# Potash and Phosphate Fertilization on Irrigated Alfalfa

C.R. Thompson, D.L. Dodds and B.K. Hoag

North Dakota has had approximately 210,000 irrigated acres annually from 1983 through 1986, of which 65 to 70,000 acres was irrigated hayland (2,7,8,9). Alfalfa may be one of the more profitable crops grown under irrigation in North Dakota because of the short growing season and cool climate. Moisture is often the limiting factor in production; however, with irrigation, fertility becomes limiting. Therefore, monitoring fertility levels on irrigated crops like alfalfa are very important for optimum production. Estimated nutrient use by alfalfa is 11.5 pounds of phosphate $P_2O_5$ (P) and 60 pounds of potash $K_2O$ (K) per ton of forage yield (10).

Bauder et al. reported that irrigated alfalfa at Oakes did not respond to surface applied phosphate and potash. Fertilization occurred in the initial harvest year only and has harvested for a five-year period (1).

Danke et al. reported that phosphate fertilization increased alfalfa yields at Langdon but did not influence yield at Carrington, Minot or Dickinson (3).

Dodds et al. report preliminary data indicating alfalfa stands respond to phosphorus fertilization when the phosphorus level of the soil as indicated by a soil test is 5 pounds or less per acre (4).

Phosphorus and potassium are relatively immobile in the soil (6). There is increased utilization of phosphorus (P) and potassium (K) when placed in the root zone compared to broadcast surface applied; however, fertilizing established alfalfa may be limited to broadcast surface application by the average producer, so P and K applied to the surface of irrigated alfalfa need to be evaluated for their benefits.

## METHODS

A study was initiated to determine the effects of P and K fertilization on alfalfa production and its economic profitability. The study was conducted at the Karlsruhe Irrigation Research Site which is located in north central North Dakota. The soil is classified as a Clontarf sandy loam which has approximately 2 feet of sandy loam soil over a medium coarse sand with sand and gravel layers at lower depths. The organic matter ranges from 2.0 to 3.0 percent and the soil pH ranges from 7.5 to 8.0. The water holding capacity of the soil is approximately 4.5 inches in the top 4 feet of soil, which is very suitable for irrigation.

*Thompson is assistant agronomist and Hoag is superintendent both at the North Central Experiment Station, Minot; Dodds is grassland specialist, Cooperative Extension Service.*

Alfalfa variety DeKalb brand 120, which is winterhardy, bacterial wilt resistant and resistant to phytophthora root rot (5), was seeded at 18 pounds per acre on the study area in June 1982. Eptam at 3.0 pounds per acre was applied preplant incorporated for weed control. An excellent stand was established. One cutting of alfalfa was harvested in September 1982, but yield was not determined.

A randomized complete block design with four replicates was used. Experimental units are 5 × 20 feet of which 3 × 16 feet was harvested for yield. A three-cut harvesting system was used with harvests occurring in June, July and August of 1983, 1984, 1985 and 1986. Specific harvest dates are given in Table 1. All fertilizer, 0-0-60 (KCL) and 0-46-0 (triple super phosphate), was applied according to treatment in late April of 1983, '84, '85 and '86. Experimental units were soil sampled in April 1983 and October 1983, '84, '85 and '86. Soil samples were analyzed by the NDSU soil testing lab.

**Table 1. Crop water use, water applied and date of forage harvest, Karlsruhe, ND 1983-1986.**

| Year | Crop Water Use | Growing Season Rainfall | Irrig. Applied | Harvest Date | | |
|---|---|---|---|---|---|---|
| | | | | Cut 1 | Cut 2 | Cut 3 |
| | ----------inches---------- | | | | | |
| 1983 | 24.00 | 9.93 | 18.20 | 6/17 | 7/21 | 8/22 |
| 1984 | 18.79 | 7.09 | 14.85 | 6/13 | 7/13 | 8/21 |
| 1985 | 19.67 | 10.88 | 12.40 | 6/12 | 7/16 | 8/26 |
| 1986 | 23.24 | 9.14 | 14.10 | 6/10 | 7/11 | 8/19 |

Irrigation water scheduling and application were determined with tensiometers, neutron probes and Jensen-Haase scheduling information for alfalfa. Annual crop water use and water applied are given in Table 1.

