Evaluation of Fertilizer on Pronghorn Winter Range in Alberta

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Abstract

Nitrogen (N) alone, and in combination with phosphorus (P), was applied to sagebrush (*Artemisia cana*)-grassland vegetation which formed part of a traditional winter range for pronghorns (*Antilocapra americana*) in southeastern Alberta. Fertilizer was applied once, in April of 1975, and forage quality, forage production, and pronghorn response were monitored for the next three growing seasons. Forage quality on fertilized plots increased initially, but by late summer of each year, nutritional content was essentially similar in fertilized and control areas. Forage production increased markedly in each of the 3 years. The application of P in addition to N had little impact on forage quality and production. In year two and three following fertilizer treatment, N levels of 84, 168, and 252 kg/ha resulted in progressively more forage produced with each increase in N. Pronghorns selectively utilized the fertilized plots more heavily than adjacent control areas. The inability to increase protein content in cured samples of sagebrush and pasture sage through fertilizer treatment detracts from the value of this procedure for improving pronghorn winter ranges. The general increases in total forage production and hence total protein production and the preference of pronghorns for treated areas, however, suggest that the procedure should be evaluated further.

For many years wildlife managers have been investigating the nutritional requirements of most species of indigenous ungulates (Bandy et al. 1956; French et al. 1956: Dietz 1965; Murphy and Coates 1966; Ullrey et al. 1967; Nagy et al. 1969). More recently, greater emphasis has been placed on the interactions of range quality, environmental factors, and bioenergetics in determining the welfare of wildlife (Silver et al. 1969, 1971; Ullrey et al. 1970; Nordan et al. 1970; Wesley et al. 1973). There has also been a proliferation of literature concerning the nutrient content of a wide variety of plant species consumed by wildlife. Some authors have outlined nutritional limitations in forage available to ungulates (Nagy et al. 1969; Ullrey et al. 1971). Wallmo et al. (1977) have modelled the protein and energy requirements of mule deer (*Odocoileus hemionus hemionus*) and suggest that estimates of carrying capacity of ranges for wildlife should reflect the nutrient supplies available.

Range managers have conducted extensive research into the value of fertilizer as a tool for increasing the quality and quantity of forage produced for domestic livestock. Wight (1976) reviewed the effect of fertilizer in the Northern Great Plains region and concluded that nitrogen (N) in particular, greatly increased forage production, water-use efficiency, forage quality, and palatability. Fertilizer application on traditional big game ranges has been explored on a limited basis for years (Gibbens and Pieper 1962; Wood and Lindzey 1967; Bailey 1968; Abell and Gilbert 1974; Anderson et al. 1974; Bayoumi and Smith 1966; George and Powell 1977) but despite obvious potential, the practice has never become a widely used tool of wildlife management.

In Alberta, winter range is critical for the survival of pronghorns (*Antilocapra americana*), as the quality of forage and the distribution of suitable vegetation types within the pronghorn winter range are limited (Barrett 1974). Numerous fertilizer trials have been conducted on the semiarid grasslands of the northern Great Plains (Kilcher et al. 1965; Johnston et al. 1967; Lorenz and Rogler 1973) but no study has focussed on the sagebrush (*Artemisia cana*)-grassland vegetation type that constitutes the critical element of pronghorn winter ranges in Canada. Furthermore, no information appears available on the results of fertilizer on any pronghorn winter range.

The general objectives of this study were to evaluate the effects of nitrogen and phosphorus (P) fertilizer on a traditional pronghorn winter range in Alberta. Specifically, efforts were made to document changes in (1) nutrient content of forage, (2) forage production, and (3) pronghorn response to forage as a result of fertilizer application.

Study Area and Methods

The study area was a fenced 256-ha pronghorn enclosure located in the extreme southeastern corner of Alberta. The enclosure was established in 1973 and is situated on a portion of a traditional pronghorn winter range. As part of a long-term study on the carrying capacity of winter range, about 22 pronghorns were contained continuously in the enclosure at the time the fertilizer trials were conducted from April 1975 to November 1977. All fertilized plots were located within the enclosure but the total plot area represented less than 0.1% of the enclosure.

