Effects of Pasture Conditions in Spring on Seasonal Forage Productivity

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J.R. Russell, professor of animal science,
S.M. Kremer, research assistant,
and D.R. Strohbehn, professor of animal science

Summary

Fifteen beef cow-calf producers in southern Iowa were selected based on locality, management level, historical date of grazing initiation and desire to participate in the project. In 1997 and 1998, all producers kept records of production and economic data using the Integrated Resource Management-Standardized Performance Analysis (IRM-SPA) records program. At the initiation of grazing on each farm in 1997 and 1998, Julian date, degree-days, cumulative precipitation, and soil moisture, phosphorus, and potassium concentrations were determined. Also determined were pH, temperature, and load-bearing capacity; and forage mass, sward height, morphology and dry matter concentration. Over the grazing season, forage production, measured both by cumulative mass and sward height, forage in vitro digestible dry matter concentration, and crude protein concentration were determined monthly. In the fall of 1996 the primary species in pastures on farms used in this project were cool-season grasses, which composed 76% of the live forage whereas legumes and weeds composed 8.3 and 15.3%, respectively. The average number of paddocks was 4.1, reflecting a low intensity rotational stocking system on most farms. The average dates of grazing initiation were May 5 and April 29 in 1997 and 1998, respectively, with standard deviations of 14.8 and 14.1 days. Because the average soil moisture of 23% was dry and did not differ between years, it seems that most producers delayed the initiation of grazing to avoid muddy conditions by initiating grazing at a nearly equal soil moisture. However, Julian date, degree-days, soil temperature and morphology index at grazing initiation were negatively related to seasonal forage production, measured as mass or sward height, in 1998. And forage mass and height at grazing initiation were negatively related to seasonal forage production, measured as sward height, in 1997. Moreover, the concentrations of digestible dry matter at the initiation of and during the grazing season and the concentrations of crude protein during the grazing season were lower than desired for optimal animal performance. Because the mean seasonal digestible dry matter concentration was negatively related to initial forage mass in 1997 and mean seasonal crude proteins concentrations were negatively related to the Julian date, degree-days, and morphology indeces in both years, it seems that delaying the initiation of grazing until pasture soils are not muddy, is limiting the quality as well as the quantity of pasture forage. In 1997, forage production and digestibility were positively related to the soil phosphorus concentration. Soil potassium concentration was positively related to forage digestibility in 1997 and forage production and crude protein concentration in 1998. Increasing the number of paddocks increased forage production, measured as sward height, in 1997, and forage digestible dry matter concentration in 1998. Increasing yields or the concentrations of digestible dry matter or crude protein of pasture forage reduced the costs of purchased feed per cow.

Introduction

Although a considerable amount of research has evaluated improved grazing practices in recent years, grazing in much of this research had been initiated in late April or early May when pastures have a sward height of at least 4 inches or a yield of at least 1,000 lb/acre. One area that has not been addressed in grazing research is the optimal conditions for initiating grazing of summer pastures in the Midwestern United States. Research in other countries has shown that management of pastures in the spring will affect seasonal forage quality and quantity not only in a single year, but possibly even over subsequent years.

In order to decrease the amounts of stored feed fed to wintering beef cows, reduce diseases associated with calving in muddy drylots, and diminish the possibility of soil compaction of crop fields used for winter grazing, producers may place their herd onto summer pastures in late winter or early spring. Because pasture soil conditions may be muddy and forage supply is short during this period, long-term forage supply may be adversely affected by this practice. Grazing excessively muddy pastures may disrupt soil structure through the process known as "poaching." Poaching increases bulk density and reduces water infiltration of the soil. In addition to damaging soil structure, poaching reduces forage plant growth by reducing aeration, increasing denitrification, and mechanically destroying leaves, growing points, and roots. The extent of damage caused by poaching is affected by soil characteristics, forage species, and grazing management. In addition to the poor uptake of nutrients, early spring forage growth is also inhibited by light intensity and the amount of leaf area available to capture that light. Excessive grazing early in the season from premature harvest and/or excessive stocking may continue to limit forage yield by limiting leaf area development and, therefore, photosynthetic capacity. This effect not only limits seasonal forage yields, but may also reduce forage root nutrient reserves. Furthermore, over-grazing of legume species in the spring will decrease the number of growth points. These effects will adversely affect forage yield, quality and persistence in subsequent years.

Although overgrazing of pastures early in the season may adversely affect long-term forage yields, undergrazing of pastures in the spring may also reduce seasonal forage yields by reducing the formation of new tillers. Furthermore, digestibility and crude protein concentration of forage in undergrazed pastures is reduced in the maturing tillers.

Therefore, an experiment was conducted with the objectives of quantifying the effects of environmental and soil properties, forage height, density, and maturity and stocking rate of summer pastures at the initiation of spring grazing on total forage yield, calf production, and cow reproduction throughout the summer and the relationship between forage productivity and the profitability of cow-calf production.

Methods and Materials

Site selection and definition

During the summer of 1996, 45 commercial cow-calf producers were interviewed to determine whether they would be appropriate for use in this project. Data collected relative to pastures included: the total acreage of their farms; the numbers of pastures; the amounts of pastureland that was owned or rented; predominant forage pasture species and weeds; pasture fertilization rates, frequency, and application methods; weed control measures; pasture renovation frequency and method; and forage maturity management. Data collected regarding grazing management included: the stocking system and rate, the historical dates of grazing initiation and termination for summer and winter feeding; the reasons for initiating or terminating grazing during the winter or summer, and the number of acres of corn crop residues or residual forage that are grazed during winter. Data relative to the cow herds included: numbers of spring-calving cows, fall-calving cows, heifers, and bulls; number and size of animal management groups; and average calf weaning weight. Animal management data included: culling procedures, identification method, breeding management, nutritional supplementation, and frequency of weighing cattle. Finally, information regarding current record-keeping strategies, and interest in participating in the project were obtained. From the 45 interviews, 15 producers in locations ranging from Williams to Clarinda, Iowa, were selected for the experiment on the bases of historical date of grazing initiation, level and consistency of pasture management, location, pasture area, numbers of herds, and interest in participation in the project. In particular, selection attempted to obtain 3 producers who initiated grazing at early, intermediate, and late dates relative to other producers within a given locality. Management of pastures and cattle on each farm were controlled by the individual producer with no alterations made because of this experiment.

In fall of 1996, each farm was visited and botanical composition of each pasture was estimated using a variation of the point-quadrant method. In this modification, pasture acreage was recorded, and 24 measurements per hectare or a minimum of 100 measurements per pasture were recorded at approximately 15 m distances. Measurements included whether each site was bare soil or covered by grass, legume, forb, or dead plants. The proportion of pasture area that was bare or covered by each plant class was calculated as a proportion of all sites measured.

During the summer of 1997, soil core samples were taken at a minimum of 3 to a maximum of 12 locations per pasture, and the soil was classified by the USDA-NRCS.

