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Forage and Supplementation for Stocker Cattle

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MANAGEMENT AND SUPPLEMENTATION STRATEGIES FOR WHEAT PASTURE STOCKER CATTLE[1]

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INTRODUCTION

Winter wheat pasture is a very unique and economically important renewable resource in Oklahoma and the southern Great Plains. Income is derived from both grain and the **increased value that is added**, as weight gain, to growing cattle that are grazed on wheat pasture. The potential for profit from grazing stocker cattle on wheat pasture is exceptionally good because of the high quality of the forage and the very favorable seasonality of prices for stocker and feeder cattle that favor price appreciation of the cattle.

Supplementation of cattle grazing wheat pasture is of interest in order to (a) provide a more balanced nutrient supply and feed additives such as ionophores and bloat preventive compounds, (b) substitute supplement for forage where it is desirable to increase stocking rate in relation to grazing management and(or) marketing decisions, and (c) substitute supplement for forage under conditions of low forage standing crops. It is said that "risk" decreases the value of cattle. Predicting performance of wheat pasture stocker cattle is particularly challenging because of the potentially large variation in weather and forage standing crop. If weight gains of growing cattle cannot be predicted with some degree of accuracy, realistic breakevens, which are prerequisite to sound marketing decisions, cannot be calculated. The ability to predict cattle performance will become more important as the feedlot and stocker segments of the industry compete for supplies of stocker/feeder cattle, and as coordinated beef productions systems come to fruition. Results of some of the supplementation studies that we have conducted over several years at Oklahoma State University (OSU) are reported herein.

MINERAL CONTENT OF WHEAT FORAGE

Wheat pasture poisoning is a non-infectious metabolic disorder of <u>cows</u> grazed on wheat pasture. It occurs most frequently in mature cows that are in the latter stages of pregnancy or are nursing calves, and that have been grazing wheat pasture for 60 days or more. Cows with wheat pasture poisoning have low blood concentrations of both calcium and magnesium. While a similar, tetany-like condition may occur in stocker cattle, its incidence is <u>extremely low</u>. Considerable variation occurs in the mineral composition of wheat forage. Until more complete data are available the data in Table 1 have been selected to indicate the calcium, phosphorus,

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magnesium, and potassium content of wheat forage in relation to the requirements for the same minerals of a 400 lb steer calf gaining 2 lb per day.

Table 1. Mineral composition of wheat forage.

Item	Calcium	Phosphorus	Magnesium	Potassium
Composition, % of DM	.35	.25 - .40	.15	3-5
Requirement[a]	.56	.26	.10	0.7

[a]400-lb medium-frame steer calf gaining 2 lb/day and consuming 11 pounds DM/day (1984 Beef Cattle NRC).

The values indicate that wheat forage contains marginal to sufficient phosphorus and magnesium, excess potassium (which is characteristic of small grains forages in general) and inadequate amounts of calcium for growing cattle. Therefore, calcium is the macromineral of primary concern in many wheat pasture grazing situations. In these situations, wheat pasture stockers should be supplemented with an **additional 10 grams of calcium per day**. While this may seem to be a very small amount of calcium (and therefore perhaps not of practical importance), for perspective the total calcium requirement of a 400 lb steer calf gaining 2 lb/day is 28 grams. The additional calcium could be included as calcium carbonate in other supplements or a mineral mixture. No mineral mixture will be efficacious if desired amounts are not consumed. Intake of mineral mixtures must be monitored.

The lower values for phosphorus content of wheat forage (Table 1) are from Bushland, Texas (Stewart et al., 1981). In this area, and perhaps the **Panhandle of Oklahoma and Southwestern Kansas**, wheat pasture stocker cattle should also receive supplemental phosphorus depending on soil type and actual mineral analysis of wheat forage. More recently we encountered a case of phosphorus deficiency in a group of growing steers grazing wheat pasture near Loyal, Oklahoma (i.e., North-Central Oklahoma). The farm had been in alfalfa for about 6 years prior to putting it into wheat. The application of phosphorus fertilizer for the wheat crop was less than recommended from soil test results. Phosphorus, calcium, magnesium and potassium contents of wheat forage samples collected on January 14 were, respectively, **0.16**, 0.26, 0.16 and 1.72 % of DM. The Angus steers appeared healthy and were fairly fleshy, but seemed to crave bones, which were present in a native grass area adjacent to the wheat pasture, from carcasses of cows that had died in previous years. Depraved appetite or pica is a classical sign of phosphorus deficiency in beef cattle. We changed the mineral mixture that was being fed from a low-phosphorus mineral (4.0 %) to a mineral mixture that contained 12% calcium, 12% phosphorus and 12% salt. According to the owner, this resolved the bone chewing problem.

The question relative to the effect of feeding mineral mixtures (**often high-magnesium mineral mixtures**) to wheat pasture stockers on the incidence of bloat is commonly raised. There is no evidence to support the suggestion that supplemental magnesium will decrease the incidence and(or) severity of bloat of stocker cattle on wheat pasture. There may be a relationship between ruminal motility (and the ability of stocker cattle to eructate ruminal gases) and the **CALCIUM** status of the cattle. Ruminal and gut motility is greatly compromised by subclinical deficiencies of calcium. Therefore, the concern of providing additional calcium to growing cattle on wheat pasture is two-fold: (1) to meet requirements for growth and (2) to perhaps decrease the bloat problem by an effect on ruminal motility. An interesting question is: Are the so-called "dry bloat" problems that are sometimes observed in wheat pasture stocker cattle related to a subclinical deficiency of calcium?

PROTEIN SUPPLEMENTATION

This section is included to briefly summarize some of the rationale and results of research conducted at OSU relative to the idea of providing undegradable intake protein to growing cattle on wheat pasture, and not as a through review of this subject. The National Wheat Pasture Symposium was held at OSU in the fall of 1983 to summarize the database relative to production and utilization of wheat pasture by cattle. Beever (1984) presented data that was interpreted to suggest that performance of rapidly growing cattle on wheat pasture may be limited by flow of inadequate amounts of non-ammonia N (NAN) to the small intestine. Johnson et al. (1974) reported CP values of wheat forage of 25 to 31% of DM during January to April with 17 to 33% of the nitrogen (N) being in the form of non-protein nitrogen (NPN). Horn et al. (1977) observed total soluble N and soluble NPN concentrations of wheat forage of 45 to 62 and 25 to 37% of total N, respectively. Beever et al. (1976), in studying different conservation methods for perennial ryegrass, observed a significant negative relationship ($r = -.98$, $P<.001$) between the amount of N flowing to the small intestine (grams per 100 g N consumed) and solubility of forage N in .01% pepsin in .1N HCl. Egan (1974), Ulyatt and Egan (1979) and Egan and Ulyatt (1980) reported large losses (i.e., 40 to 45%) of ingested N from the rumen of sheep fed high-protein ryegrass. Studies by Vogel et al. (1989a) showed that N of immature and mature wheat forage exist kinetically as two distinct pools with different rates of in situ ruminal disappearance. Approximately 50 to 75% of total forage N disappeared from a "very rapid disappearance" pool at rates of 16 to 19% per hour. Broderick (1984) also suggested the presence of two "degradation fractions" of N of alfalfa hay. MacRae and Ulyatt (1974) reported that 63% of the variation in live weight gain of sheep grazing ryegrass or white clover pasture was associated with the amount of NAN absorbed from the small intestine, and that there was no relationship between live weight gain and energy absorbed as volatile fatty acids (i.e., a measure of the "energy status" of the animals). These data indicated that the **traditional concept** that performance of growing cattle on wheat pasture is not limited by protein status should be reevaluated.

Studies were conducted at OSU over four wheat pasture years to determine the effect of feeding additional escape protein on weight gains of stocker cattle grazing wheat pasture. Details of the studies have been reported by Vogel et al. (1989b) and Smith et al. (1989). Cattle received no supplement (other than free-choice access to a commercial mineral mixture) or were fed daily 2 lb of a corn-based energy supplement or supplements that provided about .25 kg of protein from high-escape protein as cottonseed meal produced by mechanical extraction, meat meal, meat and bone meal, or corn gluten meal. The .25 kg of protein from high-escape protein is very similar to the levels used by Anderson et al. (1988) in which supplemental escape protein increased gains of steers grazing smooth brome pastures. The supplements were isocaloric and contained similar amounts of calcium, phosphorus and magnesium. Monensin was included in the supplements to supply 130 to 150 mg/steer/day.

Daily gains of the cattle were increased (P<.03) about .22 lb by the overall effect of supplementation. Provision of additional ruminal escape protein as cottonseed meal, meat meal, meat and bone meal, or corn gluten meal did not increase gains (P>.30) as compared with the corn-based energy supplement. Our conclusion was that even though wheat forage contains large amounts of N that is rapidly degraded in the rumen, intakes of fermentable OM appear to provide energy for sufficient microbial protein synthesis in the rumen for growth of stocker cattle. In a later study reported by Phillips et al. (1995), nitrogen retention of lambs fed freshly harvested wheat forage in metabolism stalls was not improved by supplemental undegradable intake protein from cottonseed meal, feather meal plus corn gluten meal, or blood meal as compared with a corn-based energy supplement.

Interestingly the Level 1 Model of the 1996 Beef Cattle NRC, with the default microbial efficiency of 13% and predicted DM intakes, indicated that metabolizable energy intake was first-limiting with respect to ADG of stocker cattle grazing wheat (Reuter and Horn, 2000).

ENERGY SUPPLEMENTATION

Feeding **moderate amounts** of an energy supplement to growing cattle on wheat pasture is a way of increasing the stability of the enterprise, improving the predictability of cattle performance (i.e., decreasing production risk), and increasing stocking rate and flexibility by having more cattle on hand for grazing during the graze-out period. Because of the seasonality of stocker/feeder cattle prices and the dynamics of breakeven selling prices in stocker cattle budgets, the latter of these can be particularly important to the economics of growing cattle on wheat pasture. be

Silage

There are areas of the southern Great Plains where silage is used very successfully to "stretch" available wheat forage and(or) allow initial stocking densities on wheat pasture to be increased. In studies reported by Vogel et al. (1987 and 1989c), use of supplemental silage allowed initial stocking density on wheat pasture to be doubled without decreasing weight gains of stocker cattle. Supplemental silage decreased wheat forage intake linearly (P<.10). Each pound of added silage DM decreased DM intake of wheat forage by .66 lb. Extent of ruminal digestion of DM and NDF of wheat forage was increased by feeding silage indicating that silage had a positive associative effect on utilization of wheat forage (Vogel et al., 1989c).

High-Starch versus High-Fiber By-Product Feed Based Supplements

The response of growing cattle on wheat and(or) other small grain pastures to supplemental grain has been variable. In studies reported by Elder (1967), Lowrey et al. (1976a, b), Utley and McCormick (1975, 1976), and Gulbransen (1976), steer grazing days/ hectare or stocking densities were increased 1.25- to 2-fold and daily gains were increased by .05 to .30 kg by feeding grain at levels of 1 to 1.5% of BW. Supplement conversions (kilograms of supplement/kilogram of increased gain/hectare) ranged from 6.7 to 10.3. To prevent adverse effects of starch on ruminal fermentation, high-fiber byproduct feeds, such as wheat middlings, soybean hulls, and corn gluten feed, offer alternatives in formulating energy supplements with fairly high energy densities. The potential for using these byproduct feeds in supplementing growing cattle on wheat pasture is particularly good because of the rapid rate of ruminal degradation of wheat forage (Zorrilla-Rios et al., 1985) and the relatively low ruminal pH (Andersen and Horn, 1987).

During the three wheat pasture years of 1989/90, 1990/91 and 1991/92, we conducted studies to evaluate **type of energy supplement** (i.e., a corn-based, high-starch versus a high-fiber by-product feed based energy supplement) for growing cattle on wheat pasture. The high-fiber energy supplement contained about 47% soybean hulls and 42% wheat middlings (as-fed basis) and potentially may have less negative effects on forage intake and utilization than the high-starch supplement. The supplements were hand-fed 6 days/week at a level of about .75% of body weight (i.e., 4 lb/day for a 533 lb steer) and stocking rate was increased 22 to 44%. Non-supplemented, control cattle had free-choice access to a high-calcium commercial mineral mixture throughout the study. The objective of this supplementation program with respect to increasing stocking density was much different from that of Grigsby et al. (1991), Rouquette et al. (1990), and Branine and Galyean (1990), who fed energy supplements at levels of .15 to .20% of BW to cattle grazing rye-ryegrass or wheat pastures without increasing stocking density. Conversions of a corn-based energy supplement of 1.3 to 3 lb/lb of increased gain/animal were reported by Grigsby et al. (1991). Details of our studies have been reported by Horn et al. (1991), Cravey et al. (1993), and Horn et al. (1995). In general, results were as follows:

Supplementation Response. Over the 3-year period, weight gains during the fall/winter and early spring grazing period (i.e., up to time of jointing of wheat) were increased by energy supplementation (regardless of **type** of energy supplement) by an average of .33 lb/day, and were 2.02, 2.33, and 2.38 lb/day for the control, high-starch, and high-fiber supplemented steers, respectively. The gain response was similar at all stocking densities which increases the scope of application of the results. Mean consumption of the supplements was **.65%** of body weight which was a little less than the target of .75%.

Type of Energy Supplement. Type of energy supplement (i.e., high-starch vs high-fiber) did not affect weight gains of the cattle. In general, one would expect the difference in response by cattle to high-fiber versus high-starch energy supplements to decrease as the amount of supplement fed decreases and as crude protein content of the forage increases. The level of supplement fed in these studies was relatively small and wheat forage contains excess crude protein. Substitution of the supplements (i.e., units change in forage OM intake per unit increase in supplement OM intake) was calculated by regression of forage intake on amounts of supplement consumed. Substitution did not differ ($P > .60$) for the two types of supplements and was -.91 (Cravey, 1993). The mechanism for substitution of the supplements for forage has not been identified, but would not be expected to be the result of a ruminal nitrogen deficiency as has often been the case in grazing studies as discussed by Horn and McCollum (1987).

Supplement Conversion. Mean conversion of the supplements (expressed as lb of as-fed supplement per lb of increased gain per acre) was about **5.0** for both types of supplement, and did not differ ($P > .95$). This is substantially less than conversions of 9 to 10 that have **traditionally**

been used in evaluating the economics of energy supplementation programs for wheat pasture stocker cattle.

Cattle Preference for Supplements. Cattle seemed to like the high-fiber supplement and consume it much more readily than the corn-based high-starch supplement. Generally, the cattle consumed the high-fiber supplement in a matter of 10-30 minutes in the morning; whereas, the corn-based supplement was eaten over at least 2 feeding periods during the day (morning and mid-afternoon). From a feed and bunk management standpoint, this difference in the supplements is extremely important on days of inclimate weather (i.e., rain, snow etc.) and in situations of bird predation where contamination of feed bunks by bird excreta was substantial for the corn-based supplement. In addition, the potential for acidosis is much less for the high-fiber supplement provided that the wheat middlings used in the high-fiber supplement don't contain a lot of fine starch.

Risk Aversion. We addressed the issue of risk aversion and input decisions relative to energy supplementation of stocker cattle under various cattle and supplement price scenarios (Coulibaly et al., 1996), and concluded that, in general, supplementation decreases production risk.

Feedlot Performance. Because wheat pasture cattle are some of the more fleshy cattle that are placed on feed, we were interested in the potential effect of energy supplementation on subsequent feedlot performance and were able to "follow the cattle through the feedlot" in two of the three years. Supplementation did not affect feed intake or feed:gain (P>.30) in one year whereas daily gain was decreased by about 0.20 lb (P<.05). In another year, supplementation did not (P>.80) affect feedlot daily gain.

Economic Analysis (a.k.a.: Will it Pay?)

There are several levels of economic analyses that can be used in evaluating the economics of supplementation programs and other management decisions in stocker cattle programs. Three of them are briefly discussed below.

Comparison to Value of Weight Gain

One approach is to simply compare cost of the additional weight gain to the gross value of weight gain in the stocker program. From the data reported by Trapp (1998) for Oklahoma City National Stockyards, we have fit price ($/cwt) to sale weight for stocker/feeder steers and heifers over two periods of time (1988-97, 10 years; and 1992-97, 5 years). Prices were related to weight as follows:

Steers, 1988 -1997	Price ($/cwt) = $150.11 - .1579x + .00008x^2$
Steers, 1992 - 1997	Price ($/cwt) = $132.03 - .1286x + .00007x^2$
Heifers, 1988 - 1997	Price ($/cwt) = $120.78 - .1166x + .00007x^2$
Heifers, 1992 - 1997	Price ($/cwt) = $104.65 - .0902x + .00006x^2$

If one then adjusts the prices for seasonality, value of weight gain for purchasing calves in October and selling feeders in March are shown in Table 2. The value of weight gain for growing steers on wheat pasture from 450 to 650 lb or from 450 to 750 lb ranged from about $54 to $61/cwt. Values for adding 200 lb to 350- or 450-weight heifers are substantially higher.

Table 2. Value of weight gain, $/cwt.

	1988 - 1997 (10 years)		1992 - 1997 (5 years)	
Wt. Range, lb	Steers	Heifers	Steers	Heifers
350 - 550	-----	$73.01	-----	$70.67
450 - 650	$60.61	$66.27	$60.72	$64.38
450 - 750	$54.77	-----	$53.45	-----

If the cost of the additional weight gain from supplementation is less than the value of weight gain, supplementation would be profitable. At a supplement conversion of **5 lb supplement per lb of increased gain per acre** and a feed cost of $140/ton, supplement cost per lb of increased gain would be $0.35. REMEMBER this is valid only if stocking density is increased since supplement conversion is expressed on an increased gain per acre basis. Also, any additional costs incurred in feeding the supplement (e.g., fuel, labor, etc.) should be included in the evaluation.

Budgeting the Stocker Operation

Microcomputer spreadsheet programs such as the "OSU STOCKER PLANNER" developed by Don Gill are excellent tools for evaluating a myriad of questions, management decisions, etc. in a stocker cattle program. Many of you are familiar with the program. Copies can be downloaded from our web site (http://www.ansi.okstate.edu/). Pasture can be priced on (1) a cost of gain basis or (2) as $/CWT of cattle/month. In addition the pasture cost input can be "finessed" to achieve any pasture cost ($/head) that you want.

