PROTEIN PRODUCTION BY RUSSIAN THISTLE: EFFECTS OF WATER AND NITROGEN ON PROTEIN YIELDS

by

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Abstract

The purpose of this study was to determine whether Russian thistle (Salsola spp.) might have potential as either a protein source or a forage under conditions of restricted water. Salsola was chosen because it was reported to be a C_4 plant which is efficient in water use, drought resistent, salt tolerant and because it had been used as a feed previously. In two seasons of field cultivation we find the following: (1) average percentage protein contents are 16% (range: 23-8.5%); (2) the protein is very well balanced with regard to amino acid content; (3) at water and nitrogen levels which provide maximal yields the nitrate content does not exceed 0.6%o of dry weight; (4) the average percentage of crude fiber content (acid detergent fiber-acid detergent lignin) is 23% (range: 27%-16%); (5) average yield of above-ground dry matter for 1975, over all water and nitrogen treatments, were 7781 kg/ha; (6) the same yield figure for 1976 was 8645 kg/ha; (7) under optimal treatments yields greater than 10,000 kg/ha were obtained; and (8) with 35 cm total applied water and 112 kg/ha of nitrogen, conditions giving optimal yields, water use efficiency was 329 g water/g above-ground dry matter. These results compare favorably with alfalfa, which is the most widely grown forage in New Mexico.

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Key words: Russian thistle, Salsola, water use efficiency, forage, protein content

I. OBJECTIVES OF THE PROJECT

A. Long Range

Two facts are coming increasingly to bear on agricultural productivity in semi-arid regions of this country: water resources are becoming more limited, as water is actually being mined in some regions, and water availability is closely linked to energy resources. With these facts in view, it would seem very desirable at this time to begin systematically looking for potentially useful agricultural products which have lower water requirements and are perhaps generally better adapted to semi-arid environments.

B. Immediate Objectives

As *Salsola* spp. (Russian thistle) had previously been used as hay (1) and requires only one-half to one-third as much water per pound of dry matter produced as alfalfa, flax and bromegrass (2), this plant was chosen as one meriting further study. It was proposed to determine the balance between nitrogen fertilization and irrigation which would result in maximal nutritional values and water use efficiency.

C. Achievement of Goals

The Total funding period has been for two years from July 1, 1974 to June 30, 1976 (extended to Dec. 30, 1976). During this period data from three seasons growing period have been collected. The results from the greenhouse study of the first year are adequately summarized in a publication (Evaluation of Protein and Fiber Content of Cultivated Russian-Thistle, Agronomy J. 68, 691-692 (1976)).

We have succeeded, using small field plots, in collecting data not only for the 1975 but also for the 1976 growing season. Information in all the areas we proposed to study is in hand.

We have confirmed the earlier greenhouse study which indicated Russian thistle has high protein concentrations at certain stages and that the protein is nutritionally well balanced as measured by its amino acid composition. We found that nutritive fiber content varies roughly with the protein content. Crude digestible fiber can be as high as 27%. Nitrate levels are not found to be excessive even at the highest rates of fertilization.

In 1975 neither the water levels used nor the amount of nitrogen applied had very much effect on the protein content or the crude fiber content. Nitrogen application did have a slight significant positive effect on the water use efficiency in both 1975 and 1976.

Both water and nitrogen were seen to have a positive effect on yields in in the 1975 studies, but only nitrogen application increased the yields in the 1976 studies. In 197 the highest water level (24 cm) caused a marked decrease in water use efficiency.

