

Effects of Protein Levels Fed During Winter on Subsequent Performance of Steers Grazing Tobosagrass

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ABSTRACT

The effect of level of supplementation on winter weight gain and subsequent spring performance was determined in a 3-year study at the Texas Tech Experimental Ranch, near Justiceburg, Texas. One of the objectives of this research was to determine if level of supplementation might influence spring gain. Cottonseed cubes (41% crude protein) were fed during the winter season to cross-bred steers grazing tobosagrass (*Hilaria mutica*) range. The average daily gain (ADG) for the control steers was 0.03, 0.26 and 0.22 lb head⁻¹ day⁻¹ during the winter of years 1, 2 and 3. The spring gains were 1.91, 1.09 and 1.68 lb hd⁻¹. The winter ADG for steers supplemented with 1.5 lb head⁻¹ day⁻¹ was 0.61, 0.63 and 0.68, while ADG in spring was 1.78, 1.46 and 1.09. The winter ADG for steers supplemented at the rate of 3.00 lb head⁻¹ day⁻¹ was 0.93, 0.95 and 1.00, while the spring ADG was 1.76, 1.32 and 1.61 for years 1, 2 and 3. We found no compensatory gain in the spring on tobosagrass rangeland. Heavier steers at the conclusion of winter supplementation remained the heaviest at the end of the spring.

KEYWORDS: winter supplement, compensatory gain, range, beef cattle, spring grazing

The production and marketing strategy used by most stocker operators in the southern Great Plains is to purchase cattle in the spring and to sell in the fall whereas cow-calf operators produce calves in the spring and sell in the fall. For both operators this pattern results in the most rapid weight gain when range grasses are most nutritious and productive. However, it also results in seasonal price patterns of highest cattle prices in the spring and lowest prices in the fall (Ethridge et al., 1990). Therefore, opportunity exists for the development of stocker operations to take advantage of the seasonal price patterns.

Maintaining cattle at a low plane of nutrition during winter is a common practice. Compensatory weight gain in the spring can therefore have a sizable economic impact on cattle production (Owens et al., 1993). If winter dietary restriction could be overcome by spring and summer grazing, a more economical approach to cattle feeding may be feasible. The magnitude of compensatory growth depends on several factors, such as age when restrictions begin, severity, duration, type of restriction,

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realimentation diet and time, as well as genetic growth potential and breed type (Fox et al., 1972; Coleman and Evans, 1986; Lewis et al., 1990). Drouillard et al. (1991) found that cattle compensated for winter restrictions such that daily gain above 0.61 lb day⁻¹ during the winter was not beneficial. Ives et al. (1993) related compensatory gain to energy intake and stated that 1.7 times maintenance was the critical energy intake when compensatory gain can be expected. No real benefit was realized from increased winter gains except a shorter finishing period (White et al., 1987).

Tobosagrass is a perennial warm season grass that dominates clay and clay loam soils of semi-arid rangeland throughout the southwestern United States and northern Mexico. Due to its wide distribution, tobosagrass constitutes an important forage resource to the range livestock producers of this region (Anderson, 1982). Tobosagrass is generally considered to have low palatability due to the accumulation of old growth which tends to be refused by the grazing animal. Substantial declines in crude protein (CP) and dry matter digestibility have been reported with tobosagrass maturation (Britton and Steuter, 1983). Crude protein in mature tobosagrass can drop below 5.0%, which is an unacceptable nutritional level (Nelson et al., 1970). During the dormant period, tobosagrass crude protein was found below 4.5% and dry matter digestibility below 35% (Britton and Pitts, 1988). In contrast, from April to July, tobosagrass ranged from 16.0% to 5.0% protein concentration (Britton and Steuter, 1983). Pitts (1989) reported a range from 10.0% to 13.0% in crude protein and 36.0% to 60.0% for *in vitro* digestible dry matter (IVDMD) during the same season.

Tobosagrass rangelands are not considered good for grazing stocker cattle, given their poor quality. However, the increasing occurrence of retained ownership programs and the poor distribution and quantity of rainfall on wheat pastures has increased interest in protein supplementation of stocker cattle grazing tobosagrass.

The first objective of this research was to evaluate the performance of steers fed different levels of protein supplementation during the winter. A second objective was to determine how the level of supplemental protein fed during winter might affect performance in spring for steers grazing tobosagrass.

EXPERIMENTAL PROCEDURES

Study Area

Field research was conducted at the Texas Tech Experimental Ranch from 1989 to 1992. The ranch is in southeast Garza County, 16 miles southeast of Post, near Justiceburg, Texas. The ranch lies in the Rolling Plains at a mean elevation of 2400 ft. The research area was dominated by clay flat range sites with gently sloping Stamford Clay soils (fine, montmorillonitic, thermic Typic Chromusterts) (Richardson et al., 1965).

