1). There were 56% fewer bloat incidents on AC Grazeland than Beaver over 5 station-years of grazing trials (Berg et al. 1997). The range was wide, from no reduction to 84%, again reflecting the variation inherent in the occurrence of bloat at different locations and times of the year.

The effect of a character like LIRD may be confounded with the effects of plant maturity and seasonal growing conditions, making comparisons difficult. Goplen et al. (1993) observed that LIRD was expressed more in vegetative growth stages than in later stages of maturity. Hall et al. (1994a) felt that increasing plant maturity reduced the DMD after a 4 h in vivo incubation.

At Lethbridge, the three grazing trials in the first year were coincident with the late vegetative, early bud and late bud stages of development in AC Grazeland (Fick and Mueller 1989). In the second grazing season, AC Grazeland was in a late vegetative to early bud stage for all three trials (Berg et al. 1996). Similarly, animals were turned into the fields in Kamloops when AC Grazeland was vegetative or budding. The Melfort dryland site was grazed when AC Grazeland was slightly more mature than at the other sites, late bud to early bloom. This was a result of the prevailing climatic conditions and a requirement to obtain sufficient growth on each field before the trial to carry stock for the entire period of the trial.

Table 3. Effect of alfalfa maturity on bloat (total incidents/days of grazing) in cattle grazing two alfalfa cultivars (cv. AC Grazeland and Beaver) at Lethbridge, AB (from Berg et al. 1996)

Alfalfa maturity	AC Grazeland	Beaver	P^z
		All distension[y]	
Late vegetative[x]	0.171	0.243	0.027
Early bud	0.117	0.133	0.306
Late bud	0.125	0.117	0.676
Overall	0.136	0.162	0.069
		Severe bloat[w]	
Late vegetative	0.064	0.143	0.003
Early bud	0.092	0.102	0.372
Late bud	0.050	0.033	0.893
Overall	0.072	0.096	0.044

[z]One tail probability test for AC Grazeland < Beaver (after Hall et al. 1994a; Cochrane 1950)
[y]Includes all sub-acute and acute bloats; all distension scores ≥2.
[x]Cumulative days of grazing on which bloats occurred: late vegetative, 140 d; early bud, 196 d; late bud, 120 d; overall, 456 d.
[w]Includes acute bloats only; distension scores ≥3.

At Lethbridge, there were 456 animal-days of grazing associated with days when bloat occurred (Table 3). Most severe bloats occurred on lush, immature forage in the fall trials (Berg et al. 1996). There were detectable differences between the two cultivars at early stages of development; alfalfa is felt to be more bloat provocative when it is immature and less as it matures. Distensions occurred 29.6% less often on AC Grazeland in the late vegetative stages of growth than on Beaver, and severe bloat was 55.2% less frequent (Table 3). These differences disappeared with increasing plant maturity and the total number of bloats declined as well. The overall occurrence of distensions on AC Grazeland pasture was 16% lower than on Beaver. Severe bloat (pressure scored, Berg et al. 1996) occurred 25% less often on AC Grazeland than on Beaver. Thus the greatest reduction in bloat was achieved by grazing AC Grazeland when the cattle appeared to be most at risk but the frequency of bloat was reduced with increasing alfalfa maturity irrespective of the cultivar. Thus, maturity is more important than either cultivar in preventing or reducing the incidence of bloat.

Field observations at Lethbridge and Kamloops suggested that the maturity of AC Grazeland advanced at a faster rate than Beaver. Varying environmental and edaphic conditions between the fields could account for these observations, but it could also be inherent, that is, AC Grazeland may be an early maturing cultivar. Further research is being conducted to determine if AC Grazeland has an inherited trait that might account for the reduction in bloat, or whether the results are a consequence of maturity differences. This could be an advantage to graziers because the risk of bloat may decline more quickly with a faster rate of maturity.

IMPLICATIONS

The LIRD strain of alfalfa is a new tool to help graziers control digestion and reduce the risk of bloat. The effectiveness of the cultivar AC Grazeland B[r] varies with feeding or grazing management practices, plant maturity and the season of use. The lack of differences under extreme bloating conditions in the early grazing and feeding studies, and the variability in the others, shows that the rancher must still exercise a high degree of care and diligence. However, most bloat preventatives are not completely effective when bloat-provoking conditions are at their worst. Thus AC Grazeland is most likely to benefit graziers when it is employed as an adjunct to a well managed, bloat repressive grazing regimen.

New cultivars from the LIRD breeding program are unlikely because of the substantial commitment of resources that were required to push the alfalfa genome in the direction of bloat resistance. Techniques other than digestion in vivo, like gas production, can be used to assess the kinetics of digestion and will be applied more frequently to breeding programs in the future. However, to make alfalfa bloat resistant will require either a major reduction in digestibility or the acquisition of other anti-quality factors. Before these steps are taken, marrying the existing level of bloat reduction with grazing tolerance and developing management strategies and breeding programs that use bloat-free legumes may be more practical.

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