II. DETAILED RESULTS

A. Methodology

1. Plot design, irrigation, fertilization, and harvesting.

The experimental plant material was grown under irrigated field conditions at Las Cruces, New Mexico, in 1975 and 1976 using seed collected locally. In 1975 seed were planted in dry soil in 25 cm double rows on 1 meter centers and irrigated up to a stand on 29 May. Trickle irrigation was used to maintain a high degree of control over the quantity of water applied. Nitrogen as urea was bonded between the two double rows at rates of 0, 28, 56, 112 and 224 kg/ha at four weeks after planting. Experimental variables included two water application levels, two harvest maturity stages (prebloom and 3/4 bloom at initial harvest), and two clipping heights (7.6 and 15.2 cm) in addition to the nitrogen application rates. As the length of the growth periods of the two maturity stages differed (prebloom-87 days; 3/4 bloom-140 days), the two water application levels resulted in total water applied (irrigation + rainfall) of 19.41 and 25.58 cm for material harvested at prebloom stage and 23.90 and 32.79 cm for that harvested at 3/4 bloom stage. Water use efficiency was calculated on the basis of units of total water applied per unit of dry matter produced. The experimental design included two separate experiments in multiple split plot arrangements with subplots in randomized complete block design. Experiment No. 1 included irrigation levels as main plots, nitrogen levels as subplots, and maturity stages as sub subplots. Experiment No. 2 included irrigation levels as main plots, maturity stages as subplots, and cutting heights as sub subplots. The layout of the pre-existing trickle irrigation system prevented randomization of the two irrigation levels thus eliminating a valid estimate of main plot effects. Four replications were laid out for each experiment with plot sizes of 22.35 m x 4 rows for main plots, 4.47 m x 4 rows for subplots and 4.47 m x 4 rows for subplots and 4.47 m x 2 rows for sub subplots. All plots were cut by hand using a commercial hedge trimmer. Two harvests were made for each maturity stage. Green weights were taken in the field and samples dried in a forced draft oven at 45 C to a constant weight for partial dry weight and nutritive determinations.

In 1976 the effect of form nitrogen levels (0, 28, 56 and 112 kg/ha) and four irrigation treatments (23.8, 34.6, 39.9 and 60.1 cm irrigation + rainfall) on dry forage yield and water use efficiency of Russian thistle was studied in a split-plot design with four replications. Irrigation treatments were laid out as main plots, 36 m x 4.1 m, with nitrogen treatments as subplots, 9 m x 4.1 m, arranged in a randomized completed block design. Plots were seeded with a Brillon broadcast seeder into dry soil, fertilized with urea, and flood irrigated. The planting operation was completed on 13 April. After the second irrigation, however, a sprinkler system was used to apply water to give better uniformity and control of water applicaion. Yield plots, 6.1 m x 0.75 m, were cut from the center of each subplot at a height of 10 cm using a small sickle-bar mower. Green weights were taken in the field and a 500 g sample was dried in a forage drier at 60 C for partial dry weight determinations. The remaining area in each plot was cut with a swather with crimping attachment. After curing, the hay was baled and removed from the field. Two harvests were made during the experimental period. No nutritional analyses were done on the plant material harvested from the 1976 field plots.

2. Preparation of sample for analysis.

Partial-dried samples of 50-100 g were chopped, then ground in a Wiley Mill until they passed through a 40 mesh screen. If samples were mixed, it was done by thoroughly shaking equal weights of ground samples. Before analysis a portion of the ground samples to be analyzed were heated overnight at 110°C to determine the amounts of residual water in order to determine true dry-weight values. The residual water was about 6%.

3. Analysis for crude protein, fiber, nitrate and amino acids.

Crude protein was determined on dried, 50 mg samples by the Kjeldahl method, employing a selenium catalyst (3). Samples were run in duplicate or triplicate. Acid detergent fiber and acid detergent lignin were determined by the method of Van Soest (4) using 1-g samples of dried material. All determinations were done in triplicate. Dried samples were analyzed for their nitrate content by extraction with buffer and cadmium reduction as described by the AOAC(5). Amino acid analyses were performed as previously described (6).

B. Data

1. Water content

Previous studies on greenhous plants indicated that water content of Salsola spp. averaged about 87%, varying from 82-91% water. (Samples of fresh plant were rapidly weighed then heated until a constant dry weight was obtained).