The study area is located in the Brown soil zone; the climate is semiarid. Mean annual precipitation (1941-1970) in the area as measured at the Agriculture Canada Research Sub-Station, Manyberries, 22 km southwest from the enclosure, is only 327 mm. Precipitation from April to July, inclusive, for the 3 years of the fertilizer trial was 295, 175, and 14 mm for 1975, 1976, and 1977, respectively (S. Smoliak, pers. comm.). General descriptions of the area have been presented by Coupland (1950; 1961) and by Mitchell and Smoliak (1971). Specifically, the fertilized sites reflected a sagebrush-grassland vegetation type (Fig. 1). The most prevalent browse, forb, and grass species, as determined by point quadrat analysis, were sagebrush, pasture sage (*A. frigida*), and western wheatgrass (*Agropyron smithii*). The sagebrush-grassland vegetation type was selected because of its importance in providing winter range for pronghorns in Alberta (Mitchell and Smoliak 1971; Barrett 1974).

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Fig. 1. *Sagebrush-grassland range on which fertilized plots were located. This vegetation type is heavily used as winter range by pronghorns in Alberta.*

Three rates of N and three rates of N plus P were applied on test plots. Firstly, ammonium nitrate was applied in combination at the rates of 84N-39P, 168N-78P, and 252N-118P kg/ha. P was applied in the form of triple superphosphate. Each of the six treatments was replicated twice, producing a total of 12 experimental plots. Two adjacent areas were used as control plots for each replicate. Plot size was 6 × 15 m. Treatment was assigned to each plot on a completely random basis. A hand-held cyclone seeder was used to apply the single application of fertilizer on April 29, 1975; at that time no visible sign of spring growth was evident.

Forage for chemical analyses was collected from each of the fertilized plots and control areas on five occasions, namely, June 1975, September 1975, October 1975, August 1976, and August 1977. Each collection consisted of a composite sample of sagebrush, pasture sage and western wheatgrass, representing the dominant species of browse, forb, and grass, respectively. Portions of current year's growth collected from 20 to 40 individual plants of each species were pooled to obtain the forage class sample from each plot for chemical analyses. Using standard analytical techniques of the AOAC (1960) determinations for moisture, protein, calcium, phosphorus, and fiber were conducted. Values for treatments were averaged for presentation and all results are expressed on a dry weight basis.

During late October 1975, soil samples from each control area were collected from depths of 0–10 cm, 10–30 cm, and 30–60 cm; the three collections were analyzed separately. Using standard techniques N, P, potassium (K), conductivity, and pH values were obtained.

In August, after the growing season, forage production was determined for three consecutive years following fertilizer application. Twenty ¼ m² areas were clipped in each of the fertilized plots and control areas. Total annual production of browse, forbs, and grasses was separated, oven-dried and weighed. Data from each replicate are combined for presentation.

Leader lengths of sagebrush in each plot were sampled. In October of 1975, 1976, and 1977, 100 leaders were measured in each plot. In 1976 and 1977, an additional 400 leaders were measured from adjacent protected areas which received no ungulate browsing. Leader lengths reflected the current year's growth only. Values obtained for each treatment replicate are combined for presentation.

The plots were inspected periodically for evidence of use by pronghorns. In November of 1977, fecal pellet counts were made in ten 1-m² plots in each of the fertilized plots and 50 1-m² plots in the adjacent control areas. At the same time, the proportion of leaders browsed on sagebrush inside each fertilized plot and in the adjacent control areas were determined using Cole's (1963) method for random transects.

Differences between sets of means were examined for statistical significance using the *t* test. Minimum level of probability for statistical significance was $P<0.05$.

Results

Protein content of sagebrush, pasture sage and western wheatgrass is summarized for the fertilizer treatments at each sampling period in Table 1. Sagebrush sampled from fertilized plots had a mean protein value significantly greater than the respective control value on June 1975 and August 1976; no significance existed between the different fertilizer rates. Protein values in samples of sagebrush collected in late summer, while generally higher than control values, were not enhanced significantly by fertilizer. Similarly, pasture sage from fertilized plots collected after the growing season did not have significantly increased protein values relative to controls (Table 1). Differences in fertilizer application rates did not produce significant differences in the protein content of pasture sage. Western wheatgrass had significantly greater protein values in samples from fertilized plots as compared to controls on each sampling occasion except August, 1977 (Table 1). The mean protein content of western wheatgrass increased progressively with each increase in N fertilizer; the mean protein value for 252 kg/ha N plots was significantly ($P<0.05$) greater than the mean protein content in western wheatgrass from the 84 kg/ha N plots. The relative increase in protein content following the application of N was more pronounced in western wheatgrass than in pasture sage or sagebrush.