Perennial vegetation was dominated by tobosagrass with alkali sacaton (*Sporobolus airoides*) present in depressions. Associated species include buffalograss (*Buchloe dactyloides*) and plains pricklypear (*Opuntia phaeacantha*), with an overstory of honey mesquite (*Prosopis glandulosa* var. *glandulosa*).

The climate is warm, temperate and subtropical. Temperature is variable with an average daily minimum of 27°F in January and hot summers with an average

daily maximum temperature in July of 95°F. Periods of drought occur frequently. Approximately 50% of the annual precipitation (19 inches) occurs from April through July (Richardson et al., 1965).

Research Animals

Studies summarized here were conducted with crossbred *Bos taurus* x *Bos indicus* Mexican steers. The average initial weight for the 3 years of evaluation ranged from 386 to 452 lb head⁻¹, and age ranged from 8 months to yearlings.

Stocking rate for pastures was based on standing crop at the beginning of supplementation each year. Estimated stocking for the study period assumed a 50% removal of available forage. Forage production was determined by randomly clipping ten 2.7-ft² quadrats in each pasture, according to Pieper (1978). An attempt was also made to maintain similar forage allowances in all pastures (Table 1).

Three levels of cottonseed meal cubes (CSM) (41% CP solvent extracted) were evaluated; 0.00 (control=CON), 1.5 (low supplement=LS) and 3.00 (high supplement=HS) lb head⁻¹ day⁻¹ on an as-fed basis. Supplement treatments were randomly allocated to pastures during the 3-winter study. Cattle were group-fed three days per week, between 1100 and 1200 h to avoid grazing interruption. Free access to a mineral mix (7% P, 13% Ca, 50% NaCl) was always available.

Two replications per level of supplementation were used each year. During the winter, six herds were composed of 15 to 41 steers for an average stocking rate of 1 steer per 4 acres over the 3 years. Six pastures were used for the winter supplementation period. Pasture areas were 55, 60, 67, 69, 73 and 87 acres. All pastures were deferred in the growing season for winter use in each year of evaluation. In spring, three herds were composed, and to determine the effect of previous nutrition status on the following grazing season, all steers were moved to six ungrazed pastures within three cells. Cattle grazed from late March to early July. Cell areas were 235, 225 and 168 acres with an average of 39 to 61 steers stocked in each cell.

Each year the steers were obtained from Lubbock Feedlots, Inc. Steers were vaccinated at the feedlot with a 7-way-vaccine, given a parasiticide (ivermectin), as well as Vitamins A-B complex and E. On arrival at the Justiceburg ranch, steers were turned into a small pasture of dormant old world bluestem (*Bothriochloa* sp). Cattle were watched closely for signs of illness and offered supplement to become familiar with the pelleted feed. After a few days, steers were moved to the tobosagrass study site.

Cost of additional weight gain by supplemented steers was estimated at two different CSM costs (\$205 and \$240 ton⁻¹). These costs were derived for the period of December to March from sales reports during the 3 years of evaluation and were calculated using the following equation: cost of additional gain = feed cost (\$ head⁻¹ day⁻¹) per gain (lb head⁻¹ day⁻¹ above control).

During the first two winters, six mature bifistulated (esophageal and ruminal) steers were used to obtain forage diet samples from each grazed pasture. Fistulated steers were kept in an adjoining pasture of similar vegetation. Forage samples were collected by permitting the steers to graze each pasture for 30 to 45 minutes after an overnight fast. Samples were dried at 104°F then ground through a Wiley mill equipped with a 0.02 inch mesh screen. Masticated samples were analyzed for dry matter, ash and Kjeldahl nitrogen (AOAC, 1991). Crude protein was estimated as

6.25 x N. *In vitro* organic matter disappearance was determined as described by Tilley and Terry (1963).

Table 1. Forage standing crop and treatments for supplementation trials conducted at the Texas Tech Experimental Ranch in 1989-90, 1990-91 and 1991-92.

Year	Cell	Pasture	Supplement level	Forage available [†]	Forage allowance [‡]
				lb acre ⁻¹	lb head ⁻¹
1989-90	1	A	HS [§]	854	3696
		B	LS	1608	3801
	2	A	HS	1514	3746
		B	CON	1495	3700
	3	A	LS	1512	3742
		B	CON	1440	3565
1990-91	1	A	LS	1877	3940
		B	CON	1651	3164
	2	A	LS	905	2745
		B	CON	1651	3164
	3	A	HS	1574	5918
		B	HS	1569	4538
1991-92	1	A	CON	2260	3696
		B	HS	1451	3801
	2	A	CON	1005	3746
		B	HS	992	3700
	3	A	LS	1512	3742
		B	LS	1441	3565

[†]Forage was sampled in each pasture of each cell before steers were allowed to graze.

[‡]Total forage available per steer at the beginning of the study.