The studies on plants grown under field conditions indicate that at later stages plants may be considerably reduced in water content. Moisture content data on the Russian thistle harvested in 1975 are given in Table I. These values are comparable to those reported by Bailey for other forages such as maize, clover, and alfalfa. Nitrogen had very little effect on moisture content but forage harvested at the later stage of maturity (3/4 bloom) contained significantly less moisture than at prebloom at both harvests.

Table 1. Effect of nitrogen application rate on moisture content of Russian thistle forage at two harvest maturity stages, 1975.

N Level	1st harvest	2nd harvest
kg/ha		
	Prebloom	
0	83.66 a+	79.95 a
28	83.20 a	79.89 a
56	83.07 a	81.20 a
112	83.19 a	80.70 a
224	85.52 a	81.33 a
	3/4 bloom	
0	80.20 a	62.90 b
28	79.78 a	61.73 b
56	80.31 a	61.52 b
112	81.04 a	67.21 a
224	80.03 a	68.64 a

+Means followed by the same letter are not significantly different at the 5% level as determined by Duncan's Multiple Range Test

2. Crude protein

We found that neither the cutting heights nor the total amount of water applied (23.9 cm or 32.8 cm) affected the percentage of content of crude protein in the 1975 samples; these measurements have been averaged together to give statistically meaningful results. It was found that application levels of nitrogen had slight but significant effects on protein content. These results are shown in Table 2.

Table 2. Effect of Nitrogen Levels and Plant Maturity on Crude Protein Levels in Salsola spp., 1975

Nitrogen Applied Kg/Ha	% Dry Weight of Protein ‡			
	Prebloom		3/4Bloom	
	1st Harvest	2nd Harvest	1st Harvest	2nd Harvest
0	20.2 c+	13.1 a	13.2 a	8.4 c
28	21.6 b	13.9 a	15.0 a	8.6 c
56	22.0 ab	12.8 a	15.2 a	9.0 bc
112	22.1 ab	14.4 a	14.7 a	10.4 ab
224	23.1 a	14.6 a	15.2 a	11.3 a

+Means followed by the same letter are not significantly different at the 5% level as determined by Duncan's Multiple Range Test.

‡Kjeldahl nitrogen multiplied by 6.25.

The most obvious conclusions to emerge from these data are: that the fertilization has relatively little effect on the protein content-which in some cases is quite substantial even in the absence of applied nitrogen; and that the maturity of the plant is very critical in determining the protein content of the plant. In general by making the first cutting at prebloom, one assures the highest average protein levels.

3. Amino acid composition.

Previous analyses on samples of Russian thistle grown in the greenhouse indicated that the protein was very well balanced with regard to amino acid composition (6). It was of interest to determine whether the same would hold true of plants grown in the field. Analyses reported in Table 3 are averaged over all levels of nitrogen fertilizer, which had no obvious effects, and are for the lower level of water application.

Table 3. Amino acid composition of Russian thistle

Amino Acid	- Weight Percent of Recovered Amino Acids - Field Samples (1975)+	Greenhouse Samples (1974)‡	Medicago sativa*	FAO Recommended
Lysine	7.3 ± 1.1	5.7 ± 0.2	6.8	4.2
Histidine	2.8 ± 0.6	2.2 ± 0.1	2.3	
Arginine	8.7 ± 2.6	4.6 ± 0.4	6.4	
Aspartic acid	12.4 ± 2.6	11.3 ± .2	10.6	
Threonine	4.2 ± .4	5.8 ± 0.3	5.1	2.8
Serine	4.3 ± 0.6	6.0 ± 0.4	4.7	
Glutamatic acid	15.6 ± 2.8	15.0 ± 0.4	11.4	
Proline	6.1 ± 1.4	5.8 ± 0.3	4.8	
Glycine	5.4 ± 0.6	6.4 ± 0.2	5.7	
Alanine	6.2 ± 0.9	7.0 ± 0.1	6.3	
Valine	5.1 ± 1.0	6.6 ± 0.2	6.4	4.2
Methionine	1.4 ± 0.5	1.6 ± 0.1	2.0	2.2
Isoleucine	4.9 ± 1.8	5.5 ± 0.2	5.3	4.2
Leucine	8.6 ± 2.3	9.8 ± 0.6	9.6	4.8
Tyrosine	2.0 ± 0.5	2.1 ± 0.2	4.5	2.8
Phenylalanine	5.2 ± 0.6	5.3 ± 0.3	6.1	2.8