Table 1. Summary of protein content (%) of sagebrush, pasture sage, and western wheatgrass following fertilizer treatment in April, 1975[1].

Forage sampled	Sampling date June 1975	Sept. 1975	Oct. 1975	Aug. 1976	Aug. 1977
Sagebrush					
Treatment mean	20.9a[2]	12.4a	7.3a	10.9a	12.2a
Control	16.7b	11.4a	7.3a	9.5b	11.6a
Pasture sage					
Treatment mean	18.7a	11.8a	8.9a	10.6a	9.7a
Control	13.6b	10.5a	8.2a	9.4a	8.7a
Western wheatgrass					
Treatment mean	17.0a	8.2a	5.6a	8.1a	8.8a
Control	10.1b	5.5b	3.9b	5.9b	7.3a

[1] For each sampling date, the mean value for each species reflects the average of all six fertilizer treatments.
[2] Within any column, the mean and control for a given forage species are significantly different ($P<0.05$) if the values are followed by a different letter.

Protein content of control samples collected in September 1975 and August 1976 and 1977 were compared for the three forage classes. Over the 3 years, the mean late summer protein content of sagebrush, pasture sage, and western wheatgrass was 10.8, 9.5, and 6.2%, respectively. The species means were significantly different ($P<0.05$).

No consistent changes in calcium, phosphorus, calcium/-phosphorus ratio, or fiber content of sagebrush, pasture sage, and western wheatgrass were evident as a result of fertilizer application. Consequently, analytical values obtained for fertilized and control samples were pooled (Table 2). The August and September samples of sagebrush had significantly more calcium and phosphor content than did samples of pasture sage or western wheatgrass. Of all parameters examined sagebrush contained higher nutrient values than did pasture sage or western wheatgrass (Table 2).

Analytical data for soil collected from the control areas are presented in Table 3. In general, soil in the test areas was deficient in nitrogen and rich in phosphorus and potassium.

Table 2. Chemical analyses of forage collected on pronghorn winter range in Alberta in late summer of 1975 to 1977, inclusive.

	Forage sampled								
	Sagebrush			Pasture sage			Western wheatgrass		
Parameter	n	Mean*	*S.D.*	n	Mean	*S.D.*	n	Mean	*S.D.*
Calcium (%)	48	0.98a	0.24	43	0.76	0.16	48	0.55c	0.16
Phosphorous (%)	48	0.36a	0.08	41	0.22b	0.03	48	0.14c	0.03
Calcium/phos. ratio	48	2.72a	0.73	41	3.45b	1.06	48	3.93b	1.32
Fiber (%)	48	34.42a	3.36	41	40.26b	3.06	48	41.39b	2.36

* Each mean was derived by pooling data for all fertilizer levels and control areas, and represent August and September samples only.
[a] Within any row, means which are significantly different ($P<0.05$) are denoted by a different letter.

Table 3. Analytical data for soil collected from control plots in October, 1975. Data from the four control plots were averaged to obtain values below.

	Soil elements (kg/ha)				
Depth of sample (cm)	N	P	K	Soil pH	Conductivity (mmhos.)
0–10	5.9	69.1	1003.7	7.3	0.2
10–30	2.8	36.2	1047.2	7.9	0.3
30–60	2.0	28.1	879.3	8.5	0.9

Forage Production

Increases in grass and total forage production were evident at each level of fertilizer application in the year of treatment (Table 4). The largest increases occurred for the grass component. Although the general conditions for plant growth deteriorated from 1975 through 1977, the increased yield of vegetation in response to fertilizer treatment was apparent in each year. The values in Table 4 do not include cactus (*Opuntia* sp.) growth because of the sporadic distribution of this species and the potential of distorting forb production for any treatment plot. Slight increases in grass and browse production, although not significant, were still evident on fertilized plots after three growing seasons (Table 4).

Increased forage production as a result of N+P application was not evident when compared to corresponding levels of N fertilizer alone (Table 4). Consequently, forage produced for each level of N, with and without P, was combined to further examine the differences between the three levels of N application (Fig. 2); these values reflect total forage produced, including cactus. In 1975, total forage production on the fertilized plots was significantly higher ($P<0.05$) for each level of N than on control plots but no significant difference existed between the fertilizer levels. In 1976 and 1977, forage production increased consistently with each corresponding increase in N application. The 1976 and 1977 forage increases, while biologically important, were not statistically different between fertilizer levels or between each fertilizer level and control.

