# Foliar-applied Urea and Ammonium Nitrate Fertilizers on Shortgrass Range

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**Highlight:** *Liquid foliar applications of urea-N fertilizer were compared with dry and foliar applications of ammonium nitrate-N fertilizer for 3 years, 1969-71. The fertilizers were applied in December, May, June, and July each year on separate plots. Treatments were repeated each year on the same plots. The source of N was far more important than method of application. Whether applied in dry form or as foliar application, the ammonium nitrate-N was superior to urea-N for increasing herbage yields, crude-protein content, and protein yields when applied in December, June, or July. When applied in May, both sources of N were equally effective, regardless of method of application. Ammonium nitrate-N in water solution may be applied as late in the growing season as early July with favorable results. The ammonium nitrate-N applied in July increased nitrate-N in herbage in the third year, although not to toxic levels.*

Previous research in the Great Plains has shown that both yield and protein content of range herbage can be increased by the use of nitrogen (N) fertilizers (Klipple and Retzer, 1959; Rogler and Lorenz, 1957). Although both low soil moisture and N availability restrict herbage production, the N supply is the most readily increased.

Increased crude-protein content of herbage can be important for livestock production. Crude-protein levels in range forage are often low—even below required nutrient levels—for 6 to 8 months of the year. Crude-protein content is also generally associated with the important forage characteristics of palatability and digestibility (Whyte et al., 1962).

The form in which N is applied (dry, granular, or liquid) may influence the response of forage yields and crude-protein content as well as the source of N (urea-N or ammonium nitrate-N).

Over the past two decades the use of liquid N fertilizers has increased substantially. The primary use has been on horticultural and row crops and less commonly on forages. Many liquid fertilizers have a higher N content, cost less per pound of N, and are more easily handled than fertilizers in the dry form. On the other hand, liquid N fertilizers are corrosive, require special application equipment and storage containers, and are more dangerous to handle (Adams and Anderson, 1965).

The most common sources of nitrogen in liquid fertilizers are anhydrous ammonia, ammonium nitrate, and urea in various proportions. Anhydrous ammonia or water solutions of ammonia require pressure containers and injection into the soil to avoid gaseous losses. Pressure injection systems are not practical on most rangelands. Solutions containing ammonium nitrate and urea are non-pressure solutions and may be applied directly to the soil surface or to foliage.

Volk (1959) showed that 55 to 60% of the N from urea applied on the soil surface was lost as gas within 7 days, but only 20% was lost when the urea was applied to sod. Both Simpson (1968) and Simpson and Melsted (1962) found high gaseous losses of N from application of urea solutions to grasslands. However, Kresge and Satchell (1960) found little gaseous loss of nitrogen from low rates of dry urea applied on the surface of either bare acidic soil or sod on acidic soil, although substantial losses of gaseous nitrogen were found from high rates of urea applied in a water solution. Plant damage from the toxic ammonia and nitrite products of urea-N and losses in crop production have been shown by Court et al. (1964).

Foliar application of liquid fertilizers (or foliar feeding) is not a new technique. Boynton (1954) reviewed the history of the practice and showed distinct increases in total leaf N as well as leaf chlorophyll in apple orchards from application of a water solution of urea. Urea is probably the most widely used nutrient spray in crop production. It is taken up rapidly by most plants and is highly mobile in the plant. The absorption of urea, as with most nutrient sprays, is most rapid in the presence of leaf surface moisture (Volk and McAuliffe, 1954). Surfactants have been found to increase speed of entry of foliar applied nutrients (Dybing and Currier, 1961).

The objectives of this experiment were to compare the effects of urea and ammonium nitrate fertilizers as sources of N for increasing range herbage productivity, protein content, and protein yield and to compare foliar applications for urea-N with dry and foliar applications of ammonium nitrate-N.

## Area and Methods

The study was conducted in north-central Colorado on shortgrass range. The soil is Ascalon sandy loam, with a pH of 6.0 to 6.7 in the surface 2.5 inches. The native vegetation is

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This work represents the cooperative investigations of Agr. Res. Serv., U.S. Dep. Agr., and Colorado State University Experiment Station (Scientific Paper No. 1783).

Manuscript received September 30, 1972.

typical of the shortgrass plains.