Grazing initiation measurements

At initiation of grazing on each farm in the springs of 1997 and 1998, twelve locations were randomly selected in each pasture and the forage sward height, mass and morphology, and soil temperature, load-bearing capacity, moisture, pH, and concentrations of phosphorus and potassium determined. Forage sward heights were measured with a falling plane meter (4.8 kg/m^2). Forage mass was determined by hand-clipping forage in a .25-m^2 area to a height of 1 cm and compositing it to yield one sample per pasture. Dry matter concentrations of forage samples were determined by drying in a forced air oven at 60^o C for 48 h. Soil temperatures were measured with a soil thermometer at a depth of 10 cm. Load- bearing capacities were determined at a depth of 1 cm with a shear vane (Torvane, ELE International, Inc., Lake Bluff, IL). Soil samples were collected with a core sampler with a diameter of 2.54 cm to a depth of 8 cm. Soil samples from each pasture were composited and divided into two subsamples. Moisture concentration of one subsample from each pasture was determined by drying in a convection oven at 100^{o}C for 48 h. The remaining subsample was analyzed for pH, and for concentrations of potassium (by atomic absorption spectrophotometry) and phosphorus (by the Bray procedure) in the Iowa State University Soil Testing and Plant Analysis Laboratory. To determine plant morphology, forage samples were collected from four additional locations per pasture by hand-clipping to the ground surface and hand-sorting and ranking according to plant characteristics.

To calculate a weighted mean for each of the above variables, values for each pasture were adjusted for the proportion of the total pastureland of a farm contributed by each pasture. Cumulative degree-days, using a base of 3.5^o, and cumulative precipitation from January 1 of each year to the initiation of grazing were calculated from records of the weather station in nearest proximity.

Seasonal environmental variables

Similar to initial data, cumulative degree-days, using a base of 3.5°C and cumulative precipitation during the grazing season on each farm were determined from the records of the weather station in nearest proximity. Stocking density for each pasture was calculated as animal units per hectare assuming that an animal unit was equal to one cow with calf, one bull, one dry cow, or two yearling cattle.

Monthly forage production and composition.

To determine forage accumulation over a 28-day period, a minimum of three 9-m^2 grazing exclosures per pasture or twelve grazing exclosures per farm were randomly placed on each pasture at the initiation of grazing. At the initiation of each period, sward heights were measured with a falling plane meter (4.8 kg/m^2) inside each exclosure. To determine initial forage mass for each month, forage was hand-clipped to a height of 1 cm from a .25-m^2 location of equal sward height proximate to the grazing exclosure. After 28 days, sward height was measured within each exclosure and the forage hand-clipped to a height of 1 cm from a .25-m^2 location within each grazing exclosure. Forage samples collected from each pasture at the initiation or termination of each period were composited to yield one initial and terminal sample per pasture. All forage samples were frozen until further analysis. Grazing exclosures were moved approximately 25 m for determination of forage production in the succeeding period.

Forage samples were dried at 60°C for 48 h in a forced air oven to determine dry matter mass and concentration. Forage production was calculated as the difference between the forage mass within the exclosures at the beginning and end of each period converted to a per hectare basis. Dried forage samples were ground through the 1-mm screen of a Wiley mill. Crude protein concentrations of grazed and ungrazed forages were determined by the Kjeldahl procedure. In vitro dry matter disappearances of grazed and ungrazed forages were also determined. Dry matter production, and the concentrations of in vitro dry matter disappearance and crude protein of forage on each farm were calculated as weighted means by adjusting the dry matter production or concentrations of IVDMD and CP for forage in each pasture by the proportion of total pastureland on each farm contributed by that pasture.

Economic records

On January 1, 1997, each producer began recording production data for the Iowa State University-Integrated Resource Management-Standardized Performance Analysis (IRM-SPA) records program. Data recorded in these records include: herd inventory, cow weights, calf birth and mortality rates, pasture grazing dates, pasture acreage, breeding dates, rebreeding rates, cow and calf sales, amounts of stored feed harvested and fed, hay production, and costs of capital, labor and resources such as facilities, land, fertilizers, and feeds.

Annually, data were summarized to determine the economic and financial costs and returns to capital, labor and management, returns to labor and management, returns to feed costs, and net profit. Unfortunately, whereas one producer did not complete the records in 1997, seven producers did not complete the records in 1998. Financial costs included cash operating expenses such as interest on operating capital and term debt and the non-cash expenses, but did not account for the economic opportunity costs of land, raised feed, or equity invested in the enterprise. Actual land mortgage, livestock, machinery, and operating capital interest are included in the financial costs. There is no net profit report in the financial costs and returns because family and operator labor are not considered in the financial expenses. Therefore, return to labor and management is the closest measurement to net profit reported in the financial category. In addition to the costs accounted for in the financial costs, economic costs included the opportunity costs of resources such as land and labor. Land opportunity costs, for example, are the estimated rental rates that would be fair for land under an equivalent production system. In addition to the economic data, land area of crop residues grazed and the amounts of harvested forages, non-purchased feeds, and purchased feeds fed per cow were calculated.

Data analysis

In all statistical analyses of the data, each farm was utilized as the experimental unit. To analyze the effects of year on the initial and seasonal variables, mean seasonal forage production, sward height accumulation and composition, and the economic variables were analyzed by one-way ANOVA for the main effect of year. Monthly forage production and sward height accumulation were also measured by one-way ANOVA for the main effect of year. Monthly crude protein and in vitro dry matter disappearance concentrations of forage samples from inside and outside of each grazing exclosure were analyzed by ANOVA for a split-plot design with main effects of year and grazing.

Forage production and composition data were analyzed by linear regression to predict the dependent variables of monthly and seasonal cumulative forage mass, monthly and cumulative sward height accumulation, crude protein concentration, and in vitro dry matter disappearance concentration from the independent variables including the sward, soil and climatological measurements at the initiation of grazing, the seasonal climatological measurements, the stocking rates, the fertilization rates, and the number of paddocks.

Results and Discussion

Pasture characteristics

As expected, the southern Iowa pastures utilized in this experiment were composed primarily of cool-season grass species, having an average of 76% grasses in the fall of

1996 (Table 1). Although legume species are recognized for their high productivity, high nutritional value and their ability to fix nitrogen in the soil, pastures on the farms used in this experiment only contained 8.3 ± 6.3% legume species. The pastures on only one farm contained greater than 20% legume species and none of the farms contained greater than 25 or 30% legumes, which is accepted as the level necessary to make a substantial contribution to the overall nitrogen needs of the sward. On the other hand, pastures in this experiment contained 15.3 ± 8.0% weeds reflecting substantial weed populations. Plant species on two of the farms contained greater than 25% weeds. In October of 1996, pastures used in this experiment contained an average of 13.4 ± 7.7% dead forage. The average number of paddocks per farm used in this experiment, defined as separate pastures or cross-fence paddocks within a single pasture, was 4.1 ± 2.1 implying that most producers involved in the project used some type of low-intensity rotational stocking management. Whereas two of the producers used continuous stocking, only four had the 6 or more paddocks needed for management intensive stocking. The average Julian dates of initiating grazing were 125 and 119 in 1997 and 1998, respectively (Table 2). These Julian dates correspond to May 5 and April 29. Although when producers were interviewed in 1996, a number claimed to initiate grazing in late March or early April only two of the 15 initiated grazing in March in 1997, and one initiated grazing in March in 1998. The standard deviations for date of grazing initiation were 14.8 and 14.1 in 1997 and 1998, respectively. These standard deviations imply that ten of the 15 producers initiated grazing from April 20 to May 20 in 1997 and from April 15 to May 13 in 1998. This homogeneity in date of grazing initiation was unexpected from information that we received in the interviews for the project. The delay in grazing initiation may have been caused by cool wet conditions, particularly in 1997, and implies that producers themselves regulate grazing initiation to limit damage to their pastures. This result also reflects the limitation of conducting on-farm research, where grazing management is regulated to limit possible negative results. Mean degree-days were 314.7 reflecting the Julian date and did not differ between years. Similarly, cumulative precipitation before the initiation of grazing was 22.8 cm and did not differ between years.

