North Dakota State University * Dickinson Research Extension Center
1089 State Avenue, Dickinson, ND 58601-4642 Voice: (701) 483-2348 FAX: (701) 483-2005

GRAZING MANAGEMENT FOR WESTERN NORTH DAKOTA RANGELANDS

Llewellyn L. Manske PhD Associate Range Scientist
NDSU, Dickinson Research Center

ABSTRACT

Adaptive tolerance mechanisms have developed in grassland plants during their long period of evolution in two main general directions as compensation to defoliation from herbivores and fire. The mechanisms are; (1) changes in the physiological responses within the grassland plants and (2) changes in the activity levels of the symbiotic soil organisms in the rhizosphere. Grassland managers can beneficially manipulate the adaptive tolerance mechanisms by timing grazing for a short period (7-15 days) of partial defoliation of young leaf material between the third leaf stage and anthesis phenophase. Grass plant tiller numbers increase, above ground herbage biomass increases, nutrient content of herbage increases, exudated material increases in the rhizosphere, and the top trophic level of the rhizosphere (mites) increases in biomass as a result of defoliation at early phenological growth stages. This allows for subsequent increases in stocking rate and for improvement in individual livestock weight performance during a second grazing period after anthesis.

INTRODUCTION

Grassland ecosystems are extremely diverse and complex, which causes considerable difficulty in development of management recommendations. Increasing knowledge of ecological principles and the intricacies of the numerous mechanisms that function in the grassland ecosystem have allowed for improvements in management strategies. Recently (within the last ten to twelve years) several greenhouse and laboratory studies have opened the way to the initial understanding of the adaptive tolerance mechanisms that grassland plants have developed during their long period of coevolution as compensation to defoliation from herbivores and fire. These adaptive tolerance mechanisms can be separated into two main general categories that function interrelatively. The first mechanism is numerous changes in the physiological responses within the grassland plant and the second is numerous changes in the activity levels of the symbiotic soil organisms in the rhizosphere.

The physiological response within the plant caused by defoliation have been reviewed and grouped into nine categories by McNaughton (1983). The physiological responses to defoliation do not occur at all times, and the intensity of the response is variable. The physiological responses can be related to different phenological stages of growth of the grass plants. The key to ecological management by effective defoliation is to match the timing of defoliation to the phenological stage of growth that triggers the desired outcome.

All of the relationships between the physiological responses and the application of the management treatment have not been worked out yet with scientific research. One of the main physiological effects of defoliation is the temporary reduction in the production of the blockage hormone, auxin, within the meristem and young developing leaves. This reduction of plant auxin in the lead tiller allows either for cytokinin synthesis in the roots or crown, or its utilization in axillary buds, which stimulate the development of vegetative tillers (Murphy and Briske 1992). Partial defoliation of young leaf material reduces the hormonal affects of apical dominance by the lead tiller and allows secondary tillers to develop from the previous years axillary buds. Secondary tillers can develop without defoliation manipulation after the lead tiller has reached anthesis phenophase, but usually only one secondary tiller develops from the potential of 5 to 8 buds because this secondary tiller suppresses additional axillary bud development hormonally by apical dominance. When the lead tiller is partially defoliated between the third leaf stage and anthesis phenophase, several axillary buds can develop subsequently into secondary tillers. Apparently no single secondary tiller is capable of developing complete hormonal apical control from the older axillary bids still suppresses development of some of the younger axillary buds. With our present level of knowledge of this mechanism, we cannot get all of the axillary buds to develop into secondary tillers.