[§]HS=high supplement, 3.00 lb head⁻¹ day⁻¹ cottonseed cubes, LS=low supplement, 1.5 lb head⁻¹ day⁻¹ cottonseed cubes, CON=control, no supplement.

On 13 Dec 1989, 104 steers, with an initial average weight of 386 lb, were individually weighed, implanted with Ralgro[®] and allocated to treatment groups. Supplementation began on 14 Dec 1989 and continued until 9 Mar 1990. Steer weights were recorded at the start of the supplementation period and 10 Mar 1990 when supplementation was terminated. Weights were also recorded on 7 Jul to determine gain during spring season.

The second year of study began on 10 Dec 1990, using 149 steers with an average

weight of 454 lb. Steers were turned out on old-world bluestem pasture and moved to tobosagrass site on 20 Dec. All steers were weighed, implanted with Ralgro® and allocated to treatments on 27 Dec 1990. Supplementation began on this date and continued until 14 Mar 1991. Individual steer weights were taken at the beginning of supplementation and 15 Mar 1991. Steers remained on fresh pastures until 7 Jul, when individual steer weights were taken to determine gain during the spring.

On 8 Jan 1992, 189 steers averaging 397 lb arrived at the Texas Tech Experimental Ranch. These cattle remained on the old world bluestem pasture for 10 days. Steers were moved to tobosagrass pastures on 18 Jan and allocated to treatments. Steers had been previously weighed and implanted. Supplementation began on 25 Jan and ended on 9 Apr. At each weighing date, steers were placed in corrals the evening prior to weighing, held overnight without water and feed, and weighed the following morning. The same procedure was done on 4 Jul to determine winter feeding effects on spring gain.

Gain data were analyzed as a completely randomized (CRD) design. Pastures (REP) were the experimental units. Mean separation was accomplished by using the Least Significant Different (LSD) at 0.05 level, when the analysis of variance indicated a significant difference.

RESULTS AND DISCUSSION

Dietary Nutritive Values

During the first winter (1989-90), the highest CP levels and IVOMD values from esophageal samples were measured at the beginning of supplementation in December, whereas the lowest values were detected in the January-February period (Fig.1). In the last part of the winter, dietary CP and IVOMD values increased again closer to those found at the beginning. The CP values measured during the winter in this type of vegetation ranged from 4.0% to 6.0%. IVOMD had a similar pattern with values from 22.5% to 38.0%.

In the second winter (1990-91), CP and IVOMD values from the esophageal samples followed similar patterns to the previous winter (Fig. 2). The highest values of CP and IVOMD were again detected at the beginning and the end of the winter. As in the first year, the lowest values were measured at mid-winter. The protein values were a little lower than the previous winter and ranged from 3.5% to 4.1% while IVOMD ranged from 32.0% to 40.0%. Forage nutrients values during this winter were more uniform compared to the previous winter (Villalobos, 1995).

Steer Performance

First Year

Average daily gain (ADG) during winter was proportional to the level of protein supplementation (Fig. 3). Steers in the HS treatment gained the most ($P \leq 0.05$) while the CON group gained the least ($P \leq 0.05$). Steers in the CON treatment maintained initial body weight, showing an ADG of 0.028 lb head⁻¹ day⁻¹. In contrast, steers in the LS and HS groups had ADG of 0.59 and 0.93 lb head⁻¹ day⁻¹

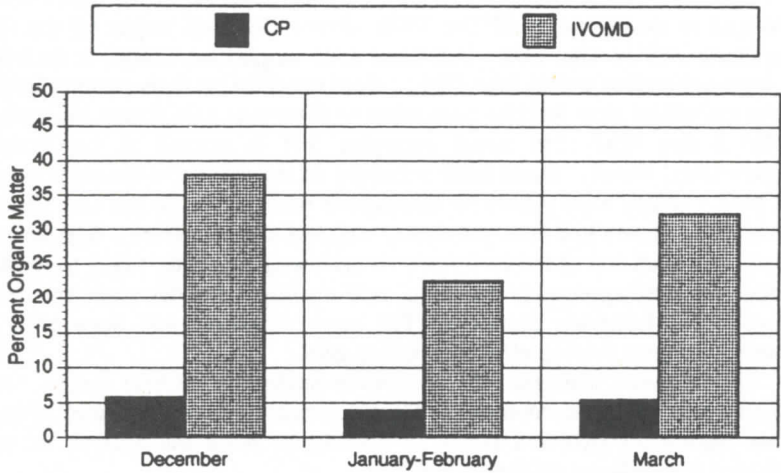


Figure 1. Dietary crude protein concentration (% of organic matter) and *in vitro* organic matter digestibility (IVOMD) of esophageal fistulated steers (1989-1990) grazing dormant tobosagrass.