Sagebrush Growth and Pronghorn Utilization

The mean leader lengths of sagebrush in response to different levels of N are summarized in Table 5. Consistently longer leaders were documented only in 1975, but presumably as a result of the great variability in individual leader lengths, the differences between the values for fertilized and control plots were not statistically significant. In each year, the growth of sagebrush in fertilized plots appeared more vigorous than in control areas, but the differences were not measurable by October of each year. By comparison, mean leader lengths of sagebrush in areas protected from browsing was 8.1 cm in 1976 and 10.5 cm in 1977.

On numerous inspections each summer, increased use of the fertilized plots by pronghorns was evident. All species of grass,

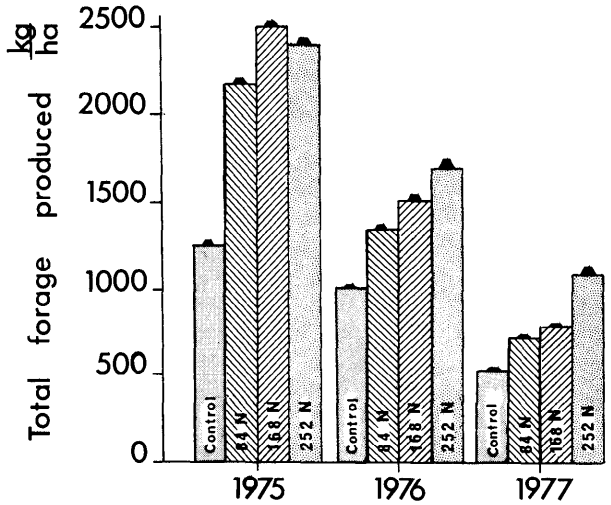

Fig. 2. *Annual forage production on pronghorn winter range following fertilizer application in April, 1975. Projection at apex of each histogram represents one standard deviation.*

Table 4. Annual forage production (kg/ha) on sagebrush-grassland vegetation type in Alberta as determined one, two, and three growing seasons after fertilizer treatment.

Fertilizer rate (kg/ha)		Forage production (kg/ha)											
		First growing season, 1975				Second growing season, 1976				Third growing season, 1977			
N	P	Grasses	Forbs*	Browse	Total*	Grasses	Forbs*	Browse	Total*	Grasses	Forbs*	Browse	Total*
84	0	1403.9[a]	35.2	141.6	1580.7[a]	964.6	6.0	111.5	1082.1	134.2	24.4	240.2	398.8
84	39	1701.3[a]	29.6	806.1[a]	2537.0[a]	1063.7[a]	12.4	96.7	1172.8[a]	308.7	13.4	230.3	552.4
168	0	1883.9[a]	45.8	615.2	2544.9[a]	839.2	7.7	199.5	1046.4	337.2	4.2	378.7	720.1
168	78	1788.7[a]	42.8	483.8	2315.3[a]	1002.4[a]	6.8	55.3	1064.5	297.5	2.6	206.5	506.6
252	0	1717.7[a]	37.0	657.6	2412.3[a]	964.7	3.9	405.9	1374.5[a]	284.9	4.0	441.3	730.2
252	118	1640.2[a]	39.0	354.5	2033.7[a]	919.2	26.3	202.3	1147.8	298.5	20.0	304.5	623.0
Control		928.2	30.8	264.9	1223.9	747.7	21.4	190.1	959.2	275.1	17.9	177.5	470.5

* These forage production values do not include data for *Opuntia* sp. which was encountered sporadically.
[a] Within any column, values which are significantly different ($P<0.05$) than control values, are denoted by a letter.

Table 5. Mean leader lengths (cm) of sagebrush associated with different levels of nitrogen fertilizer on pronghorn winter range.