The dominant species is blue grama (*Bouteloua gracilis* (H.B.K.) Lag. ex Steud.). Other abundant species are sun sedge (*Carex heliophylia* Mack.), plains pricklypear (*Opuntia polyacantha* Haw.), scarlet globemallow (*Sphaeralcea coccinea* (Pursh) Rydb.), and wooly indian-wheat (*Plantago purshii* Roem. and Schult.). Sixweeks fescue (*Vulpia octoflora* (Walt.) Rydb.) varies widely in abundance, depending on weather.

The treatments applied were 0, 20, and 40 lb of urea-N per acre and 40 lb of ammonium nitrate-N per acre. Treatments were applied in December of 1968, 1969, and 1970, and in mid-May, mid-June, and early July of 1969, 1970, and 1971. Each date of application was placed in a separate block, with three replications. Plot size was 15 by 50 ft. Treatments were repeated on the same plots each year. At each date of application, the urea-N was applied in a water solution to which 0.1 percent X-77 surfactant (v/v) was added. Rate of liquid application was 20 gal per acre. The ammonium nitrate-N was broadcast in dry form in December and in May each year. For the June and July applications, the ammonium nitrate was dissolved in water with surfactant added. A compressed-air plot sprayer was used for applying the aqueous solutions.

Total herbage was harvested from 4.8-ft$^2$ subplots. Plots treated in December and May were harvested in June, July, August, and September each year. Plots treated in June and July were harvested in July, August, and September. The herbage samples were oven-dried at 70°C. Samples were weighed and ground in a Wiley mill to pass through a 1 mm screen. Nitrogen content was determined by standard Kjeldahl method. Herbage samples from all harvest dates in 1969 and 1970 from the December application were analyzed for nitrate-N by the xylenol method described by Sabatka et al. (1972). In 1971, herbage samples from the first harvests of all dates of application were analyzed for nitrate-N by the method described by Johnson and Ulrich (1959). Species frequency was determined in late June each year (Hyder et al., 1965).

Statistical treatment was by conventional analysis of variance. Duncan's multiple range test (1955) was used to compare means.

## Weather

During the crop-year of 1969, total precipitation was 18% above average. Precipitation was 80% above average in June (Table 1). Precipitation was well below average during the crop-year of 1970 and slightly below average during 1971. In both years moisture was below average during the growing season of May through August. A series of storms during late April-early May of 1971 occurred before blue grama had begun growth.

## Results

### Herbage Yields

Foliar applications of both rates of urea-N significantly ($P<0.05$) increased average yields over the 3-year period of study, whether applied in December, in May, or in June (Table 2). When urea-N was applied in July, neither rate increased average herbage yields. When applied in May, 40 lb urea-N per acre produced essentially the same average yields as did 40 lb of dry ammonium nitrate-N per acre.

The dry form of 40 lb of ammonium nitrate-N applied in December and the foliar applications in both June and July produced greater herbage yields than foliar applications of the same rate of urea-N applied at the same times. When applied in December or in June, both rates of urea-N increased average

**Table 1. Monthly precipitation (inches) for the crop years (September through August) of 1969, 1970, and 1971, crop-year totals, and 33-year mean at Central Plains Experimental Range, Nunn, Colorado.**

| Year | Month | | | | | | | | | | | | Crop-Year Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | S | O | N | D | J | F | M | A | M | J | J | A | |
| 1969 | 0.4 | 1.0 | 0.7 | 0.2 | 0.1 | 0.3 | 0.2 | 1.6 | 2.3 | 4.5 | 1.8 | 1.4 | 14.5 |
| 1970 | 1.2 | 2.9 | 0.1 | T | T | T | 1.4 | 1.4 | 0.8 | 1.1 | 1.6 | 0.2 | 10.7 |
| 1971 | 1.5 | 1.2 | 0.2 | 0.2 | 0.4 | 0.3 | 0.9 | 2.9 | 1.7 | 1.2 | 0.6 | 0.4 | 11.3 |
| 33-year mean, 1939–1971 | 1.1 | 0.8 | 0.2 | 0.2 | 0.3 | 0.2 | 0.6 | 1.1 | 2.1 | 2.5 | 1.8 | 1.4 | 12.3 |