Over the two years, mean soil moisture concentration at the initiation of grazing was 23.0% and did not differ between years. This value of 23.0% is well below the lower "plastic-limit" moisture level of 46% determined for poorly drained soils in New Zealand, which are similar in structure to those in southern Iowa. At soil moistures between the lower and upper plastic- limits for a soil, soil compaction will occur if roots are not present. The lack of a difference in soil moisture and the presence of roots may have also been responsible for the lack of difference in soil load-bearing capacity between the two years. The mean load-bearing capacity of 1118 kPa is considerably higher than the pressures of 195 to 390 kPa exerted by the hooves of standing and walking cattle.

Soil phosphorus concentrations in 1998 were nearly 2 times greater than those in 1997. The reason for this increase is not immediately apparent, but would seem to have been caused by increased fertilization with manure or commercial fertilizer. However, neither the soil concentration of potassium nor the level of nitrogen fertilization differed between years. The standard deviation of nitrogen fertilization rate implied that ten of the producers fertilized with nitrogen at a rate between 0 and 53 kg N per ha. Five producers fertilized at rates higher than this implying a broad range in nitrogen fertilization. Mean soil temperatures at the initiation of grazing did not differ between the two years. However, whereas the standard deviation in initial soil temperature was 2.5 in 1997, it was 5.3 in 1998. This greater variation in 1998 may be related to the larger variation in degree-days in this year.

Initial forage mass of the pastures in 1998 was nearly 50% greater than that in 1997. Similarly, the standard deviation of forage mass in 1998 was 68% greater than that in 1997. Mean sward heights, plant morphology indeces and forage dry matter concentrations were 8.0 cm, 1.4 on a 5 point scale, and 32.6% and did not differ between the two years. The mean standard deviation in sward height for the two years was 6.4, implying that sward heights on two-thirds of the farms ranged between 1.6 and 14.4 implying a broad range in sward heights. The mean morphology index was equivalent to the late vegetative stage (one tiller with four leaves), and had little variation between farms within years.

Mean degree-days over the grazing season were 9% greater in 1998 than in 1997. Because the mean daily temperature in 1998 was only 3.2% greater than 1997, the difference in degree-days related to the greater length of grazing season in 1998. Seasonal precipitation was 38% greater in 1998 than 1997. Stocking density and number of paddocks grazed did not differ between the two years. The mean stocking rate was 1.7 animal units per hectare, which is equivalent to .69 animal units per acre. The high standard deviation for stocking density implies that two-thirds of the farms had stocking rates between .45 to 2.95 animal units/hectare or .2 to 1.2 animal units per acre.

Table 1. Proportion of dead forage, forage botanical composition, soil classes, and number of paddocks in pastures at the initiation of the experiment.

Producer #	Grass	Legume	Weed	Dead	# paddocks
	% of live plants			% of total plants	
1	85	4	11	6	4
2	79	16	5	5	6
3	73	12	15	11	5
4	89	3	8	4	1
5	77	2	21	11	2
6	72	8	20	25	7
7	56	14	30	19	3
8	84	7	9	24	6
9	98	0	2	8	3
10	76	14	10	3	4
11	60	21	19	11	4
12	77	5	18	21	8
13	65	7	28	15	1
14	80	0	20	14	3
15	74	12	14	24	5

1 Soil classification: Nira silty clay loam, fine-silty, mixed, mesic Oxyaquic hapludolls
2 Soil classification: Clinton silt loam, fine, smectitic, mesic Chromic Vertic hapludalfs
3 Soil classification: Lamoni silty clay loam, fine, smectitic, mesic Aquertic argiudolls
Clarinda silty clay loam, fine smectitic, mesic Vertic argiaquolls
4 Soil classification: Shelby clay loam, fine-loamy, mixed, mesic, Typic argiudolls
5 Soil classification: Armstrong loam, fine, smectitic, mesic, Aquertic hapludalfs
6 Soil classification: Sharpsburg silty clay loam, fine, smectitic, mesic, Typic argiudolls
7 Soil classification: Adair clay loam, fine, smectitic, mesic, Aquertic argiudolls
8 Soil classification: Shelby clay loam, fine-loamy, mixed, mesic, Typic argiudolls
9 Soil classification: Judson silty clay loam, fine-silty, mixed, mesic Cumulic hapludolls
10 Soil classification: Arispe silty clay loam, fine, smectitic, mesic Aquertic argiudolls
11 Soil classification: Armstrong loam, fine, smectitic, mesic, Aquertic hapludalfs
Adair clay loam, fine, smectitic, mesic, Aquertic argiudolls
12 Soil classification: Arispe silty clay loam, fine, smectitic, mesic Aquertic argiudolls
Shelby clay loam, fine-loamy, mixed, mesic, Typic argiudolls
13 Soil classification: Ladoga silt loam, fine, smectitic, mesic Vertic hapludalfs
14 Soil classification: Olmitz loam, fine-loamy, mixed, mesic Cumulic hapludolls
Ladoga silt loam, fine, smectitic, mesic Vertic hapludalfs
15 Soil classification: Gara loam, fine-loamy, mixed, mesic Mollic hapludalfs

Forage production and composition

Mean daily dry matter production of forage during the grazing season in 1998 was 30.8% greater (P= .09) than in 1997 (Table 3). The standard deviations were ± 45 and 38% of the mean values in 1997 and 1998, respectively, implying a broad range of production. Daily forage dry matter productions ranged from 46.5 to –6.2 kg/ha/day in 1997 and from 56.0 to –7.7 kg/ha/day in 1998 (Figure 1). Forage dry matter production in May and June accounted for 75.2 and 71.2% of the forage produced in 1997 and 1998, respectively. Although it is not surprising that most forage production from the cool grasses occurred in the May and June, these high percentages with little late summer growth seem to imply that greater management of the pastures are needed to control excessive forage growth in early spring to maintain forage in a vegetative state. Daily forage dry matter production in June was greater (P<.01) in 1998 than in 1997. However, daily forage dry matter production in July was greater (P<.05) in 1997 than in 1998.