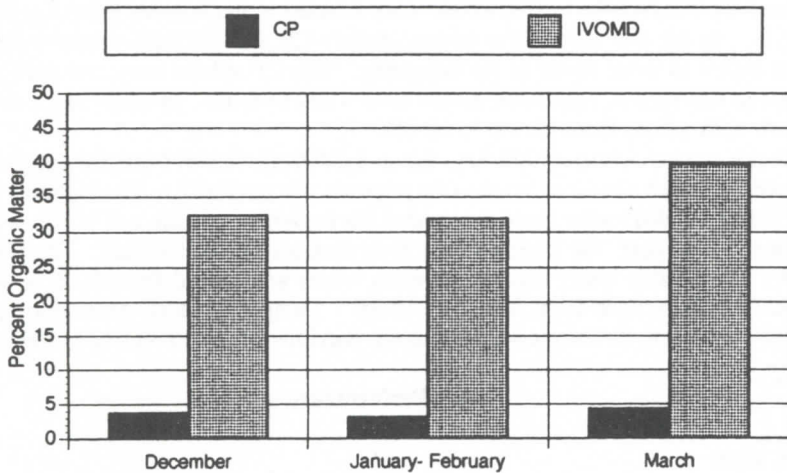


Figure 2. Dietary crude protein concentration (% of organic matter) and *in vitro* organic matter digestibility (IVOMD) of esophageal fistulated steers (1990-1991) grazing dormant tobosagrass.

During the spring season, ADG was opposite of winter gain (Fig. 3). Steers that gained more in the winter season gained less in the spring. However, differences were not detected among treatments. HS and LS treatments showed a similar ($P \geq 0.05$) ADG of 1.76 and 1.78 lb head⁻¹ day⁻¹, in the spring period, whereas steers in the winter CON group gained more ($P \leq 0.05$) than those that were supplemented during the winter, with an ADG of 1.91 lb head⁻¹ day⁻¹. In this case, the winter weight differences were minimized but maintained at the end of the grazing season. The total gain (winter+spring) was different ($P \leq 0.05$) among treatments. The steers that were heaviest after wintering remained heaviest at the end of the spring; however the weight margins varied. At the end of the grazing season, the steers that were in the HS group gained 57.0 and 24.0 lb head⁻¹ more ($P \leq 0.05$) than those that were in the CON and LS treatments, respectively. In contrast, at the end of the spring, steers in the LS rate gained 33.0 lb head⁻¹ more ($P \leq 0.05$) than those that were in the CON group. This indicates that no compensatory gain was shown for this kind of vegetation in this first year of study.

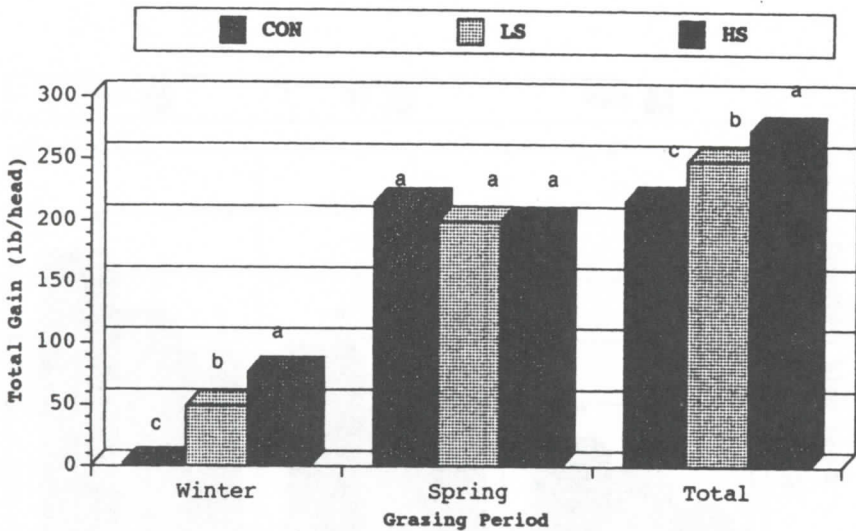


Figure 3. Total gain (lb hd⁻¹) of steers fed 3 levels of cottonseed meal pellets while grazing dormant and spring season on a tobosagrass range, 1989-1990. CON=Control (no supplement), LS=Low supplement (1.5 lb hd⁻¹ day⁻¹ cottonseed meal pellets), HS=High supplement (3.00 lb hd⁻¹ day⁻¹ cottonseed meal pellets). Letters denote differences among treatments within periods ($P \leq 0.05$).

Second Year

The response obtained during the second winter was similar for the two levels of supplementation to that observed in the previous year (Fig. 4). However, the CON steers gained 87.0% more than in the first year. This was probably due to the mild winter in the second year. During this year ADG between the two levels of supplementation was similar ($P \leq 0.05$). In addition, the ADG for CON and LS was similar ($P \leq 0.05$) at the end of the winter (Fig. 4). However, differences were detected between HS and CON. Steers in the HS gained 73.0% more ($P \leq 0.05$) than CON steers. (Villalobos, 1995).