Whole-Farm Economic Analysis

As stated earlier, this energy supplementation program has the potential advantage of allowing stocking density to be increased by about one-third. This allows more cattle to be purchased in the fall on seasonally low markets and to be available to graze-out a greater proportion of wheat in the spring. In a previous report (Horn et al., 1992), whole-farm net returns were estimated for three government farm program alternatives for the 1990/91 wheat pasture year (non-participation, the 5-month option and 0/92) and three cattle price scenarios that reflected stocker/feeder price spreads in real dollars of -$22.00 (low profitability), -$16.00 (moderate profitability) and -$7.00 (high profitability). The energy supplementation program (and increased stocking density) increased exposure to down-side price risk and resulted in lower whole-farm net returns under the low cattle price scenario. On the other hand, the energy supplementation program captured the benefits of favorable cattle price movements, and increased whole-farm net returns under the moderate and high price scenarios. More recently we have developed a microcomputer decision support program (Epplin et al., 1999) to assist in evaluating the economic consequences of alternative wheat and wheat-stocker production systems.

THRESHOLD HERBAGE ALLOWANCE FOR INITIATION OF ENERGY SUPPLEMENTATION PROGRAMS

Two studies were conducted (Redmon et al., 1995) to determine the relationship between in vitro organic matter (OM) disappearance in diets of cattle grazing wheat pasture and herbage allowance, the relationship between wheat forage intake (kg OM/100 kg BW) and herbage allowance, and the relationship between estimated daily gain of growing beef cattle grazing wheat pasture and herbage allowance. Paddocks were differentially grazed with growing beef cattle to produce an array of different herbage mass levels, expressed as kg dry matter (DM)/hectare. Each experimental paddock was then continuously stocked with three steers during each 7-day forage intake trial. Estimated daily gain was calculated from forage intake and net energy values calculated from diet organic matter disappearance data. Forage intake, organic matter disappearance, and estimated daily gain were related to daily herbage allowance, expressed as kg DM/100 kg BW/ day, and herbage mass utilizing a quadratic equation with a plateau function. Plateaus for diet OM disappearance, forage intake, and daily gain were achieved at herbage allowance between 20 to 24 kg DM/ 100 kg BW/ day, and decreased markedly at herbage allowances below this range. These data were interpreted as suggesting that a herbage allowance of 20 to 24 kg DM/ 100 kg BW/ day may provide a threshold allowance for initiation of energy supplementation programs for growing cattle on wheat pasture. Similarly, Ellis et al. (1984) reported that DM digestibility by steers grazing annual ryegrass was progressively decreased ($P<.01$) as herbage allowance was reduced to less than 30 kg/100 kg BW.

IONOPHORES FOR WHEAT PASTURE STOCKER CATTLE AND DEVELOPMENT OF A SMALL-PACKAGE MONENSIN-CONTAINING ENERGY SUPPLEMENT

Two ionophores, monensin and lasalocid, are available for wheat pasture stocker cattle. Both of them, if delivered in the proper dosage, increase weight gains of growing cattle on wheat pasture by .18 to .24 lb/day over that of the carrier supplement (Horn et al., 1981 and Andersen and Horn, 1987), and improve the economics of supplementation programs. In addition, producer experience and research (Branine and Galyean, 1990) indicate that monensin decreases the incidence and severity of bloat from wheat pasture. Other characteristics of the two ionophores are listed below. The **"+" sign** indicates a more favorable or greater response of one over the other.

	Monensin	Lasalocid
Weight Gain Response	Equal if achieve proper dosage of ionophore	
Bloat protection	+	
Palatability		+
Potential for toxicity	+	
FDA clearance for every-other-day feeding	+	

If the ionophore is included in a mineral mixture with a relatively low target intake (i.e., .25 to 1 lb/head/day) it has to be present at a greater concentration in order to supply the daily dosage of 150 to 200 mg/head than if it is included in a larger amount of some other feed or supplement. Therefore, the palatability advantage of lasalocid favors its use over monensin in mineral mixtures. In a preliminary study that we conducted many years ago (Horn and Phillips, 1985) consumption of a cottonseed meal- and wheat middling-based mineral mix, which contained either monensin or lasalocid, by stocker cattle on wheat pasture was .28 and .53 lb/head/day for the monensin and lasalocid-containing supplements, respectively. The supplements contained 400 mg ionophore/lb and the target daily intake was .50 lb/head.

During the **1991/92** wheat pasture year we measured voluntary intake of three different commercial mineral mixtures by cattle at the Marshall Wheat Pasture Research Unit. Pastures ranged from 18 to 42 acres and small numbers of cattle, as compared with the industry, grazed each pasture. The mineral mixtures were fed in a single weather vane-type mineral feeder in each pasture. No salt or other supplement was fed during the trial. Water from a rural water system was supplied in each pasture by a single water fountain. Intake of the different mineral mixtures is shown in Table 3.

Table 3. Intake of different mineral mixtures (1991/92 wheat pasture year).

Mineral	Wheat Gainer Mineral[a]	Wheat Pasture Pro Mineral B1440[b]	Purina Wheat Pasture Mineral RM[c]
Manufacturer:	Farmland	Farmland	Purina Mills
Ionophore Concentration:	None	720 mg lasalocid/lb	150 mg monensin/lb
Target intake, lb/head/day	0.25	0.25	1.0
Mean (± SD) intake, Lb/hd/day	.30 ± .09	.23 ± .06	.14 ± .04 (Mix 1) .34 ± .11 (Mix 2)
Number of pastures	2	6	1
Head/pasture	12	5 to 7	22 to 26

[a]**Presently named "Wheat Pasture Pro Mineral".** Contained 20% salt, 16% calcium, 4% phosphorus, 5.5% magnesium and 150,000 I.U. Vitamin A per pound. Eleven observations at 6-day intervals per pasture mean.

[b]Contained same mineral and vitamin concentrations as footnote "a" above. Eleven observations at 6-day intervals per pasture mean.

[c]Contained 20% salt, 7% calcium, 6.75 magnesium and 30,000 I.U. Vitamin A per pound. Ten and eight observations at 6- and 5-day intervals for mix 1 and 2, respectively.

Intake of the Wheat Gainer Mineral was excellent and averaged .30 lb/head/day. This level of intake would provide 21 grams of calcium, and is consistent with the type of mineral needed to supply additional amounts of calcium to growing cattle on wheat pasture. Intake of the lasalocid-containing mineral was also good and would have supplied 166 mg of lasalocid. In previous research (Andersen and Horn, 1987), we observed a weight gain response by wheat pasture stockers to 200 mg/day of lasalocid but NOT to 100 mg/day of lasalocid. In general, intake of the monensin-containing mineral mix was low and was consistent with previous experience (Horn and Phillips, 1985) where we compared intake of a monensin- *versus* lasalocid-containing mineral mixture. Intake of the monensin-containing mineral mixture was too low to provide sufficient monensin to increase cattle performance.

During the last few years, several feed manufacturers have marketed a "*new*" monensin-containing mineral mixture for stocker cattle. This mineral mixture is an "R1620" formulation and contains 810 mg monensin/lb, about 10 % calcium, and a much lower concentration of magnesium than the mineral mixture (6.75% Mg) that we used in the 1991/92 study (Table 3). The lower concentration of magnesium may improve intake of the mineral. Brazle and Laudert (1998) reported that weight gains of yearling steers given free-choice access to a "R1620" mineral mixture while grazing either intensive early stocked or season-long native summer grass tended to be increased by .22 lb/day (NS) or were increased .16 lb/day ($P<.08$), respectively, as compared with the mineral mixture without monensin. Daily intake of the "R1620" mineral mixture was about 3.4 oz/steer *versus* 5.0 oz/steer for the mineral mixture without monensin. Thus, monensin intake was about 170 mg/steer, and may have been too low for maximum gain improvement of the steers that averaged about 670 to 700 lb during the study. During the **2000/2001** wheat pasture year we conducted a study (Horn et al, 2001) relative to the effect of mineral supplementation with or without ionophores on mineral intake and growth performance of wheat pasture stocker cattle. One-hundred and thirty six (136) fall-weaned steer calves were randomly allotted within weight groups to four treatments as follows: (1) control, no mineral or any other supplement, (2) mineral mixture without an ionophore, (3) R-1620 "Blue Bird" mineral mixture with monensin included at 1,620 grams/ton, and (4) B-1440 mineral mixture with lasalocid included at 1,440 grams/ton. Weekly intakes of the mineral mixtures (and calculated ionophore intakes), and weight gains of the steers were measured during the fall/winter (70 days) and grazeout (21 days) periods. Daily intake of the mineral mixture without an ionophore averaged 0.47 lb/steer and was greater ($P<.001$) than the mineral with monensin. Daily intake of the mineral with monensin averaged only 0.10 lb/steer and provided only 83 mg monensin. Intake of the monensin-containing mineral mixture was less ($P<.002$) than the mineral with lasalocid. Steers consumed 0.36 lb/day of the lasalocid mineral which provided 258 mg lasalocid/day. Weight gain of steers of all treatments averaged only 0.90 lb/day during the first 70 days, were excellent during the short grazeout period, and averaged 1.10 lb/day over the entire 91-day grazing period. Weight gain of steers of the control vs mineral, mineral vs the average of the two ionophores, and monensin vs lasalocid treatments were not different ($P\geq.11$) during both grazing periods and over the entire 91-day trial. The 2000/2001 wheat pasture year was one of the worst that we have ever experienced. There was very little forage during the very short fall/winter grazing period, and performance of cattle was poor. Therefore, this study will be repeated this year.

Variation in daily intake of supplements as well as mean overall supplement intake affect the response of grazing cattle to supplementation programs, and should be considered when selecting among the different strategies for getting appropriate additives into grazing cattle. In the study reported by Andrae et al. (1994), improvements in weight gain of cattle grazing wheat pasture and hand-fed a monensin-containing energy supplement decreased as variation in daily supplement intake increased. Also, improvement in weight gains of cattle that consumed greater than 150 mg monensin/head/day was greater than that of cattle that consumed less than 150 mg/head/day of monensin.

Self-Limited Monensin-Containing Energy Supplement

Because of problems associated with delivering a sufficient amount of monensin by mineral mixtures and other considerations as discussed above, one of our initial research objectives within the **Expanded Wheat Pasture Research Program** was to develop a small-package, self-limited monensin-containing energy supplement for wheat pasture stocker cattle. The target level of consumption of this supplement is 2 to 3 lb/head/day and the supplement should:

1. Help balance the energy:crude protein ratio of wheat forage as discussed, from a conceptual standpoint, by Hogan (1982).
2. Provide monensin to:
    A. Improve the economics of the supplementation program.
    B. Decrease the incidence of bloat.
3. Provide additional calcium for growth of stocker cattle.
4. Provide a means from a **management standpoint** of getting other feed additives into the cattle when needed [i.e., Bloat Guard (poloxalene) in cases of severe or protracted bloat outbreaks].

Details of the individual year studies have been reported by Horn et al. (1990), Horn et al. (1992), and Beck et al. (1993). **Note:** Because of the low targeted level of intake of the supplement, stocking densities were not changed when this supplement was fed. The supplement is designed to "supplement" wheat forage rather than to "substitute" for wheat forage.

Composition of this supplement is shown in Table 4, and the mean (± standard deviation) of supplement and monensin intakes are shown in Table 5. The supplement was fed as a 3/16-inch pellet during the first two years and in the **meal form** during the third and fourth years. While we experienced some over consumption (i.e., **mean overall daily consumption of monensin greater than 200 mg**) of the supplement by one group of cattle during each of the first two years, mean intakes were "close" to the target. In general, the target supplement intake of 2 to 3 lb/head/day was more closely achieved by feeding the supplement in meal form. Feeding the supplement in meal form probably slowed rate of consumption of the supplement and may have increased the taste of salt. Control of intake of the self-limiting supplement was particularly challenging during the 1992/93 wheat pasture year because it was so wet. There were times in which the cattle just didn't seem to want to fight the mud and, therefore, stayed closer to the feeder and source of water.

Table 4. Composition (as-fed basis) of self-limiting monensin-containing energy supplement[a].

Ingredient	%
Ground milo	62.81
Wheat middlings	20.97
Sugarcane molasses	4.79
Calcium carbonate	4.00
Dicalcium phosphate	2.54
Magnesium oxide	.75
Fine mixing salt	4.00[b]
Rumensin 60 Premix	.125[c]

[a]Fed as 3/16-inch pellet during the first two years and in the meal form during the third year.
[b]Increased to 6%, at the expense of milo, depending on supplement intake.
[c]To provide 75 mg monensin/lb of supplement.

Table 5. Daily consumption of self-limited monensin-containing energy supplement[a]. (Mean ± std. dev.).

Pasture	1	2	n[b]
	Trial 1 (1989 - 90)		
Supplement, lb/head	2.63 ± 1.00	4.24 ± 1.02	34
Monensin, mg/head	197 ± 75	318 ± 77	34
	Trial 2 (1990 - 91)		
Supplement, lb/head	4.08 ± 1.29	2.41 ± 1.19	33
Monensin, mg/head	306 ± 96	181 ± 89	33
	Trial 3 (1991 - 92)		
Supplement, lb/head	2.00 ± .71	2.00 ± .77	34
Monensin, mg/head	150 ± 53	150 ± 58	34
	Trial 4 (1992 - 93)		
Supplement, lb/head	2.67 ± 1.28	3.13 ± 1.52	34
Monensin, mg/head	200 ± 95	235 ± 114	34

[a]Supplement was fed as a 3/16-inch pellet during the first two trials and in the **meal form during trials 3 and 4.**
[b]Number of observations. Consumption of supplement was measured twice weekly.

Cattle performance data is shown in Table 6. Weight gains were consistently increased by about .5 lb/day by the supplement. At feed costs of $80, 110 and 140/ton, per-head profits were increased by $15 to $31 (1990 dollars) depending on profit potential that existed during the 10-year period, 1980-89. These increased per-head returns do not include additional profits as a result of decreased death loss due to bloat as a result of feeding the monensin-containing energy supplement. Each one percent decrease in death loss would be worth another $5 to $7/head depending on cost of the cattle and when they died.

Table 6. Effect of self-limited monensin-containing energy supplement on daily gains (lb) of steers.

		Treatment		
Trial No.	Dates (Days)	Control	Monensin/energy Supplement	Supplement Response
1	October 26, 1989 to February 24, 1990 (120 days)	1.76	2.29[a]	+.53
2	November 13, 1990 to March 14, 1991 (120 days)	2.42	2.91[b]	+.49
3	November 17, 1991 to March 6, 1992 (120 days)	2.31	2.76[c]	+.45
4	November 13, 1992 to March 14, 1993 (122 days)	1.65	2.12[a]	+.47

[a]Greater than control ($P < .03$).
[b]Greater than control ($P < .003$).
[c]Greater than control ($P < .15$).

While this supplement was designed to be self-limited, **it has not been approved by the Food and Drug Administration (FDA) for free-choice feeding** and it does **require close management. Monensin in large amounts will kill cattle.** However, if one considers the LD_1 for monensin to be 5.5 mg/kg body weight (Potter et al., 1984) or 1250 mg/head/day for a 500-lb steer, then there is a theoretical safety ratio of 4.17 for 500-lb cattle consuming 300 mg monensin/day. Each year of these studies, cattle had free-choice access to large round bales of grass hay during periods of low wheat forage availability and(or) snow(ice) cover of wheat in an attempt to curb appetite and prevent over consumption of the self-limited supplement. Other management practices that may help achieve the desired level of intake of self-limited supplements by cattle on pasture include placement (location) of feeder(s) with respect to water and other cattle loafing areas, adjustments of the feed hopper door (i.e., How readily does the supplement flows out of the feeder or how difficult is it for the cattle to get at the supplement?), and availability of other sources of salt such as block salt. Proportional adjustments in drug concentration of the supplement can also be made to achieve the desired level of intake.

Modifications of the Formula

We had an additional opportunity to study this supplementation program during the 1995/96 wheat pasture year at the Marshall Wheat Pasture Research Unit. The "original" formula for this supplement contained about 67% ground milo and 21% wheat middlings. The wheat middlings were included primarily to improve pellet quality during the first two years of the study. The objective of the 1995/96 study was to determine if substitution of equal proportions of wheat middlings and soybean hulls **(midds/hulls)** for the ground milo and wheat middlings of the original formula affected intake of the self-limited supplement and cattle growth performance. The monensin concentration of the supplement was also decreased from 75 mg/lb ("original" formula) to **60 mg/lb** in order to provide a greater margin in relation to the FDA approved level of monensin intake.

Mean intake of the milo-based ("original" formula) and the midds/hulls-based supplements from December 7, 1995 through March 13, 1996 (98 days) was 2.06 and 2.33 lb/steer/day, respectively. There was no difference between intake of the two supplements. This will give greater flexibility in formulating this supplement depending on the availability and cost of energy feedstuffs. Monensin consumption averaged 124 and 140 mg/steer/day for the milo- and midds/hulls-based supplements, and was lower than the desired level of 180 to 200 mg.

Daily weight gain of steers during the 98-day study averaged 2.12 lb (non-supplemented, control), 2.41 lb (milo-based supplement), and 2.36 lb (midds/hulls-based supplement), and was increased by supplementation but not by type of supplement (i.e., milo- versus midds/hulls-based supplement). The gain response to supplementation was substantially less than that of our previous studies, and probably due to the lower mean intake of supplement and monensin particularly during the early part of the study.

What are the Limiters of Intake?

Salt. During the first year of these studies we sometimes increased the level of salt in the supplement from 4 to 6% when consumption was greater that desired and(or) provided plain block salt for the cattle. These levels of salt were based on initial conversations with some of you, and in subsequent years we have stuck with the 4% level, and have not conducted studies to evaluate the sensitivity of supplement consumption to salt level.

Monensin. Using four wheat pastures equipped with Pinpointer feeders near Stillwater, we (Paisley and Horn 1996a and 1996b) examined the effect of monensin on voluntary consumption of the self-limited supplement. Each 22-acre pasture was grazed by 11 fall-weaned steer calves from one of the OSU beef cow herds. The pastures were about 681 meters long and 125 meters wide and had automatic waterers at the south end of each pasture. The Pinpointer feeders were located within 17 meters of the waterers in each pasture. The steers had free-choice access to the milo-based supplement with 4% salt and either no monensin or 75 mg monensin/lb as-fed. Supplements were fed in meal form, and were sampled each time feed was added to the hopper bin to verify monensin concentrations. Supplement intakes of each group of steers from January 17 to April 12 (84 days) were calculated from feed and weekly weigh-backs because of large discrepancies between the calculated data and Pinpointer data. Thus, no data was obtained relative to frequency of supplement intake and meal size by the individual steers.