## RESULTS AND DISCUSSION

Initial levels of soil P and K were quite variable among experimental units with P ranging from 8 to 37 pounds per acre and K from 120 to 300 pounds per acre (data are not presented). When soil testing levels were averaged over replicates by treatment, P ranged from 13 to 16 pounds per acre (Table 2) and K from 164 to 244 pounds per acre (Table 4). Based on NDSU soil testing procedures, the 0-6 inch soil depth testing 0-9 pounds per acre of P is rated low, 10-19 medium, 20-29 high and 30+ very high. In contrast,

**Table 2. Phosphate Soil Test Results 0 to 6-Inch, Karlsruhe, ND (1983-1986).**

| Treatment | | 'P' soil test 0 to 6-inch | | | | | |
|---|---|---|---|---|---|---|---|
| $P_2O_5$ | $K_2O$ | 4/83 | 10/83 | 10/84 | 10/85 | 10/86 | Avg. |
| ---lb/A--- | | ---lb/A--- | | | | | |
| 0 | 0 | 13.0 | 5.3 | 4.3 | 4.5 | 5.0 | 6.4 |
| 50 | 0 | 16.3 | 13.3 | 16.3 | 15.3 | 16.0 | 15.4 |
| 0 | 100 | 16.0 | 11.5 | 6.0 | 4.5 | 7.5 | 9.1 |
| 50 | 100 | 14.3 | 9.5 | 9.0 | 11.0 | 11.3 | 11.0 |
| 100 | 250* | 16.3 | 18.5 | 27.0 | 37.5 | 34.3 | 26.6 |
| LSD (5%) | | NS | NS | 6.9 | 11.4 | 5.5 | 3.7 |
| LSD (5%) Year × Treatment = 8.2 | | | | | | | |

*200 lb $K_2O$ applied in 1983.

**Table 3. Phosphate Soil Test Results 6 to 24-Inch, Karlsruhe, ND (1983-1986).**

| Treatment | | 'P' soil test 6 to 24-inch | | | | | |
|---|---|---|---|---|---|---|---|
| $P_2O_5$ | $K_2O$ | 4/83 | 10/83 | 10/84 | 10/85 | 10/86 | Avg. |
| ---lb/A--- | | ---lb/A--- | | | | | |
| 0 | 0 | 4.0 | 2.8 | 3.3 | 1.8 | 3.3 | 3.0 |
| 50 | 0 | 4.0 | 3.8 | 4.3 | 3.8 | 5.3 | 4.2 |
| 0 | 100 | 3.8 | 2.8 | 2.8 | 2.0 | 3.5 | 3.0 |
| 50 | 100 | 3.8 | 3.8 | 4.0 | 3.8 | 4.0 | 3.9 |
| 100 | 250* | 3.3 | 6.8 | 10.0 | 7.0 | 10.0 | 7.4 |
| LSD (5%) | | NS | 1.6 | 2.4 | 2.1 | 2.2 | 0.9 |
| LSD (5%) Year × Treatment = 1.9 | | | | | | | |

*200 lb $K_2O$ applied in 1983.

soil testing 0-99 pounds per acre of K is rated low, 100-199 medium, 200-299 high and 300+ very high. Initial soil P and K test levels were medium ranged except the unfertilized treatment initial K level was high ranged.

Phosphorus and K levels in the soil appeared to have an influence on alfalfa yield during the first year of the study. Forage yields by fertility treatments were not significantly different under the three-cut management system (Table 5). Alfalfa yields ranged from 4.94 tons of 15 percent moisture forage on the unfertilized treatment of 5.38 tons on the highest fertility treatment the first year of study.