During the second spring, steers that gained more in the winter also gained more during spring (Fig. 4). The ADG between CON and LS was similar ($P \geq 0.05$) at 1.10 lb head⁻¹ day⁻¹ for both treatments. In contrast, HS steers gained more ($P \leq 0.05$) than CON and LS steers, with an ADG of 1.30 lb head⁻¹. Similar to the previous year, steers that were heaviest at the end of the winter remained heaviest at the end of the spring grazing season. Steers in the HS group at the end of the grazing season gained about 79.3 and 48.5 lb head⁻¹ more than those in the CON and LS group. The total gain for the LS steers was 31.0 lb head⁻¹ more than those in the CON group which also indicated that compensatory gain was not shown in the second year.

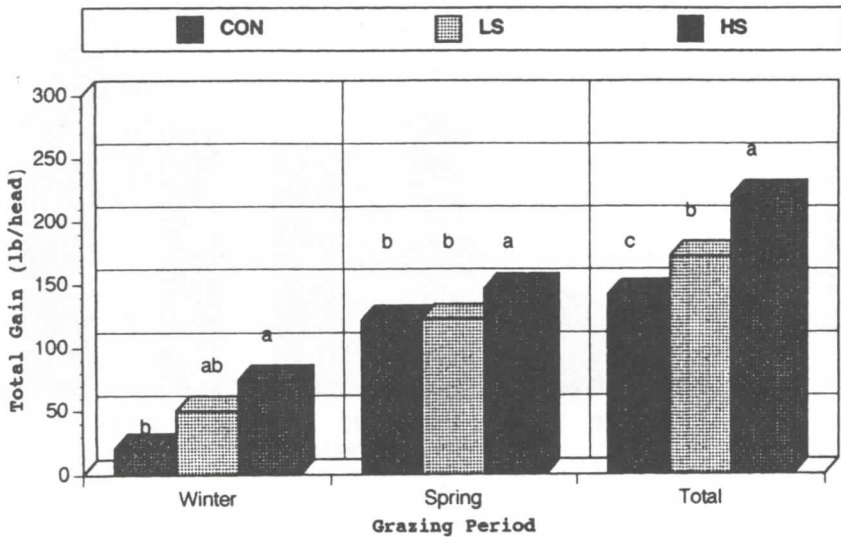


Figure 4. Total gain (lb head⁻¹) of steers fed 3 levels of cottonseed meal pellets while grazing dormant and spring season on a tobosagrass range, 1990-1991. CON=Control (no supplement), LS=Low supplement (1.5 lb head⁻¹ day⁻¹ cottonseed meal pellets), HS=High supplement (3.0 lb head⁻¹ day⁻¹ cottonseed meal pellets). Letters denote differences among treatments within periods ($P \leq 0.05$).

Third Year

Winter gains in the third year were again proportional to the level of protein supplementation. However, differences were not detected ($P \geq 0.05$) between the 2 levels of supplementation. The HS steers had ADG of 1.0 lb head⁻¹ day⁻¹ while the steers in the LS treatment average 0.66 lb head⁻¹ day⁻¹ (Fig. 5). In the winter period, the gain obtained from the two levels of supplementation was higher ($P \leq 0.05$) than the CON.

In spring, ADG was similar ($P \geq 0.05$) between the CON and the HS groups (Fig. 5). The CON steers showed an ADG of 1.67 lb head⁻¹ day⁻¹, whereas ADG for the HS group was 1.61 lb head⁻¹. This gain was 13.0% and 10.0% higher ($P \leq 0.05$) for the CON and HS steers than for LS steers. Again, the heaviest cattle at the end of the winter remained the heaviest at the end of the spring. The total gain for HS steers was 57.0 lb head⁻¹ more ($P \leq 0.05$) than CON steers and 40.0 lb head⁻¹ more ($P \leq 0.05$) than steers in the LS treatment. Steers in the LS rate gained just 18.00 lb head⁻¹ more than those in the CON. According to the economic analysis (Table 2), the response of steers to winter supplementation was remarkably high during colder rather than milder winters and increased steer performance easily offset supplemental costs.