Supplement intakes were analyzed as a repeated measures design with week and treatment in the model. Because there were no week by treatment interactions ($P>.15$), the data were pooled across weeks. Mean intakes ($\pm$ std. Dev.) of the supplements were: 4.72 $\pm$1.52 and 5.35 $\pm$ 0.93

lb DM (0 mg monensin); and 1.34 ± 0. and 1.54 ± 0.52 lb DM (75 mg monensin/lb), and were decreased by monens (P<.001). Overa.i weight gain of steers of the two treatments were not different (P=.24) even though they consumed much lo er amounts of the monensin-containing supplement.

Magnesium Oxide. Similar studies as described above for monensin were conducted by Paisley (1998) with the milo-based supplement containing 4% salt, 75 mg monensin/lb, and four levels of magnesium oxide (BayMag) using the Pinpointer feeders. Levels of magnesium oxide were .25, .75. 1.25, and 1.75 % of the as-fed supplement. Actual magnesium concentrations were .49, .85, 1.17, and 1.56 % as-fed, and the supplements analyzed 80 to 85 mg monensin as-fed. Forty eight spring-born Angus X Hereford crossbred steers were obtained from one of the OSU beef cow herds. Steers were initially weighted November 8 and assigned to one of four pastures. Cattle were fitted with pinpointer collars on November 13 and allowed to adapt to feeders for 8 days prior to the intake measurements. Final weights were taken December 20, with both initial and final weights recorded after a 14-h shrink.

Because supplement intakes of individual animals were measured, steer weights and daily gains were analyzed as a completely randomized design with animal as the experimental unit. Supplement intakes were analyzed using two models. Model I included treatment, steer(treatment), day, and treatment x day as sources of variation, and was used to analyze all 1344 intake observations (28 days x 48 steer). For Model II, individual supplement intakes were averaged across the 28-day intake period, and the 48 observations were analyzed with treatment as the only independent variable. For both models, pre-planned linear, quadratic, and cubic orthogonal contrasts were used to interpret the effect of increasing levels of magnesium oxide on supplement intake and animal performance.

Table 7. Effect of energy supplementation with increasing levels of magnesium oxide on performance of steers grazing winter wheat.

	Level of magnesium oxide, %					Contrast[a]		
Item	.25	.75	1.25	1.75	SE[b]	L	Q	C
BW Nov. 8, lb	562	556	548	533	15.5	.18	.80	.96
BW Dec. 20, lb	632	637	616	605	16.2	.16	.62	.62
ADG, lb/d	1.71	1.98	1.67	1.74	.132	.74	.45	.11

[a]Observed significance level for linear (L), quadratic (Q), and cubic (C) contrasts.
[b]Standard error of the means

Final weights and daily gains of steers were not affected (P>.11; Table 7) by increasing levels of MgO. Both Models I and II indicated that supplement intake increased linearly (P<.05) with increasing levels of magnesium oxide (Table 8). Differences in intake among the supplements were small, and mean consumption of ll supplements was less than the target of 2 to 3 lb/steer/day. Time (minutes/day) that the stee pent in the feeders was influenced in a quadratic manner (P<.01) by level of MgO. Altho n not significant (P>.05), visits/day appeared to follow the same quadratic trend as eating time. These results indicate that inclusion of MgO at levels up to 1.75% of supplement does not limit intake. Coffey and Brazle (1994) reported that magnesium-mica at levels up to 50% did not limit intake of a ground milo supplement by steers grazing smooth bromegrass supplements.

Table 8. Intake of a self-limited monensin-containing energy supplement with increasing levels of magnesium oxide.

	Level of magnesium oxide, %					Contrast[a]		
Item	.25	.75	1.25	1.75	SE[b]	L	Q	C
		Model I						
Intake, $lb\text{-}hd^{-1}\text{-}d^{-1}$	1.31	1.45	1.27	1.93	.055	.01	.07	.07
Min. eating suppl.	15.5	13.5	13.7	20.2	.54	.03	.01	.55
Visits to feeder	2.66	2.53	2.52	3.13	.075	.16	.09	.62
		Model II						
Intake, $lb\text{-}hd^{-1}\text{-}d^{-1}$	1.31	1.45	1.27	1.93	.162	.03	.12	.13
Min. eating suppl.	15.5	13.5	13.7	20.2	1.37	.02	.01	.53
Visits to feeder	2.66	2.53	2.52	3.13	.190	.11	.06	.57

[a]Observed significance level for linear (L), quadratic (Q), and cubic (C) contrasts.
[b]Standard error of the means

Hand-Fed Monensin Supplement

While some producers prefer self-limiting supplements that can be fed free-choice, others prefer to hand-feed supplements. **Hand-feeding** obviously allows much better control of supplement intake, and monensin has FDA approval for every other day feeding to stocker cattle. During the 1992/93 wheat pasture year we (Andrae et al., 1994) made slight modifications to the self-limited supplement and hand-fed it every other day at the level of 4 lb/head (or 360 mg monensin) to steers (552 lb mean initial weight) in individual feeding stalls adjacent to wheat pasture. Feedstuff composition of the hand-fed supplement is shown in Table 11. Daily weight gains were increased by **.56** lb/steer, which is similar to that observed in the free-choice studies. We also looked at variation in supplement intake by individual steers and partitioned them into low, moderate, and high variation groups based on the standard deviations of supplement intake. Variation of supplement intakes decreased as mean supplement intakes increased (i.e., the two were inversely related) as shown in Table 9, and mean supplement intakes were significantly different among all three levels of variation. This suggest that cattle with the least variable intakes tended to consume the entire amount of supplement that was offered more often than those in more variable groups. Daily gains also increased as variation in supplement intake decreased. Supplemented steers with monensin intakes greater than 150 mg/day tended to have greater weight gains than those with monensin intakes less than 150 mg/day (Table 10). These data accentuate the importance of not only formulating supplements and managing supplementation programs in order to achieve desired mean intakes by the herd, but to also minimize variability of supplement intake.

Table 9. Effects of variation in supplement intake on performance.

	Low[a] Variation	Moderate[b] Variation	High[c] Variation
Number of steers	8	11	6
Supplement intake, lb/day	1.82^{d}	1.57^{e}	1.16^{f}
Daily Gain, lb	3.06^{d}	2.83^{de}	2.56^{e}

[a]Supplement intake standard deviation < .9 lb/feeding.
[b]Supplement intake standard deviation .9 to 1.25 lb/feeding.
[c]Supplement intake standard deviation > 1.25 lb/feeding.
[d,e,f]Rows with uncommon superscripts differ (P<.05).

Table 10. Effects of monensin intake levels on performance.

	Low[a] Monensin Intake	High[c] Monensin Intake
Number of steers	14	11
Monensin intake, mg/day	123^{c}	161^{d}
Daily Gain, lb	2.75^{c}	2.95^{d}

[a]Monensin intake < 150 mg/hd/day.
[b]Monensin intake > 150 mg/hd/day.
[c,d]Rows with uncommon superscripts differ (P<.07).

An additional study regarding this supplementation strategy was conducted during the 1997/98 wheat pasture year by Paisley et al. (1998). The hand-fed supplement (also shown in Table 11) was similar to that used before except that Smectite was used as a pellet binder and Rumensin 80 Premix was used at a concentration of 0.125% of the as-fed supplement to provide 100 mg monensin/lb of supplement. One-hundred and ten (110) steers and eight wheat pastures were used, and the steers had (1) free-choice access to a high-calcium mineral supplement without an ionophore or (2) were hand-fed 4 lb of the monensin-containing energy supplement every other day. Results are shown in Table 12. Daily consumption of the supplements averaged 0.30 and 1.83 lb/steer for the mineral and monensin-containing energy supplements, respectively. Daily gains of cattle fed the energy supplement were increased by **0.39** lb as compared with cattle fed the mineral supplement. Supplement conversion, expressed as lb of supplement per lb of increased gain, was 4.69.

Table 11. Feedstuff composition (% as-fed) of **hand-fed** monensin-containing energy supplements.

Ingredient	1992/93[a]	1997/98[b,c]
Ground milo	66.65	62.15
Wheat middlings	21.00	21.00
Sugarcane molasses	4.80	5.00
Limestone	4.00	4.30
Dicalcium phosphate, 21% P	2.55	2.55
Magnesium Mica (Smectite)		4.00
Fine Mixing Salt[d]	.50	.50
Magnesium oxide	.35	.22
Rumensin 60 Premix	.15[e]	
Rumensin 80 Premix		.125[f]
Vitamin and Trace-Mineral Premix		.10
Vitamin A-30		.05

[a]Andrae et al., 1994.
[b]Paisley et al., 1998.
[c]Appreciation is expressed to Farmland Industries, Inc. for providing this supplement as an 11/64-inch pellet.
[d]Fine mixing salt (99.5% NaCl).
[e]To provide 90 mg monensin/lb of supplement.
[f]To provide 100 mg monensin/lb of supplement.

Averaged over the two years, this supplementation program has increased weight gain of wheat pasture stocker steers by **0.48** lb/day.

Further Studies On Bloat

In a study reported by Paisley and Horn (1998), twelve rumen cannulated steers that grazed the same wheat pasture near Stillwater were randomly allotted to three experimental groups. Gelatin capsules containing nothing, monensin, or lasalocid were placed directly into the rumen of each steer each day. Dosage of the ionophores was 300 mg/day because the steers weighed 1164 ± 67 lb. After a preliminary period of 16 days, the steers were assigned a bloat score each morning from March 15 through March 28 (14 days). While the wheat was in a rapid growth stage during this time, it was fairly immature. Hard freezes on the mornings of March 14, 15 and 16 increased the incidence of bloat and slowed the rate of wheat growth. Bloat scores were as follows:

0 = Normal, no visible signs of bloat.
1 = Slight distention of left side of animal.
2 = Marked distention of left side of animal. Rumen distended upward toward top of back. Animal has asymmetrical (egg-shape) look when walking away from observer.
3 = Severe distention. Distension is above top of back and visible from right side of animal.

Steer days of bloat (i.e., the number of days that steers had a bloat score of 1, 2 or 3) and the mean bloat score for each group of steers is shown in Table 13. Monensin decreased ($P<.05$) both the incidence and severity of bloat and was more efficacious for prevention of bloat than lasalocid. This study supports the earlier suggestions, as referenced in the first paragraph of this paper, relative to the use of monensin for prevention of bloat of wheat pasture stocker cattle.

Table 12. Forage availability, supplement intake, and performance of steers grazing winter wheat and receiving either the alternate day energy supplement or mineral[a].

Item	Mineral-supplemented[b]	Monensin/energy supplement[c]	SE
Pastures	4	4	
---------- Forage Mass ----------			
Dec. 5, lb DM/acre	2681	2565	334.5
Jan. 20, lb DM/acre	2378	2351	196.6
Feb. 20, lb DM/acre	2059	1989	201.1
---------- Supplement intake- ----------			
Supp. Intake, lb/day	.30	1.83	--
Monensin, mg/day[d]	0	183	--
Calcium, g/day[e]	21.9	18.7	2.73
Phosphorous, g/day[e]	5.5	7.5	.67
Magnesium, g/day[e]	7.5[j]	5.6[i]	.95
---------- Cattle performance ----------			
No. of steers	52	53	
Initial wt, lb[f]	512	515	11.9
Final wt, lb	802[j]	848[i]	2.8
Daily gains, lb[g]	2.53[j]	2.92[i]	.029
Supp. conversion[h]	--	4.69	--

[a]Least squares means for treatment.
[b]Steers had free-choice access to Wheat Pasture Pro Mineral™ (Farmland Industries, Inc.).
[c]Steers were fed 4 lb/steer every other day.
[d]Based on supplement monensin concentration of 100 mg/lb.
[e]Calculated from supplement and mineral analysis.
[f]Weights included initial steers as well as steers added December 5, 1997.
[g]Calculated based on 127 and 113 grazing days, respectively, for Marshall and Stillwater locations.
[h]Supplement conversion, lb of supplement/lb of added weight gain.
[i,j]Means within a row with uncommon superscripts differ ($P<.05$).

Table 13. Effect of Ionophore on the incidence and severity of bloat[a,b]

Item	Control	Monensin	Lasalocid	SE[c]	Control vs Ionophore[d]	Monensin vs Lasalocid[d]
No. of steers	4	4	4			
No. of steers that bloated[e]	4	2	4			
Total steer days of bloat	40	4	33			
Mean days of bloat/steer	10.0	1.0	8.3	2.25	.083	.049
Mean bloat score/steer	.88	.05	.77	.206	.097	.036

[a]From March 15 to March 28, 14 days.

[b]Bloat scores consist of: 0 = no visible signs of bloat; 1 = slight distention of left side; 2 = marked distension of left side; 3 = left and right sides distended

[c]Standard error of least squares means.

[d]P-value associated with orthogonal contrasts.

[e]Steers given a bloat score greater than zero on one or more days.

ENERGY SUPPLEMENTS TO STRETCH A SHORTAGE OF WHEAT PASTURE

The 1991/92 wheat pasture year was very dry, and many pastures were extremely short of forage at the time of "traditional" turnout. In some of our pastures we had as little as 300 lb of forage dry matter per acre. While this was a problem, it did present us with an opportunity to compare some different types of energy supplements for stretching this severe shortage of wheat pasture. Our objective was to compare **limited amounts (i.e., 1% of mean body weight)** of whole corn, dry-rolled corn or a 50/50 mix of pelleted wheat middlings/soybean hulls. The supplements were hand-fed 6 days/week. Our target gain for the cattle was 2 lb/day. Nine pastures were used in the study and **initial** stocking density was 3.5 acres/steer to provide an initial forage allowance of 1300 lb of forage DM/steer. Because of the very mild winter and continued growth of wheat forage, cattle of three pastures were distributed by treatment through the other six pastures on January 30, 1992 in an attempt to provide equal and lessor amounts of forage to all cattle. Forage availability in each of the pastures on January 21 was about 1500 lb DM/steer and greater than we would have liked for the initial objective of the trial. Forage growth after January 30 was excellent. Because wheat jointed so early, the cattle were removed on February 28. Performance of the steers is shown in Table 14.

Table 14. Energy Supplements for Stretching Wheat Pasture.

	Whole Corn	Dry-rolled Corn	Wheat midds/ soybean hulls
No. Pastures	2	2	2
No. Steers	10[a]	12	12[b]
Initial Weight, lb (12/5/91)	438	438	439
Final Weight, lb (2/28/92)	622	630	625
Daily Gain, lb[c] (84 days)	2.17	2.25	2.19

[a]Increased to 14 on January 30.

[b]Increased to 18 on January 30.

[c]Add-on steers of January 30 were not included in calculation of mean daily gains.

Differences among treatments are not significant (P>.62).

Weight gain of all steers was about 2.2 lb/day during the 84-day trial, and was not different (P>.62) among treatments which is in general agreement with our other results where we have not observed a difference in gain between steers supplemented with a high-starch, corn-based supplement *versus* a high-fiber, byproduct feed-based supplement on wheat pasture. Steers consumed the whole corn much more readily than the rolled corn, and usually had slick bunks by mid-afternoon. Two steers fed rolled corn foundered and showed signs of lameness throughout most of the trial. Because of the small numbers of pastures and steers in this trial, this data should be considered only preliminary. However, from a feed and bunk management standpoint, the whole corn was clearly more desirable than the rolled corn.

The 1995/96 wheat pasture year presented us with another opportunity to evaluate a limit feeding program with whole shelled corn for steers on wheat pasture. Three pastures with 10 to 13 steers/pasture were used. Wheat forage standing crops on December 7 (date of turnout), January 17, and March 12 were 511, 376, and 251 lb DM/acre, respectively. Forage allowances on these same dates were 1024, 749, and 725 lb DM/ steer. Steers had free-choice access to a high-calcium mineral mixture (footnote "a", Table 3). While our target level of intake of whole corn was 1% of body weight, the cattle did not achieve this level of intake until about January 17 or day 41. Corn intake was very consistent among pastures, and averaged .75% of body weight from December 7 to March 15 (98 days). Mean weight of the steers at the start of the trial was 540 lb, and they gained 1.86 ± 0.11 (std. dev.) lb/day.

SUMMARY

Supplementation of cattle grazing wheat pasture is of interest in order to (a) provide a more balanced nutrient supply and feed additives such as ionophores and bloat preventive compounds, (b) substitute supplement for forage where it is desirable to increase stocking rate in relation to grazing management and(or) marketing decisions, and (c) substitute supplement for forage under conditions of low forage standing crops.. Two different strategies for providing energy supplements to growing cattle on wheat pasture are presented. One strategy was to develop a "small package" (i.e., target intake of 2 to 3 lb/day) self-limited monensin-containing energy supplement to provide a more balanced DOM:CP ratio in the total diet. The supplement very consistently increased daily gain approximately .50 lb, and increased profits by $15 to $31/steer depending on supplement cost and profit potential of the cattle. The milo-based supplement contained (as-fed basis) 4% fine mixing salt, 75 mg monensin/lb, and .75% magnesium oxide. Monensin itself limited intake, but MgO at concentrations up to 1.75% did not limit intake. Substitution of equal proportions of wheat middlings and soybean hulls for the ground milo did not affect consumption of the self-limited supplement. Modification of the formula for every-other-day hand-feeding resulted in similar improvements in weight gain as achieved with the self-limited supplement. An additional study using small numbers of rumen cannulated steers in a completely randomized design compared the effects of monensin or lasalocid *versus* no ionophore on wheat pasture bloat. Monensin decreased ($P<.05$) both the incidence and severity of bloat and was more efficacious for prevention of bloat than lasalocid. A second strategy was to feed two types of energy supplements (i.e., high-starch, corn-based supplement *versus* a high-fiber byproduct feed based supplement) at a level of .75% of body weight. Over the 3-year study, mean daily supplement consumption was .65% of body weight. This energy supplementation program increased daily gain by .33 lb and allowed stocking rate to be increased one-third. Type of supplement did not influence daily gain, supplement conversion, or the substitution ratio of supplement for forage. Supplement conversion was about 5 lb of as-fed supplement per lb of increased gain per acre, and was substantially less than conversions of 9 to 10 that have traditionally been used in evaluating the economics of energy supplementation programs for wheat pasture stocker cattle. Weight gain of steers placed on wheat pastures with very low initial standing crops (i.e., 300 lb DM/acre) but "stocked" so as to provide initial forage allowances of 1000 to 1300 lb DM/steer, and limit-fed whole shelled corn at a level of .75 to 1.0% of body weight have been about 2.0 lb/day during two separate wheat pasture years.