Mean daily sward height accumulation over the grazing seasons did not differ between the two years (Table 3). The standard deviations were ± 42 and 45% of the mean values in 1997 and 1998, respectively (Figure 2). Similar to sward height accumulation, 69.6 and 70.3% of the total forage accumulation occurred during May and June. Daily sward height accumulation in July was higher (P<.05) in 1998 than 1997 and in September was greater (P<.05) in 1997 than in 1998.

The mean concentration of in vitro dry matter disappearance (IVDMD) of grazed and ungrazed forage in

Table 2: Initial and seasonal pasture soil, forage and climatological characteristics in experimental pastures over two years.

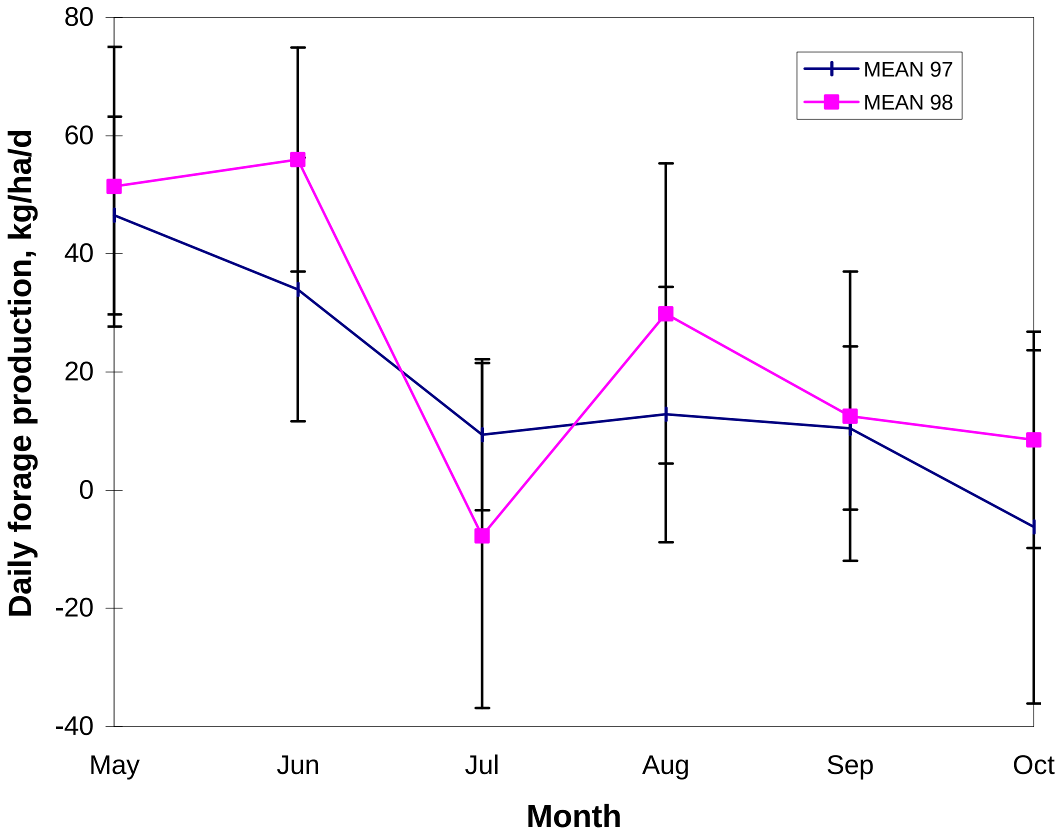
Variable	1997 x	1997 ± SD	1998 x	1998 ± SD	p<F
Initial					
Grazing date[1]	125.1	14.8	119.2	14.1	.27
Degree days[2,3]	320.1	106.4	309.4	133.5	.81
Precipitation[3], cm	21.2	7.2	24.6	6.9	.21
Soil					
Moisture, %	23.4	2.6	22.6	2.9	.45
Load-bearing capacity,	1127	137.2	1108	117.7	.65
Phosphorus, ppm	30.6	15.5	58.5	23.0	.00
Potassium, ppm	200.7	51.4	225.6	5 4.7	.21
pH	5.8	0.2	5.3	0.5	.00
Nitrogen fertilization, kg ha^{-1}	24.1	27.2	24.4	27.9	.97
Temperature, °C	13.4	2.5	13.6	5.3	.87
Forage					
Mass, kg ha^{-1}	802.4	404.4	1204.5	681.1	.06
Height, cm	7.0	6.0	9.0	6.8	.41
Morphology index[4]	1.5	0.5	1.3	0.3	.30
Dry Matter, %	34.9	15.5	30.3	7.3	.31
Seasonal[5]					
Degree days	2700.6	147.3	2944.9	134.8	.00
Precipitation, cm	42.7	10.0	59.1	8.6	.01
Stocking density, au ha^{-1}	1.7	1.3	1.7	1.2	.94
Number of paddocks/farm^{-1}	4.1	2.1	3.9	2.0	.79
Days Grazed	173	23.2	183	16	.21

[1] In Julian Days . Jan 1 = 1, Dec 31 = 365.
[2] Accumulated from Jan 1 of that year to grazing initiation. Base = 3.5°C.
[3] From Jan 1 to grazing initiation.
[4] 0-5 index. 0 = germination, 5 = mature plant with seed development
[5] From grazing initiation to grazing termination.

Table 3: Mean seasonal forage production, sward height accumulation, crude protein concentration, and in vitro dry matter disappearance in pastures over two years

Variable	1997 x	1997 ± SD	1998 x	1998 ± SD	p<F
Seasonal					
Dry matter accumulation, kg ha^{-1} d^{-1}	15.9	7.1	20.8	8.0	.09
Sward height accumulation, mm d^{-1}	1.69	.71	1.69	.76	.99
Mean IVDMD, %	44.1	2.1	46.2	2.7	.02
Mean crude protein, %	11.6	2.1	11.9	1.7	.70

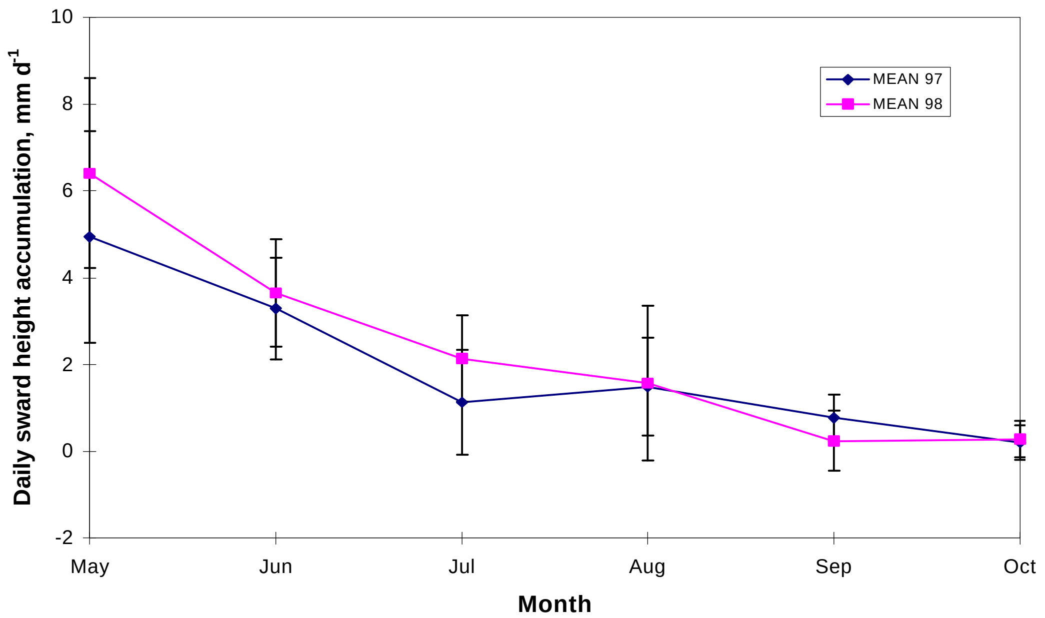
Figure 1. Mean daily forage production in pastures over two years