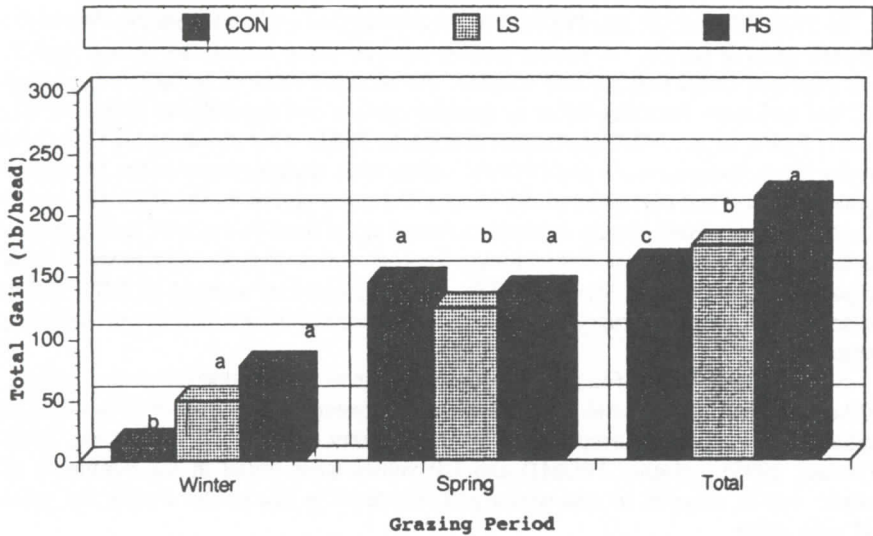


Figure 5. Total gain (lb hd⁻¹) of steers fed 3 levels of cottonseed pellets while grazing dormant and spring season on a tobosagrass range, 1991-1992. CON=Control (no supplement), LS=Low supplement (1.5 lb hd⁻¹ day⁻¹ cottonseed meal pellets), HS=High supplement (3.00 lb hd⁻¹ day⁻¹ cottonseed meal pellets). Letters denote differences among treatments within periods ($P \leq 0.05$).

Table 2. Cost of added gain by steers grazing dormant tobosagrass at the Texas Tech Experimental Ranch, supplemented with two levels of cottonseed cubes in the winters of 1989-90, 1990-91 and 1991-92.

	Supplement Level (lb head ⁻¹ day ⁻¹)			
	1.5 [†]	1.5 [‡]	3.0 [†]	3.0 [‡]
	-----\$ lb ⁻¹ -----			
1989-90	0.26	0.31	0.33	0.40
1990-91	0.40	0.48	0.43	0.52
1991-92	0.32	0.39	0.38	0.46

†Feed cost (\$ lb⁻¹) \$0.10 lb⁻¹ cottonseed meal cubes.

‡Feed cost (\$ lb⁻¹) \$0.12 lb⁻¹ cottonseed meal cubes.

DISCUSSION

In 1989-90, diet CP and IVOMD of the tobosagrass declined from the first to the second grazing period. A similar pattern was followed during the second winter. As livestock select first for leaf fraction, the nutritive value of the diet will change as leaf and stem fractions differ in nutrient content and digestibility (Poppi et al., 1981; Fisher et al., 1987; McCollum and Horn, 1990). Our results agree with these researchers; forage protein and IVOMD values were always greater in the December grazing period and decreased in the January-February period during the years of this study. Forage crude protein content increased again from mid-winter to late winter in both years. Protein content of forage for both years of study were close to those reported by Britton and Steuter (1983). They reported an average of 5.0% CP in tobosagrass during February and March, which covers the months in our sampling periods.

Values for IVOMD followed a pattern similar to protein content in the forages. Other research has noted similar relationship between digestibility *in vitro* and diet crude protein content (Campbell, 1989; Brandyberry et al., 1992; Park et al., 1989; Gunter, 1993). Higher IVOMD and CP values were found in the beginning of winter which dropped in mid-winter and recovered in late winter during the years of evaluation.

In many supplementation trials, year effects contribute more to the variation in response than the supplement treatments (McCollum and Horn, 1990). In the current study, winter animal performance for the two levels of supplementation showed little variation during the 3 years, with an ADG range from 0.93 to 1.00 lb head⁻¹ day⁻¹ for the HS steers and 0.61 to 0.68 lb head⁻¹ day⁻¹ for the LS steers. In contrast, the CON gain had wide variation, from 0.02 lb head⁻¹ day⁻¹ to 0.26 lb head⁻¹.

Our research agrees with Parker et al. (1974), who illustrated described increased winter weight gains of cottonseed meal supplemented weaning calves. Bellido et al.

(1981) and Smith (1981) also reported improved weight gains of range livestock as a result of protein supplementation. Soybean meal cubes fed at 1.10 lb head⁻¹ day⁻¹ increased gains by 0.50 lb head⁻¹ day⁻¹ for supplemented versus non-supplemented steers according to Cantrell et al. (1985). Judkins et al. (1987) observed increased weight gains by supplemented heifers compared to non-supplemented heifers.

