SOIL APPLIED AND WATER APPLIED PHOSPHORUS APPLICATION

M. J. Ottman, T. L. Thompson, M. T. Rogers, and S. A. White[1]

ABSTRACT

Many agricultural workers feel that 10-34-0 is a superior fertilizer for alfalfa since it is thought to move deeper in the soil with irrigation, be more available to the plant, and result in higher yields at equivalent rates compared to 11-52-0. We found in our study with 24 cuttings over 3 years that alfalfa yields were similar if fertilized with 10-34-0 or 11-52-0 at equivalent rates. Total plant P was not affected by P fertilizer form or method of application. Broadcast 11-52-0 resulted in higher soil P levels than water-run 10-34-0 and moved deeper in the soil profile. Broadcast 11-52-0 and water-run 10-34-0 appear to be equally effective P fertilizers for alfalfa in the irrigated southwest.

Key Words: alfalfa, phosphorus, fertilizer, yield, phosphorus movement, soil phosphorus.

INTRODUCTION

Comparisons of alfalfa yield response and P movement in the soil of broadcast granular phosphorus fertilizer and solution forms applied in water of surface flood irrigation systems apparently have not been reported in the literature. The depth of movement of phosphorus fertilizer materials applied on the surface or in sprinkler irrigation water has been reported (Lauer, 1988; Stanberry et. al., 1955) as well as the relative effectiveness of preplant incorporated and sprinkler applied form in the case of corn (Hergert and Reuss, 1976). In surface flood irrigation systems, phosphate fertilizer dissolved in the water may penetrate deeper into the soil and be more effective than fertilizer applied to the surface of established alfalfa due to preferential flow of water and fertilizer through soil macropores (cracks, worm holes, root channels).

The objectives of this experiment are: 1) Determine effectiveness of 10-34-0 applied in irrigation water and 11-52-0 top-dressed as a granule in increasing alfalfa yield, soil test phosphorus, and alfalfa tissue phosphorus concentration and 2) Determine depth of movement in the soil of 10-34-0 applied in irrigation water, 10-34-0 sprayed on the soil surface, and 11-52-0 surface applied as a granule.

MATERIALS AND METHODS

Experimental Design

An experiment was conducted at the University of Arizona Maricopa Agricultural Center with a randomized complete block experimental design with 12 treatments and 4 replications. The treatments consisted of different rates of phosphorus applied as 10-34-0 in the irrigation water or sprayed on the soil surface or top-dressed as 11-52-0 (Table 1). The treatments were applied annually in December (19-21 Dec. 96, 16-18 Dec. 97, and 9-10 Dec. 98) on plots 12 feet wide _____

[1] M. J. Ottman, Agronomy Specialist, Plant Sciences Department; T. L. Thompson, Associate Professor, Soil, Water and Environmental Sciences Department; M. T. Rogers, Research Specialist, Plant Sciences Department; S. A. White, Soil, Water and Environmental Sciences Department; University of Arizona, Tucson, AZ 85721.

and 20 feet long. Earthen dikes are erected between plots at this time prior to when fertilizer treatments are applied. The fertilizer was broadcast on the surface of the soil and irrigated or injected into the

irrigation water. About 4 inches of water are applied. After treatments are applied, the earthen dikes are leveled and the plots were irrigated simultaneously by surface flooding for all other surface irrigations. Soil was sampled in January (30 Jan. 97, 20 Jan. 98, 20 Jan 99, and 27 Jan. 00) before the next irrigation was applied in February.

Soil Characteristics

The soil type is a Casa Grande sandy loam [coarse, loamy, mixed (calcareous), hyperthermic, Typic Natrargid (reclaimed)] with a bicarbonate extractable P level of 6.1 ppm before planting . This soil is relatively deep with uniform texture with the exception of occasional clay lenses from 2 to 5 feet and gravel at 6 to 8 feet. Soil chemical analysis for this soil type is typified: pH=8.2, P=5-18 ppm, OM=0.5%, ECe=1.6 dS m^{-1}, CEC=10.6 cmol kg^{-1}. The bulk density of the soil ranges from 1.4 g cm^{-3} in the surface soil to 1.6 g cm^{-3} in the subsoil. The field was laser leveled and is well-drained.