The second type of influence by defoliation on grassland plants is changes in the activity levels in the rhizosphere. The rhizosphere is that narrow zone of soil around living roots of perennial grassland plants where the exudation of sugars, amino acids, glycosides, and other compounds affects microorganism activity. Bacterial growth in the rhizosphere is stimulated by the presence of carbon from the exudates (Elliott 1978, Anderson et al. 1981). Protozoa and nematodes graze increasingly on the increased bacteria, and accelerate the overall nutrient cycling process through the "fast" pathway of substrate decomposition as postulated by Coleman et al. (1983). The activity of the microbes in the rhizosphere increases the amount of nitrogen available for plant growth (Ingham et al. 1985, Clarholm 1985). The presence of vascular-arbuscular mycorrhizal (VAM) fungi enhances the absorption of ammonia, phosphorus, other mineral nutrients and water. Rhizosphere activity can be manipulated by defoliation at early phenological growth stages when a higher percentage of the total nitrogen of the plant is in the above ground parts. At that time, partial defoliation disrupts the plants carbon to nitrogen ratio. Bacteria in the rhizosphere are limited by access to simple carbon chains under conditions with no defoliation. The rhizosphere bacteria increase in activity in response to the increase in exuded carbon under conditions with defoliation. The increases in activity by the bacteria triggers increases in activity in the other subsequent trophic levels of the rhizosphere organisms. This ultimately increases available nutrients for the defoliated grass plant.

Rhizosphere activity can be stimulated by disrupting the carbon-nitrogen ration through defoliation at early phenological growth stages. During middle and late growth, the carbon and nitrogen are distributed more evenly throughout the plant, defoliation does not remove a disproportionate amount of nitrogen, and very little or no carbon is exuded into the rhizosphere. Soil water levels generally decrease during the middle and late portions of the grazing season and also limit rhizosphere organism activity levels. The relationship between plants and organisms in the rhizosphere is truly symbiotic.

The adaptive tolerance mechanisms that work within grassland plants and symbiotic organisms in the rhizosphere following defoliation are the key to understanding beneficial manipulation of these mechanisms under field conditions and the development of ecologically sound recommendations for management of our grassland natural resource. These were the goals of a research project developed to study the ecological effects of defoliation at the Dickinson Research Center in western North Dakota (1983-1994).

The objectives of this study were to evaluate changes in plant exudation, soil organism activity and biomass, grass plant tiller development, above and below ground plant biomass, and livestock weight performance between a twice over rotation grazing treatment (Jun - Oct), a 4.5 month seasonlong (Jun - Oct), a 4.0 month deferred seasonlong (mid Jul - mid Nov), and a 6.0 month seasonlong (mid May - mid Nov) treatments, and a long term nongrazed treatment.

METHODS AND MATERIALS

The long-term study site is located 20 miles north of Dickinson in southwestern North Dakota, U.S.A. (47°14'N.lat., 102°50'W. long.) on the Dickinson Research Center operated by North Dakota State University.

Soils are primarily Typic Haploborolls. Average annual precipitation is 356 mm (14 in.) with 80% falling as rain between April and September. Temperatures average 19°C (66°F) in summer with average daily maximums of 27°C (80°F) and -11°C (13°F) in winter with average daily minimums of -17°C (2°F). The vegetation is the Wheatgrass-Needlegrass Type (Barker and Whitman 1988) of the mixed grass prairie. The dominant native range species are western wheatgrass (Agropyron smithii), needleandthread (Stipa comata), blue grama (Bouteloua gracilis), and threadleaved sedge (Carex filifolia).

The native rangeland treatments were organized as a paired plot design with two replications. The twice over rotation grazing treatments have three pastures with each grazed for two periods, one period of 15 days between 1 June and 15 July followed by a second period of 30 days prior to mid October for a total of 4.5 months (1 June - 17 October) at a stocking rate of 0.49 AUM's/acre. Three seasonlong treatments were used, a 4.5 month seasonlong grazed between 16 June to 30 October at a stocking rate of 0.35 AUM's/acre, a 4.0 month deferred seasonlong grazed between 16 July to 15 November at a stocking rate of 0.45 AUM's acre, and 6.0 month seasonlong grazed between 15 May and 15 November at a stocking rate of 0.25 AUM's/acre. The long term nongrazed treatments had not been grazed, mowed, or burned for more than 30 years prior to the start of data collection. Commercial crossbred cattle were used on all treatments in this trial.