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Agronomic Practices for Optimizing Small Grain Forage Production

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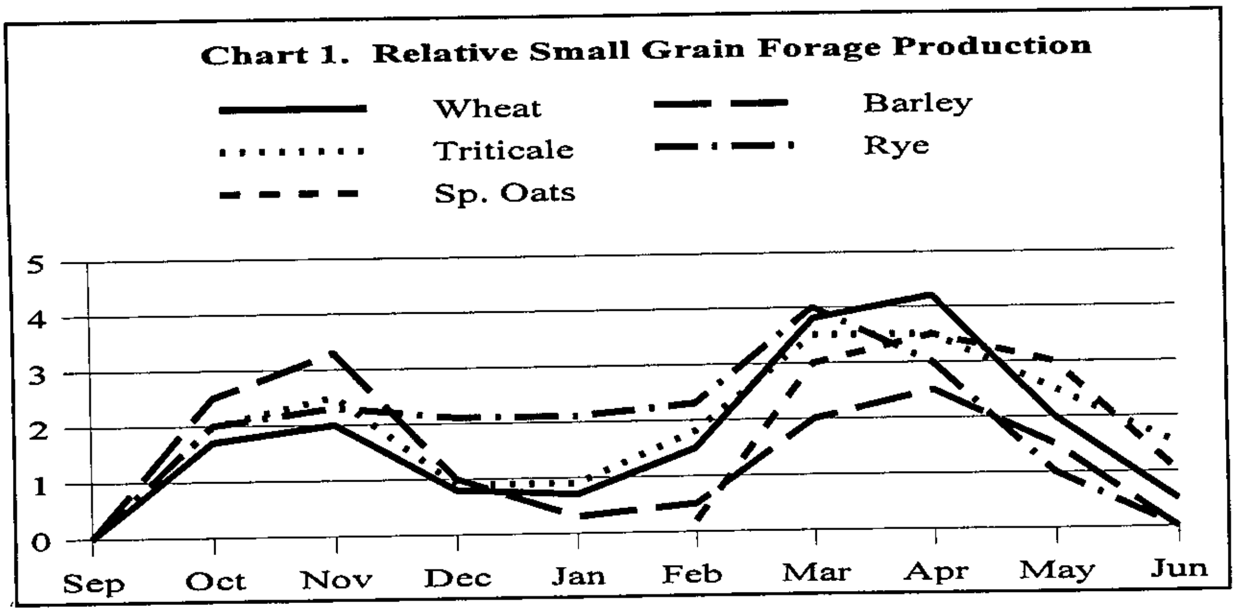
Best management practices for the farmer who is primarily interested in grain yield and the cattleman whose interest lies in optimizing forage production are not always the same and can be quite different. This paper will primarily discuss those management practices that will optimize forage production with little regard to their effect on grain yield. Wheat forage yields can vary greatly from year to year making it difficult for cattlemen to plan stocking rates in advance. This is especially true under dryland conditions. However, management practices can greatly influence the amount of forage produced in any given year. Since wheat produces over two-thirds of its total forage in the spring, forage available in the fall and winter months are usually the limiting factor in determining stocking rate. For this reason those management practices that increase forage production for fall and winter grazing are most critical. Cultural practices that influence early forage production the most are: small grain selection, early season moisture, seed quality, planting date, variety selection, seeding rate, row spacing, fertility, and grazing initiation.

Small Grain Selection

This paper will primarily focus on forage production from wheat. However, other small grains should be considered as they can offer certain advantages over wheat in different scenarios.



Rye is an excellent choice for winter forage if grazing during the winter months is the primary objective. Rye does not go as dormant as the other small grains and will continue producing forage at cooler temperatures. It also seems to yield better than other small grains under poor soil conditions. The disadvantage of rye is that it begins its reproductive stage early in the spring and thus will not produce as much forage in the late spring for graze-out as some of the other small grains. If rye is allowed to produce grain, volunteer rye can be a problem in future wheat crops.

Triticale is a cross between wheat and rye. When it produces forage and its level of winter hardiness are dependent on the characteristics of its parents. Some are very winter hardy while others are much less so. Most triticales sold for pasture are blends of two or more varieties. It generally emerges faster than wheat but then is slower in tillering. The main disadvantage of triticale is that if graze-out is not desired there is not a ready market for the grain.

Barley is generally thought of as being a better early fall forage producer than the other small grains when planted very early. However, most varieties are not cold tolerant and will freeze out under harsh winter conditions.

Oats make a good choice for planting in the early spring for graze-out or possibly for hay. When planted in the fall they make good early season grazing but do not perform well during the middle of the winter. Most varieties are subject to freezing out under harsh winter conditions. For this reason, oats are usually not planted as a stand alone crop for winter pasture in the Texas High Plains and areas north.

Early Season Moisture

For most areas of the High Plains early season moisture is necessary for achieving significant fall and winter forage. If irrigation is not an option then soil storage of precipitation that occurs in the summer months is essential. Conservation tillage systems are the key in storing soil moisture. The more crop residue left on the surface the greater the amount of precipitation will be stored in the soil. Crop residue can be maintained on the surface by using herbicides or shallow sweep plowing for weed control. Unless a deep hard pan exists avoid deep plowing. In general, the deeper the soil is plowed the more soil moisture is lost. Surface residue will be minimal when following grazed-out wheat resulting in less soil storage of precipitation. This problem is made worse by soil compaction caused by the cattle. This soil compaction is actually quite shallow and can easily be corrected with sweep tillage running no deeper than 3 inches. Research at Bushland, TX, conducted by Dr. Steve Winter, strongly suggests that sweep tillage is preferred over both no-tillage and deep tillage (paratill) for increasing stored soil moisture when following wheat graze-out. Deep tillage is not necessary to correct shallow soil compaction caused by grazing cattle.

Do not under estimate the importance of weed control during the fallow period prior to wheat planting. A high population of weeds can use up to three inches of soil moisture in 30 days. Weeds must be controlled either with sweep tillage or herbicides.

If moisture conditions are dry and irrigation is an option, water should be applied as soon after emergence as is practical. One week delay in irrigation can make a significant difference in forage produced for fall and winter grazing. Even if deep moisture is available it may be necessary to irrigate, especially with a center pivot, to ensure that the crown roots (secondary roots) of wheat become established. Contrary to popular belief, roots will not grow to moisture. If moisture is not around the root as it begins to grow from the crown it will stop growing. The root will grow from a region of low water concentration to a region of higher concentration, but some water must be available to the root for growth to occur.

Seed Quality

Seed quality is often overlooked in its importance in forage production. However, seed quality is likely as important, if not more so for early season forage production, as it is for achieving a good grain yield. Getting the crop established and growing quickly is crucial for fall and winter forage production. Poor quality wheat seed is likely to have low germination and poor seedling vigor. Seedling vigor is a term used to describe how quickly a wheat plant becomes established and actively growing following germination. In choosing a seed source look for seed that is plump (not shriveled) with a high test weight. A test weight of at least 57 lb/Bu is desirable. The influence of poor seed quality will be particularly noticeable under poor soil conditions or if wheat is planted too deep. If poor wheat seed must be used have the seed cleaned and plan for a high percentage of clean-out. Increase seeding rate by 25% and plant in as good of soil conditions as possible, while avoiding planting too deep.

Planting Date and Depth of Planting

Early season forage production can only occur if wheat is planted relatively early (Table 1). In Oklahoma, forage yield was reduced as much as 1000 lbs/Ac for a two week delay in planting.

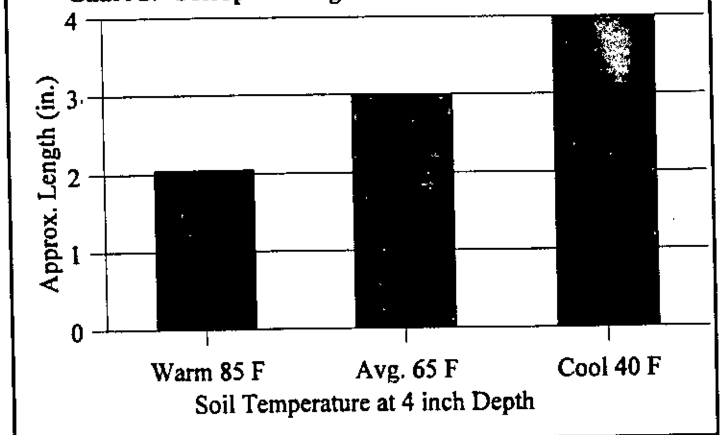
Table 1. Fall Forage (lb/Ac) (Clipped to soil surface)

	4-Sep	12-Sep	24-Sep	10-Oct	24-Oct	4-Nov	18-Nov	Mean	LSD (0.05)
1992-93	120	-	150	220	-	-	-	150	30
1993-94	210	-	370	400	240	-	-	300	80
1994-95	-	1770	1120	280	0	-	-	790	260
1996-97	-	2280	1880	630	0	-	-	1200	450
1997-98	-	3640	2650	1030	0	-	-	1830	610
1998-99	-	-	-	4070	1290	0	0	2680	790
1999-00	-	3760	3550	2390	0	-	-	3230	300
4-Year Avg.		2860	2300	1080	0				

Krenzer, G., Thacker, R., and Kelly, T. Planting Dates for Wheat in Southwestern Oklahoma. Plant & Soil Science Dept. Vol 12: no. 13. PT 2000-13.

The ideal soil temperature for germination and early growth is 65 to 70° F. Soil temperature is especially important if wheat must be planted deep in order to place the seed into moisture. Warm soil temperatures cause the coleoptile of wheat to shorten preventing the wheat from emerging. The coleoptile is the leaflike structure that originates from the seed and pushes through the soil protecting the first true leaf. As soil temperature increases from 65° to 85° F at the 4 inch depth, the coleoptile length on average decreases about 30% (Chart 2). For this reason it is advisable to plant a variety that is known to have a long coleoptile if early planting in warm soil temperatures is desirable, particularly if the wheat must be planted deep. See your Extension agronomist for recommendations on varieties with long coleoptiles. For adequate fall and winter forage production, wheat should be planted two to four weeks prior to the ideal planting date for grain production in a given region. A good rule of thumb is to plant wheat for forage when soil temperatures at the 4 inch depth have dropped below 75° F.

Chart 2. Coleoptile Length Shortened in Warm Soil



Martin, Joe. 2000 Kansas Performance Tests with Winter Wheat Varieties. Progress Report 857, July 2000.

Seed depth will always influence how fast wheat becomes established. For this reason try to avoid deep planting. This is especially true when planting early in a warm soil that could cause a reduction in the length of the coleoptile. Keep in mind that only a few days in establishment time can make big difference in how much forage is available going into the winter months.

Another consideration when planting early under high soil temperatures is a condition in wheat called post-harvest dormancy. Dr. Gene Krenzer at Oklahoma State University has recently shown that varieties differ considerably in their expression of this trait. Post-harvest dormancy refers to the inability of wheat to germinate soon after it has been harvested. The wheat requires a period of 'ripening' before it will germinate. Post-harvest dormancy is expressed more when soil temperatures are high. As shown in Table 2. Lockett exhibited little decrease in germination when temperatures were increased, as compared to 2174 which

Table 2. Post-Harvest Dormancy Expression of Different Wheat Varieties

Variety	% Germination in August	
	75° F Day, 55° F Night	95° F Day, 75° F Night
Lockett	97	93
Custer	98	77
Jagger	97	67
2137	98	47
Triumph 64	99	19
2174	100	16

Krenzer, Gene. Oklahoma State University. Personal communication.

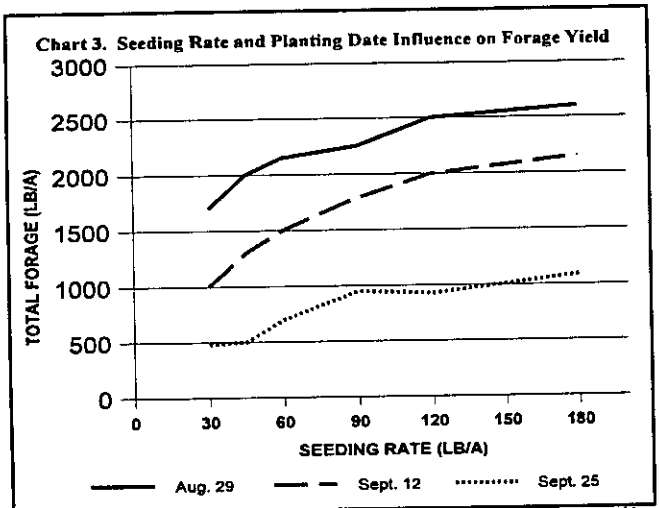
dropped from 100 to 16% germination. This data would suggest that Lockett may be a better choice when planted early in high soil temperatures.

Variety Selection

Choosing a variety based on forage trials is probably not as important as choosing a variety based on specific characteristics such as coleoptile length, post-harvest dormancy, tolerance to acid soils, disease and insect tolerance. My experience has been that these characteristics, in addition to the other cultural practices discussed in this paper, are more important than which variety may have yielded two or three hundred pounds more in a given forage trial. Contact your area Extension specialist for a list of varieties that have performed well in your area. Beardless wheats are often desirable for graze-out. Beardless varieties that are most popular are Longhorn and Lockett. Others to consider are Wintex, Weathermaster 135, El Dorado, and TAM 109. Some of those varieties considered later in maturity may also be desirable for graze-out.

Seeding Rate and Row Spacing

Seeding rate can influence early season forage production more than just about any other management practice. A common misconception is that a low seeding rate for forage production will be offset by an increase in tillering. For grain production this is often the case. However, for forage production prior to jointing, tillering will not occur early enough to greatly affect forage yield. For this reason seeding rate must be increased over what would normally be used for grain production. Even when moisture is limited increasing seeding rate will seldom have a detrimental effect on early season forage production and can greatly increase the amount of forage under irrigation or when water is available from the soil or rainfall. If moisture conditions are favorable or if irrigation is available, a seeding rate of at least 90 lb/Ac should be used and when planting early use a 120 lb/Ac seeding rate (Chart 3). Although these high seeding rates may be detrimental in some cases for grain yield, they should be used if early forage production is the main objective.



Krenzer, Gene. Wheat For Pasture. Plant & Soil Science Dept. F-2586.

Row spacing can also influence forage yield. Where possible use as narrow a row as can be planted. Narrow rows will increase the competitiveness of wheat over early season weeds and will reduce water evaporation from the soil. Narrows rows can sometimes be difficult to achieve if heavy residue is present without special no-till equipment.

Fertility

Wheat forage production can only be maximized if soil nutrients are not limiting. Soil testing is the only way to accurately determine soil nutrient status. Once a soil nutrient analysis has been done the amount of fertilizer needed to meet a potential yield goal can be determined. Nitrogen and phosphorus are the nutrients in soils most often found to be deficient.

Nitrogen

When nitrogen deficiency is severe wheat leaves will appear yellow, particularly at the leaf tip and along the margins. Symptoms will be expressed more in the lower leaves. Spots in the field where cattle have left manure will often appear more green and robust. Listed below are three ways to determine how much nitrogen fertilizer needs to be applied for wheat forage production:

1) Base the nitrogen fertilizer rate on the nitrogen needed if the wheat were going to be used to produce grain. The Texas A&M soils lab recommends that 1.5 lb/Ac nitrogen be available for every bushel of expected grain yield. For example a 30 bu/Ac grain crop would need to have 45 lb/Ac nitrogen available in the soil. If the field is going to be grazed as well as taken to grain, then the Texas A&M recommendation is 2 lb/Ac nitrogen per bushel applied at preplant followed by another application of 0.5 to 0.75 lbs/Ac nitrogen per expected bushel following cattle removal in the spring.

2) Another way to estimate nitrogen need is to assume that a 400 to 500 pound steer will remove 15 pounds of nitrogen per month. So if the stocking rate is 1 steer for every 2 acres and the grazing duration is 5 months then 37.5 pounds of nitrogen would need to be available (5 months X 15 lbs N X 0.5 = 37.5).

3) The third method to calculate nitrogen need is to base fertilizer rate on the expected pounds of dry forage that will be produced. Wheat forage at 20% protein will contain approximately 0.16 lb N for every 5 lb of dry forage. Forage yields generally range from 1500 to 2500 lbs for dryland and 5000 to 6000 lbs under irrigation. So for a 2000 lb/Ac dry forage yield goal 64 lb/Ac nitrogen would be required (2000 ÷ 5 X 0.16 = 64).

Keep in mind that any residual nitrogen in the soil (determined by soil test) must be subtracted from the amount of nitrogen fertilizer that needs to be applied.

Phosphorus

Although nitrogen is often applied for wheat pasture, phosphorus is often overlooked. However, research has consistently shown that phosphorus application can make a significant effect on forage yield. In table 3., 60 lb/Ac of phosphorus as liquid 10-34-0 was applied either broadcast and incorporated with a disk or rolling cultivator, or injected in a band approximately 8 inches deep with chisels or knives spaced 15 inches apart.

Table 3. Irrigated Wheat Response to P Fertilization

Fertilizer Placement	Total Forage yield, lb dry forage/Ac			
	1992	1993	1994	Average
P Deep Banded	4,137	5,475	5,502	5,038
P Broadcast Incorporate	4,957	3,759	4,590	4,435
0 P	2,317	3,294	1,999	2,537
Soil Test P Level: Medium				Etter, TX

Miller, Travis, and B. Bean. Phosphorus Fertility and Placement Enhance Wheat Forage Yields. Better Crops. Vol. 79 (1995. No. 3).

In this study, even though the soil test indicated a medium level of phosphorus was present, forage yield was greatly increased with the fertilizer application. The most consistent results were when the phosphorus was deep placed in bands. On average, forage yield was doubled from 2,537 to 5,038 lb/Ac. Assuming a conversion rate of 15 pounds dry forage for every 1 pound of cattle weight gain, this was equal to potentially an additional 166 lb/Ac cattle weight gain. Under irrigation a 60 lb/Ac application of phosphorus is recommended for a soil P test analysis considered moderate or less. Under dryland conditions 30 to 40 lb/Ac phosphorus application would likely be sufficient.

Grazing Initiation

Grazing can be initiated once the crown roots have anchored the plant to the soil and tillering has occurred. Once two or three tillers are present the crown roots have normally grown sufficiently to anchor the plant. If you can grab a plant and easily pull it from the soil so can the cattle when grazing. Also, if wheat is grazed before it has sufficiently tillered the regrowth of the wheat will be slowed.