Nitrogen rate[a] (kg/ha)	n	Mean leader length[b] (cm) 1975 Mean	1975 S.E.	1976 Mean	1976 S.E.	1977 Mean	1977 S.E.
84	400	9.28	0.28	6.23	0.20	5.28	0.18
168	400	9.90	0.33	7.08	0.20	5.78	0.20
252	400	9.80	0.33	6.70	0.23	6.30	0.20
Control	400	7.63	0.25	6.65	0.15	5.75	0.23

[a] Fertilizer applied on April 29, 1975.
[b] Based on current year's growth as measured in October of each year.

forbs, and browse appeared to be more heavily utilized inside each fertilized plot than in adjacent areas. A count of pronghorn fecal pellets in November 1977 indicated that 20.8% more pellets were located in fertilized plots than in adjacent control areas. Similarly, a browse use study conducted in November 1977, showed that 34.4% of the 420 sagebrush leaders examined inside fertilized plots were browsed while only 17.5% of 350 leaders examined in adjacent control areas were browsed; these differences were high significant ($P<0.01$). Although supporting quantitative data are unavailable, signs indicated that pronghorns consumed significantly more grasses and forbs from within fertilized plots than from control areas.

Discussion

Forage Quality

The lack of persistent increases in protein content of forbs and browse sampled from fertilized plots represents a limitation in the value of the technique for improving pronghorn winter range in Alberta. Although forage quality of cured plants was not enhanced greatly by fertilization, increased dry matter production, and hence increased total protein yield, resulted. Protein content in winter samples of sagebrush collected from Alberta winter ranges was only 7.6 (Barrett 1974) and appears to be less than optimal for overwintering pronghorns. Murphy and Coates (1966) reported that deer restricted to dietary protein rations of only 7% were less productive, had lower survival, and were in poorer condition than animals on a higher protein diet; pronghorn requirements may be similar to those of deer.

Pronghorns in Alberta do not appear restricted in terms of available summer nutrition and therefore little emphasis was placed on monitoring the forage quality during the growing season. Pronghorns would derive the most benefit by increasing protein values in sagebrush and pasture sage during the fall and winter. Our findings, however, were consistent with most studies conducted in the Great Plains which showed that fertilizer generally increases protein content of forage most significantly during the growing season (Goetz 1975a, 1975b; Hanson et al. 1976; Wight 1976). Goetz (1975b) reported a progressive decline in protein content of all grass species as they approached maturity, irrespective of fertilizer treatment. He also reported that fertilizer treatment accelerated the rate of protein loss in late summer. In my study, fall samples of western wheatgrass from fertilized plots (Table 1) reflected the effect of fertilizer application more than did corresponding samples of cured sagebrush or pasture sage. During fall and winter, however, pronghorns in Alberta consume practically no grass (Mitchell and Smoliak 1971; Barrett 1974).

The addition of P in combination with N, produced few consistent benefits in terms of increasing forage production or quality. A similar lack of significant response to P application was reported by Goetz (1975a), Bayoumi and Smith (1976), and Wight (1976). The phosphorus content in winter samples of sagebrush in Alberta was only 0.16% and probably reflected a near minimum concentration for overwintering pronghorns (Barrett 1974). Phosphorus content in cured forage did not appear to be augmented by the application of P fertilizer. By contrast, Johnston et al. (1968) observed an increase in P content of rough fescue (*Festuca scabrella*) on southern Alberta grasslands in the Black soil zone that received much higher rates of P fertilizer than used in my study.

Forage Production

Total forage production generally increased each year as a result of the single application of fertilizer (Table 4, Fig. 2). These findings are consistent with most reports on the effects of fertilizer on native range in the Northern Great Plains (Wight 1976). Treatment differences in total forage production as a result of differences in the rate of N application rates were not detected until the second and third growing seasons following fertilizer application (Fig. 2). Similarly, Wight (1976) stated that single applications of N at 56 kg/ha or less show limited carry-over effect, while applications of N over 112 kg/ha may have a residual effect for several years. Kilcher et al. (1965) reported that residual effects of 67 kg/ha N on grasslands in western Canada were evident for several years, probably as a consequence of low annual precipitation.

The production of forbs on fertilized plots was difficult to assess. Frequent visual inspections suggested that forb production on fertilized sites increased markedly each year but because pronghorns preferentially consumed them during the growing season, forb production was not accurately measured in August clippings. Also, growth of forbs in 1977 may have been restricted by the dry conditions during the growing season. An initial large increase in forb production following N fertilization, particularly at high application rates, has been reported by several authors (Kilcher et al. 1965; Johnston et al. 1967; Wight 1976). Wight (1976) indicated that pasture sage, in particular, responds readily to fertilizer but that the response decreases after the first year. Contrary to objectives for cattle grazing, increased forb production following fertilizer application would enhance the range for pronghorns but if the response of forbs is short-lived as Kilcher et al. (1965) suggested, then the technique is of less value.