the pastures, an estimate of digestibility, was greater (P<.05) in 1997 than in 1998 (Table 3). The standard deviations for mean IVDMD concentration were only ± 4.2 and 5.8% of the mean values in 1997 and 1998. From May to October, IVDMD concentrations of ungrazed forages decreased from 55.6 to 38.7% in 1998 (Figure 3). These values imply that the quality of this forage was moderate to low. The relatively low digestibility of the forage in May corresponds to the late morphological stage of the forage at grazing initiation, and the decreasing values imply that forage maturity was not adequately controlled in early summer. Mean IVDMD concentrations of grazed and ungrazed forages in July, September, and October of 1997 were greater (P<.01) than those in 1998. The IVDMD concentration of grazed forage was lower (P<.05) than the ungrazed forage in July, August, and September. In July, August, and September, IVDMD concentrations of ungrazed forage were 7.2, 8.7 and 6.5% greater than grazed forage in 1997 and 3.3, 3.5, and 5.9% greater than grazed forage in 1998, implying that cows were selectively grazing higher quality forage.

Mean concentrations of crude protein (CP) of grazed and ungrazed forage did not differ between 1997 and 1998 (Table 3). The standard deviations of mean CP concentration were ± 18.1 and 14.3% of the mean value. Crude protein concentrations of ungrazed forage decreased from 13.6% in May to 10.8% in June of 1997 and from 15.4 % in May to 11.1% in June of 1998 (Figure 4). The low mean values and high standard deviations for CP concentrations in June and July imply that CP may be deficient in the forage consumed by cows in some herds. Although the mean CP concentration of grazed and ungrazed forages over the grazing season did not differ between years, CP concentrations of grazed and ungrazed forages in 1998 were greater (P<.05) than those in 1997. Concentrations of CP in August and September in grazed forage were 11.0 and 11.6% lower than ungrazed forage in 1997 and 9.4 and 8.3% lower than ungrazed forage in 1998 (P<.05).

Figure 2. Mean daily sward height accumulation in pastures for two years



Relationships between forage production and composition and initial and seasonal pasture conditions

Although it was hypothesized that initiating grazing at an early date might reduce seasonal forage production by generating soil compaction and damaging immature forages, initiating grazing at an earlier date did not affect seasonal forage production in 1997 and increased forage production ($y = 69.5 - .40x$; $r^2 = .41$) in 1998 (Table 4). The lack of an effect of earlier grazing date likely was caused by the late date and little variation in date when grazing was initiated. Thus, there was little variation in factors such as soil moisture, soil load-bearing capacity, and plant morphology index that may have been associated with a reduction in seasonal forage production. As mentioned previously, it seems that by allowing the producers to initiate grazing when they felt it was most appropriate, the producers did adjust grazing initiation to avoid problems of excessive mud and immature forage. Because the degree-days are related to total days, it is not surprising that the relationships of forage accumulation to degree-days were similar to those with grazing date. In 1998, seasonal forage production decreased with increasing degree-days ($y = 34.1 - .041x$; $r^2 = .39$).

Of the initial and seasonal environmental, soil and forage characteristics measured in 1997, the only variable that was significantly related to seasonal forage accumulation was soil phosphorus concentration ($y = 9.96 + .204x$; $r^2 = .22$). Soil P concentration was not related to seasonal forage accumulation perhaps because of the high mean concentrations of the soils in these pastures in 1998. However, in 1998, seasonal forage production increased with increasing soil potassium concentration ($y = 4.56 + .074x$; $r^2 = .21$). Similarly, in 1998, seasonal forage production increased with increasing soil pH ($y = -33.7 + 10.39x$; $r^2 = .33$) and decreasing soil temperature ($y = 35.43 – 1.03x$; $r^2 = .38$). The increasing pH may have resulted in better nutrient uptake to allow better growth. The higher mean and smaller standard deviation in soil pH in 1997 likely caused the lack of a relationship between soil pH and forage production in 1998. However, the cause of the difference in soil pH between the two years is unknown. Because soil temperature would be a relatively short-term response, the effects of soil temperature would seem to be indirectly associated with the grazing date. In 1998, seasonal forage production also increased with decreasing morphology index ($y = 49.5 - 21.65x$; r2 = .52). Forage with a lower morphology index would be more vegetative, allowing greater production. The lack of a relationship between morphology and forage production in 1997 implies that the mean morphological index was so high that morphology would not greatly affect forage production. It was suprising that nitrogen fertilization did not affect seasonal forage production as measured by clipping even though there was considerable variation in the N-fertilization rate.

Sward height has been found to be highly related to live forage yield. Thus, it was felt that cumulative sward height would have the advantage of allowing forage production to be measured in the same location at the initiation and termination of each period. Similar to forage accumulation, sward height accumulation increased with earlier grazing date ($y = 2.76 - .034x$; $r^2 = .39$) and fewer degree-days ($y = 2.76 - .0035x$; $r^2 = .37$). Forage sward accumulation, as measured by sward height, also increased with increasing soil phosphorus concentration ($y = .87 + .0266x$; $r^2 = .34$), soil potassium concentration ($y = -.01 + .0084x$; $r^2 = .37$), and nitrogen fertilization ($y = 1.38 + .0126\ x$; $r^2 = .23$) in 1997. In 1998, however, sward height accumulation was not related to fertility. The lack of difference in the relationship of forage sward height accumulation and the concentrations of phosphorus and potassium may have been caused by the considerably higher mean concentrations of these nutrients in 1998. Similar to forage accumulation determined by clipping, forage sward height accumulation increased with decreasing soil temperature ($y = 2.9 - .089x$; $r^2 = .38$), which was related to earlier grazing initiation in 1998. Forage sward height accumulation increased with shorter initial sward height ($r^2 = .59$) and morphological index ($y = 3.84 - 1.644x$; $r^2 = .41$), which also would be related to earlier grazing initiation in 1998. In 1997, forage sward height accumulation increased with increasing numbers of paddocks ($y = .167 + .993x$; $r^2 = .24$) implying that more intensive grazing management will increase forage production. However, there was no relationship between forage production, based either on clipping or sward height, and mean stocking density.