Each of the treatments were stratified on the basis of three range sites (sandy, shallow, and silty sites). Samples from the grazed treatments were collected on both grazed and protected with cages (ungrazed) quadrats. Above ground plant biomass was collected on 7 sampling dates from May to October. Below ground plant biomass and soil microorganism data were collected on 4 sampling periods. Above ground and below ground net primary productivity (NPP) was determined by methods outlined by Sala et al. (1981), and Bohm (1979), respectively. The major components sampled were live material (by species), standing dead, and litter. Plant materials were analyzed for nutrient content using standard procedures (A.O.A.C. 1984). Plant species composition was determined by the ten pin point frame method (Cook and Stubbendieck 1986) between mid July and mid August. root exeudates were determined using procedures outlined by Haller and Stolp (1985). Statistical methods used to analyze differences between means was a standard paired plot t-test (Mosteller and Rourke 1973).

Individual animals were weighed on and off each treatment and on each rotation date. Cow and calf mean weights were adjusted to the 8th and 23rd day of each month of the grazing period. Biweekly live weight performance periods of average daily gain and accumulated weight gain for cows and calves were used to evaluate each treatments. Response surface analysis (Kerlinger and Pedhazur 1973) with a repeated observation design was used to compare animal response curves among treatments. These response surface analysis curves were reported by Manske et al. (1988).

RESULTS AND DISCUSSION

Percent basal cover of grasses increased 25% (from 15% to 19% basal cover) on the rotation grazing treatments compared to 4.5 month seasonlong treatments (Table 1). Basal cover of sedges and forbs decreased by 4% and 36%, respectively, on the rotation treatments compared to seasonlong treatments. Relative percent composition (Table 2) increased by 14% for grasses and decreased by 14% and 40% for sedges, and for forbs plus shrubs, respectively, on the rotation treatments compared to seasonlong treatments.

The amount of herbage that remained standing on 1 September after the rotation treatments was greater than the amount of total current years growth on the long term nongrazed treatments (Table 3). This does not account for the amount of vegetation removed by livestock on the rotation treatments. During the entire grazing season an average of 15% more herbage biomass was standing after each grazing period on the rotation treatments compared to long term nongrazed treatments. The relatively greater amount of photosynthetic leaf area remaining on the rotation treatments at the end of the grazing season was beneficial for the continued development of the grassland ecosystem at a higher production level. This remaining herbage also provides a benefit as wildlife habitat. Seasonlong treatments averaged 8% and 29% less herbage biomass standing after grazing than on the nongrazed and rotation treatments, respectively.

Grass plant tiller development and resulting increase in above ground herbage biomass was greater on the rotation treatments than on the nongrazed and seasonlong treatments. This suggests that removal by defoliation of some young leaf material at early phenological stages has some effect on the reduction of auxin and the subsequent stimulation of cytokinin which caused axillary buds to develop into secondary tillers. Thus, defoliation of grass plants at an early phenological stage has beneficial effects on tiller development.

Preliminary interpretation of the rhizosphere data collected so far indicates that greater amounts of exudates were released into the rhizosphere on the rotation treatments than on nongrazed or seasonlong treatments. These data also indicate that soil mite biomass was greater on the rotation treatments compared to the nongrazed or seasonlong treatments. This suggests that removal by defoliation of some young leaf material at early phenological stages has some effect on increasing exudated material, which presumably stimulates activity of the bacteria, which causes increases in protozoa and nematodes, which causes increases in springtails and mites, which are the top trophic levels in the rhizosphere. This increase in activity levels of organisms in the rhizosphere increases the amount of nitrogen available for plant growth. Thus, defoliation of grass plants at an early phenological stage has beneficial effects on symbiotic rhizosphere activity.

The period of defoliation of grass plants that has shown beneficial effects on the increase of tillers and symbiotic rhizosphere activity during this study has occurred between the third leaf stage and anthesis phenological phenophase.