Despite heavy utilization by pronghorns, increased browse production was a consistent measurable response to fertilizer treatment (Table 4). Increased leader length and a proliferation in growth of lateral twigs were most evident. The substantial increase in sagebrush production on fertilized plots, 3 years after treatment, was encouraging in view of the importance of sagebrush in the diet of pronghorns in Alberta (Mitchell and Smoliak 1971; Barrett 1974). The deep root system of sagebrush may account for the continuing response to fertilizer. Bayoumi and Smith (1976) reported an increase in production of big sagebrush (*A. tridentata*) in Utah following fertilizer application but they observed very little carry-over effect.

The great variation in total forage production between the 3 years of this study (Fig. 2) is a direct response to differences in precipitation. As the April to July precipitation declined from 295 mm in 1975 to only 175 mm and 114 mm in 1976 and 1977, respectively, forage production of grasses declined proportionately. The close relationship between spring precipitation and annual forage production in southeastern Alberta has been demonstrated by Smoliak (1956). Forage production may be particularly enhanced on dry years by fertilizer because of the better water use efficiency.

Palatability

Pellet group counts and forage utilization surveys indicated conclusively that pronghorns spent more time in fertilized plots and consumed significantly more of the available forage therein. Increased preference for fertilized range by domestic livestock has been a consistent finding. Similarly, fertilized range is usually preferentially utilized by wildlife (Gibbens and Pieper 1962; Anderson et al. 1974; Bayoumi and Smith 1976). Johnson et al. (1967) reported that hare (*Lepus townsendi*) pellets on native range increased proportionately with increased levels of N and N-P fertilizer. The ability of pronghorns to select higher quality forage in winter has been documented previously (Bruns 1969; Barrett 1974). The continuation of their selection for fertilized range during the growing season, when most plants are comparatively high in palatability, underscores the sensitivity of their ability to detect differences in forage quality.

This paper represents the first published information available on the influence of fertilizer application on pronghorn range and consequently, the results should be considered as preliminary. Some of the findings are encouraging and further studies are required to more fully evaluate the technique. Particular attention appears warranted on the long range effect of fertilizer on forb and browse production, species composition, and palatability of forage for pronghorns.

Literature Cited

Abell, D.H., and F.F. Gilbert. 1974. Nutrient content of fertilized deer browse in Maine. J. Wildl. Manage. 38:517-524.

Anderson, B.L., R.D. Pieper, and V.W. Howard, Jr. 1974. Growth response and deer utilization of fertilized browse. J. Wildl. Manage. 38:525-530.

A.O.A.C. 1960. Official methods of analysis (9th Ed.). Washington, D.C.

Bandy, P.J., I. McT. Cowan, W.D. Kitts, and A.J. Wood. 1956. A method for the assessment of the nutritional status of wild ungulates. Can. J. Zool. 34:48-52.

Bailey, J.A. 1968. Effects of soil fertilization on the concentration of crude protein in witchhobble browse. New York Fish and Game J. 15:155-164.

Barrett, M.W. 1974. Importance, utilization, and quality of *Artemisia cana* on pronghorn winter ranges in Alberta. Proc. Sixth Antelope States Workshop. 26-57.

Bayoumi, M.A., and A.D. Smith. 1976. Response of big game winter range vegetation to fertilization. J. Range Manage. 29:44-48.

Bruns, E.H. 1969. A preliminary study of behavioural adaptations of wintering pronghorn antelopes. M Sc Thesis, Univ. Calgary, Calgary, Alta. 60 p.

Cole, G.F. 1963. Range survey guide. U.S. Dep. Int., Nat. Park Service, Moose, Wyo.

Coupland, R.T. 1950. Ecology of mixed prairie in Canada. Ecol. Monogr. 20:272-315.

Coupland, R.T. 1961. A reconsideration of grassland classification in the Northern Great Plains of North America. J. Ecol. 49:135-167.

Dietz, D.R. 1965. Deer nutrition research in range management. Trans. North Amer. Wildl. Nat. Res. Conf. 30:275-285.

French, C.E., L.C. McEwen, N.D. Magruder, R.H. Ingram, and R.W. Swift. 1956. Nutrient requirements for growth and antler development in the white-tailed deer. J. Wildl. Manage. 20:221-232.