Grazing Termination

If grazing is to be terminated in order to allow for the development of a grain crop, cattle should be removed once the reproductive stage of the wheat begins at stem elongation. This stage is identified by watching for the development of a hollow stem. Cut the stem in half longitudinally just above the roots. If the stem is hollow above the roots then the reproductive stage has begun. The immature grain head is just above the hollow portion of the stem and jointing of the wheat will soon occur. Check wheat for hollow stem in an ungrazed portion of the field since grazing will tend to delay the onset of the reproductive stage.

Brown midrib forage sorghums and sorghum X sudan hybrids for summer grazing and silage production

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Brown midrib mutants are present in corn (Kuc'and Nelson, 1964; Porter et al., 1978), sorghums and sudangrasses (Porter et al., 1978), and pearl millet (Cherney et al., 1988). Brown midrib refers to the brown color of the leaf midrib that is a phenotypic characteristic of these mutants. The brown color is also obvious in the pith of the stem.

Chemcial composition

These mutants will typically contain less lignin (Lechtenberg et al., 1974, Porter et al., 1978; Cherney et al., 1988).). In addition, the lignin in brown midribs is less polymerized and contains less phenolic monomers that may affect digestion (Jung and Fahey, 1983). Because of these two attributes the brown midribs are generally more digestible than their near isogenic cohorts that do not display the brown midrib trait (Lechtenberg et al., 1974, Porter et al., 1978; Cherney et al., 1988; Wedig et al., 1988).

Production characteristics

Although the brown midrib mutants have been known for some time, only recently has their popularity increased. The lack of use and reogniton may be partially associated with production problems that accompany some of the brown midrib varieties. Lodging and reduced forage yields been associated with some of the some of the brown midrib mutant varieties ((Gourley and J.W. Lusk, 1978). However, there are more than one genotype of brown midrib mutants (Porter et al., 1978; Gourley and Lusk, 1978) and quality and production characters vary among the genotypes.

Genotype variation

As mentioned, the presence of the brown midrib phenotype does not guarantee reduced lignin, improved digestibility, reduced yields or increased lodging. There are least 4 brown midrib mutants in corn and at least three in sorghum (Porter etal., 1978, Gourley and Lusk, 1978). Of 13 mutants in sorghum, Porter etal. (1978) identified four mutants that had higher in vitor digestibility and lower lignin than their near isogenic non-BMR cohorts. The "BMR 12" mutants showed the lower lignin content and higher digestibilities. Gourley and Lusk (1978) used seed from seven of the brown midrib sorghums and their near isogenic lines from Porter et al. (1978). They confirmed that the BMR 12 mutants had higher digestibility and lower lignin than their near isogenic cohorts. In addition, the BMR 12 mutants had several desirable production characteristics, including reduced lodging, compared to other BMR mutants and therefore were more attractive for silage production. Subsequent studies by Rivera (1980, as cited by Lusk et al., 1984) and Karau (1981, as cited by Lusk et al., 1984) further demonstrated that the BMR 12 mutants were superior in lignin and digestibility.

Based on these studies, the mutants displaying the brown midrib phenotype but with the BMR 12 mutation are the better varieties to use in production. Other mutants, despite displaying the brown midrib phenotype, may not have as desirable production or digestibility characteristics and may not be any better than the non-brown midrib line.

Texas A&M Trials, Bushland, Texas

Over the past two years, we have compared brown midrib and non-brown midrib sorghum X sudangrass under grazing. AgriBioTech SS 200 BMR and Dekalb SX17 were the varieties that were compared. The varieties were selected on the recommendations of the seed supplier (Seed Resource, Inc. Tulia). During 1999 and 2000, these varieties were planted in late May, fertilized according to soil test, and irrigated initially to aid establishment. All irrigation, fertilization practices were similar among varieties. In both years, steers averaging about 530 lbs were stocked on four pastures of each variety. Grazing was initiated when the forage was 24-30 inch tall and was terminated when the pastures had been grazed to a similar degree and leaf material was not present. Put-and-take grazing was used to control grazing pressure.

Results of the two-year study are in table 1. Average days of grazing were 41 and 58.5 in 1999 and 2000, respectively. Average stocking rates were 2.72 and 2.06 head/acre in 1999 and 2000, respectively. Grazing days per acre were not significantly different between the varieties. This indicated that forage production was similar among the two forage types. However, the steers grazing the brown midrib mutant, gained an average of 0.32 lbs/day more than the steers on the non-brown midrib variety. As a result, the gain per acre averaged 37 lbs more for the brown midrib forage. Also, visual observation suggested that steers on the brown midrib pastures more readily grazed the stalks of the plants. This has been noted by others. The lower lignin value and possibly lower content of phenolic monomers in the plant improves palatability of the stalks.

Performance of steers grazing non-brown midrib and brown midrib sorghum X sudan hybrids, Texas A&M University, Bushland, TX, 1999-2000[1].

Item	Non-BMR	BMR	P
Daily gain, lbs	2.62	2.94	0.065
Gain/acre, lbs	300	337	0.12

[1]Initial weights averaged 531 lbs.

In 2000, a large variety test was established to compare various sorghum and sorghum X sudan varieties. A full report of the data can be obtained from Bean et al. (2000). The second summer of this evaluation was just completed and the analysis are not complete.

Seventeen brown midrib varieties and 48 non-brown midrib varieties were in the 2000 test. Variety plots were replicated three times. All varieties were treated similarly. All were fully irrigated and fertilization was according to soil test. The forages were harvested as near to soft dough as possible. Actual harvest dates were August 30, September 6, and September 27. At harvest, forage was weighed fresh, then dried down to determine dry forage yield. Samples from each plot replicate were chopped then sent to the Dairy One Lab in Ithaca New York for analysis. In addition to crude protein, fibers, and minerals, in vitro true digestibility was determined for each sample.

Averages for the brown midrib and non0brown midrib varieties are shown in table 2. Scatter diagrams of relationships among selected variables are shown in the figures. An appreciation for the range of values for the different types can be gained from the scatter diagrams.

On average, there was no statistical difference in yield or lodging between the the two forage types (Table 2). In figure 1, note that the distribution of both yields and lodging indicate that the variety within a type is as important as the presence or absence for the brown midrib trait. This concurs with the observations of Porter et al. (1978) and Gourley and Lusk (1978) that the presence of the BMR trait does not necessarily mean more problems with lodging or yield drag.

Table 2. Comparative data for non-brown midrib and brown midrib sorghums and sorghum X sudan hybrids harvested for silage, Texas A&M University, Bushland, TX, 2000

Character	Non-BMR	BMR	P
Varieties	17	48	-
Yield, lbs DM/ac	16702	16306	0.588
Lodging, %	29.4	21.9	0.196
Crude protein, %	6.7	7.2	0.019
NDF, %	48.1	44.8	0.013
ADF, %	28.4	26.1	0.009
Lignin, %	4.4	3.1	0.0001
In vitro true digestibility, %	75.4	81.7	0.0001

Based on averages the brown midrib mutants contained more crude protein, less of both NDF and ADF, and less lignin. The brown midrib mutants also had a higher in vitro true digestibility (IVTD) than the non-brown midrib mutants. The classic reltionship between lignin and digestible is shown in figure 2. Forage with lower lignin have higher IVTD. Because of the lower lignin values for the brown midrib mutants, they generally had better digestibilities. The relationship between ADF and lignin is shown in figure 3. At the same ADF concentration, the brown midrib mutants contained less lignin. In figure 4, the relationship between ADF and IVTD sohows that at the same ADF concentration, the brown midrib mutants are generally more digestible. Hence, testing these varieties for ADF only will not necessarily allow one to differentiate energy availability in varieties.

Figures 5 through 10 demonstrate that it is not necessary to sacrifice yield or experience more lodging problems when selecting a variety that contains less lignin and is more digestible. The figures show that resulting lodging, yield, lignin digestibility vary with the variety selected whether this be a brown midrib or a non-brown midrib variety.

Conclusion

Brown midrib mutants provide the opportunity to improve weight gain in grazing stocker cattle or harvest silages with higher digestibility and energy availability. Improved energy availability does not have to obtained at the expense of reduced yields and more lodging. Also, the brown midrib phenotype does not guarantee that a forage will be more digestible. Overlap exists among varieties in the brown and non-brown midrib types. Knowledge of the varieties is a key to selecting the most desirable variety or mutant.

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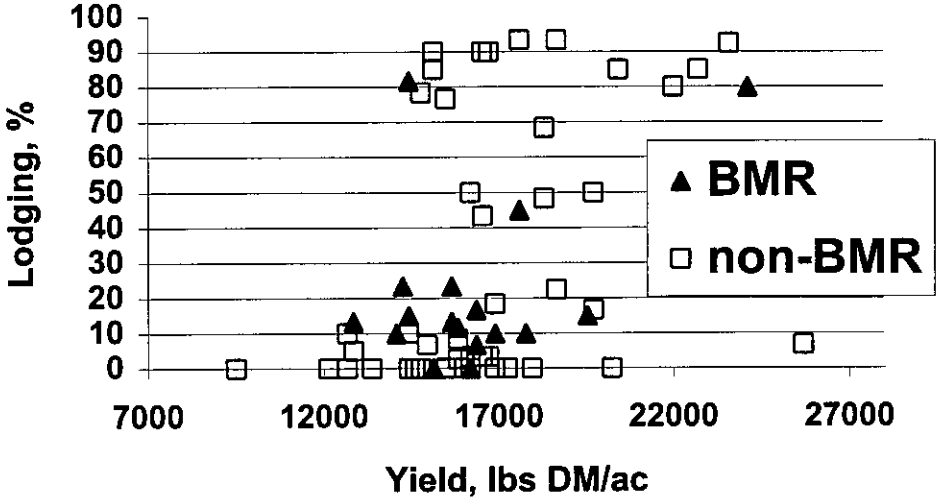

Figure 1. Relationship between lodging and yield in brown midrib and non-brown midrib sorghum and sorghum X sudan hybrids grown for silage, Texas A&M University, Bushland, TX, 2000.

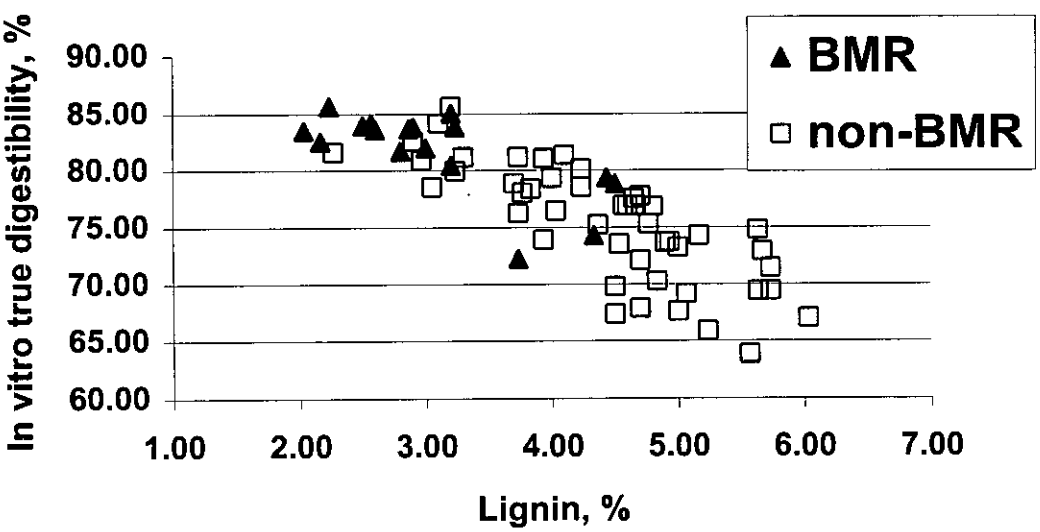

Figure 2. Relationship between lignin concentration and in vitro true digestibility in brown midrib and non-brown midrib sorghum and sorghum X sudan hybrids grown for silage, Texas A&M University, Bushland, TX, 2000.

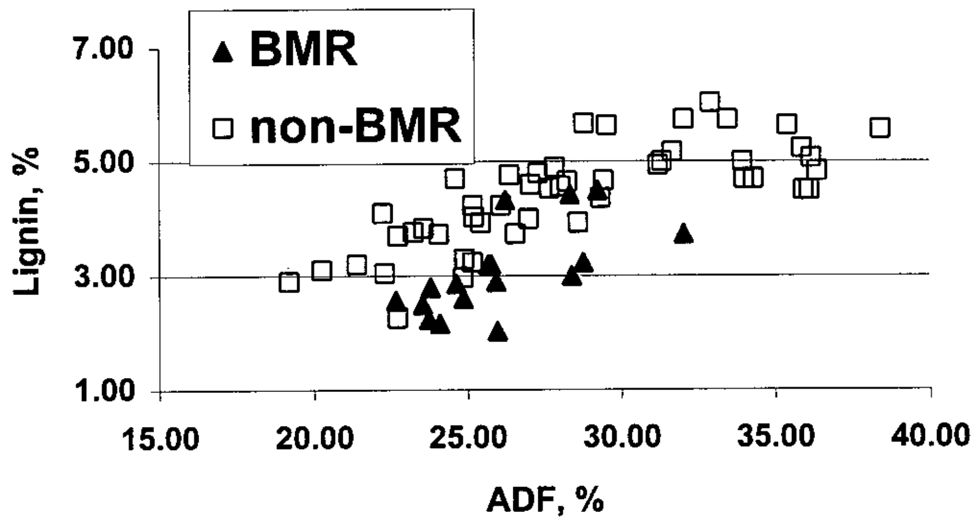

Figure 3. Relationship between ADF and lignin concentration in brown midrib and non-brown midrib sorghum and sorghum X sudan hybrids grown for silage, Texas A&M University, Bushland, TX, 2000.

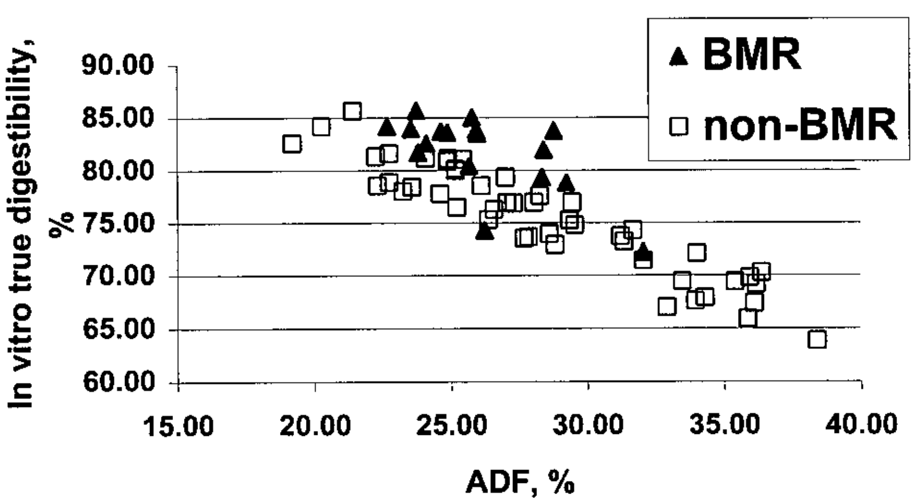

Figure 4. Relationship between ADF and in vitro true digestibility in brown midrib and non-brown midrib sorghum and sorghum X sudan hybrids grown for silage, Texas A&M University, Bushland, TX, 2000.

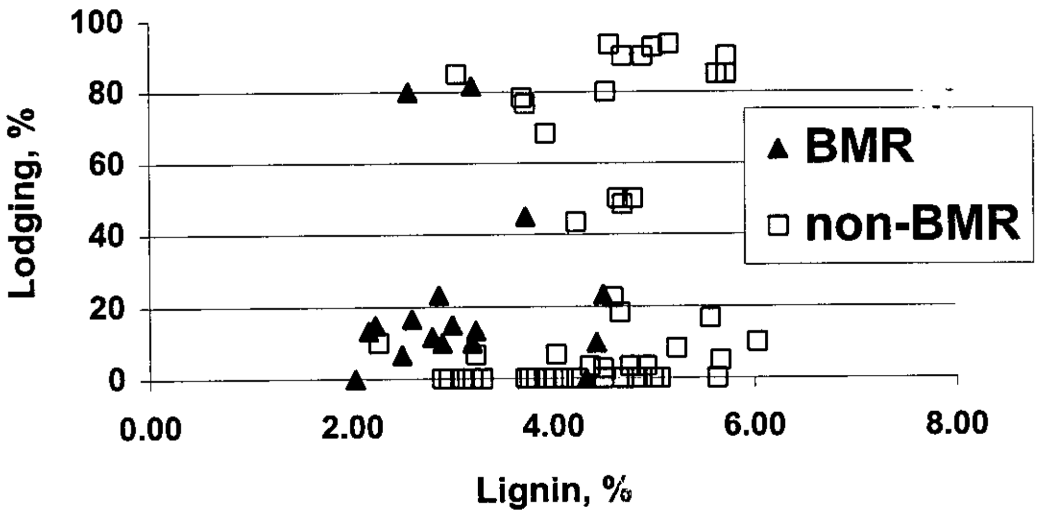

Figure 5. Relationship between lignin concentration and lodging in brown midrib and non-brown midrib sorghum and sorghum X sudan hybrids grown for silage, Texas A&M University, Bushland, TX, 2000.

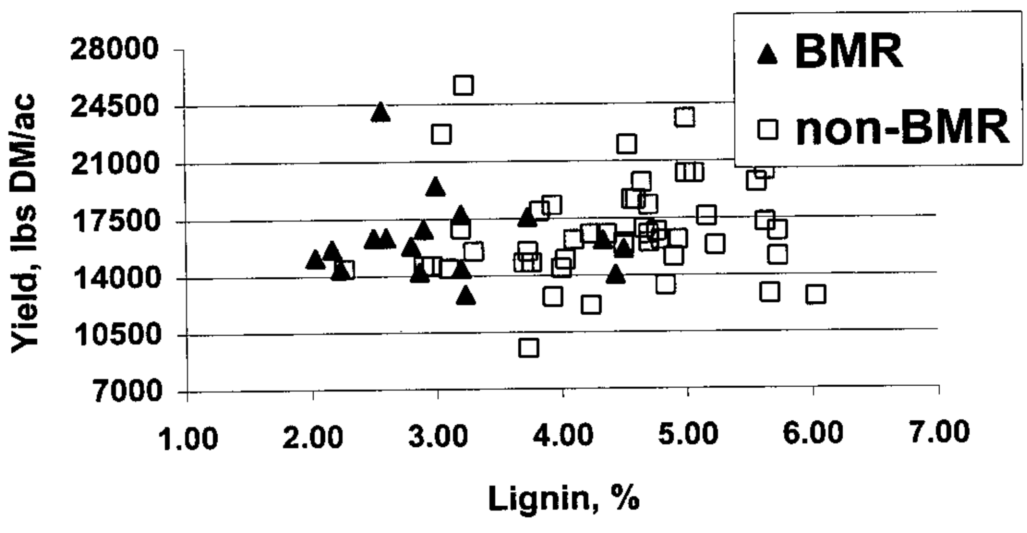

Figure 6. Relationship between lignin concentration and yield in brown midrib and non-brown midrib sorghum and sorghum X sudan hybrids grown for silage, Texas A&M University, Bushland, TX, 2000.