Annual soil test levels of P and K indicate fertility levels were influenced by application of fertilizers and alfalfa yields. Phosphorus levels in the 0 to 6-inch soil depth of the unfertilized treatment were reduced from 13 to 5.3 pounds per acre the first harvest year and then tended to stabilize (Table 2). Unfertilized treatment K levels fell from 244 to 108 pounds per acre from April 1983 to October 1986 (Table 4). Unfertilized treatment K levels in the 6-24 inch depth remained constant from 90 pounds per acre in 1983 to 73 pounds per acre in 1986 (data not presented). This would indicate that K uptake occurred primarily in the top 6-inch soil layer.

Alfalfa yields from the unfertilized treatments have fallen from 4.94 ton per acre in 1983 to 3.89 ton per acre in 1985 and 4.51 ton per acre in 1986, indicating a shortfall of available soil phosphate and potash (Table 5). The unfertilized yield of alfalfa increased in 1986 from 1985 yields due to better growing conditions in 1986.

Phosphorus levels of the 50 pound per acre $P_2O_5$ treatment remained constant over the four-year period (Tables 2 and 3); however, K levels fell significantly from 174 pounds per acre in April 1983 to 100 pounds per acre in October 1986 (Table 4) and yields were reduced from 5.04 to 4.71 ton per acre during the same period (Table 5), indicating a shortfall in $K_2O$ availability.

Phosphorus levels in the 0 to 6-inch depth on the 100 pounds per acre $K_2O$ treatment were reduced significantly from April 1983 to October 1984 with an additional reduction from the 1985 harvest (Table 4). Like the unfertilized treatment, the 100 pounds per acre $K_2O$ treatment alfalfa yield declined from 5.06 to 4.84 ton per acre from 1983 to 1986, respectively, indicating a shortfall in phosphate availability (Table 5).

**Table 4. Potassium Soil Test Results 0 to 6-Inch, Karlsruhe, ND (1983-1986).**

| Treatment | | 'K' soil test 0 to 6-inch | | | | | |
|---|---|---|---|---|---|---|---|
| $P_2O_5$ | $K_2O$ | 4/83 | 10/83 | 10/84 | 10/85 | 10/86 | Avg. |
| ---lb/A--- | | ---lb/A--- | | | | | |
| 0 | 0 | 244 | 103 | 103 | 125 | 108 | 136 |
| 50 | 0 | 174 | 89 | 96 | 118 | 100 | 115 |
| 0 | 100 | 164 | 85 | 128 | 178 | 146 | 140 |
| 50 | 100 | 164 | 115 | 104 | 150 | 133 | 133 |
| 100 | 250* | 175 | 118 | 203 | 215 | 159 | 174 |
| LSD (5%) | | 46 | 18 | 73 | NS | NS | 23 |
| LSD (5%) Year × Treatment = 51 | | | | | | | |

*200 lb $K_2O$ applied in 1983.

**Table 5. Irrigated Alfalfa Forage Yields By Fertilizer Treatment, Karlsruhe, ND (1983-1986).**

| Treatment | | Alfalfa yield | | | | |
|---|---|---|---|---|---|---|
| $P_2O_5$ | $K_2O$ | 1983 | 1984 | 1985 | 1986 | Avg. |
| ---lb/A--- | | ---ton/A at 15% $H_2O$--- | | | | |
| 0 | 0 | 4.94 | 4.63 | 3.89 | 4.51 | 4.49 |
| 50 | 0 | 5.04 | 5.11 | 4.18 | 4.71 | 4.76 |
| 0 | 100 | 5.06 | 4.85 | 4.04 | 4.84 | 4.69 |
| 50 | 100 | 5.09 | 5.33 | 4.85 | 5.36 | 5.16 |
| 100 | 250* | 5.38 | 5.45 | 5.11 | 5.54 | 5.37 |
| AVG. | | 5.10 | 5.07 | 4.41 | 4.99 | |
| LSD (5%) | | NS | 0.53 | 0.35 | 0.53 | 0.26 |
| LSD (5%) Year = 0.23 Year × Treatment = NS | | | | | | |

*200 lb $K_2O$ applied in 1983.