George, J.F., and J. Powell. 1977. Deer browsing and browse production of fertilized American elm sprouts. J. Range Manage. 30:357-360.

Gibbens, R.P., and R.D. Pieper. 1962. The response of browse plants to fertilization. California Fish and Game 48:268-281.

Goetz, H. 1975a. Availability of nitrogen and other nutrients on four fertilized range sites during the active growing season. J. Range Manage. 28:305-310.

Goetz, H. 1975b. Effect of site and fertilization on protein content of native grasses. J. Range Manage. 28:380-385.

Hanson, C.L., G.A. Schumaker, and C.J. Erickson. 1976. Influence of fertilization and supplemental runoff water on production and nitrogen content of western wheatgrass and smooth brome. J. Range Manage. 29:406-409.

Johnston, A., S. Smoliak, A.D. Smith, and L.E. Lutwick. 1967. Improvement of southeastern Alberta range with fertilizers. Can. J. Plant Sci. 47:671-678.

Johnston, A., L.M. Bezeau, A.D. Smith, and L.E. Lutwick. 1968. Nutritive value and digestibility of rough fescue. Can. J. Plant Sci. 48:351-355.

Kilcher, M.R., S. Smoliak, W.A. Hubbard, A. Johnston, A.T.H. Gross, and E.V. McCurdy. 1965. Effects of inorganic nitrogen and phosphorus fertilizers on selected sites of native grassland in western Canada. Can. J. Plant Sci. 45:225-237.

Lorenz, R.J., and G.A. Rogler. 1973. Growth rate of mixed prairie in response to nitrogen and phosphorus fertilizer. J. Range Manage. 26:365-368.

Mitchell, G.J., and S. Smoliak. 1971. Pronghorn antelope range characteristics and food habits in Alberta. J. Wildl. Manage. 35:238-250.

Murphy, D.A., and J.A. Coates. 1966. Effects of dietary protein on deer. Trans. North Amer. Wildl. Nat. Res. Conf. 31:129-139.

Nagy, J.G., T. Hakonson, and K.L. Knox. 1969. Effects of quality on food intake in deer. Trans. North Amer. Wildl. Nat. Res. Conf. 34-146-154.

Nordan, H.C., I. McT. Cowan, and A.J. Wood. 1970. The feed intake and heat production of the young black-tailed deer (*Odocoileus hemionus colubianus*). Can. J. Zool. 48:275-282.

Silver, H., N.F. Colovos, J.B. Holter, and H.H. Hayes. 1969. Fasting metabolism of white-tailed deer. J. Wildl. Manage. 33:490-498.

Silver, H., J.B. Holter, N.F. Colovos, and H.H. Hayes. 1971. Effect of falling temperature on heat production in fasting white-tailed deer. J. Wildl. Manage. 35:37-46.

Smoliak, S. 1956. Influence of climatic conditions on forage production of shortgrass rangeland. J. Range Manage. 9:89-91.

Ullrey, D.W., W.G. Youatt, H.E. Johnson, L.D. Fay, and B.L. Bradley. 1967. Protein requirements of white-tailed deer fawns. J. Wildl. Manage. 31:679-685.

Ullrey, D.E., W.G. Youatt, H.E. Johnson, L.D. Fay, B.L. Schoepke, and W.T. Magee. 1970. Digestible and metabolizable energy requirements for winter maintenance of Michigan white-tailed does. J. Wildl. Manage. 34:-863-869.

Ullrey, D.E., W.G. Youatt, H.E. Johnson, L.D. Fay, D.B. Purser, B.L. Schoepke, and W.T. Magee. 1971. Limitations of winter aspen browse for the white-tailed deer. J. Wildl. Manage. 35:732-743.

Wallmo, O.C., L.H. Carpenter, W.L. Regelin, R.B. Gill, and D.L. Baker. 1977. Evaluation of deer habitat on a nutritional basis. J. Range Mange. 30:-122-127.

Wesley, D.E., K.L. Knox, J.G. Nagy. 1973. Energy metabolism of pronghorn antelopes. J. Wildl. Mange. 37:563-573.

Wight, J.R. 1976. Range fertilization in the Northern Great Plains. J. Range Manage. 29:180-185.

Wood, G.W., and J.S. Lindzey. 1967. The effects of forest fertilization on the crude protein, calcium, and phosphorus content of deer browse in a mixed oak forest. Pennsylvania Coop. Wildl. Res. Unit Pap. 126.