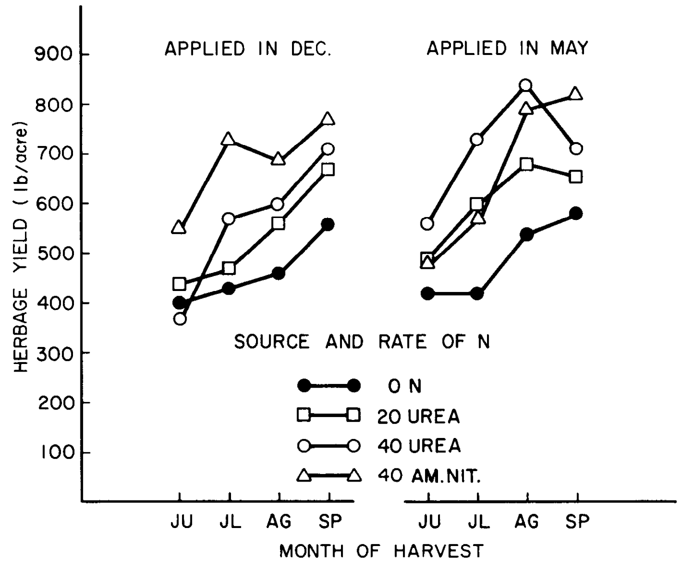


**Fig. 1.** *Average herbage yields (lb per acre) over 3 years (1969–71) by month of harvest at four N treatments and two dates of application.*

**Table 2. Yield of total herbage (lb/acre) in 1969, 1970, and 1971 and 3-year average from 0, 20, and 40 lb per acre of N as urea (U) and 40 lb per acre of N as ammonium nitrate (AN). Treatments applied in December, May, June, and July on separate plots and repeated each year. Yields averaged over 4 monthly harvests each year for December and May applications and over 3 monthly harvests for June and July applications.**

| Month of application | Rate and source of N | Yields | | | |
|---|---|---|---|---|---|
| | | 1969 | 1970 | 1971 | Avg |
| Dec. | 0 | 700c[1] | 360c | 320c | 460c |
| | 20 U* | 740c | 490b | 370b | 530b |
| | 40 U* | 830b | 490b | 370b | 560b |
| | 40 AN | 1030a | 580a | 440a | 680a |
| May | 0 | 700c | 430c | 340c | 490c |
| | 20 U* | 820b | 580b | 420b | 600b |
| | 40 U* | 1030a | 600b | 500a | 710a |
| | 40 AN | 890b | 710a | 400b | 670ab |
| June | 0 | 1000c | 520c | 370b | 630c |
| | 20 U* | 1200b | 660b | 420b | 760b |
| | 40 U* | 1090bc | 670b | 510a | 760b |
| | 40 AN* | 1370a | 830a | 510a | 910a |
| July | 0 | 1020c | 620bc | 430b | 690b |
| | 20 U* | 990c | 710ab | 500a | 730b |
| | 40 U* | 1170b | 560c | 520a | 750b |
| | 40 AN* | 1430a | 770a | 490a | 900a |

[1] Column means for each month of application by year of harvest or by 3-year average, when followed by the same letter, are not significantly different at the 5% level.
*Fertilizer foliar applied in aqueous solution.

yields, but not as much as the 40 lb of ammonium nitrate-N.

The foliar application of 20 lb of urea-N per acre applied in December or June significantly increased yields in 2 out of 3 years. When applied in May it increased yields all 3 years, and when applied in July it increased yields in only 1 out of 3 years. The 40 lb of foliar-applied urea-N applied in December or May increased yields all 3 years, but when applied in June or July it increased yields in only 2 out of 3 years. In contrast, the 40 lb of ammonium nitrate-N significantly increased yields every year, regardless of date of application and whether broadcast or as a foliar spray. When applied in December, the 40 lb of urea-N had no effect on average herbage yields in the first month of harvest, but when applied in May (Fig. 1) it increased yields in the first month of harvest. In the remaining harvests, the December application of 40 lb of urea-N increased average yields more than the 20 lb of urea-N, but less than the 40 lb of ammonium nitrate-N.

Foliar application of 40 lb of urea-N in May increased average herbage yields in June and July more than any other rate or N source. When the herbage was harvested in August, yields were about the same for the two N sources. At the September harvest the 40 lb of ammonium nitrate-N increased yields most.