Cultural Practices

1. Field history - sudangrass was grown in the summer of 1996 prior to planting of alfalfa
2. Tillage - double disk, laser plane, spring-tooth harrow
3. Crop rotation - alfalfa was grown for 3 years.
4. Planting date – 11 Oct 96.
5. Variety - CUF 101.
6. Seeding rate and row width - 25 lbs seed/acre in 6 inch rows.
7. Irrigation - border flood, two to three irrigations of 4-6 inches each per cutting.
8. Fertilizer – 11-52-0 applied by hand, 10-34-0 injected into irrigation water, or 10-34-0 sprayed on the soil surface at various rates.

Parameters Measured

1. Soil phosphorus (0-3") was determined for each plot in January. Twelve soil cores 2 inches in diameter were removed per plot.
2. Plant phosphorus was determined for each plot on an annual basis in May (23 May 97, 20 May 98, and 20 May 99).
3. Soil phosphorus from 0-3, 3-6, 6-9, 9-12, and 12-24 inch depth increments for the control, 10-34-0 applied in the irrigation water at the 100 lb/A rate, 10-34-0 surface applied at the 100 lb/A rate, and 11-52-0 topdressed at the 100 lb/A rate. Twelve soil cores were removed per plot. The soil was sampled in January each year.
4. Yield - The center 4 feet of each plot were cut and weighed fresh with a small plot forage harvester. The remaining 4 feet on either side of this center strip was harvested with a 14 foot mower-conditioner and laid into windrows. The hay was baled when dried to the appropriate moisture content. Forage yields were converted to hay yields by assuming 80% moisture in the fresh forage. Alfalfa was harvested eight times between March and December of each year.

RESULTS AND DISCUSSION

Yield

Phosphorus fertilizer form and method of application generally had little influence on alfalfa hay yield. In 1997, broadcast 11-52-0 resulted in higher yields than water-run 10-34-0 for the first two cuttings in spring and for the sum of the cuttings for 1997 (Table 2a). In 1998, no differences in alfalfa yields were detected regardless of P fertilizer form or method of application (Table 2b). In 1999, P fertilizer form had no effect on hay yield, although a response to P was detected over the sum of the cuttings since some of the fertilized plots yielded higher than the control (Table 2c). Hay yield summed over three years was similar for water-run 10-34-0 and broadcast 11-52-0. Whether 10-34-0 is sprayed on the surface of the soil or water-run did not affect yield except for the first cutting in 1999 where water-run gave a slightly higher yield. The results of this study suggest that water-run 10-34-0 does not result in higher yields than broadcast 11-52-0 at equivalent rates of P.

Plant and Soil Phosphorus

Total plant P of alfalfa sampled in May was not affected by P fertilizer form or method of application (Table 3). Increased P rate, however, resulted in higher P concentration in the plant. Soil P in the surface 0 to 3 inches was affected by P fertilizer form (Table 4). Broadcast 11-52-0 resulted in higher levels of P in the surface 0 to 3 inches than water-run 10-34-0 each year the soil was sampled. Soil P in the surface 0 to 3 inches was similar whether or not 10-34-0 was water-run or sprayed on the soil surface. Water-run 10-34-0 does not appear to move deeper in the soil profile than broadcast 11-52-0. In fact, the opposite may be the case. Broadcast 11-52-0 resulted in equal or greater soil test P compared to water-run 10-34-0 for all sampling dates and depths except for the 0 to 3 inch depth sampled 30 Jan. 97. Specifically, soil P was increased for broadcast 11-52-0 compared to water-run 10-34-0 on 30 Jan 97 for the 6 to 9 inch and 12 to 24 inch depths, on 20 Jan 98 for the 0 to 3 inch depth, on 20 Jan 99 for the 0 to 3 inch and 3 to 6 inch depths, and on 27 Jan 00 for the 0 to 3 inch depth. Averaged over the four sampling times, broadcast 11-52-0 resulted in higher soil P than water-run 10-34-0 at the 0 to 3 inch and 6 to 9 inch depths, and averaged over all depths.

REFERENCES

Hergert, G. W., and J. O. Reuss. 1976. Sprinkler application of P and Zn fertilizer. Agron. J. 68:5-8.

Lauer, D. A. 1988. Vertical distribution in soil of sprinkler-applied phosphorus. Soil Sci. Soc. Am. J. 52:862-868.

Stanberry, C. O., C. D. Converse, H. R. Haise, and A. J. Kelly. 1955. Effect of moisture and phosphate variables on alfalfa hay production on the Yuma mesa. Soil Sci. Soc. Am. Proc. 29:677-678.