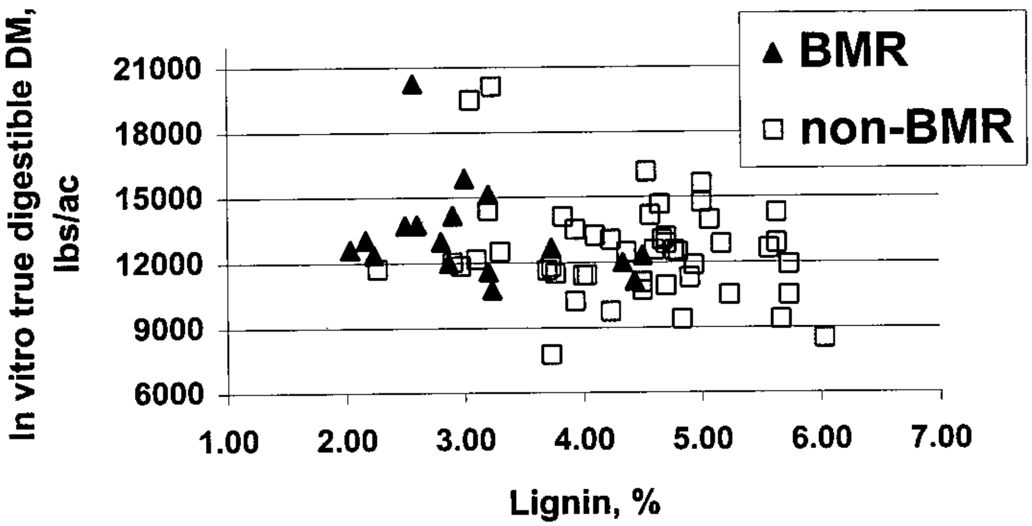

Figure 7. Relationship between lignin concentration and in vitro true digestibility (lbs/ac) in brown midrib and non-brown midrib sorghum and sorghum X sudan hybrids grown for silage, Texas A&M University, Bushland, TX, 2000.

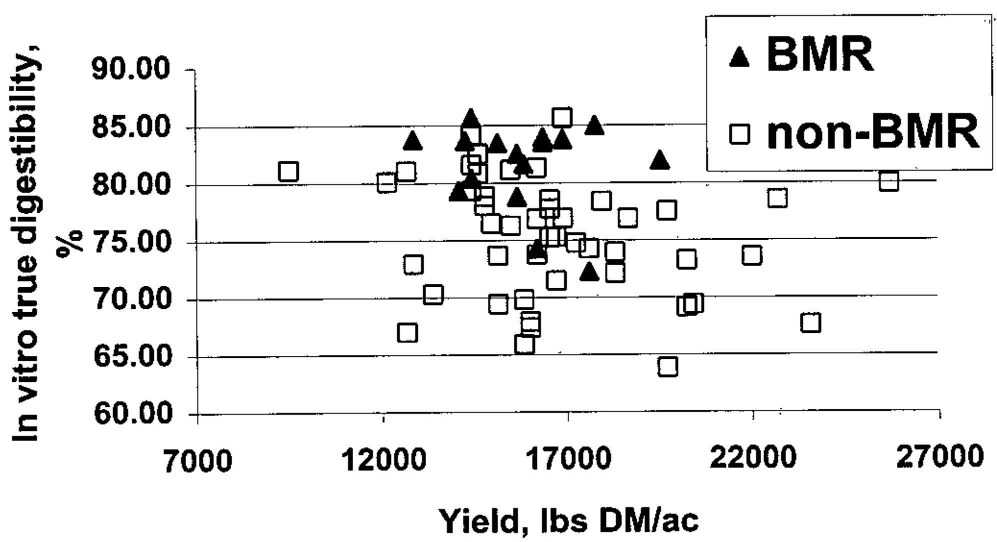

Figure 8. Relationship between yield and in vitro true digestibility in brown midrib and non-brown midrib sorghum and sorghum X sudan hybrids grown for silage, Texas A&M University, Bushland, TX, 2000.

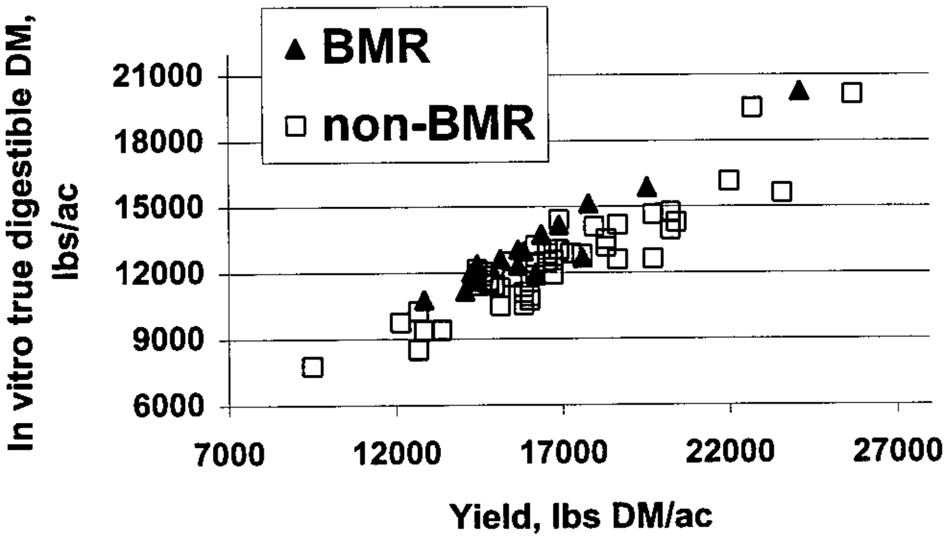

Figure 9. Relationship between yield and in vitro true digestibility (lbs/ac) in brown midrib and non-brown midrib sorghum and sorghum X sudan hybrids grown for silage, Texas A&M University, Bushland, TX, 2000.

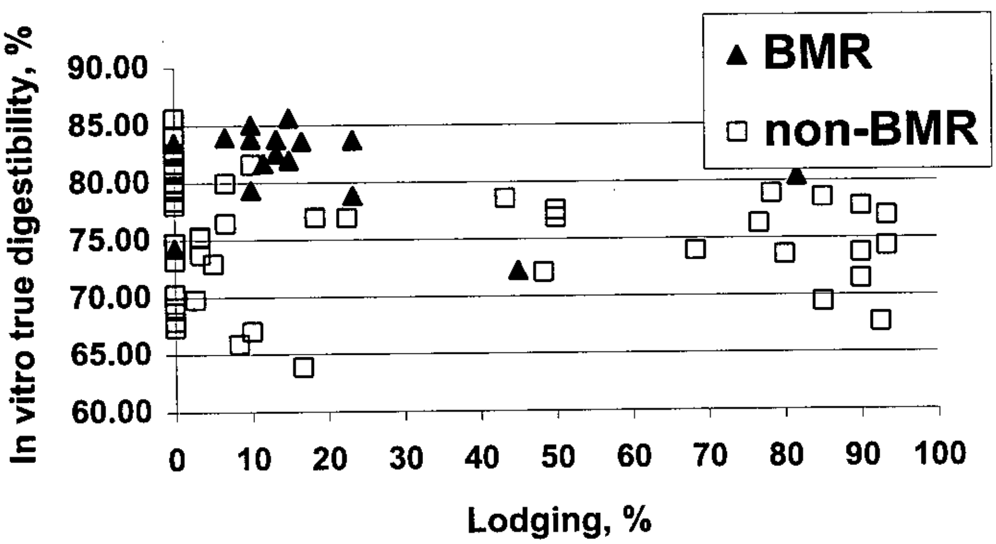

Figure 10. Relationship between lodging and in vitro true digestibility in brown midrib and non-brown midrib sorghum and sorghum X sudan hybrids grown for silage, Texas A&M University, Bushland, TX, 2000.

Self-Fed Supplements for Beef Cattle

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Supplementation programs rely on the assumption that animals consume a targeted amount of supplement. If animals consume less than the target amount, then the formulated nutrient intake is not received. If animals consume more than the target amount, supplementation costs are increased, and there can be potential negative impacts on forage intake and digestibility. Deviation from the targeted supplement intake can negatively impact animal production (Bowman and Sowell, 1997).

Intake of supplement is usually measured by dividing the supplement disappearance by the number of animals. This method does not consider variation in intake by individual animals. To demonstrate the importance of variation in individual animal supplement consumption, consider the following example of the calculation of consumption as a percent of target intake. If 20 lb of supplement with a target intake of 2 lb per cow per day is fed to a group of 10 cows, average supplement consumption is 2 lb, and it is assumed that the target consumption is met. However, if supplement consumption by individual cows is measured, and there are three cows that consume no supplement, and two cows that consume 1 lb/d, then only 50% of the animals consumed at least the target amount. This results in some animals below and some animals above the target supplement intake.

Common measures used to measure intake variation include: the proportion of animals that consume no or a low level of supplement (non-feeders), the coefficient of variation (CV) for individual animal supplement intake, and the percentage of animals consuming the desired or target amount of supplement (Bowman and Sowell, 1997).

Factors Affecting Supplement Consumption

Trough Space. Changes in trough space per animal can influence competitiveness and variation in supplement consumption. The proportion of sheep not consuming supplement fed once daily in troughs increased from 0 to 31% as trough space was decreased (Arnold and Maller, 1974). However, excess trough space can increase variation in hand-fed supplement consumption. California workers observed that with 36 inches of trough space per cow, less fighting and dominance/submissive behavior occurred during supplementation than when 71 inches/cow was allowed. According to these authors, 36 inches of trough space did not allow cows to fight without backing away from the trough, and therefore, fewer animals were pushed away from the supplement. When excessive trough space was allowed, dominant cows were observed to chase others away from one side of the trough, and to spend more time fighting than eating (Wagnon, 1966).

Supplement Allowance. Larger quantities of supplement provided per animal reduce the variation in individual animal supplement consumption (Foot et al., 1973), and the proportion of non-feeders. However, greater supplement allowance does not necessarily result in a greater percentage of animals consuming the target amount. The proportion of grazing ewes not consuming block supplement was found to be highest when average flock supplement consumption was low, and decreased as average flock supplement consumption increased (Ducker et al., 1981). When supplement allowance was high, trough space had little effect on variation in supplement intake, however, when supplement allowance was low, trough space had a large effect on supplement intake variation (Kendall et al., 1980b).

Supplement Form. Liquid and block supplements, classified as self-fed, can be thought of as delivery methods that attempt to allow unlimited trough space per animal, and theoretically should increase an animal's opportunity to consume supplement, or reduce the percentage of non-feeders. With self-fed supplements, form and/or formulation can be used with some success to control supplement intake. Traditional dry supplements, being hand-fed, allow tight control of supplement allowance, but depending on feeding method, include the effects of trough space on variation in supplement intake. Over a wide range of animals, environments, and supplement formulations, the percentage non-feeders averaged 14.3% for blocks, 15% for dry supplements, and 23.5% for liquid supplements. The CV of individual supplement consumption averaged 79% for block, 41% for dry, and 60% for liquid supplements. Summarizing studies that made direct comparisons between hand-fed (dry) and self-fed (block or liquid) supplements indicated an average of 5% non-feeders for hand-fed, and 19% non-feeders for self-fed supplements (Lobato et al., 1980b; Kendall et al., 1983; Holst et al., 1994). The CV of individual supplement consumption averaged 38% for hand-fed and 71% for self-fed supplements (Kendall et al., 1980a; Lobato et al., 1980b; Kendall et al., 1983; Holst et al., 1994).

Supplement Formulation. Supplement characteristics such as hardness and nitrogen content may influence variation in consumption. Block supplement intake by cattle decreased as block hardness increased (Zhu et al., 1991). In addition, the CV of supplement intake increased as block hardness increased, averaging 17% for soft blocks, 23% for medium blocks, and 58% for hard blocks. The CV for individual supplement intake of molasses-urea blocks by grazing sheep and the percentage of non-feeders decreased as the CP content of the blocks increased (Ducker et al., 1981).

Animal-Related Factors. A number of factors influencing livestock acceptance of feeds appear to be independent of palatability. Livestock are sometimes reluctant to sample new feeds initially, but usually overcome this reluctance with time and experience. Animals fed in groups often consume less feed, but have lower variation in intake than animals fed individually. Older, more dominant animals typically consume more supplement than younger animals, but this may be altered by changes in supplement delivery methods.

Exposure Time and Previous Experience. Livestock exposed to new feeds often exhibit a cautious sampling or rejection of the feed which is not related to palatability, followed by a period of low feed intake, and then increased consumption leading to a relatively stable level of intake (Launchbaugh, 1995). Individual supplement intake variation usually decreases with time (Lobato and Pearce, 1980; Coombe and Mulholland, 1983). Animals with previous experience consuming a particular feed accept that feed more readily than nonexperienced animals. Early dietary experience may increase intake of a novel feed at a later date. Exposing sheep to molasses-urea blocks during the preweaning period had beneficial effects on supplement intake when blocks were offered post-weaning (Lobato et al., 1980a). Sheep without previous experience consuming grain took up to 2 weeks before they were consuming their entire ration of grain (Juwarini et al., 1981). Coefficients of variation of supplement intake usually decrease with increased exposure time to supplements.

Social Interactions. Social interactions play an important role in supplement consumption by cattle and sheep. Dominant animals often consume large amounts of supplement and prevent other animals from consuming desired levels. It may be possible to change dominance patterns by altering feeder design. Inexperienced animals commonly increase supplement intake in the presence of more experienced animals. Lambs exposed to supplement for the first time in the presence of their mothers, ate more supplement during post-weaning tests than lambs exposed to supplement without their mothers (Lynch et al., 1983).

Forage Factors. The percentage of non-feeders increases as forage availability increases (Wagnon, 1966; Ducker et al., 1981). Variation in individual intake of supplements increases with greater forage availability, possibly due to less competition for a limited nutrient supply.

MONTANA STATE UNIVERSITY RESEARCH

Growth and Reproductive Performance by First Calf Heifers and Their Calves

Sixty-eight 2-year-old cows (with March-born calves) were used to determine the effects of a self-fed liquid supplement fed after calving on reproductive performance and gain of first calf heifers and their calves. Thirty-four cow/calf pairs were assigned to one of two treatments following calving beginning April 2: 1) control, hay or pasture only; and 2) liquid supplement, hay or pasture and free access to a Loomix blend in an open trough. Both groups were observed for estrus twice daily beginning June 1 through June 21, and were bred by artificial insemination. On June 21 the supplementation period ended, and all cows were grouped together, exposed to clean-up bulls, and grazed together throughout the summer. Supplemented cows gained 57.8 lb more ($P = 0.0001$) during the supplementation period than unsupplemented cows. Calves of supplemented cows gained 22.3 lb more ($P = 0.002$) than calves of unsupplemented cows during the supplementation period. Calf weaning weight in the fall did not differ ($P = 0.69$) between calves of supplemented or unsupplemented cows (avg 582 lb). No differences ($P > 0.10$) were seen in reproductive performance between supplemented and unsupplemented cows.

Table 1. Effect of postpartum self-fed liquid supplement on weight gain and reproductive performance in 2-year-old cows and their calves.

	Control	Loomix	SE	*P*-value
No. of cow/calf pairs	34	34		
April 2 – Cow wt, lb	1057.8	1054.9	17.44	0.91
June 21 – Cow wt, lb	1058.9	1113.8	18.45	0.04
Cow gain, lb	1.1	58.9	6.68	0.0001
April 2 – Calf wt, lb	143.7	137.6	5.46	0.45
June 21 – Calf wt., lb	296.4	312.6	8.90	0.13
Calf gain, lb	152.7	175.0	4.86	0.002
Calf ADG, lb	1.91	2.19	0.061	0.002
October 17 – Calf wt., lb	578.3	585.3	12.12	0.69
June to Oct calf ADG, lb	2.39	2.31	0.052	0.31
Cows bred AI, %	23/34 = 67.7	27/34 = 79.4		0.27* Chi-square
Cows pregnant, %	28/34 = 82.4	27/34 = 79.4		0.75* Chi-square

Liquid Supplement Delivery Method and Forage and Supplement Intake by Grazing Beef Cows – Bowman et al., 1999

Sixty crossbred 2- and 3-yr-old pregnant cows were assigned to one of three native range pastures from October to December to evaluate forage and supplement intake, and supplement feeding behavior as affected by cow age (2 vs. 3 yr) and liquid supplement delivery method. Treatments were: 1) no supplement; 2) ad libitum access to a liquid supplement feeder (ADLIB); and 3) ad libitum access to the Regulate liquid feed delivery system that was computer controlled to dispense 40 lb/d liquid supplement (2 lb/cow/d) divided into nine equal aliquots every 1.5 h between 0600 and 1800. Liquid supplement (28.5% CP as-fed) used in both feeders contained YbCl to estimate individual supplement intake. Forage 48 h in situ DM and NDF digestibility were greater ($P < 0.01$) for supplemented than for unsupplemented cows (avg 67.1 vs. 49.4% for DMD; avg 63.7 vs. 42.7% for NDF digestibility). Three-yr-old cows consumed 11% more ($P < 0.05$) forage DM than 2-yr-old cows (33.7 vs. 30.4 lb/d), but DMI was not different ($P > 0.10$) when expressed on a body weight basis. Supplemented cows consumed 49% more ($P < 0.01$) forage DM than unsupplemented cows (avg 35.9 vs. 24.3 lb/d). Individual supplement consumption ranged from 0.007 to 10.0 lb/d as-fed. A cow age by treatment interaction was detected for supplement consumption. Two- and 3-yr-old cows on REGULATE and 2-yr-old cows on ADLIB consumed less ($P < 0.01$) supplement than 3-yr-old cows on ADLIB. Liquid supplement increased forage intake and digestibility by cows grazing fall native range. A computer controlled liquid supplement feeder equalized supplement intake by 2- and 3-yr-old cows.