The increase in grass tiller development and symbiotic rhizosphere activity on the rotation treatments allowed a mean increase in stocking rate of 40% greater than on the 4.5 month seasonlong treatments, 96% greater than on six month seasonlong treatments, and 9% greater than the four month deferred seasonlong treatments. Initial turn out of the livestock on the deferred seasonlong treatments was delayed until near peak herbage production in mid to late July.

Cow and calf individual accumulated weight performance (Table 4) (Fig. 1 and 2), average daily gain (Table 5) (Fig. 3 and 4), and weight gain per acre (Table 6), were greater on the rotation treatments compared to the seasonlong and deferred seasonlong treatments. Cow and calf weight performance on the three grazing treatments was generally not significantly different during the first grazing period of June and July, but during the second grazing period after early August, the animal weight performance on the rotation treatments was significantly greater than on the seasonlong and deferred seasonlong treatments (Manske et al. 1988) (Fig. 1,2,3 and 4). The individual animal performance is improved on the twice over rotation grazing system with an increase in calf average daily gain of 6 % greater than 4.5 month seasonlong and 23% greater than deferred seasonlong grazing treatments. Cow average daily gain is improved on the twice over rotation system by 82% greater than 4.5 month seasonlong and 94% greater than deferred seasonlong grazing treatments.

The combination of increases in stocking rate and individual animal performance gives the twice over rotation system a considerable increase in animal weight gain per acre over the other grazing treatments. Calf weight gain per acre on the twice over rotation system was 39% greater than 4.5 month seasonlong and 40% greater than deferred seasonlong treatments. Cow weight gain per acre on the twice over rotation system was 179% greater than 4.5 month seasonlong, and 212% greater than deferred seasonlong grazing treatments. The improved livestock weight performance during the later portion of the grazing season on the rotation treatments was primarily attributed to the increase in available nutrients from the addition of secondary tillers which had developed from axillary buds and were phenologically at an early growth stage. Generally, the available herbage on the rotation treatments was 1.5 and 2.5 percentage points greater in protein content than the herbage on the seasonlong and deferred seasonlong treatments during the later portion of the grazing season.

The grassland plant community can generally be beneficially changed when grazing is properly timed with the phenological development of the grass plants. The grass plant density is increased and total herbage production is increased. A greater amount of vegetation can remain at the end of the grazing season, which causes a noticeable change in the vegetation canopy cover. There is a decrease in the amount of bare ground present in the pastures.

Additional research needs to be done to quantify exudation material, soil organism activity and biomass, nitrogen, carbon and phosphorus cyclic flows, and axillary bud development into tillers, in order to completely understand the adaptive tolerance mechanisms developed by grassland plants to compensate for defoliation and thereby be able to manipulate the defoliation to be increasingly beneficial for the grassland ecosystem. Data collected to date has shown that defoliation of grass plants between the third leaf stage and anthesis phenological stage has beneficial effects on the physiological responses within the plant, which allows for greater tiller development and beneficial effects on the symbiotic rhizosphere activity, which presumable increase the amount of available nitrogen for plant growth. Deliberate and intelligent manipulation of these adaptive tolerance mechanisms can increases secondary tiller development and total herbage biomass. The secondary tillers increase the nutrient content of the herbage, which allows for improvement in individual animal weight performance during the later portion of the grazing season. The increase in herbage biomass allows for an increase in stocking rate and greater amount of herbage left after grazing. Plant density, canopy cover, and litter cover increase as a result of increased tiller growth, which in turn, reduces the impact of raindrops, reduces and slows runoff, reduces erosion, and increases water infiltration. Grazing management recommendations that systematically rotate 7 to 15 day periods of defoliation between the third leaf stage and anthesis phenophase (which is 1 June -15 July in western North Dakota) on each pasture should maximize beneficial effects on the adaptive tolerance mechanisms of grassland plants.

Table 1. mean percent basal cover.

	Treatments		% Difference
	Seasonlong	Rotation	
Grass	14.7	18.6	+25.2
Sedge	7.7	7.6	-3.8
Forb	3.8	2.4	-35.9
Shrub	0.1	0.1	---

Table 2. Mean relative percent composition of plant communities.