+Averages of 11 determinations.
‡Averages of 30 determinations.
*Data of Byers (7)

As can be seen, although the variations in amino acid composition is greater for the field samples than for the greenhouse-grown plants, the average results are closely comparable. The levels of nutritionally critical amino acids meets or exceeds the FAO recommended values in all cases except methionine and tyrosine. The values for methionine are certainly minimal estimates as we did not oxidize methionine to the sulfone before analysis. Tyrosine is very close to the recommended levels. The values also compare very favorably with those of alfalfa.

4. Nitrate Content

One concern associated with high protein plants generally is that they are frequently high in free nitrate ion-which at levels of 1-2% can cause toxic effects in animals fed on such plants. For this reason we tested for nitrate levels in Russian thistle grown with the two highest levels of nitrogen fertilization. Table 4 shows these results.

Table 4. Effect of Nitrogen fertilizations and water levels on the nitrate content of Russian thistle, 1975.

Nitrogen Applied kg/ha	Total water Applied cm	Nitrate,‡ % Dry Weight as NO_3^-
112	24	0.34 ± .12
112	33	0.62 ± .26
224	24	0.30 ± 0.17
224	33	0.91 ± .74

‡Averaged over cutting heights, maturity and harvest number.

It is clear that even at the highest water and fertilizer applications free nitrate only begins to approach levels which would be considered excessive. Further, the uncertainty in this number is quite large. Of a total of 32 samples analyzed only 3 samples exceeded 1% nitrate content. There should be little difficulty in obtaining forage with suitable low levels of nitrate.

5. Acid detergent fiber and acid detergent lignin.

Variation of water application did not significantly affect the crude fiber content. As indicated by Table 5, nitrogen had even less effect crude fiber content then it did on crude protein content.

Table 5. Effect of nitrogen application rate on acid detergent fiber (ADF) and acid detergent ligin (ADL) content of Russian thistle forage at two harvest maturity stages, 1975.

N	1st harvest ADF	1st harvest ADL	2nd harvest ADF	2nd harvest ADL
kg/ha	- % Dry Weight -			
	Prebloom			
0	20.8 a[+]	4.36 a	32.57 a	7.86 a
28	19.5	3.57 a	30.65 a	6.27 a
56	19.01 a	3.54 a	32.52 a	7.48 a
112	19.27 a	3.37 a	30.78 a	8.64 a
224	19.10 a	3.87 a	32.59 a	7.60 a
	3/4 Bloom			
0	29.15 a	6.19 a	35.07 a	7.48 a
28	28.03 a	4.92 a	35.03 a	7.10 a
56	28.39 a	4.87 a	34.17 a	6.20 ab
112	29.36 a	5.39 a	31.78 ab	7.00 a
224	30.29 a	4.74 a	30.67 b	5.18 b

[+]Means followed by the same letter are not significantly different at the 5% level as determined by Duncan's Multiple Range Test.

The factor which had by far the most dramatic effect on acid detergent lignin, acid detergent fiber as well as protein content was the stage of maturity of the plant at the time of harvesting. Table 6 summarizes all of this data.

Table 6. Effect of stage of maturity on the crude protein acid detergent fiber (ADF) and acid detergent lignin (ADL) content of Russian thistle forage, 1975.[‡]

Maturity Stage	Crude Protein	ADF	ADL
	- % Dry Weight -		
Prebloom			
1st harvest	21.8	19.6	3.7
2nd harvest	13.8	31.8	7.6
3/4 Bloom			
1st harvest	14.6	29.0	5.2
2nd harvest	9.5	33.3	6.6

[‡]Means in table are averages of all cutting heights, nitrogen levels, water levels and replications.

