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Abstract: The effects of big game grazing of winter wheat on grain yield were studied during 12 trials in northern Utah between 1990-92. Differences in yield were measured for each trial using 20 sets of 1-m^2 plots protected and variously grazed by mule deer (*Odocoileus hemionus*), pronghorn (*Antilocapra americana*) and Rocky Mountain elk (*Cervus elaphus*) in a randomized block design along the edges of sampled fields. Plots were hand cut at the beginning of commercial harvest. Grazing impacts were indexed by nighttime counts of game animals, pellet-group counts, and ocular estimates of percent track cover and forage use between protected and grazed plots. Results indicated that ungulate foraging in these trials did not significantly decrease grain yields despite high utilization percentages on wheat leaves in fall and early spring.

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Few studies of big game depredation have dealt with production and economic impacts on cereal grains. Thomas and Irby (1991) showed that mule deer (*Odocoileus hemionus*) made extensive use of wheat fields during winter in southern Idaho. Wiggers et al. (1984), studying the potential of purposefully planting cereal grains in Texas to support overwintering mule deer, reported that use was heavy in November-December. Deer used 51% of the available grass biomass. Unfortunately, no comparisons with grain yield were made. Tebaldi and Anderson (1982) found no damage on 7 winter wheat fields in Wyoming during 1977-78. Putnam (1986) found that light use (<5%) of cereal grasses by roe deer (*Capreolus capreolus*) in March-May caused no significant loss of grain. Torbit et al. (1993) reported that pronghorn (*Antilocapra americana*) use of winter wheat in eastern Colorado did not significantly affect grain yield in either free-ranging or fenced enclosure trials. In this paper we present data describing various levels of utilization by big game on winter wheat in Utah and the measured effects of that use on grain yield. This report is a contribution of the Utah Division of Wildlife Resources, Federal Aid Project W-105-R.

METHODS

We conducted 12 field trials between 1990-92 in northern Utah on non-irrigated fields planted in fall to winter wheat. All areas were known to receive use by mule deer, with some trials receiving use by pronghorn or Rocky Mountain elk (*Cervus elaphus*). During each trial 20 sets of 1-m^2 plots were established. One or more plots in each set were protected from grazing with 15-cm mesh wire baskets 1.2 m high and secured with 2 steel posts. The wire was arranged in a circle exceeding the perimeter of the protected plot. Distance between plot centers was 4 m. Treatments during all trials included protected and continuously grazed plots.

Additional treatments varied by trial, as limited by time and materials, and included treatments of grazed only during fall (fall planting to Feb 28), spring (Mar 1 to Apr 15), or summer (Apr 16 to harvest). We also added a continuously-grazed-with-clipping treatment during 3 trials to simulate maximum utilization. For this treatment, in addition to grazing, plots were hand-clipped to about 1 cm height, once in the fall (Nov 1991) and again in the spring (Mar 1992) at the beginning of the jointing stage.

For trial 1, sets were established on a predetermined, equal-spaced grid. For trials 2-12 all sets of plots were established about 10-20 m from and parallel to the edges of the fields to maximize use by big game and minimize trampling by investigators. Sets were separated by $\geq$15 m. To compare grain production on plots clipped after jointing, we also clipped a limited number (8) of previously unmarked, paired, continuously grazed plots in April between the second and third joint.

At the beginning of commercial harvest all plots were hand-clipped at about 10 cm height, using 1-m^2 square or rectangular plot frames and pocket knives or hand clippers. Plot frame size was selected to include 4 rows of wheat regardless of the spacing between rows. Clipped wheat biomass was placed in large paper bags. Wheat grain was separated by using a hand-operated thresher. Air-dry weight of total biomass and weight of threshed wheat were determined.

The number of big game animals during all trials was counted at least twice monthly between plot establishment and harvest; 1-2 hours following sunset with spotlights and binoculars (Austin and Urness 1992). However, during trials 9 and 10 only 1 fall count was available. In all 1992 trials, biomass production was ocularly estimated by the same individual on protected plots during 3 periods, 1-10 March, 17-28 April, and 11-12 June, by comparing production on protected plots with previously unmarked, randomly selected plots adjacent to established sets. Unmarked plots were clipped at ground level and dry weight of biomass was determined (Pechanec and Pickford 1937). Percent use was also ocularly estimated at each set by comparing the protected and grazed plots during the same 3 time periods. Also, during the 1-10 March period, the percentage of the ground visually imprinted by tracks on each continuously grazed plot was ocularly estimated to the nearest 5% interval.