The Julian date and degree-days at the initiation of grazing did not affect the mean concentration of IVDMD in either year (Table 5). This may have resulted from the small amount of variation in the mean IVDMD concentration of the forage in the pastures on the 15 farms, which likely resulted from the maturity of the forage at grazing initiation on most of the farms. In 1997, mean forage IVDMD concentration decreased with increasing concentrations of soil phosphorus ($y = 46.05 - .065x$; $r^2 = .24$) and potassium ($y = 49.55 - .027x$; $r^2 = .46$), but soil fertility did not affect forage IVDMD concentrations in 1998. In 1998, mean forage IVDMD concentration also decreased with increasing initial forage mass ($y = 46.20 - .002x$; $r^2 = .27$). The decreasing IVDMD concentrations with soil fertility and initial mass also implies that excessive grazing at the initiation of or during the grazing season reduces forage digestibility. In 1998, mean forage IVDMD concentration increased with increasing soil pH ($y = 31.79 + 2.73x$; $r^2 = .25$) and paddock number ($y = 43.65 + .657x$; $r^2 = .24$). The relationship with number of paddocks implies that forage digestibility can be increasing by increased the number of paddocks to allow greater management of grazing.

Figure 3. Mean in vitro dry matter disappearance concentration of grazed and ungrazed forage by month in pastures for two years

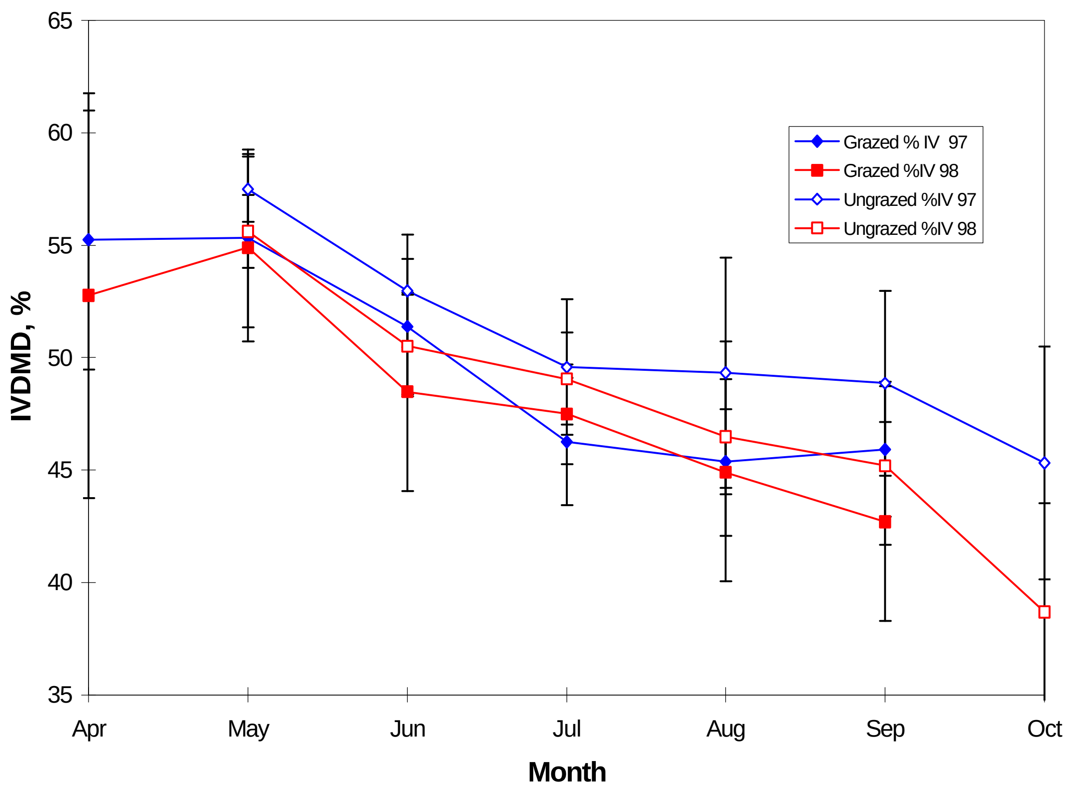


Table 4. Partition coefficients of linear regressions predicting seasonal forage production from initial climate, soil, and forage variables and from seasonal climate and management variables.

	Forage Accumulation kg ha^{-1} d^{-1}		Sward height accumulation mm d^{-1}	
Variable	1997	1998	1997	1998
Initial				
Grazing date[1]	.15	.41*	.06	.39*
Degree days[2,3]	.15	.39*	.10	.37*
Precipitation[3], cm	.05	.06	.00	.18
Soil				
Moisture, %	.05	.15	.02	.12
Phosphorus, ppm	.22[a]	.14	.34*	.04
Potassium, ppm	.08	.21[a]	.37*	.09
pH	.00	.33*	.06	.05
Temperature °C	.18	.38*	.01	.38**
Load-bearing capacity, kg m^{-2}	.05	.08	.16	.01
Nitrogen fertilization, kg ha^{-1}	.07	.00	.23[a]	.03
Forage				
Mass, kg ha^{-1}	.03	.01	.31[a]	.01
Height, cm	.02	.05	.59**	.02
Morphology index[4]	.01	.52**	.01	.41*
Dry matter, %	.13	.19	.00	.18
Seasonal[5]				
Degree days	.02	.04	.01	.03
Precipitation, cm	.17	.00	.06	.00
Stocking density, au ha^{-1}	.04	.03	.08	.00
Number of paddocks/ farm $^{-1}$	.07	.00	.24[a]	.10

[a, *, **], P<.10, P<.05, P<.01, respectively.
[1] In Julian Days . Jan 1 = 1, Dec 31 = 365.
[2] Accumulated from Jan 1 of that year to grazing initiation. Base = 3.5°C.
[3] From Jan 1 to grazing initiation.
[4] 0-5 index. 0 = germination, 5 = mature plant with seed development
[5] From grazing initiation to grazing termination.

In contrast to IVDMD concentration, mean forage CP concentrations decreased with increased Julian date in 1997 (y = 22.29 - .085x; r^2 = .37) and 1998 (y = 19.43 - .063x; r^2 = .27) and degree-days in 1997 (y = 15.91 - .013x; r^2 = .47) and 1998 (y = 14.00 -.007x; r^2 = .28). In both years, CP concentration also decreased with increasing morphology index (1997; y = 15.00 – 2.30x; r^2 = .32, and 1998; y = 16.25 – 3.35x; r^2 = .34). Similar to IVDMD concentration, these regressions imply that CP concentration decreased with increasing date of grazing initiation and plant maturity. In 1997, mean season CP concentration also decreased with increasing initial precipitation (y = 15.12 - .164x; r^2 = .32) and increased initial sward height (y = 12.86 - .174x; r^2 = .25). In 1998, mean forage CP concentration increased with increasing soil potassium concentration (y = 8.11 + .016x; r^2 = .30), soil pH (y = 1.49 + 1.96x; r^2 = .32), and N fertilization rate (y = 11.23 + .028x; r^2 = .21).