### Percent Protein

Except for the 20-lb rate of urea-N applied in December, both rates of foliar applied urea-N and both the dry and foliar applied ammonium nitrate-N significantly increased average protein content of herbage over the 3-year period of study regardless of date of application (Table 3). The 20 lb of urea-N increased average protein content of herbage progressively more with progressively later dates of application. December application increased average protein content 10%, June application increased average protein content by only 5%, May application increased average protein content 10%, June application 14%, and the July application 22%.

**Table 3. Crude protein (%) of herbage in 1969, 1970, and 1971, and 3-year average from 0, 20, and 40 lb per acre of N as urea (U) and 40 lb per acre of N as ammonium nitrate (AN). Treatments applied in December, May, June, and July on separate plots and repeated each year. Percent crude protein averaged over 4 monthly harvests each year for December and May applications and over 3 monthly harvests for June and July applications.**

| Month of application | Rate and source of N | Crude protein | | | |
|---|---|---|---|---|---|
| | | 1969 | 1970 | 1971 | Avg. |
| Dec. | 0 | 6.9b[1] | 7.1d | 7.5c | 7.2c |
| | 20 U* | 7.0b | 7.7c | 8.0c | 7.6c |
| | 40 U* | 7.5b | 9.2b | 9.3b | 8.7b |
| | 40 AN | 8.5a | 9.8a | 11.1a | 9.8a |
| May | 0 | 6.8b | 7.0c | 7.6c | 7.1c |
| | 20 U* | 7.2b | 7.3c | 8.9b | 7.8b |
| | 40 U* | 8.7a | 9.0b | 11.2a | 9.6a |
| | 40 AN | 8.5a | 9.9a | 11.6a | 10.0a |
| June | 0 | 5.9b | 6.5d | 7.4d | 6.6c |
| | 20 U* | 6.2b | 7.5c | 8.9c | 7.5b |
| | 40 U* | 7.3a | 8.6b | 10.5b | 8.8a |
| | 40 AN* | 7.3a | 9.1a | 11.3a | 9.2a |
| July | 0 | 6.1c | 7.9c | 7.8c | 7.3c |
| | 20 U* | 7.7b | 9.2b | 9.9b | 8.9b |
| | 40 U* | 8.1a | 10.4a | 11.7a | 10.0a |
| | 40 AN* | 8.2a | 10.6a | 10.4b | 9.7a |

[1] Column means for each month of application by year of harvest or by 3-year average, when followed by the same letter, are not significantly different at the 5% level.

*Fertilizer foliar applied in aqueous solution.

application 14%, and the July application 22%.

Foliar application of 40 lb of urea-N resulted in the smallest increase—21%—when applied in December. Applications in May, June, and July increased average protein content by about 35%.

The 40 lb of ammonium nitrate-N was most effective in increasing average protein content when applied in May in dry form (41% increase) or in June as foliar application (39% increase).

Application of 20 lb of urea-N in December or in May significantly increased protein content of herbage in only 1 out of 3 years. Significant increases were obtained in 2 out of 3 years when application occurred in June, and in all 3 years when it took place in July. The 40 lb of urea-N increased protein content each year for all dates of application, except in the first year after December application. The 40 lb of ammonium nitrate-N consistently increased protein content each year for all dates of application.

Foliar application of 20 lb of urea-N had virtually no effect on average protein content of herbage (Fig. 2). When applied in May, 20 lb of urea-N increased average protein content only 1.3 percentage points.

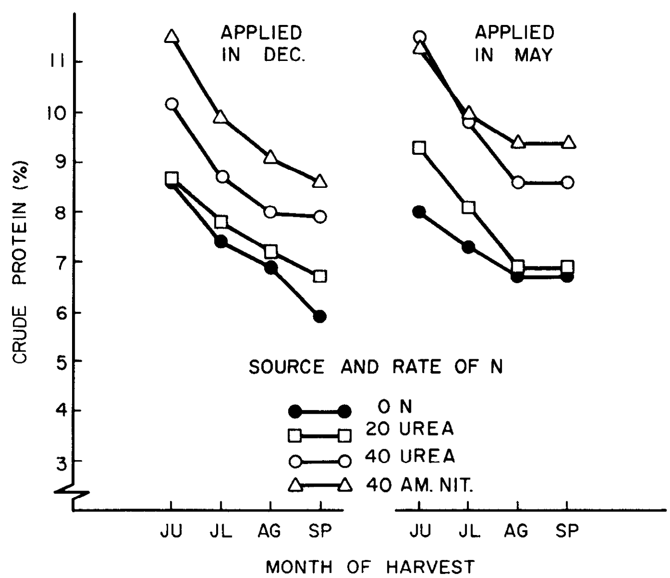


**Fig. 2.** *Average percent crude protein over 3 years (1969–71) by month of harvest at four N treatments and two dates of application.*