	Treatments		% Difference
	Seasonlong	Rotation	
Grass	55.1	63.2	+14.1
Sedge	30.6	28.0	-13.6
Forb & Shrub	14.5	8.7	-39.6

Table 3. mean monthly above ground herbage biomass remaining after grazing on three range sites.

Treatments	Sample periods				
	1 Jun.	1 Jul.	1 Aug.	1 Sep.	1 Oct.
Nongrazed lb/ac	822a	1010a	1144a	888a	
Seasonlong lb/ac	974a	1017a	785b	717a	
Rotation lb/ac	990a	1211b	1231a	993b	987

Means of same column followed by the same letter are not significantly different (P<0.05).

Table 4. Mean annual calf and cow accumulated weight gain.

	Treatments		
	Deferred Seasonlong	Seasonlong	Rotation
Calf lbs	204	284	309
Cow lbs	34	40	107

Table 5. Mean annual calf and cow averages daily gain.

	Treatments		
	Deferred Seasonlong	Seasonlong	Rotation

Calf lbs	1.80a	2.09b	2.21b
Cow lbs	0.32a	0.34a	0.62b
Means of same row followed by the same letter are not significantly different (P<0.05).			

Table 6. Mean annual calf and cow weight gain per acre.

	Treatments		
	Deferred Seasonlong	Seasonlong	Rotation
Calf lb/ac	20.4a	20.5a	28.5b
Cow lb/ac	2.6a	2.9a	8.1b
Means of same row followed by the same letter are not significantly different (P<0.05).			