When 100 pounds per acre of $K_2O$ was applied with 50 pounds per acre $P_2O_5$, the soil test levels of P were slightly lower than the 50 pounds per acre $P_2O_5$ treatment alone (Table 2) and the soil test levels of K were generally lower than the 100 pounds $K_2O$ treatment alone (Table 4). Alfalfa yields from the 50 pounds $P_2O_5$ + 100 pounds $K_2O$ treatment were 5.09 to 5.36 ton per acre from 1983 to 1986, respectively, indicating this to be a maintenance level of fertilization on this soil type. The yield of forage harvested from this treatment was significantly greater than the unfertilized,

50 pounds $P_2O_5$ and 100 pounds $K_2O$ treatment yields (Table 5), indicating improved nutrient use efficiency when crop nutrient needs were in balance.

Phosphorus and K levels on the 100 $P_2O_5$ + 250 $K_2O$ treatment increased from the fall of 1983 to the fall 1986, indicating an excess of nutrients being applied (Tables 2 and 4). The 100 $P_2O_5$ + 250 $K_2O$ treatment produce more alfalfa than all other treatments but was not significantly greater than the 50 $P_2O_5$ + 100 $K_2O$ treatment (Table 5).

Potassium levels from the 6 to 24-inch depth were not influenced by fertilizer applied or alfalfa yield, indicating that K uptake occurred primarily in the top 6-inch soil layer and that K was not being leached downward into the sandy loam soil (data not presented).

Nitrate nitrogen soil tests were similar regardless of fertility treatment. Nitrate nitrogen was quite low ranging from 11 to 26 pounds per acre in the 0 to 24 inch soil depth (data not presented).

Alfalfa yield data were analyzed on the basis of individual cuttings (Figure 1). June and July cut alfalfa yielded significantly more forage when the P and K combination was applied compared to P or K alone or no fertilizer applied. August cut alfalfa treated with 50 P + 100 K tended to yield more than alfalfa treated with 50 P or 100 K alone and yielded significantly more forage than the unfertilized alfalfa. The increased yield from balanced fertilization occurred at all cuttings; however, the June and July cuttings received most benefit.

The dollar returns to fertilizing irrigated alfalfa on coarse textured soil in the Karlsruhe area are provided in Table 6. This data was calculated by using the average annual forage yield at 15 percent moisture and $46 per ton alfalfa hay (four-year average price). Costs were $P_2O_5$ at 17.5 cents per pound, $K_2O$ at 7 cents per pound and a $3 per acre per year application charge.

Returns to fertilizer were negative in 1983, the first year of the study (Table 6). The negative returns resulted when