Pellet groups were counted during the mid-tillering stage on 26-28 March using 1.2 m wide strip transects. Because of the range in size and shape of fields, transects varied in length from 1,000-5,000 m. To approximate the same level of use received by the paired plots, transects were located parallel to and 10-20 m from the edge of wheat fields. Increased vegetative growth of wheat foliage prevented counts of both tracks and pellet groups at later dates.

To determine differences in grain yield among trials, we used the mean value of treatments for each field in a single classification analysis of variance with unequal sample sizes (Sokal and Rohlf 1981). We tested treatments among trials as experimental units because treatments (big game use) were the same.

To determine differences in wheat yield within trials, we used paired plots as experimental units. Because differences in levels of use by big game were highly variable among trials, each trial was considered a separate experiment for this part of our analysis. Our analyses included using a *t*-test for paired comparisons where only protected and grazed plots were established, and single classification analysis of variance where each set contained 3-5 plots. Level of significance was set at $P = 0.05$. An exception occurred during trial 12 where 14 plots were inadvertently destroyed during commercial harvest. In this trial the 9 complete sets were analyzed by a single classification analysis of variance, and the entire data set was analyzed using a single classification analysis of variance with unequal sample sizes (Sokal and Rohlf 1981). Conclusions were the same, and data from the 9 complete sets are presented. We also used product-moment correlation (Sokal and Rohlf 1981) to obtain the coefficient of determination to estimate grain yield as a determinant of total biomass for each treatment within each trial.

RESULTS

No differences in grain yield were found among trials due to treatments ($F = 0.17$; 5,35 df; $P > 0.50$). Furthermore, no decreases in wheat yield within any trial were found between plots protected and variously grazed by big game (Table 1). During trial 7 a significant increase in grain production occurred on the grazed plots, and during trial 11 a significant decrease in production was found between plots protected and continuously grazed with clipping; the latter constituted a more severe impact than normally would be expected with grazing alone.

Size of wheat fields varied from 2.0-27.4 ha, and the period of treatment protection during snow-free conditions varied from 83-255 days (Table 2). Combined big game use (deer + pronghorn + elk) ranged from 5-219 days/ha, and total pellet groups counted in March ranged from 29-431/ha. Track cover ranged from 10-53%. Biomass production was low in fall ($\bar{x} = 20$ g m^{-2}), increased rapidly during spring ($\bar{x} = 113$ g m^{-2}), and summer ($\bar{x} = 360$ g m^{-2}), and slowly increased after mid-June until harvest ($\bar{x} = 442$ g m^{-2}). Use of wheat forage varied from 9-60% during fall, decreased to 0-28% by spring, and was only -4-10% by early summer.

A significant decrease ($t = 5.06$, 7 df, $P = 0.01$) in grain yield was found between unprotected grazed plots ($\bar{x} = 186$ g m^{-2}) and plots grazed and later clipped during jointing ($\bar{x} = 79$ g m^{-2}). Coefficients of determination between biomass and grain weight were very high ($\bar{x} = 0.86$, SE = 0.13, $n = 41$); for 22 coefficients $r^2 > 0.90$.

DISCUSSION

Although studies on cereal grain depredation by big game are limited, numerous studies relating grain yield to various types and timing of foliage removal are available. Grazing of cereal grains by livestock in fall and spring during tillering growth stages, but before jointing, has been a common farming practice throughout most of the United States. Farmers apparently receive forage benefits of livestock grazing while experiencing no loss of grain yields (Swanson 1935). However, when sheep were allowed to remove all of the available wheat, rye, oats, and barley once in the fall and again in the spring, yield losses were 23.2, 28.6, 38.6, and 46.7%, respectively (Washko 1947). Cattle grazing on wheat, rye, and oats resulted in a mean increase in yield of 14% under fall grazing, a mean decrease of 19% under spring grazing, and a mean decrease of 6% under combined fall and spring grazing, for the 3 species (Sprague 1954). Neither of these studies considered jointing phenology.