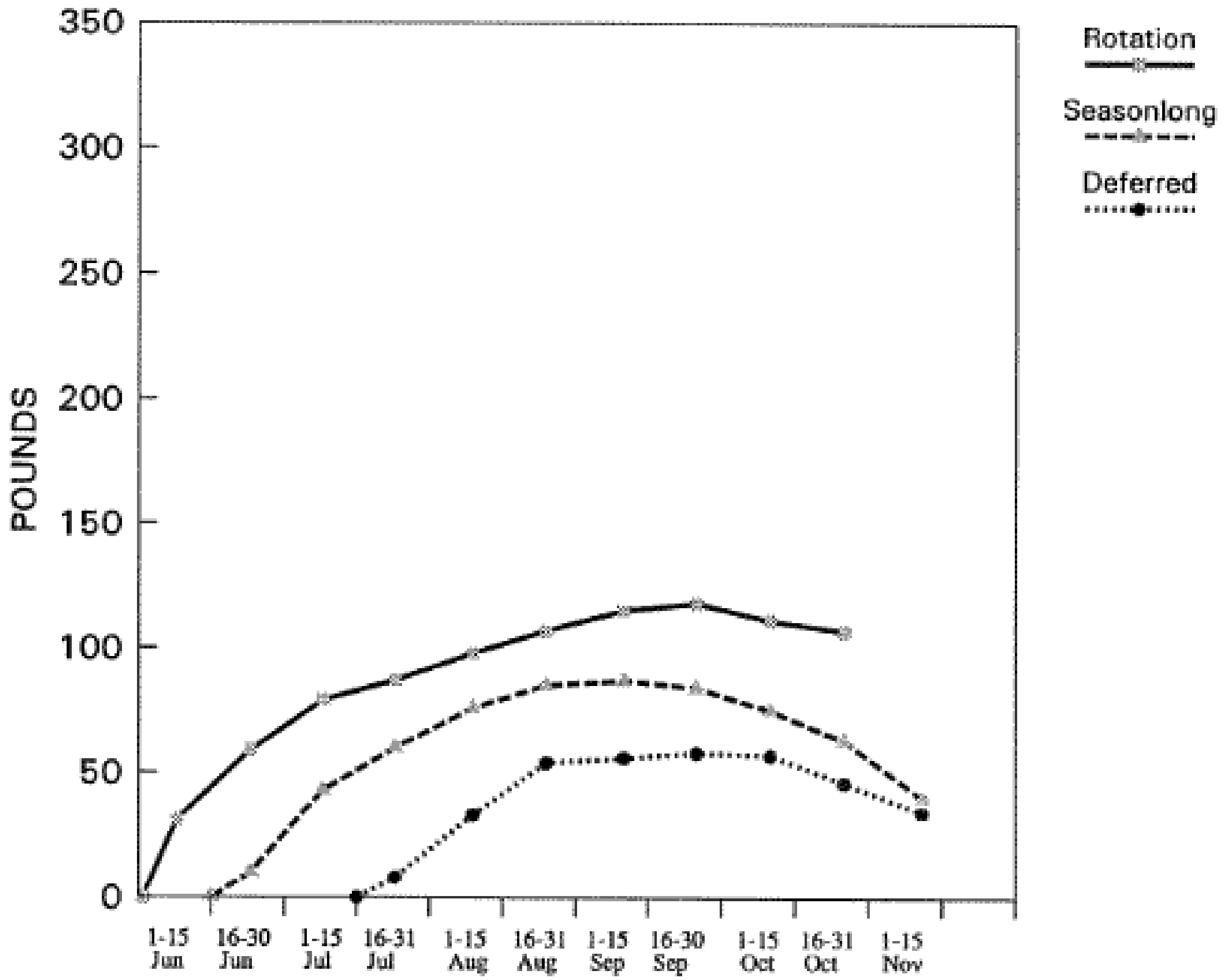

Fig 1. COW ACCUMULATED WEIGHT GAIN

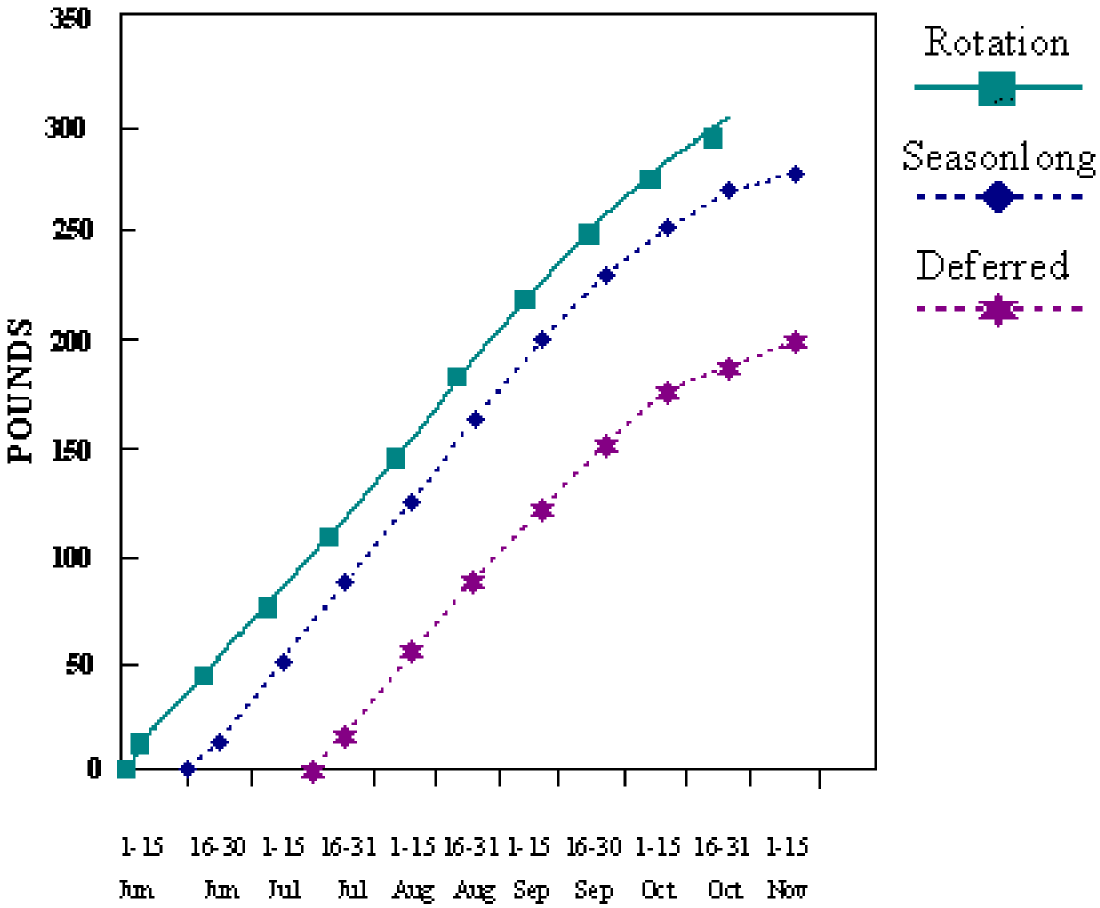

Fig. 2. CALF ACCUMULATED WEIGHT GAIN