It should be noted that the protein and acid detergent fiber have an inverse relationship. The protein is highest and the fiber content lowest when the first cutting is made at prebloom whereas the opposite is true for the second cutting of the material first cut at 3/4 bloom. Proposed use of the forage would determine at what stage a cutting should be made.

6. Effects of water, nitrogen and harvesting practices on yields.

Water, nitrogen, cutting height and harvesting time each had significant effects on the overall yields of Russian-thistle hay. The effects of water on yields in 1975 and 1976 are shown in Tables 8 and 9, respectively.

Table 8. The effects of water levels on yield of Russian thistle, 1975

Total water Applied, cm	Yields (1st + 2nd cuttings)‡ kg/ha
	Prebloom
24	5554
33	6423
	3/4 Bloom
24	6878
33	8280

‡Averages over all nitrogen levels, each of which was determined in quadruplicate.

Table 9. Effect of water application rate on dry forage yield of Russian thistle, 1976

Total H_2O Applied	1st Harvest	2nd Harvest	Total
cm		- kg/ha+ -	
23.8	3392 a++	4715 a	8107 a
34.6	4162 a	5195 a	9357 a
39.9	3677 a	5920 a	9597 a
60.1	4688 a	2825 b	7513 a

+Values are means over all fertilizer application levels

++Means followed by the same letter are not significantly different at the 5% level as determined by Duncan's Multiple Range Test.

It should be noted that the highest level of water used in 1975 corresponds to the median level used in 1976. Up to levels of 24 cm of applied water no significant effect on yield was seen; however, when water applications were raised to 33 cm increases of 16% and 20% for prebloom and 3/4 bloom harvesting, respectively, were observed. It is also interesting that even the lowest water application of 9.4 cm for 1976 provided yields essentially identical to those of the highest application (33 cm) of 1975.

In both 1975 and 1976 nitrogen fertilization was seen to increase significantly the overall yields under some cutting regimens. These data are shown in Tables 10 and 11.

Table 10. Effect of nitrogen application rate on dry forage yield of Russian thistle at two harvest maturity stages, 1975

N level	1st harvest	2nd harvest	Total harvest	Averaged over all N
		- kg/ha -		
		Prebloom		
0	1157 a[+]	4328 a	5484 a	
28	1237 a	4416 a	5654 a	
56	1165 a	4905 a	6070 a	
112	1280 a	4997 a	6277 a	
224	1317 a	5176 a	6493 a	
				5995
		3/4 Bloom		
0	6447 a	2363 bc	8810 bc	
28	6448 a	2164 c	8612 c	
56	6841 a	2741 abc	9582 abc	
112	6696 a	3445 ab	10141 ab	
224	6983 a	3709 a	10692 a	
				9567

[+]Means followed by the same letter are not significantly different at the 5% level as determined by Duncan's Multiple Range Test.

[++]Values are means of both water levels.

As Table 12 clearly shows, the cutting height has a very significant effect on the total yields recovered. Eight % and 15% increases in yields are observed for the higher cutting heights for the prebloom and 3/4 bloom harvests, respectively. This is probably due to the superior regrowth potential of the plants cut at the greater height.

Table 11. Effect of nitrogen application rate on dry forage of Russian thistle, 1976.

N level	1st harvest	2nd harvest	Total
	- kg/ha -		
0	3752 a+	3566 b	7318 c
28	3570 a	4972 a	8541 b
56	4236 a	4511 ab	8747 b
112	4362 a	5606 a	9968 a

+Means followed by the same letter are not significantly different at the 5% level as determined by Duncan's Multiple Range Test.