Dunphy et al. (1982, 1984) in their literature review and clipping studies determined the critical period of herbage removal with respect to grain yield was at the initiation of the jointing stage. Apparently, herbage removal during the jointing stage removes the main stem growing point, and kernel yield becomes dependent on the development of alternative, but weaker, shoots. Their papers indicated herbage removal before jointing would have little or no effect on grain yield, whereas herbage removal during the jointing stages would decrease yield, especially if herbage were removed during the later jointing stages. Our results clearly show that herbage removal before jointing has no effect on grain yield. The conclusions of Dunphy et al. (1982, 1984) and the parallel research by Torbit et al. (1993) are confirmed with this finding.

Our data also indicate that grazing in wheat fields by big game following jointing did not decrease yield. Even though we observed big game grazing in wheat fields following initiation of jointing, we found no herbivory removal of wheat leaves or stems. Indeed we consistently observed big game grazing weeds within wheat fields. These weeds included field bindweed (*Convolvulus arvensis*), common sunflower (*Helianthus annuus*), blue mustard (*Chorispora tenella*), prickly lettuce (*Lactuca serriola*), western salsify (*Tragopogon dubius*), and tumble mustard (*Sisymbrium altissimum*). This dietary shift from grasses to forbs in mid to late spring is consistent with other reports (Austin and Urness 1983, Torbit et al. 1993, Willms and McLean 1978). Although no data were

Table 1. Site parameters and wheat grain harvested (g m^{-2}) from plots protected from or grazed by big game, in Utah.

Trial	Harvest year	Area of field (ha)	Date established	Harvest date	No. snow-free days	Treatments[a]					
							Grazed				
						Protected	Continuously	Continuously and clipped	Fall	Spring	Summer
1	1990	2.0	4/10	7/1	83	360A	381A	—	—	—	—
2	1991	7.7	4/3	8/2	114	76A	75A	—	—	76A	71A
3	1991	25.2	11/7	8/6	196	143A	155A	—	142A	157A	160A
4	1992	7.6	10/3	7/7	202	110A	126A	—	—	—	—
5	1992	11.5	10/8	7/16	206	207A	212A	—	230A	208A	214A
6	1992	14.0	10/1	7/7	204	210A	217A	—	—	—	—
7	1992	8.0	8/28	7/24	255	50A	61B	—	—	—	—
8	1992	12.7	9/23	7/15	220	135A	140A	125A	—	—	—
9	1992	10.3	10/15	7/17	200	217A	226A	—	218A	210A	222A
10	1992	27.4	10/17	7/10	191	173A	181A	159A	—	—	—
11	1992	5.2	11/4	7/8	171	281A	264AB	236B	—	—	—
12	1992	11.7	11/6	7/19	180	308A	275A	—	326A	376A	290A

[a]Within row, means with the same letter are not significant at $P < 0.05$.

collected, we observed during our harvest clipping of plots that several protected plots contained a much higher density of weeds than the paired grazed plots. The increase in uncontrolled weeds may have reduced grain yield.

We selected trial locations where big game use reportedly was high and, in most cases, the landowner had complained about depredation damage. Our indices reflect moderate to high levels of use at most locations during fall and spring and low levels of summer use. Use by mule deer occurred at all trials with elk or pronghorn use observed at additional trials. Use was particularly high at trial 11 (Table 2). During this trial, deer and elk use in the fall and early spring accounted for counts of >400 pellet groups/ha, >50% track cover, and 60% utilization of the fall foliar biomass. Unfortunately, none of our counts were taken when a herd of about 150 elk were using the trial area. Nonetheless, by early spring, extreme differences in herbage production were visually obvious between grazed and protected plots, and a decrease in grain yield was anticipated. However, no significant loss was found, similar to the conclusions of Kahl and Samson (1984). These results suggest that effective grain yield is dependent on other factors, such as soil moisture and temperature, and not upon herbage removal during fall or early spring. Still, at some level of intensive use exceeding the levels we measured, a decrease in grain yield would be realized as suggested by our grazing-plus-clipping treatment during trial 11.