Spring gains showed a greater variation between years than those detected during the winter. The ADG of CON steers ranged from 1.10 to 1.91 lb head⁻¹. Also, LS steers gained from 1.10 to 1.78 lb head⁻¹. These values agree with those of Pitts (1989) who found an average of 1.47 lb head⁻¹ day⁻¹ for the CON and 1.56 lb head⁻¹ day⁻¹ for steers that were supplemented at 0.00 and 1.5 lb head⁻¹ day⁻¹ during a 3-year study in similar vegetation at the same time of year. Steers in the HS rate gained 1.32 lb head⁻¹ day⁻¹ to 1.76 lb head⁻¹. Spring gains were more closely related to rainfall quantity and distribution. The ADG in the spring of 1990 and 1992 exceeded ADG in the spring of 1991. In both years spring rainfall was above the long term average and was well distributed during the winter months (Fig. 6). In contrast, the lowest ADG for all treatments occurred in the second spring. This gain was related to rainfall in the research area where adequate precipitation did not occur until June 1991 (Fig. 6).

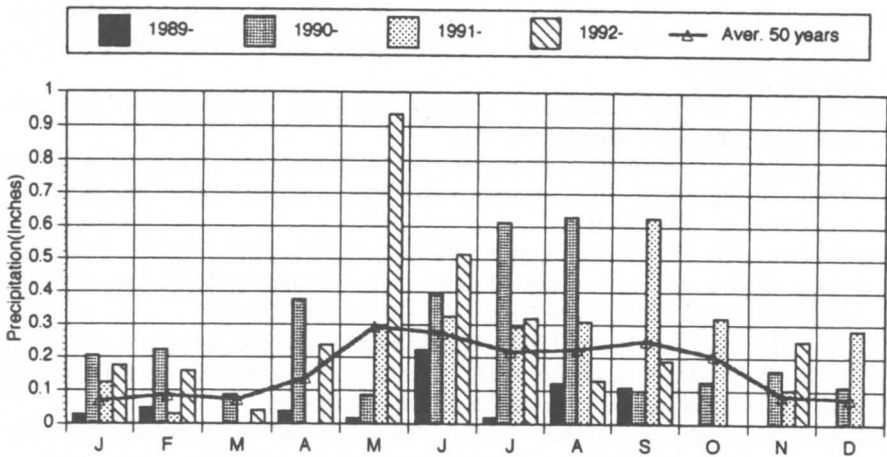


Figure 6. Precipitation at the Texas Experimental Ranch from 1989, 1990, 1991 and 1992. Average precipitation is taken from the Garza County Soil Survey.

One of the objectives of this research was to determine if level of supplementation might influence spring gain. We found no compensatory gain in the spring on tobosagrass rangeland. Heavier steers at the conclusion of winter supplementation remained the heaviest at the end of the spring.

Two options for ranchers grazing livestock tobosagrass range are to sell cattle in March or April when prices are higher or to sell in July to take advantage of spring gains. However, they would have to accept that the extra pounds would be offset by lower prices in the summer months. One important finding of this study was that 99%, 87% and 92% of the total gain for CON steers was made during spring in all 3 years. By comparison, LS steers achieved 80%, 71% and 71% of total weight gain in spring and 72%, 66% and 64% of total gain by HS steers was acquired during the spring in Years 1, 2 and 3. This indicated that steers in the CON groups only maintained weight during the winter.

Results indicate that protein supplementation is beneficial to steers grazing tobosagrass rangelands during the winter. Consequently, winter gain seemed to favor spring performance. The level of supplementation should be determined by expected response coupled with economic and management considerations. The implications for the performance of animals up to a commercial slaughter weight in the feedlot requires further investigation.

REFERENCES

- Anderson, D.M. 1982. Seasonal grazing for semidesert tobosa rangeland in southern New Mexico. *In* Graz. Manage. Tech. Proc. Texas A&M Univ., College Station.
- AOAC. 1991. Official methods of analysis (14th Ed). Association of Official Analytical Chemists, Washington, DC.
- Bellido, N.M., J.D. Wallace, E.E. Parker, and M.D. Finkner. 1981. Influence of breed, calving season, supplementation and year on productivity of range cows. *J. Anim. Sci.* 52:455-468.
- Brandyberry, S.D., T. DelCurto, R.K. Barton, and J.A. Rose. 1992. Year and season effects on diet quality of beef cattle grazing northern Great Basin rangeland. *Proc. West. Sec. Amer. Soc. Anim. Sci.* 43:418.
- Britton, C.M., and J.S. Pitts. 1988. Protein supplementation for steers on tobosagrass. *In* Research highlights-1988. Noxious brush and weed control. Range and Wildlife Management. Texas Tech Univ., Lubbock.
- Britton, C.M., and A.A. Steuter. 1983. Production and nutritional attributes of tobosagrass following burning. *Southwestern Nat.* 28:347-352.
- Campbell, R.R. 1989. The influence of advancing season on diet quality, intake and rumen fermentation of cattle grazing tallgrass prairie. Ph.D. Diss. Oklahoma State Univ., Stillwater.
- Cantrell, J., G. Bryan, and K.S. Lusby. 1985. Effect of protein supplementation on stockers grazing native grass in southeastern Oklahoma. *Oklahoma Agr. Exp. Sta. Misc. Pub.* MP-117,252-253.
- Coleman, S.W., and B.C. Evans. 1986. Effect of nutrition, age, and size on compensatory growth in two breeds of steers. *J. Anim. Sci.* 63:1968.
- Drouillard, J.S., C.L. Ferrel, T.J. Klopfenstein, and R.A. Britton. 1991. Compensatory growth following metabolizable protein or energy restrictions in beef