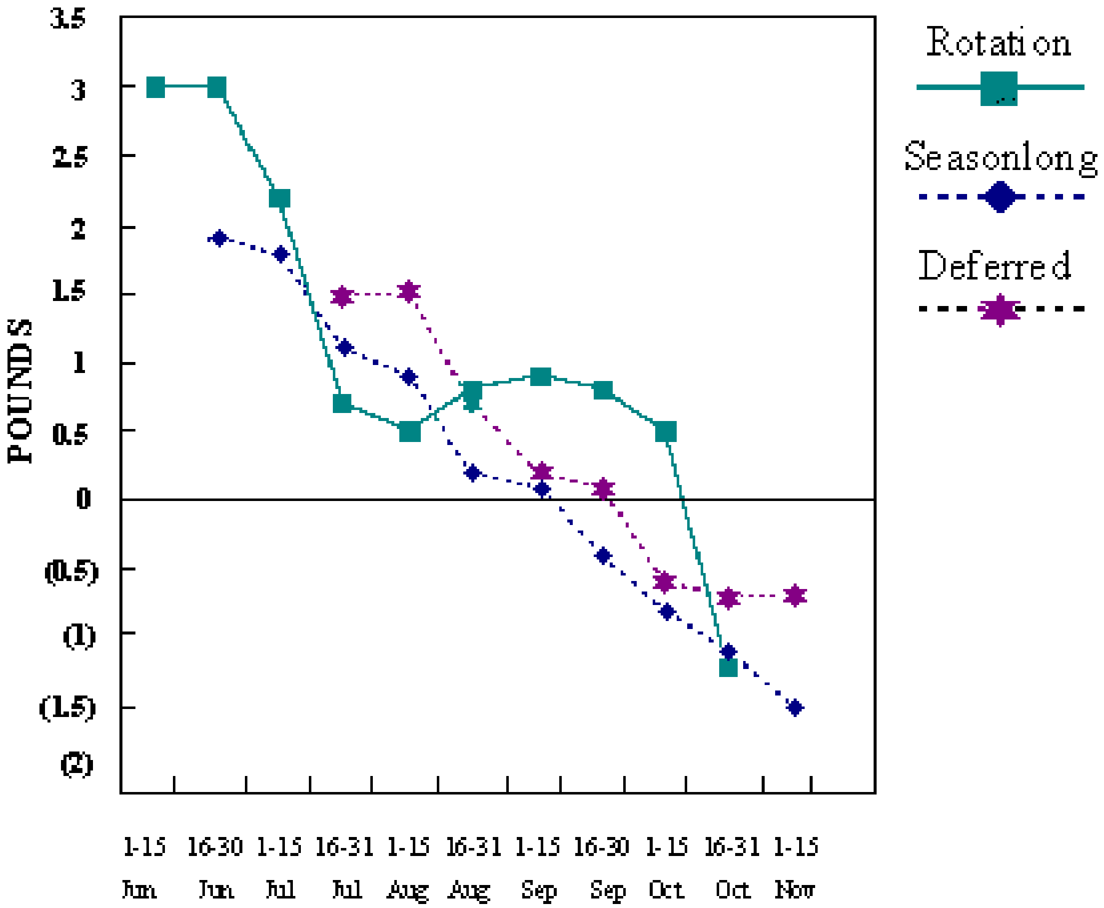

Fig. 3. COW AVERAGE DAILY GAIN

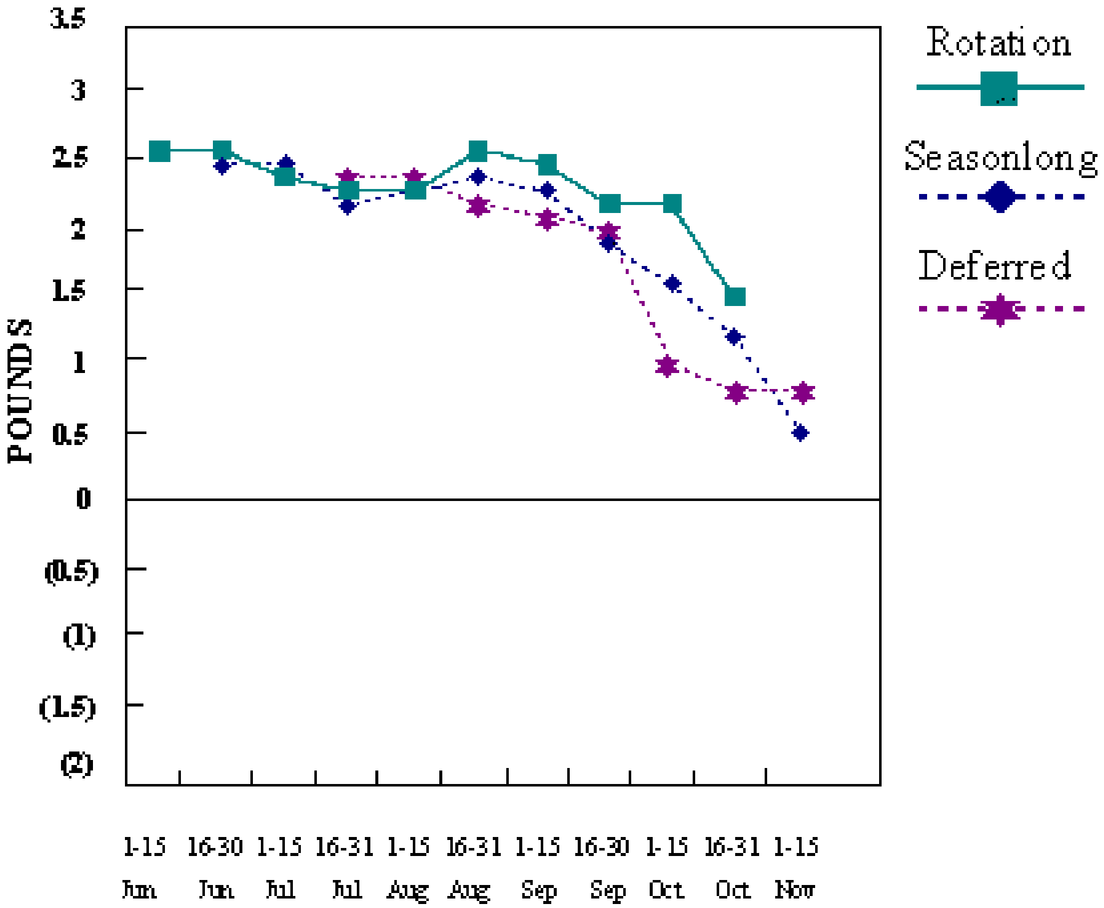

Fig. 4 CALF AVERAGE DAILY GAIN

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Back to 1994 Research Report Table of Contents
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