Table 12. Effect of cutting height on dry forage yield of Russian thistle, 1975

		Dry Forage Yield+	
Cutting Height	1st harvest	2nd harvest	Total harvest
cm		- kg/ha -	
		Prebloom	
7.5	1531 a‡	4292 b	5823 b
15.00	931 b	5363 a	6294 a
		3/4 Bloom	
7.5	6733 a	2146 b	8879 b
15.0	6633 a	3623 a	10255 a

‡Means followed by the same letter are not significantly different at the 5% level as determined by Duncan's Multiple Range Test.

+Averages of all replications, water levels and nitrogen levels.

7. Water use efficiency of Russian thistle.

In the 1975 season only two levels of water were used so no trends in water use efficiency could be seen. Average water use efficiency of 370g water/g dry matter (prebloom) and of 410g water/g dry matter (3/4 bloom) were measured. In 1976 widely varying levels of water were applied. The effect of these levels of water and their interactions with nitrogen on water use efficiency is shown in Table 13.

Table 13. Effect of nitrogen and water application rate on water use efficiency of Russian thistle, 1976

Total H_2O applied	Water use efficiency				
	N applied, kg/ha				
	0	28	56	112	Mean
cm	-Units H_2O applied/unit above ground dry wt.-				
23.80	399	298	309	241	312
34.57	438	412	395	329	393
39.98	512	437	423	403	444
60.35	1106	869	773	791	885
Mean	614	504	475	441	508

At the highest level of water applied, there was a significant decline in water use efficiency. Data in Table 9 suggest that this decrease in efficiency is due to an actual decline in the yields obtained.

In both 1975 and 1976 increasing nitrogen fertilization had the expected effect of increasing water use efficiency. Table 14 shows that in 1975 levels of nitrogen greater than 56 kg/ha caused no statistically significant increases in water use efficiency, but Table 13 shows that in 1976 levels of fertilizer up to 112 kg/ha improved water use efficiency. As Table 13 shows, at water levels of 60.35 cm, water use efficiency is greatly decreased. If these values are excluded the water use efficiency figures for the two seasons are very similar; they range between 300-400g water/g dry matter.

Table 14. Effect of nitrogen application rate on water use efficiency of Russian thistle at two harvest maturity stages, 1975

N level	- Water use efficiency[‡] - Prebloom	3/4 bloom
kg/ha	- g H_2O/g dry wt.[+] -	
0	416 a[++]	323 a
28	419 a	333 a
56	388 ab	298 a
112	363 ab	290 a
224	352 b	272 a

‡Values are means over all water levels.

+Units of water applied (irrigation and rainfall)/units of above ground dry matter.

++Means followed by the same letter are not significantly different at the 5% level as determined by Duncan's Multiple Range Test.

III. DISCUSSION

A. Nutritional Parameters

Several potentially important nutritional parameters of Russian thistle were measured in the 1975 growing season: water, acid detergent fiber, acid detergent lignin, nitrate ion, and protein content, as well as amino acid composition were monitored. The values observed for each of these with the exception of nitrate ion proved to be only very slightly changed with variation in fertilizer application (0 - 224 kg/ha of urea) or water application (24 or 33 cm total water). As indicated in Table 4 nitrate ion was elevated to potentially trouble-some levels only at 33 cm of water and 224 kg/ha of urea applied. As indicated below these levels of water and nitrogen are in excess of the optimal ones. No decision could be made as to optimal culturing conditions based on variation of water and nitrogen alone.

Studies on the amino acid content were very encouraging. First the results from the field samples, while showing greater variation than for the greenhouse samples, agreed very satisfactorily with amino acid analyses of the latter (Table 3). Second, the amino acid composition of Russian thistle is closely similar to that of alfalfa and meets or exceeds the recommended guidelines of FAO for all amino acids, with the possible exception of tyrosine.

The relative amounts of protein and acid detergent fiber (and lignin) found in Russian thistle were dramatically affected by the stage of maturity at which the plant was first harvested. Table 6 shows that when the plant is at prebloom the protein content is 21.8% (slightly in excess of the average value for alfalfa of 20.5%), whereas by 3/4 bloom the protein content has fallen to 14.6%. On the other hand at the same harvesting time crude digestible fiber (ADF-ADL) rises from 16% to 24%. In comparison average values for alfalfa are 26%. Even greater extremes are observed for the second cutting. The harvesting time is very important, then, in determining what the nutritional values will be.