- steers. *J. Anim. Sci.* 69:811.
- Ethridge, D.E., P. Zhang, B.E. Dahl, R.T. Ervin, and J. Rushmeza. 1990. Cattle ranching production and marketing strategies under combined price and weather risks. *Western J. of Agric. Econ.* 15(2):175-185.
- Fisher, D.S., K.R. Pond, and J.C. Burns. 1987. p. 3-20. In F.P. Horn, et al. (eds) *Grazing lands research at the plant-animal interface*. Winrock International, Morrilton, AK.
- Fox, D.G., R.R. Johnson, R.L. Preston, T.R. Docherty, and E.W. Klosterman. 1972. Protein and energy utilization during compensatory growth in beef cattle. *J. Anim. Sci.* 34:310.
- Gunter, S.A. 1993. Nutrient intake and digestion by cattle grazing midgrass prairie rangeland and plains bluestem pasture. Ph.D. Diss. Oklahoma State Univ., Stillwater.
- Ives, D.S.C., S.J. Bartle, and R.L. Preston. 1993. Critical energy intake of steers for compensatory gain. *Animal Sci. and Technology Research Report*. Department of Animal Sci. and Food Technology. Texas Tech Univ., Lubbock.
- Judkins, M.B., J.D. Wallace, M.L. Galyean, L.J. Krysl, and E.E. Parker. 1987. Passage rates, rumen fermentation and weight change in protein-supplemented grazing cattle. *J. Range Manage.* 40:100.
- Lewis, J.M., T.J. Klopfenstein, and R.A. Stock. 1990. Effects of rate of gain during winter on subsequent grazing and finishing performance. *J. Anim. Sci.* 68:2525.
- McCullum III, F.T., and G.W. Horn. 1990. Protein supplementation of grazing livestock: A review. *Prof. Anim. Scientist* 6(2):1.
- Nelson, A.B., C.H. Herbel, and H.M. Jackson. 1970. Chemical composition of forage species grazed by cattle on an arid New Mexico range. *N. Mex. State Univ., Agr. Exp. Sta. Bull.* 561, Las Cruces.
- Owens, F.N., P. Dubeski, and C.F. Hanson. 1993. Factors that alter growth and development of ruminants. *J. Anim. Sci.* 71:3138-3150.
- Park, K.K., L.J. Krysel, M.B. Judkins, D.W. Holcombe, and B.A. McCracken. 1989. Influence of season and year on nutrient quality, forage intake, digesta kinetic and serum metabolites in steers grazing slender wheatgrass pasture. *Proc. West. Sec. Amer. Soc. Anim. Sci.* 41:482.
- Parker, E.E., J.D. Wallace, A.B. Nelson, and R.D. Pieper. 1974. Effects of cottonseed meal supplement and age at first calving on performance of range cattle. *N. Mex. State Univ. Agr. Exp. Sta. Bull.* 627, Las Cruces.
- Pieper, R.D. 1978. Measurement techniques for the herbaceous and shrubby vegetation. Department of Animal and Range Sci., New Mexico State Univ., Las Cruces.
- Pitts, J.S. 1989. Effect of protein supplementation on relationship among performance, nutrient intake and blood and fecal components of steers grazing tobosagrass. Ph.D. Diss., Oklahoma State Univ., Stillwater.
- Poppi, D.D., D.J. Minson, and J.H. Ternouth. 1981. Studies of cattle and sheep eating leaf and stem fractions of grasses. 1. The voluntary intake, digestibility and retention time in the reticulorumen. *Aust. J. Agric. Res.* 32:99.
- Richardson, W.E., D.G. Grice, and L.A. Putnam. 1965. Soil survey of Garza County, Texas. USDA-SCS.
- Smith, E.F. 1981. Growing cattle on grass. *Kansas Agr. Exp. Sta. Bull.* 638, Manhattan.

- Tilley, J.M.A., and R.A. Terry. 1963. A two-stage technique for the *in vitro* digestion of forage crops. J. Brit. Grassl. Soc. 18:104.
- Villalobos, J.C. 1995. Effects of protein supplementation to steers grazing dormant tobosagrass. Ph.D. Dissertation. Texas Tech University, Lubbock.
- White, T.W., F.G. Hembry, P.E. Humesm, and A.M. Saxton. 1987. Influence of wintering weight change on subsequent pasture and feedlot performance by steers. J. Anim. Sci. 64:32.