Similar to forage production, mean stocking density was related to neither mean IVDMD or CP concentration over the grazing season. However, if the stocking density on a given farm was varied over the grazing season to remove excess early forage production, this management might be used to improve forage quality and production.

Stored feed utilization

There were no differences in the land area of corn crop residues grazed or stored feeds fed each year (Table 6). However, there were large differences in these variables between farms within years. The standard deviations in the hectares of corn crop residues grazed were 106 and 126% of the means in 1997 and 1998, respectively. The standard deviations in the amounts of raised and purchased hay were 68 and 202% of the means in 1997 and 43 and 289% of the means in 1998. The standard deviations in the amounts of purchased supplements were 116 and 186% of the means in 1997 and 1998. The standard deviations in the amounts of total stored feeds were 48 and 34% of the means in 1997 and 1998. Because stored feed costs are the largest costs in beef cow calf production, such costs would be expected to result in large variations in returns.

Economic analysis

Financial returns to capital, labor, and management and labor and management tended to be lower in 1998 than in 1997 (Table 7). In both years, there were large variations in both of the variables. Financial returns per $100 feed fed, pasture costs per cow, harvested forage costs per cow, nonpurchased feed costs per cow, purchased feed costs per cow, and total feed costs per cow did not differ between years. Similar to financial returns, economic returns to capital, labor, and management and labor and management tended to be lower in 1998 than in 1997, but with large variations in both of the variables. Furthermore, net losses tended to be lower in 1997 than in 1998. Economic returns per $100 feed fed, pasture costs per cow, harvested forage costs per cow, nonpurchased feed costs per cow, purchased feed costs per cow, and total feed costs per cow did not differ between years.

Effects of forage production and quality on economic costs and returns.

Apparently because of the low number of producers involved in this project and the even lower number of producers who completed the SPA records, relationships were not strong even for relationships that would have seemed strong. For example, the total hay fed per cow only accounted for 24 and 18% of the variation of the hay financial costs per cow in 1997 and 1998, respectively. Similarly, total feed fed per cow accounted for 47 and 18% of the variation in feed financial costs in 1997 and 1998. This variation seems to imply that the costs of feed per unit of weight largely affected the total costs per cow. The slope of these lines showed the total feed financial costs decreased by $5.12 and $5.09 per cow for every 100 lb decrease in stored feed fed per cow, thus showing the importance of reducing stored feed costs.

In 1997, increasing seasonal forage accumulation tended to increase pasture economic costs by $2.57/gm extra pasture forage/d ($r^2 = .18$) and decreased harvested feed costs by $.96 /gm extra pasture forage/d ($r^2 = .12$; Table 8). In 1998, increasing seasonal forage accumulation reduced total feed fed by 21 lb/gm extra forage/day ($r^2 = .15$), and reduced financial and economic costs of raised feed other than hay ($r^2 = .27$) and purchased feed ($r^2 = .39$) by $.83 and $1.65/gm extra forage/day. Increasing sward height accumulation reduced the amounts of purchased hay fed per cow in 1997 ($r^2 = .12$) and 1998 ($r^2 = .23$) and total feed fed per cow in 1998 ($r^2 = .21$). However, sward height accumulation was not significantly related to financial and economic costs and returns. The relatively weak relationships between seasonal forage accumulation or seasonal sward height accumulation with total stored feed, hay, raised feed other than hay or purchased feed may have resulted from calculating forage production or sward height on a per day basis as opposed to the total grazing season. However, in regressions the amount of raised hay fed per cow increased with increasing days of summer pasture grazing and decreased with increasing hectares of corn crop residues grazed in both 1997 (y= -289+.98xdays grazed-6.38xhectares cornstalks grazed/cow; $r^2 = .83$) and 1998 (y= 318+.58xdays grazed-90.7xhectares cornstalks grazed/cow; $r^2 = .60$). This result seems to imply that although producers that do not graze corn crop residues in the fall grazed their summer pastures longer, they still feed more hay than those that graze corn crop residues.

In 1997, increasing the mean IVDMD concentration of the grazed forage by 1% unit increased return above $100 of feed costs by $10.41/cow in 1997 ($r^2 = .18$), and reduced return above $100 of feed costs by $5.76/cow in 1998 ($r^2 = .17$; Table 9). Increasing the mean IVDMD concentration of the grazed forage by 1% unit reduced the financial costs of purchased feed cost per cow ($r^2 = .26$) by $3.79/cow in 1998. Increasing the mean crude protein concentration of the grazed forage by 1% decreased the amount of purchased hay by 41 and 92 lb/cow in 1997 ($r^2 = .20$) and 1998 ($r^2 = .40$). Thus, purchased feed cost was reduced by $4.67/cow for every 1% increase in mean CP concentration of grazed forage in 1997 ($r^2 = .20$).

Table 5. Partition coefficients predicting seasonal forage quality from initial climate, soil, and forage variables and from seasonal climate and management variables.

	Crude Protein, %		In Vitro Dry Matter Digestibility, %	
Variable	1997	1998	1997	1998
Initial				
Grazing date[1]	.37*	.27*	.03	.01
Degree days[2,3]	.47**	.28*	.02	.00
Precipitation[3], cm	.32*	.12	.01	.02
Soil				
Moisture, %	.00	.02	.00	.03
Phosphorus, ppm	.08	.14	.24[a]	.03
Potassium, ppm	.01	.30*	.46**	.03
pH	.01	.32*	.13	.25[a]
Temperature °C	.03	.39*	.18	.00
Load-bearing capacity, kg m^{-2}	.02	.00	.03	.00
Nitrogen fertilization, kg ha^{-1}	.06	.21[a]	.03	.05
Forage				
Mass, kg ha^{-1}	.05	.02	.27*	.00
Height, cm	.25[a]	.01	.00	.01
Morphology index[4]	.32*	.34*	.00	.07
Dry matter, %	.04	.04	.22[a]	.00
Seasonal[5]				
Degree days	.33*	.11	.01	.10
Precipitation, cm	.10	.04	.06	.16
Stocking density, au ha^{-1}	.00	.05	.08	.06
Number of paddocks/ farm $^{-1}$	.07	.18 `	.06	.24[a]

[a], *, **, P<.10, P<.05, P<.01, respectively.
[1] In Julian Days. Jan 1 = 1, Dec 31 = 365.
[2] Accumulated from Jan 1 of that year to grazing initiation. Base = 3.5°C.
[3] From Jan 1 to grazing initiation.
[4] 0-5 index. 0 = germination, 5 = mature plant with seed development
[5] From grazing initiation to grazing termination.

Conclusions

Although grazing studies in the literature have shown that initiating grazing too early reduces seasonal forage production because of soil compaction and forage damage, seasonal forage production was not affected or decreased with earlier date of grazing initiation in this study. One reason for the lack of a relationship between date of grazing initiation and seasonal forage production seems to be the lateness of the mean and the little variability in the date of grazing initiation of the fifteen producers used in this study. This small variation occurred even though the producers in the study were selected on the basis of the variability in the historical date of grazing initiation. However, because individual producers were allowed to make their own management decisions, most of the producers made the decision to initiate grazing very close to the same date in a

Table 6. Annual area of crop residues grazed and amounts of supplemental feeds offered to cows of 15 producers with different grazing systems.