We observed 2 conditions where grain yield was probably reduced on small portions of wheat fields. In trial 12, deer and elk trampled trails, which bisected our plots, during spring and summer to a perennial spring at the edge of the wheat field. Even though no significant losses were detected, trampling of trails in mature wheat appeared to have caused some loss of grain. A second condition which likely could reduce grain yield was observed outside of our study areas. Big game in late fall or early winter scraped away the protective snowcover in small areas to reach the wheat foliage. Apparently, sudden exposure of the plants to harsh climatic conditions, including frost heaving, affected yield.

Our high coefficients of determination (r^2) values indicated that biomass may be used in place of grain weight to estimate effects of ungulates on yield in future investigations. We also suggest that weeds as well as wheat be separately harvested from plots to determine interactions between big game grazing, weed production, and grain yield. Furthermore, because of the high variability in nighttime counts, numerous observations should be taken (Mullen and Rongstad 1979).

The application of these results to big game and farm management is unusual. Unlike results from depredation studies on alfalfa (Austin and Urness 1993, Palmer et al. 1982) and mature apple orchards (Austin and Urness 1989, Katsma and Rusch 1980) where big game use caused significant crop loss, grain yield loss of wheat is minor. Although additional studies may be needed, a compatible relationship between big game grazing and dryland wheat farming potentially exists. That is, similar to planned grazing by livestock, landowners may receive dual economic benefits from harvest of big game, through hunter access fees or personal harvest of wildlife, and unaffected harvest of wheat. This additional benefit could provide cooperative incentives for landowners and wildlife managers for reduced land use conflicts and improved big game management.

Table 2. Indices of big game use and estimates of wheat biomass production on depredation study areas in Utah.

	Big game days/ha from nighttime-counts (SE)									Spring[c] pellet groups/ha	
	Mule deer			Pronghorn			Elk				
Trial No.	Fall[a]	Spring	Summer	Fall	Spring	Summer	Fall	Spring	Summer	Deer and pronghorn	Elk
1	—	5(3)	0	—	0	0	—	—	—		
2	—	9(12)	20(40)	—	0	0	—	0	—	—	—
3	11(6)	9(9)	13(17)	0	0	0	0	—	0	—	—
4	52(42)	0	0	0	0	0	0	0	0	31	0
5	43(43)	29(8)	9(15)	0	0	0	0	0	0	56	0
6	12(17)	0	2(6)	6(17)	0	0	0	0	0	54	0
7	14(17)	0	1(2)	4(11)	42(4)	0	0	0	0	78	0
8	53(32)	13(12)	0	0	0	0	0	0	0	55	0
9	134[b]	20(22)	7(12)	0	0	0	0	0	0	29	0
10	23[b]	50(15)	0	0	0	0	0	0	0	188	0
11	21(4)	39(18)	12(31)	0	0	0	26(3)	4(6)	0	89	342
12	26(17)	33(42)	44(35)	0	0	0	27(32)	48(13)	41(71)	41	135

[a]Fall-between fall planting and 28 February, Spring-1 March to 15 April, Summer-16 April to harvest.
[b]Only one count available for the fall period.
[c]Data collected 3/26-28 March, during mid-tillering growth period.

Table 2. Extended.

Spring[d] % track cover	Estimated % use of wheat			Estimated biomass production (g m^{-2})			
Deer, pronghorn, and elk	Fall[e]	Spring[f]	Summer[g]	Fall[e]	Spring[f]	Summer[g]	Harvest
—	—	—	—	—	—	—	891
—	—	—	0	—	—	—	213
—	—	—	1	—	—	—	391
22	23	5	-1[h]	15	63	267	272
11	9	9	8	13	72	484	507
30	30	13	5	21	241	394	512
10	15	13	-4[h]	30	74	202	197
50	58	25	10	15	62	214	293
20	20	0	3	26	106	388	461
32	38	31	5	23	97	308	418
53	60	16	8	24	179	408	638
42	33	28	6	16	126	576	679

[d]Percent track coverage between elk and deer plus pronghorn was not separated. Data collected 1-10 March, mostly before spring growth began.

[e]Data collected 1-10 March, mostly before spring growth began.

[f]Data collected 17-28 April, at the beginning of the jointing period.

[g]Data collected 10-13 June, plants beginning to dry.

[h]Biomass estimate was greater on the continuously grazed rather than protected plots.

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