B. Protein and Dry Matter Yields

Measurements of quantities of both protein and total dry matter indicate that several experimental manipulations dramatically alter yields of dry matter obtained. Water levels, nitrogen application levels, cutting height and maturity of plant at first harvest all had a significant influence on total yields.

Tables 8 and 9 indicate that increasing water levels up to 33 cm appear to increase yields (not significant in 1976) but higher levels do not improve yields of dry matter any further. Tables 10 and 11 show that increasing nitrogen to 56 kg/ha (in 1975) or 112 kg/ha (in 1976) caused statistically significant increases in total dry matter production. It is impressive to note that the average yields at 56-112 kg/ha of nitrogen nearly match the average annual yields of alfalfa for New Mexico (Dr. William Melton, personal communication).

Cutting height proved also to be quite important. Table 12 shows that significantly higher yields of dry matter are obtained, regardless of the maturity at the first harvest, when the plants are cut at 15 instead of 7.5 cm. We believe the higher cutting height allows more rapid regrowth of those plants.

Tables 8-12 all show that greater yields can be realized if the plants are first harvested sometime after blooming has begun. We do not yet know precisely what blooming stage would give maximal yields. It must be remembered that protein content is declining from prebloom onward; that factor must be weighed against yield consideration.

Tentatively, we conclude that maximal yields may be obtained by applying 35 cm of water, 56-112 kg/ha of urea, first harvesting when plants reach 3/4 bloom stage and cutting at a height of 15 cm. Under these conditions we can obtain about 10 kg/ha of dry matter.

In analyzing the data collected, we were struck by the amount of nitrogen recovered; this is set out in Table 15. Particularly striking, for example, is the case where 168 kg/ha of nitrogen was recovered in a plot in which no nitrogen had been applied. If we use the rule of

Table 15. Amounts of total nitrogen recovered from harvested Russian thistle.

	- kg N/ha -					
	Prebloom			3/4 Bloom		
Nitrogen applied (kg/ha)	1st	2nd	Total	1st	2nd	Total
0	37.4	90.7	128.1	136.2	31.8	168.0
28	42.8	98.2	141.0	154.8	29.8	184.6
56	41.0	100.5	141.5	166.4	39.4	205.9
112	45.3	115.1	160.4	157.5	57.3	214.8
224	48.7	120.9	169.6	169.8	67.1	236.9

thumb that a plant does not take up more than about 1/2 the applied nitrogen we are confronted with three possibilities: (1) the residual content of useable nitrogen in the plot was in excess of 300 kg/ha equivalents, (2) Russian thistle is exceedingly efficient at absorbing nitrogen from the soil, or (3) Russian thistle has some associated nitrogen fixing process. The first seems unlikely; the latter two are very deserving of further study and are interesting from a theoretical as well as practical viewpoint.

C. Water Use Efficiency

The data from both seasons, summarized in Tables 13 and 14, indicate that Russian thistle, under conditions which are otherwise optimal uses about 1/2 as much water as the perennial forage alfalfa. Furthermore with optimal fertilization (112 kg/ha) we observed in 1976 water use efficiencies more than 3X greater than is typical for alfalfa (based on 790 g water/g dry matter for alfalfa. This was calculated from data for Dona Ana County (8). Baker has reported (9) a dry matter yield of 15,700 kg/ha of field-grown Russian thistle using only 209 g water/g dry matter. This represents nearly 1/4 the amount of water which would be required to produce similar yields of alfalfa.

To date, all the agronomic and chemical factors which have been examined look very promising. The next logical step is to study the digestibility both *in vitro* and with test animals. If these studies appear to be equally promising, Russian thistle may be suggested as an agricultural product which could result in enormous savings of water in New Mexico as well as other semi-arid states.

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