Variable	1997 x	± SD	1998 x	± SD	p<F
Corn crop residues, ha per cow	.77	.81	.91	1.15	.72
Raised hay fed per cow, kg, DM basis	1111.61	752.46	936.23	399.58	.51
Other home-raised feed fed per cow, kg, DM basis	148.81	173.47	124.32	167.00	.74
Purchased hay fed per cow, kg, DM basis	86.61	175.24	76.77	222.20	.91
Purchased supplements fed per cow, kg, DM basis	33.18	38.69	34.41	63.88	.96
Purchased silages and concentrates fed per cow, kg, DM basis	49.37	79.34	36.91	56.52	.68
Total feed fed per cow, kg, DM basis	1429.58	692.87	1208.59	408.45	.38

Table 7. Financial and economic returns from beef cow-calf enterprises in 1997 and 1998.

	Year			
	1997		1998	
	Mean	SD	Mean	SD
	Financial			
Return to capital, labor and management, $/farm	5349	9485	3578	8578
Return to labor and management, $/farm	4959	9437	2368	8213
Return/$100 feed	178	61	195	58
Pasture cost, $/cow	104	50	79	38
Harvested forage, $/cow	41	22	43	28
Nonpurchased feed, $/cow	11	14	9	12
Purchased feed, $/cow	24	20	28	20
Total feed, $/cow	181	51	158	49
	Economic			
Return to capital, labor and management, $/farm	4541	7620	-2198	9262
Return to labor and management, $/farm	62	8507	-6867	9330
Net profit, $/farm	-3520	11386	-9538	8566
Return/$100 feed	171	52	145	38
Pasture cost, $/cow	105	40	109	36
Harvested forage, $/cow	46	18	55	32
Nonpurchased feed, $/cow	11	14	9	12
Purchased feed, $/cow	24	20	28	20
Total feed, $/cow	188	40	201	38

given year. Because the soil moisture concentration at the initiation of grazing between years did not greatly differ, it seems that producers manage date of grazing initiation to effectively avoid the adverse effects of muddy conditions. Unfortunately, one of the limitations of on-farm research such as this is that there are no negative controls, in which there would be intentionally a treatment to test the effects of initiating grazing in adverse environmental conditions. The difference between the results of this study and the previous literature may have been caused by the differences in the environmental and soil conditions of different locations. Previous research in which early grazing was shown to adversely affect soil conditions and forage productivity had been done in locations such as England, Argentina and New Zealand with more temperate and wetter climates and little freeze-thaw activity on the soil.

Instead of showing any adverse effects of early initiation of grazing, results of the present study showed that earlier initiation of grazing increased forage production in 1998 and increased mean forage crude protein concentrations in both years. The low mean IVDMD and CP concentrations of pasture forages in this experiment imply that although producers may limit adverse effects of grazing muddy pastures on forage production, they delay grazing so long that it adversely effects forage production and quality. This low forage productivity and quality is associated with the high morphological index of the forage and likely limits productivity of grazing animals. Thus, in order to increase the productivity of grazing animals, producers should either initiate grazing earlier and/or harvest more early forage as hay to maintain forage in a more vegetative state that would be more productive and nutritious.

The significant relationships between forage productivity or composition with pasture management variables imply that different management practices do affect forage production and quality. Increasing soil phosphorus concentration increased forage productivity and IVDMD concentration in 1997, when there was a lower mean soil phosphorus concentration than 1998. Increasing soil potassium concentration increased forage production in both years, forage IVDMD concentration in 1997, and forage CP concentration in 1998. Because increasing the number of paddocks increased forage production in 1997 and forage IVDMD concentration in 1998, the results support the theory that more intensively managed grazing will improve forage production and quality.

Implications

Results of this study imply that producers commonly delay initiation of grazing in the spring until soil moisture concentration decreases below 23%, and, thus, pastures are moderately dry. Because of these conditions and the generally firm sod, hoof damage to the soil and plants is limited. Unfortunately, by delaying the initiation of grazing until soils are less muddy, forages are allowed to become excessively mature. The increased maturity of forages reduce forage productivity, digestibility and protein concentration. In fact, the digestibility and crude protein concentration of mid-season forage may be low enough to adversely affect animal growth and reproductive performance unless grazing selectivity is allowed. Thus, to maximize forage productivity and nutritional value, these results imply that producers should initiate grazing at an earlier date. Starting grazing ten days earlier will increase seasonal forage production by 6% and increase forage crude protein concentration by 4%. However, the results of this experiment should not be interpreted to say that no adverse effects will occur from grazing excessively early, and, therefore, producers should still be careful to avoid grazing short forage under excessively muddy conditions. An alternative approach to maintaining forage production and quality would be to harvest more early forage growth either by hay harvesting or increasing the stocking rate. Additional improvements in P and K fertility and stocking management will also increase forage production and quality.

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Table 8. Partition coefficients of forage financial and economic returns and costs on forage production and sward height accumulation.

	Forage accumulation, g/ha/day		Sward height accumulation, mm/day	
	1997	1998	1997	1998
		Financial		
Return/$100 feed	0	.06	.05	.02
Pasture cost, $/cow	.04	.01	.05	0
Harvested forage cost, $/cow	.11	.02	0	.05
Other raised feed cost, $/cow	.01	.27	.12	.02
Purchased feed cost, $/cow	.06	.39	.09	.06
Total feed cost, $/cow	0	.05	.03	0
		Economic		
Return/$100 feed	0	0	.05	.09
Pasture cost, $/cow	.18	.08	.10	.04
Harvested forage cost, $/cow	.12	.01	.01	.07
Other raised feed cost, $/cow	.01	.27	.12	.02
Purchased feed cost, $/cow	.06	.39	.09	.06
Total feed cost, $/cow	.01	.03	.05	.02

Table 9. Partition coefficients of forage financial and economic returns and costs on grazed forage IVDMD and CP concentrations.

	IVDMD, %		CP, %	
	1997	1998	1997	1998
		Financial		
Return/$100 feed	.06	.01	.03	.01
Pasture cost, $/cow	0	.03	0	.09
Harvested forage cost, $/cow	.06	.20	.02	.04
Other raised feed cost, $/cow	0	.04	0	0
Purchased feed cost, $/cow	.08	.26	.20	.03
Total feed cost, $/cow	.01	.03	0	0
		Economic		
Return/$100 feed	.18	.17	.13	.01
Pasture cost, $/cow	.05	.08	0	.02
Harvested forage cost, $/cow	.01	.24	.02	.12
Other raised feed cost, $/cow	0	.04	0	0
Purchased feed cost, $/cow	.08	.13	.20	.03
Total feed cost, $/cow	.08	.09	.12	.07

Figure 4. Mean crude protein concentration of grazed and ungrazed forage by month in pastures for two years