Table 2. Intake by cows grazing native range and either unsupplemented or supplemented with one of two liquid supplement delivery systems

	Control	REGULATE	ADLIB	2-yr-old	3-yr-old	SE
No. cows	20	20	20	30	30	---
48-h in situ DMD, %[x]	49.4[a]	65.8[b]	68.3[b]	---	---	1.70
Forage DMI, lb/d[x,y]	16.5[a]	24.0[b]	25.4[b]	20.7	23.1	0.90
Forage DMI, %BW[x]	1.42[a]	2.04[b]	2.16[b]	1.88	1.86	0.88
Supplement DMI below target, %	---	70	50	80	40	---
Intake CV, %	---	105	109	150	95	---
Supplement intake range (lb/d)	---	0.04-9.3	0.01-10.0	0.04-3.2	0.04-10.0	---

x = Treatment effect ($P < 0.001$), y = Age effect ($P < 0.05$).

Liquid Supplementation of Grazing Cows and Calves – Earley et al., 1999

One hundred and one Angus cows (average wt 1354 lb) and their bull calves (average wt 470 lb) grazing improved summer pastures were used to determine cow and calf intake of liquid supplement, and its effect on forage intake and performance. Forty-seven pairs had access to a 22% CP (41% CP DM basis) molasses-based liquid supplement in an open feeder and 54 pairs were not supplemented. Cows consumed more supplement (1.2 lb/d as-fed) than calves (0.4 lb/d as-fed) but both consumed similar amounts of supplement on a body weight basis (0.08% BW/d). Supplemented cows gained 0.27 lb/d more ($P<0.05$) than unsupplemented cows. Average daily gain by supplemented calves (2.87 lb/d) was 30% greater ($P<0.01$) than ADG by unsupplemented calves (2.20 lb/d). Forage intake (% BW) by both supplemented cows and calves was 64% greater ($P<0.01$) than forage intake by unsupplemented cows and calves. There was no difference ($P>0.10$) in milk intake between supplemented and unsupplemented calves. There was no difference ($P>0.10$) in time spent at the supplement feeder between cows and calves (average 5.0 min/d). Liquid supplementation increased forage intake and average daily gain by cows and calves grazing improved forages in late summer. The cost for additional weight gained by the supplemented calves was $ 0.15/lb and October cattle prices in Montana were $0.74/lb. Liquid supplementation was cost effective under the conditions of this study.

Table 3. Average daily gain, and forage and supplement intake by cows and calves grazing improved pastures with or without liquid supplementation

	Unsupplemented	Supplemented	SE	*P*-value
No. of pairs	54	47	---	---
48-h in situ DMD, %	55.5	69.8	1.35	0.05
Cow				
ADG, lb	0.26	0.53	0.077	0.03
Forage DMI, lb	31.1	49.2	3.50	0.001
Forage DMI, %BW	2.2	3.6	0.26	0.001
Supplement intake, lb	---	1.23	---	---
Calf				
ADG, lb	2.20	2.87	0.044	0.0001
Forage DMI, lb	7.7	15.7	1.30	0.0003
Forage DMI, %BW	1.7	2.8	0.24	0.004
Supplement intake, lb	---	0.41	---	---
Milk intake, lb/d	19.8	33.1	7.72	0.27

Liquid Supplement and Forage Intake by Range Beef Cows – Sowell et al., 2001 (Submitted)

One hundred-eighty crossbred cows were assigned to one of six native range pastures during two winters to evaluate forage and supplement intake as affected by liquid supplement delivery method and cow age (2, 3, 4, 5 or 6 yr). Treatments were: 1) no supplement (Control); 2) a lick-wheel feeder containing liquid supplement (ADLIB); and 3) a computer-controlled lick-wheel feeder that dispensed 2.2 lb/cow/d of liquid supplement (REGULATE). Each treatment was applied to two pastures. Forage digestibility was increased ($P = 0.001$) by supplementation both years. Supplemented cows lost less ($P = 0.05$) body condition than unsupplemented cows (average -0.3 vs -0.6). Blood urea nitrogen (BUN) was highest ($P = 0.001$) for ADLIB (8.7 mg/dL), intermediate for REGULATE (6.2 mg/dL), and lowest for Control (2.3 mg/dL). There was a year by treatment interaction ($P < 0.06$) for forage DMI. Supplemented cows consumed more DM than Control cows in the first year, but in the second year, ADLIB cows had similar DMI to Control cows, while REGULATE cows consumed more DM. Supplement intake by cows on ADLIB was higher ($P = 0.001$) than by cows on REGULATE in both years. Supplement intake was lowest ($P = 0.002$) by 2-yr-old cows, intermediate by 3-yr-olds, and greatest by 4-, 5-, and 6-yr-old cows. Variation in supplement intake by individual cows on the REGULATE treatment was reduced ($P < 0.10$) by modifications in the liquid supplement delivery method and its dosing frequency. The proportions of cows consuming less than 1 lb/d supplement and consuming less than the target amount of supplement (2 lb as-fed) were less ($P = 0.001$) for ADLIB than for REGULATE during both years. The ADLIB cows spent more ($P = 0.001$) time at the supplement feeder and had more ($P < 0.002$) supplement feeding bouts than REGULATE cows during both years. During the first year, 2- and 3-yr-old cows spent less ($P < 0.01$) time at the feeder and had fewer feeding bouts per day than 6-yr-old cows. Age had no effect ($P > 0.10$) on feeding behavior during the second year.

Table 4. Performance by beef cows grazing native winter range and either unsupplemented or supplemented with one of two liquid supplement delivery systems during two years

	Control	Ad lib	Regulate	SE	P-value
No. of cows	119	120	118	---	---
48-h in situ DMD, %	42.6[a]	57.8[b]	62.2[b]	1.06	0.001
Weight gain, lb	-46	-82	-62	50.5	0.81
BCS change	-0.6[a]	-0.3[b]	-0.3[b]	0.11	0.05
Pregnancy rate, %	78	75	80	0.2	0.73* Chi-square
Calving interval, d	372	371	366	1.9	0.31* Chi-square
Calf birth wt, lb	86	84	86	1.76	0.80
Calf adjusted WW, lb	419	419	423	6.83	0.89

Table 5. Intake by beef cows grazing native winter range and either unsupplemented or supplemented with one of two liquid supplement delivery systems during two years

	Year 1			Year 2			
	Control	Ad lib	Regulate	Control	Ad lib	Regulate	SE
No. of cows	60	60	58	59	60	60	---
Forage DMI, lb[x,y,z]	27.8[a]	41.0[c]	50.9[d]	29.1[a]	28.0[a]	32.4[b]	1.85
Supplement intake, lb[x,y,z]	---	4.9[d]	1.1[a]	---	3.4[c]	1.9[b]	0.15
Supplement intake CV, %[x,y,z]	---	68[a]	117[b]	---	56[a]	67[a]	11.5
Supplement intake range, lb	---	0–17.9	0–4.6	---	0–15.4	0–5.6	---
Cows < target suppl. intake, %[y,z]	---	15.4[a]	73.4[c]	---	21.0[a]	50.1[b]	8.60
Blood urea N, mg/dL[y]	---	---	---	2.3[a]	8.7[c]	6.2[b]	0.47

x = Year effect ($P < 0.06$), y = Treatment effect ($P < 0.02$), z = Year x Treatment effect ($P < 0.06$).

Pellet and Block Supplements for Grazing Ewes – Taylor et al., 2001 (In press)

Pregnant Targhee ewes (N = 120; 2- to 6-yr-old) grazing native winter range were used to determine the effects of a 25% CP (as-fed) supplement provided in pellet or block form on supplement and forage intake and bodyweight change. Ewes receiving pellets were group-fed 0.25 lb/ewe/d of a wheat middling-soybean meal based pellet in troughs. Block-fed ewes had ad libitum access to a cooked molasses based block. The study was conducted for 41 d starting December 1. Supplement DMI was greater ($P = 0.001$) for pellet than block supplemented ewes with a CV for individual supplement intake of 32 and 99.5%, respectively. The proportion of ewes consuming less than 20% of mean supplement DMI was 2% for pellet-fed ewes, and 35% for block-fed ewes. Delivery method affected individual animal consumption of supplement and younger ewes consumed less supplement.

Conclusions

Postpartum access to self-fed liquid supplement increased gain by first calf heifers and their calves, but no improvement was seen in animals detected in heat during a 21-d AI period or in pregnancy rate.

Cows consuming self-fed liquid supplement while grazing native range in the fall had greater forage intake and digestibility than unsupplemented cows. However, a large variation in supplement intake by individual cows was found (CV of 95-150%) and there may be a substantial proportion (32.5%) of cows in a herd which consume only trace amounts of liquid supplement. Two-year-old cows consumed less supplement than 3-year-old cows on a traditional lick-wheel supplement feeder, but a modified feeder design (computer controlled Regulate system) equalized liquid supplement intake between age groups.

Liquid supplement intake and use by grazing calves has been documented. Calves consumed the same amount of self-fed liquid supplement on a % body weight basis and spent the same amount of time at the supplement feeder as mature cows. Liquid supplementation increased ADG and forage intake by cows and suckled calves. Older cows spent more time at the feeder than younger cows; however, there was no difference in the frequency of visits between age groups. Late summer supplementation improved performance of suckled calves and was economical under conditions of the study.

Supplying liquid supplement to cows grazing winter native range increased forage digestibility, and reduced body condition score loss. Forage intake was increased by 48% when cows had ad libitum access to liquid supplement, and by 83% when liquid supplement consumption was limited by a computer-controlled delivery system, compared to unsupplemented cows in a year where snowfall did not limit forage availability. With heavier snowfall, forage intake was only increased by 11% for cows that were using the computer-controlled supplement delivery system. Greater competition for supplement, as provided by the computer-controlled supplement delivery system, resulted in greater forage intake. Variation in supplement intake by individual cows was reduced by modifications in the liquid supplement delivery method and its dosing frequency. Social interactions by a mixed-age group of cows at liquid supplement feeders resulted in lower supplement consumption by 2-year-old cows compared with older age groups.

Variation in supplement intake was greater and mean consumption of supplement was lower for ewes with ad libitum access to a self-fed block supplement than for ewes hand-fed a pelleted supplement. Younger ewes consumed less supplement than older ewes. Pasture size and forage availability may have more influence on forage intake and body weight change than supplement delivery methods. Achieving individual ewe target intake of supplemental nutrients appears to be best accomplished using a limit fed pellet supplement than allowing ewes ad libitum access to a cooked molasses based block supplement.

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Effect of Liquid and Dry Supplements on Forage Intake

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Introduction

Grazing cattle consume forages that vary widely in quality and availability. Often, intake of nutrients from forage alone may not be adequate to meet desired rates of animal performance (i.e., daily gain, reproduction, or milk production). In such cases, supplements may be provided in order to increase performance. When concentrate feeds are fed as supplements, however, observed animal responses may be larger or smaller than expected. The discrepancy between expected and observed performance may be due to "associative effects" defined as non-additive interactions between supplements and forages. Associative effects may have positive or negative effects on voluntary forage intake, nutrient digestion, and animal performance. Although associative effects are well recognized, they have not been included in nutritional models because equations to predict them have not been available.

Because of the increasing interest in use of liquid supplements for grazing beef cattle, the question has been raised "do liquid and dry supplements have different associative effects on forage utilization?" To address this question and others, we constructed and analyzed a database on non-lactating cattle consuming a variety of forages and supplements (Moore et al., 1999). Our objectives were to determine the nature of associative effects between forages and supplements on voluntary forage intake, diet TDN, and daily gain, and develop equations to predict these effects. This paper summarizes that study, with emphasis on comparing liquid and dry supplements.

Description of Database

A literature review provided 66 references that met the requirements for inclusion in the database, i.e., voluntary forage intake, supplements fed separately, non-lactating cattle, and a non-supplemented control treatment. The 66 references included studies of 126 different forages: 73 harvested and 53 grazed. There were 444 comparisons of a non-supplemented control with a supplemented treatment (Table 1). Liquid supplements included molasses alone, molasses-urea mixtures, and a few slurries, but none of them were formulated using modern stabilization technology or slow-release urea. Types of forages and supplements were confounded to some degree in that liquid supplements were fed most often in studies of cattle grazing low-quality native forages.

If cows were used in the study, intake and digestibility data were included, but their daily gains were not. If full body weights and gains were reported, they were converted to the shrunk basis using equations derived from full and shrunk weights on forage-fed cattle (Kunkle and Moore, unpublished data). Intake data were converted to a percentage of mean shrunk body weight (% of BW). Data on forage characteristics were limited to those provided in the references. Digestibility data were limited to those from in vivo trials. In some cases, digestion trials were conducted with sheep and these data were used without adjustment. Forage TDN was assumed to be equivalent to digestible organic matter (OM). Composition data on supplements were taken from the reference,

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or calculated from supplement ingredient formulas, as given in the reference, and tabulated values of CP and TDN concentration. Because of wide variation in ash concentrations, all data were converted to the OM basis.

Table 1. Distribution of comparisons between unsupplemented and supplemented treatments (444 total comparisons)

By forage type	n	By supplement type	n
temperate	122	liquid	150
tropical	125	dry	255
native	175	combined	39
straw	22		

By sources of supplemental energy and protein

Energy	n	Protein	n
protein feeds only	43	energy feeds only	148
molasses	178	non-protein nitrogen	142
grain	129	protein feeds	143
by-products	35	combinations (NPN+feeds)	22
forages	27		
combinations	22		

Associative Effects of Supplements

Voluntary Forage Intake. Associative effects on voluntary forage intake were very evident; i.e., intake was increased, decreased, and unchanged by supplement (Fig. 1). Most of the increases in forage intake occurred with forages having intakes when fed alone less than 1.75% of BW. Supplements did not decrease intake when intake of native forages fed alone was less than 1.25% of BW. When intake of improved forages fed alone was greater than 1.75% of BW, supplement generally decreased forage intake.

The changes in forage intake due to supplement ranged from increases of more than 1% of BW to decreases of more than 1.2% of BW (Fig. 2). A major factor determining whether the forage intake change was positive or negative was the ratio of TDN to CP in the forage. When TDN:CP is greater than 7, there is a deficit of CP relative to TDN. When supplement increased intake of forage, those forages had a deficit of CP (TDN:CP > 7), except for some ammoniated straws, and intake change was not related to supplemental TDN intake. When forages had adequate CP (TDN:CP < 7), supplements generally decreased forage intake. Supplemental TDN intake greater than 0.7% of BW decreased forage intake even for those forages having a CP deficit.

There were no obvious differences among types of supplement in their effects on forage intake (Fig. 3); both liquid and dry supplements increased and decreased forage intake. At any level of CP intake, supplements both increased and decreased forage intake (Fig. 4). There was no apparent difference among sources of added protein in the effect of supplement on forage intake. When supplement increased forage intake, NPN and meal forms of supplemental protein were equally effective.

Diet TDN. The associative effect of supplement on diet TDN was examined in terms of the difference between expected TDN concentrations and actual observed TDN as determined in digestion trials. Expected TDN concentration was calculated as follows: (forage OM intake with supplement * forage TDN) + (supplement OM intake * supplement TDN)] / [(forage OM intake with supplement + supplement OM intake)] * 100. All OM intake values were expressed as % of BW and TDN values as % of OM. This approach measures the overall associative effect on digestion, but makes no assumption as to whether there were changes in the digestibility of forages, supplements, or both.

Observed diet TDN was both larger and smaller than expected (Fig. 5), but the predominant effect was a depression in TDN with all types of forages. When TDN was greater than expected, forages were native and warm season grasses. Deviations from expected diet TDN were rather large in some cases, ranging from increases greater than 7% of OM to decreases greater than 12% of OM (Fig. 6). There was no apparent difference among types of supplements in the deviation from expected TDN. Deviations were not related closely to supplemental TDN intake, but when supplemental TDN intake was greater than 0.7% of BW, diet TDN was always less than expected.

Daily Gain. There was a wide range in average daily gain by cattle fed forage alone (< -0.5 to >1.0 kg/d; Fig. 7). Supplements generally, but not always, increased daily gain. In a few cases, gains with supplements were less than those without. Associative effects were evident in the lack of a relationship between supplemental TDN intake and the change in gain due to supplement (Fig. 8). With native forages, small intakes of supplement (often liquid) frequently resulted in large increases in gains.

In those few cases when supplements decreased gain, the supplement was often based on molasses (Fig. 9), contained either NPN or no added N, and supplemental CP intake was less than 0.1% of BW (Fig. 10). In most cases, however, liquid supplements increased gains. There was not a close relationship between supplemental CP intake and change in gain, but when supplement CP intake was greater than 0.1% of BW, supplement always increased gains.

When forage quality was low (i.e., low voluntary intake when fed alone, and a deficit of CP relative to TDN), liquid supplements increased both forage intake and gain, but gains remained small or even negative (Moore et al., 1996). In contrast, when forage quality was high (i.e., high voluntary intake, and adequate CP relative to TDN), liquid supplements decreased forage intake generally, but increased gains if the supplement contained meal or a combination of meal and NPN. When supplements contained meal forms of protein, gain responses at given levels of supplemental TDN tended to be greatest when the supplement included a source of escape protein (i.e., undegradable intake protein; Fig. 11).

Types of Associative Effects on Forage Intake

Based on this study and others, it is evident that there are several types of associative effects on forage intake. If associative effects do not occur, then forage intake is not changed due to supplementation, and the supplement intake can be added to the forage intake to determine total diet intake (Fig. 12a). One of the simple associative effects on voluntary forage intake is decreased forage intake that often occurs with high-quality forages (i.e., substitution; Fig. 12b). Even though total diet intake is unchanged, animal performance may be increased when substitution occurs because of the greater

TDN concentration in the supplement than in the forage it replaces. Also, substitution can be used to extend a limited supply of forage. Another simple associative effect is an increase in intake (Fig. 12c) and diet TDN that occurs with low-quality forages; increases in total TDN intake and animal performance are likely.

In practice, it is unlikely that only simple associative effects occur. Substitution may be only "partial" such that total intake increases even though forage intake decreases (Fig. 12d). Complex associative effects combining two or more of the simple effects may either increase or decrease forage intake depending on the amount of supplement consumed (Fig. 12e). In addition, the decrease in forage intake may be greater than the amount of supplement consumed (Fig. 12f). If forage intake and diet TDN are depressed by supplement enough, then animal performance may not be increased by supplement and may even be decreased.