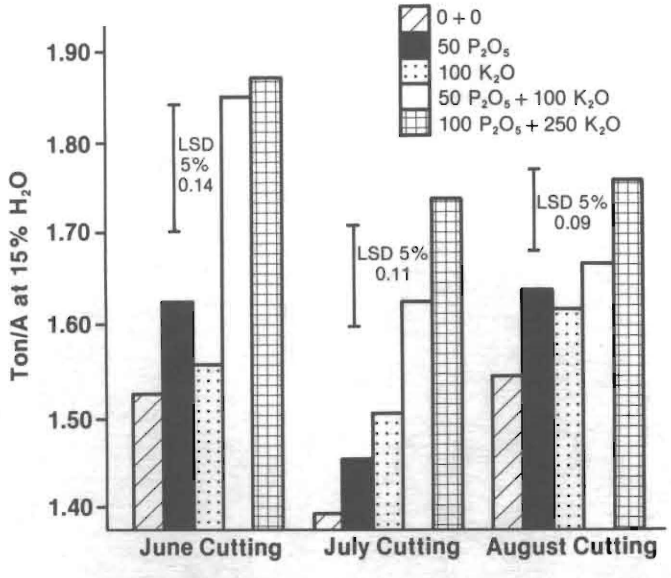


**Figure 1. Influence of Fertilizer Treatment on Irrigated Alfalfa Yield by Cutting, Karlsruhe 1983-1986.**

**Table 6. Fertilizer Cost and Return Summary by Treatment and Year, Karlsruhe, ND (1983-1986).**

| Treatment | | Return/acre | | | | |
|---|---|---|---|---|---|---|
| $P_2O_5$ | $K_2O$ | 1983 | 1984 | 1985 | 1986 | Total |
| lb/A | | $ | | | | |
| 0 | 0 | 227 | 213 | 179 | 207 | 826 |
| 50 | 0 | 220 | 223 | 181 | 205 | 829 |
| 0 | 100 | 223 | 213 | 176 | 213 | 825 |
| 50 | 100 | 215 | 226 | 204 | 228 | 873 |
| 100 | 250* | 213 | 213 | 197 | 217 | 840 |

*200 lbs $K_2O$ applied in 1983.

average soil P levels were medium and K levels were medium to high as determined by soil test. Summation of the annual returns by fertilizer treatment indicate a four-year return above fertilizer and application costs of $47 per acre when a combination of 50 pounds $P_2O_5$ and 100 pounds $K_2O$ was applied per acre annually. This treatment was far more economical than other treatments, which indicates the need for P and K applications when soil tests are low.

## SUMMARY

The results of this study indicate that producers must soil test and apply $P_2O_5$ and $K_2O$ to maximize yields of aging alfalfa stands on irrigated coarse textured sandy soils in the Karlsruhe area. A maintenance level of $P_2O_5$ and $K_2O$ should be applied annually or by the second production year on irrigated alfalfa when soil test levels are in the low-medium to low range, P less than 10 and K less than 100 pounds per acre.

## LITERATURE CITED

1. Bauder, J.W., and A. Bauer. 1978. Irrigated Alfalfa Forage Production on a Well-Drained Sandy Loam at Oakes, North Dakota. North Dakota Farm Research Bimonthly Bulletin 36(2):19-24.
2. Burbank, W.E. 1984. 1983 Irrigation Survey - North Dakota. Irrigation Journal 34(1).
3. Danke, W.C., and L.J. Swenson. 1974. Soil Test Values and Alfalfa and/or Grass Response to Fertilizer. Annual report, Dept. of Soils, North Dakota Agri. Exp. Station.
4. Dodds, D.L., D.W. Meyer, and B. Rice. 1983. Alfalfa Management in North Dakota. North Dakota Coop. Ext. Service, Circular R-571 (Revised).
5. Dodds, D.L., D.W. Meyer. 1985. Alfalfa Variety Selection. Nroht Dakota Coop. Ext. Service, Circular R-681 (Revised).
6. Follett, R.H., L.S. Murphy, and R.L. Donahue. 1981. Fertilizers and Soil Amendments. Prentice-Hall Inc., Englewood Cliffs, New Jersey. P. 89-100, 160-170.
7. Lundstrom, D.R. 1985. 1984 Irrigation Survey - North Dakota. Irrigation Journal 35(1):29.
8. Lundstrom, D.R. 1986. 1985 Irrigation Survey - North Dakota. Irrigation Journal 36(1):25.
9. Lundstrom, D.R. 1987. 1986 Irrigation Survey - North Dakota. Irrigation Journal 37(1):23.
10. Rhykerd, C.L., and C.J. Overdahl. 1982. Nutrition and Fertilizer Use. In C.H. Hanson (ed.), Alfalfa Science and Technology. Agronomy 15:445-449. American Society Agronomy, Madison Wisconsin.