When applied in December, the dry application of 40 lb of ammonium nitrate-N increased protein content of herbage significantly more at all harvest dates than did foliar application of 40 lb of urea-N. However, when applied in May, 40 lb of ammonium nitrate-N increased protein content more than 40 lb of urea-N only during the last 2 months of harvest—August and September. When both sources of N were applied on the foliage in June or July, little effect on protein content was found for either source of N at any harvest date.

### Protein Yield

All rates of urea-N and ammonium nitrate-N increased average protein yield (dry-matter yield times percent crude-protein) over the 3-year study, regardless of date or method of application (Fig. 3). The smallest average increase (22%) resulted from 20 lb of urea-N applied in December. The 40 lb of ammonium nitrate-N produced the greatest increases in protein yield of all treatments when applied in December,

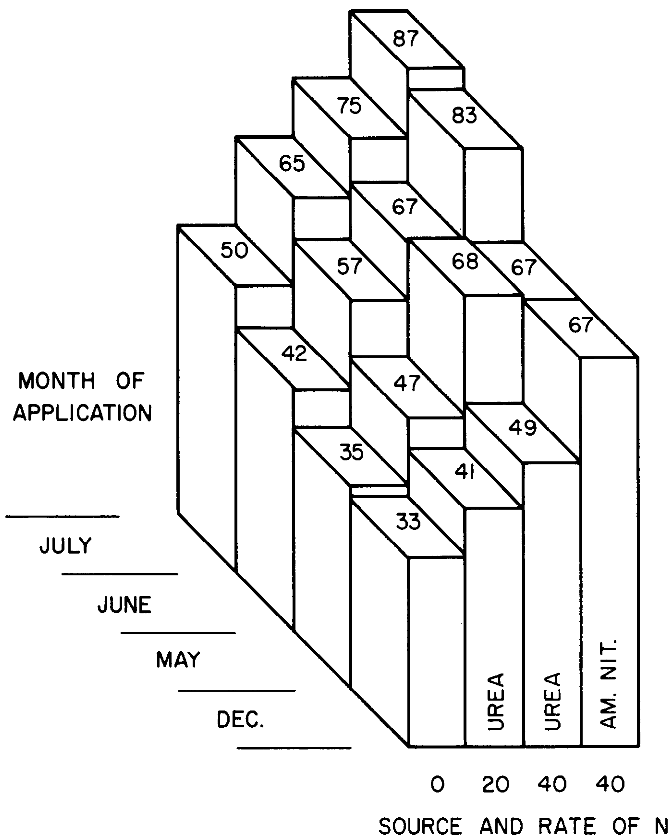


**Fig. 3.** *Average yield of crude protein (dry matter yield in lb per acre multiplied by percent crude protein) over 3 years (1969–71) at four N treatments and four dates of application.*

May, or June; the 40 lb of urea-N produced the greatest yield of protein of all N treatments when applied in May. Average increases in protein yield for the 40-lb rate of the two N sources ranged from 91 to 102%.

When applied in July, ammonium nitrate-N produced the greatest increase in average protein yields—74%. The 40 lb of urea-N produced a 49% average increase; 20 lb of urea-N produced an average increase of 30%.

### Nitrate-N

The nitrate-N content of total herbage was not affected in 1969 or 1970 by method of application or source or rate of N from December applications (Table 4). In 1971, only the December application of N failed to increase the nitrate-N content of herbage. In 1971, all rates and sources of N increased nitrate-N levels when applied in May and harvested in June or applied in early July and harvested in late July. When applied in June and harvested in late July, only the high rates of both urea and ammonium nitrate increased nitrate-N. When applied in early July and harvested in late July, both rates of urea-N about doubled nitrate-N and 40 lb of ammonium nitrate-N increased nitrate-N ninefold.