Prediction of Associative Effects

Even though associative effects of supplements on forage intake and diet TDN could have important effects on predictions of animal performance, equations to predict them have not been available. The database described above was used to develop and evaluate acceptable multiple regression equations to predict associative effects on voluntary forage intake and diet TDN concentration (Moore et al., 1999).

Voluntary forage intake when fed with supplement. Inputs for the best intake equation included concentrations of CP and TDN in forages and supplements (as % of OM), voluntary forage OM intake when the forage is fed alone (as % of BW), and intakes of supplemental CP and TDN (as % of BW). The best equation was:

Voluntary forage OM intake when fed with supplement, as % of BW = - 1.9875
+ 1.0101 * voluntary forage OM intake when fed alone (VFIalone)
+ 0.0587 * $(\text{VFIalone})^2$
- 0.0195 * forage CP concentration
- 0.0408 * forage TDN concentration
- 0.911 * supplement TDN intake
+ 0.0204 * supplement CP concentration
+ 0.0699 * supplement TDN concentration
- 0.000569 * $(\text{supplement TDN concentration})^2$
+ 5.87 * supplement CP intake
- 9.74 * $(\text{supplement CP intake})^2$
- 0.221 * VFIalone * supplement TDN intake
- 0.0143 * VFIalone * supplement CP concentration
+ 0.000509 * forage TDN concentration* supplement TDN concentration
+ 0.211 * forage type code
- 0.0638 * supplemental energy code

Forage type codes were: 1 = temperate or tropical forages, and 2 = native mixed forage or straw. Supplemental energy codes were: 1 = protein supplements only (e.g., soybean meal), 2 = molasses, 3 = grains or by-products, and 4 = forages (e.g., alfalfa).

The equation given above should not be used outside the range of data used to develop it, as follows:

Forage OM intake when fed alone = .46 to 3.11% of BW
Forage CP = 2.1 to 23.0% of OM

Forage TDN = 34.9 to 78.4% of OM
Supplement OM intake = .04 to 1.85% of BW
Supplement CP = 6.7 to 98.4% of OM
Supplement TDN = 52.7 to 95.4% of OM

Forage CP and TDN concentrations should be obtained by submitting samples to forage testing laboratories rather than by referring to tables of feed composition.

Diet TDN concentration. Input into the best TDN equation was expected diet TDN concentration (% of OM, as described above). That equation was:

Total diet TDN, as % of OM = 59.71
- 0.8948 * expected diet TDN concentration
+ 0.01399 * (expected diet TDN concentration)^2

Voluntary forage intake when fed alone. An accurate estimate of voluntary forage intake when fed alone is a critical input for the equations given above. This estimate must be obtained independently. We used the data in this study and others to develop and evaluate intake prediction equations (Moore and Kunkle, 1999). An acceptable equation for forage fed alone was:

Voluntary forage dry matter intake when fed alone, as % BW = - 2.318
+ .442 * forage CP concentration, as % of DM
- .0100 * (forage CP concentration)^2
- .0638 * forage TDN concentration, as % of DM
+ .000922 * (forage TDN concentration)^2
+ .180* forage acid detergent fiber (ADF) concentration, as % of DM
- .00196 * forage ADF concentration)^2
- .00529 * forage CP * forage ADF

This estimate of forage dry matter intake when fed alone should be converted to organic matter intake before being used in the equation to estimate forage organic matter intake when fed with supplement.

Take Home Messages

1) Associative effects on forage intake and diet TDN were both positive and negative, and biologically significant.
2) There was no inherent difference between liquid and dry supplements in their associative effects on forage intake, diet TDN, and average daily gain.
3) Supplements often increased voluntary intake of low-quality forages (i.e., when voluntary intake of forage fed alone was less than 1.75% of BW, and when forage CP was deficient relative to TDN).
4) When forage intake was increased by supplements, natural protein and NPN were equivalent in their effect.
5) Supplements often decreased intake of high-quality forages (i.e., when voluntary intake of forage fed alone was greater than 1.75% of BW, and forage CP was adequate relative to TDN).
6) When supplement increased TDN diet concentration more than was expected, forages were generally native and warm season grasses.
7) When supplemental TDN intake rates were more than 0.7 % of BW, voluntary forage intake was decreased, and diet TDN concentration was less than expected, independent of the forage and supplement.

8) The associative effects of supplements on intake and TDN, and the source and level of CP in the supplement, determined the effects of supplements on daily gain.
9) Gains were generally, but not always, increased by supplementation, even at small rates of TDN and CP intakes.
10) When supplemental CP intake was greater than 0.1 % of BW, gains were always increased by supplement.
11) At a given level of supplemental TDN intake, increases in gains were greatest when the supplement included a source of escape protein.
12) Multiple regression equations based on a few simple inputs described the associative effects of supplements on voluntary forage intake and deviation from expected TDN concentration of mixed diets.
13) Practical forage-livestock feeding models should include equations that account for associative effects of supplements on forage utilization.
14) Research must continue to develop practical methods of estimating the inputs to nutritional models, especially the intake and nutritive value of grazed forages.

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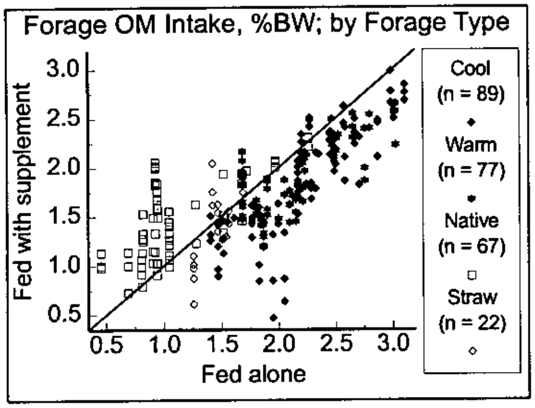

Figure 1. Voluntary forage organic matter (OM) intake with and without supplement.

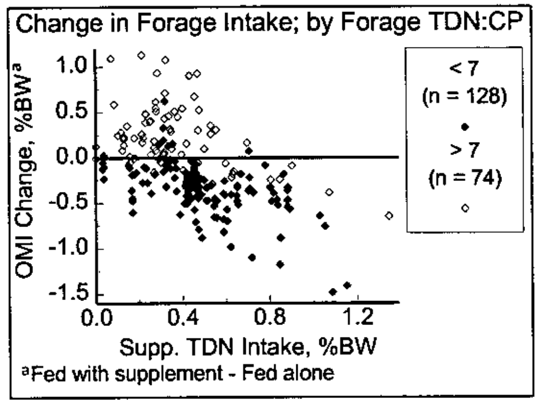

Figure 2. Effect of supplemental TDN and forage TDN:CP ratio on change in forage intake due to supplement.

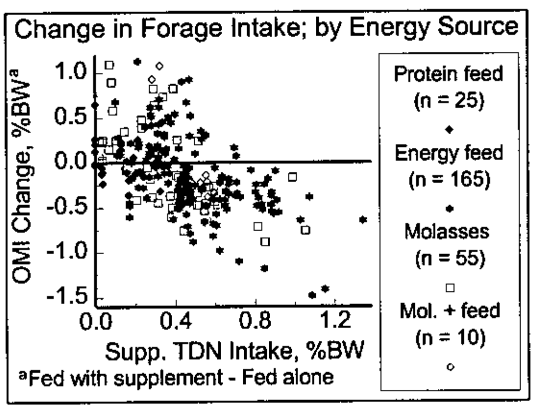

Figure 3. Effect of supplemental TDN and type of supplement on change in forage intake due to supplement.

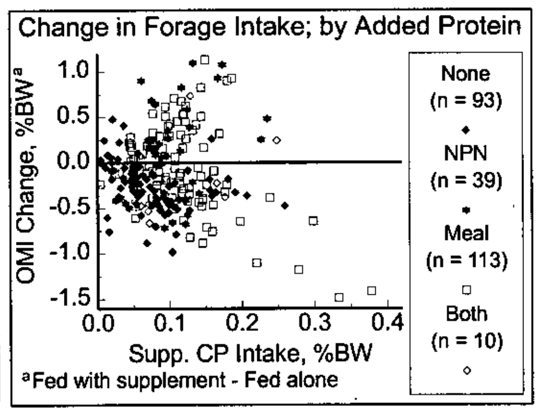

Figure 4. Effect of supplemental CP and type of added protein on change in forage intake due to supplement.

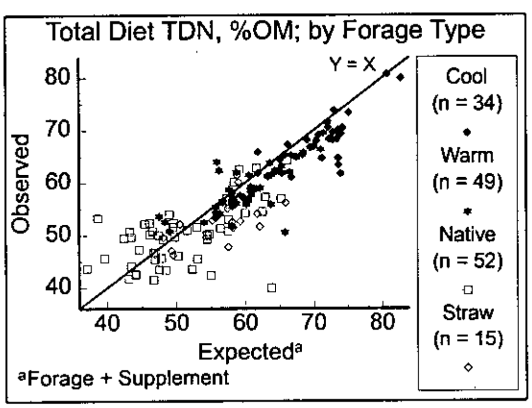

Figure 5. Observed vs. expected TDN concentrations of total diets (forage plus supplement).

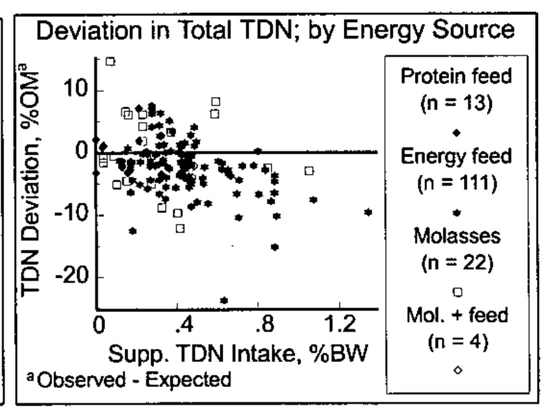

Figure 6. Effect of supplemental TDN and type of supplement on deviation from expected diet TDN.

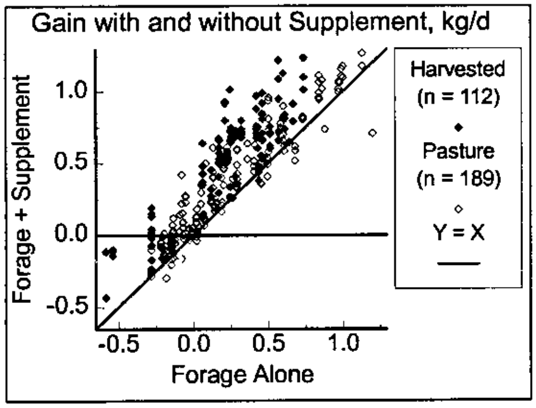

Figure 7. Average daily gain by cattle with and without supplement.

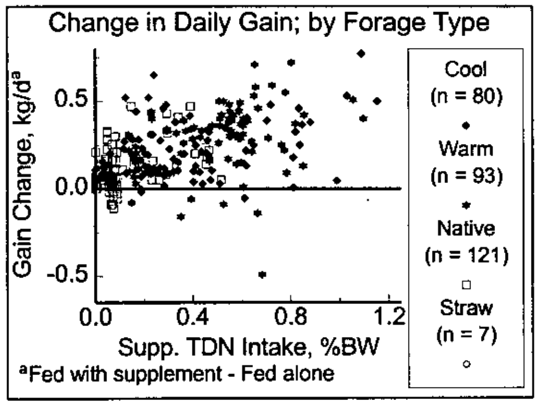

Figure 8. Effect of supplemental TDN and forage type on change in daily gain due to supplement.

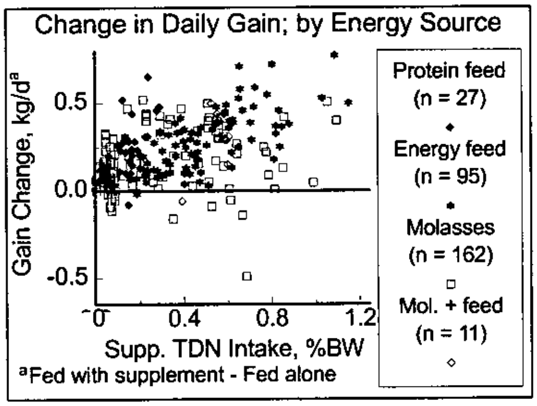

Figure 9. Effect of supplemental TDN and type of supplement on change in daily gain due to supplement.

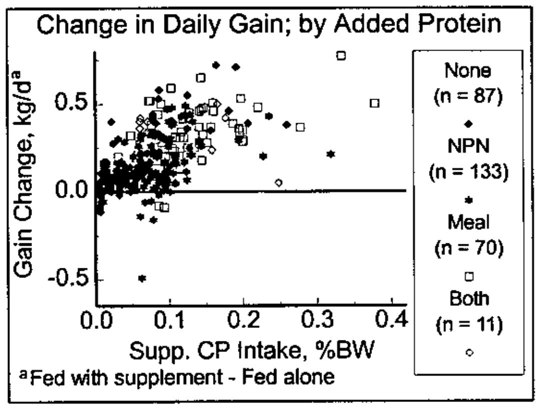

Figure 10. Effect of supplemental CP and type of added protein on change in daily gain due to supplement.

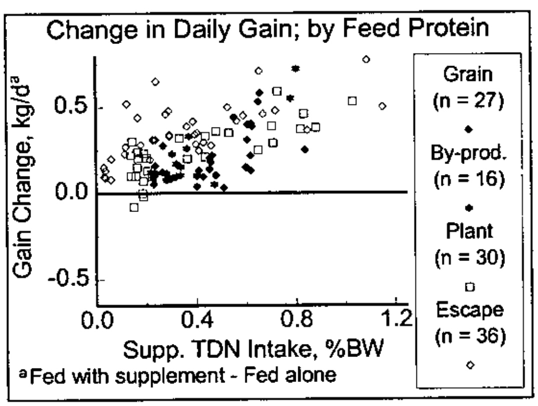

Figure 11. Effect of supplemental TDN and type of natural protein on change in gain due to supplement.

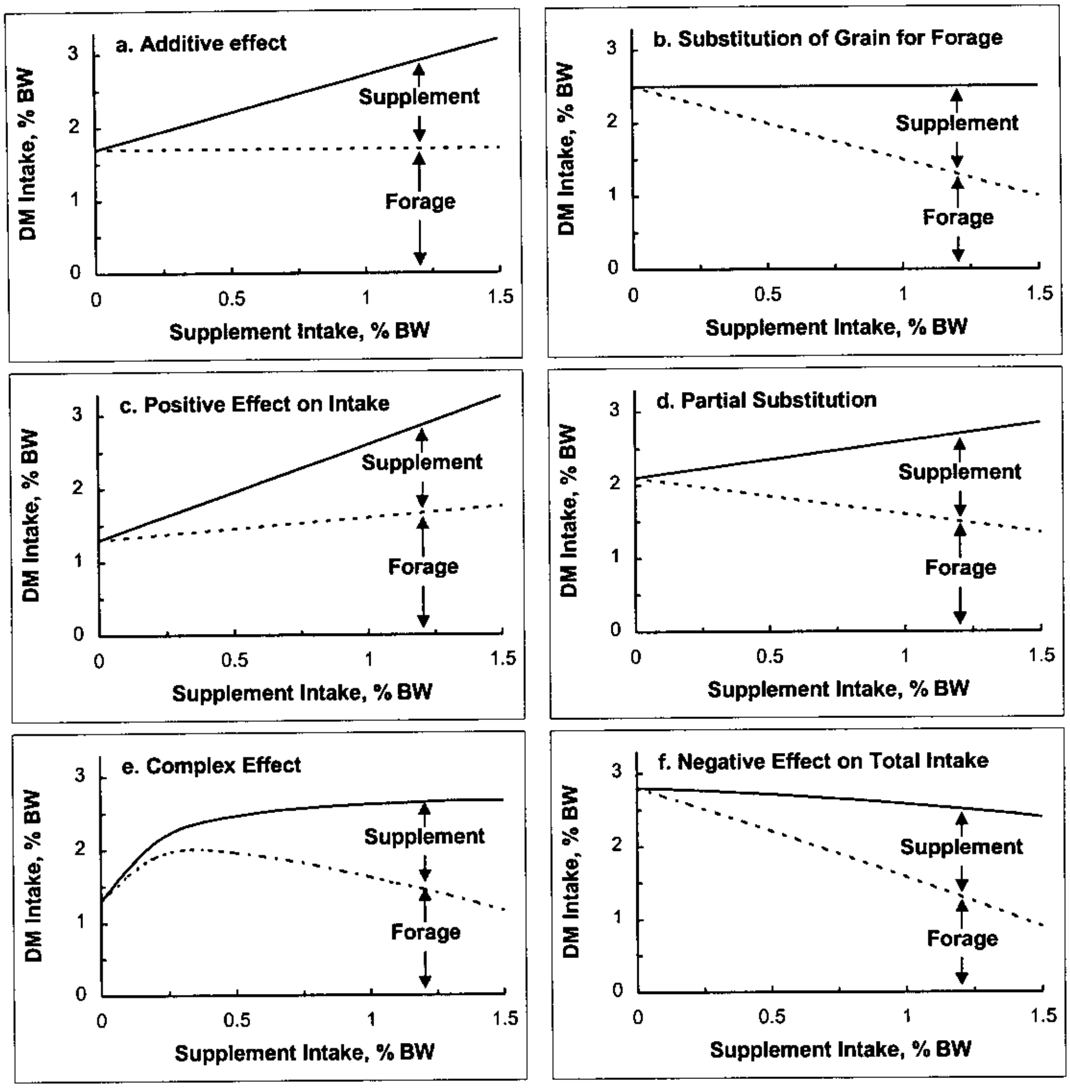

Figure 12. Examples of associative effects of supplemental feeds on intake of forage and total diet: (a) supplement has no effect on forage intake (supplement and forage are "additive"), and total intake increases in direct proportion to supplement intake; (b) supplement "substitutes" for an equal amount of forage, and total intake does not change; (c) supplement increases intake of both forage and total diet across the entire range of supplement intake; (d) there is partial substitution and decreased forage intake, but total diet intake increases; (e) small amounts of supplement increase intake of low-quality forage, but larger amounts have a substitution effect and total intake plateaus; and (f) when large amounts of supplement are fed with high-quality forage, forage intake decreases to an extent greater than is accounted for by substitution alone, and total diet intake decreases.

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