**Table 4. Nitrate-N (ppm) content of herbage in 1969, 1970, and 1971 from 0, 20, and 40 lb per acre of foliar applied N as urea (U) and 40 lb per acre of both dry and foliar applications of N as ammonium nitrate (AN). Treatments applied in December, May, June, and July on separate plots and repeated each year.**

| Month of application | Month of harvest | Nitrate-N | | | |
|---|---|---|---|---|---|
| | | 0 | 20 U | 40 U | 40 AN |
| Dec. | 1969[1] | 52a[2] | 55a | 51a | 51a |
| Dec. | 1970[1] | 51a | 50a | 56a | 62a |
| Dec. | June 1971 | 50a | 60a | 70a | 70a |
| May | June 1971 | 40b | 80a | 80a | 100a |
| June | July 1971 | 70b | 90b | 150a | 180a |
| July | July 1971 | 90c | 160b | 200b | 930a |

[1] All plots were harvested in June, July, August, and September each year. Data are means over 4 months of harvest.
[2] Row means for individual months of application, when followed by the same letter, are not significantly different at the 5% level.

### Species Composition

Abundance of only two species was significantly affected by the N treatments during the study (Table 5). Percentage frequency of both slimleaf goosefoot (*Chenopodium leptophyllum* Nutt.) and Russian thistle (*Salsola kali tenuifolia* Tausch) increased during the 3 years. The annual increases were greatest on the 40-lb ammonium nitrate-N treatment.

**Table 5. Species composition by percent frequency of two annual forbs during 1969-70-71 from 0, 20, and 40 lb per acre of N as urea (U) and 40 lb per acre of N as ammonium nitrate (AN). N treatments repeated each year on same plots.**

| Species | Year | Composition | | | |
|---|---|---|---|---|---|
| | | 0 | 20 U | 40 U | 40 AN |
| Slimleaf goosefoot | 1969 | 1c[1] | 1c | 1c | 1c |
| | 1970 | 2c | 2c | 6b | 7ab |
| | 1971 | 3c | 7ab | 7ab | 10a |
| Russian thistle | 1969 | 1d | 1d | 1d | 1d |
| | 1970 | 1d | 1d | 2cd | 4bc |
| | 1971 | 2cd | 6ab | 7a | 7a |

[1] Means for each species, when followed by the same letter, are not significantly different at the 5% level.

## Discussion and Conclusions

Overall, the source of N was far more important for increasing herbage yields, crude-protein content of herbage, and total yield of protein than method of application. The most effective source of N was ammonium nitrate. The greatest advantage of ammonium nitrate over urea was from application in December. When applied in May, urea and ammonium nitrate-N at the 40-lb rate were about equally effective in increasing herbage yields, protein content, and protein yields. When applied in June or July, the ammonium nitrate-N was superior to urea-N for increasing both herbage and protein yields, but was not superior to urea-N for increasing crude protein content.

The reduced effectiveness of urea-N from the December application was no doubt due to gaseous losses of ammonia from urea-N after hydrolysis during the winter months. Occasional warm days that would promote hydrolysis are not infrequent during the winter. The reduced effectiveness of urea-N from application in June and July was probably related to losses of volatile ammonia-N caused by high temperatures and dry weather (Simpson, 1968).

The similarity of herbage responses from May application of the same rate of both sources of N suggested that gaseous losses from urea-N are negligible when applied at this date. For this date of application, the choice of nitrogen source for range fertilization is only a matter of economics.

The substantial increases in herbage yields, crude protein content, and protein yields from applications of N as late in the growing season as early July lengthen the period when the

N may be applied. However, the presence of adequate soil moisture or precipitation after application, which is needed for best response, is less common in July.

Although nearly all N treatments increased nitrate-N content of herbage in 1971, by far the greatest increase was from the ammonium nitrate fertilizer applied in early July and harvested in late July. However, even this large increase in 1971 did not reach the level of nitrate-N considered toxic to livestock (2,000 ppm [Bradley et al., 1940]).

The effect of nitrogen fertilizers on species composition may be both desirable and undesirable. The increased abundance of Russian thistle from N fertilization may be desirable, because Russian thistle is a fair to good forage plant. The increased abundance of slimleaf goosefoot may be undesirable. There is evidence that slimleaf goosefoot tends to concentrate nitrate-N under N fertilization (Houston et al., 1973). This could conceivably create nitrate-toxicity problems for livestock unless the species was controlled. Slimleaf goosefoot is easily controlled with atrazine herbicide (Houston and van der Sluijs, 1973).

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