ACKNOWLEDGMENT

This research was supported by the Potash and Phosphate Institute.

Table 1. Phosphorus fertilizer, method of application, and rate.

Treatment ID	Fertilizer	Method of application	Phosphorus rate
			lbs P_2O_5/A
1	Control	N/A	0
2	10-34-0	Water-run	20
3	10-34-0	Water-run	40
4	10-34-0	Water-run	60
5	10-34-0	Water-run	100
6	11-52-0	Broadcast	20
7	11-52-0	Broadcast	40
8	11-52-0	Broadcast	60
9	11-52-0	Broadcast	100
10	11-52-0	Broadcast	150
11	10-34-0	Sprayed on surface	40
12	10-34-0	Sprayed on surface	100

Table 2a. Hay yields in 1997 as affected by phosphorus fertilizer form, method of application, and rate.

Fertilizer	Method of	P	Hay Yield in 1997 (0% moisture)								
Form	Application	Rate	3/4	4/15	5/23	6/17	7/15	8/20	10/2	12/4	Sum
		lbs P_2O_5/A	---------- tons/A----------								
Control	N/A	0	0.88	1.03	1.68	1.83	1.77	1.29	0.83	1.12	10.4
10-34-0	Water-run	20	0.97	1.11	1.72	1.89	1.85	1.29	0.84	1.12	10.8
10-34-0	Water-run	40	1.02	1.26	1.84	2.02	1.99	1.35	0.88	1.11	11.5
10-34-0	Water-run	60	1.06	1.23	1.84	2.01	1.84	1.40	0.87	1.13	11.4
10-34-0	Water-run	100	1.13	1.27	1.85	2.04	1.82	1.47	0.87	1.16	11.6
11-52-0	Broadcast	20	1.17	1.23	1.75	1.97	1.81	1.33	0.86	1.09	11.2
11-52-0	Broadcast	40	1.31	1.35	1.94	2.03	1.91	1.40	0.85	1.16	12.0
11-52-0	Broadcast	60	1.47	1.44	1.96	2.18	2.04	1.49	0.88	1.17	12.6
11-52-0	Broadcast	100	1.35	1.37	1.84	1.97	1.88	1.42	0.86	1.14	11.8
11-52-0	Broadcast	150	1.56	1.44	1.99	2.03	1.89	1.42	0.89	1.16	12.4
10-34-0	Sprayed	40	1.08	1.29	1.83	1.98	2.03	1.36	0.85	1.11	11.5
10-34-0	Sprayed	100	1.17	1.31	1.91	2.10	1.92	1.48	0.88	1.14	11.9
	LSD(5%)†		0.16	0.12	0.15	0.17	0.16	0.10	NS	NS	0.6
10-34-0	Water-run	20,40,60,100	1.04	1.22	1.81	1.99	1.87	1.38	0.86	1.13	11.3
11-52-0	Broadcast	20,40,60,100	1.32	1.35	1.87	2.03	1.91	1.41	0.86	1.14	11.9
10-34-0 vs. 11-52-0			**	**	NS	NS	NS	NS	NS	NS	**
10-34-0	Water-run	40, 100	1.12	1.30	1.87	2.04	1.97	1.42	0.87	1.12	11.7
10-34-0	Sprayed	40, 100	1.07	1.27	1.85	2.03	1.90	1.41	0.87	1.13	11.5
Water-run vs. sprayed			NS	NS	NS	NS	NS	NS	NS	NS	NS

†NS = not significant at P = 0.05 and ** = significant at P=0.01.

Table 2b. Hay yields in 1998 as affected by phosphorus fertilizer form, method of application, and rate.

Fertilizer Form	Method of Application	P Rate	Hay Yield in 1998 (0% moisture)								
			3/4/98	4/23	5/20	6/18	7/16	8/20	10/1	12/3	Sum
		lbs P_2O_5/A	tons/A								
Control	N/A	0	1.46	1.16	1.93	2.15	1.83	0.72	1.08	1.46	11.8
10-34-0	Water-run	20	1.53	1.17	1.97	2.05	1.84	0.71	1.07	1.56	11.9
10-34-0	Water-run	40	1.62	1.27	2.17	2.07	1.94	0.72	1.04	1.61	12.4
10-34-0	Water-run	60	1.61	1.33	2.09	2.12	1.91	0.69	1.02	1.59	12.4
10-34-0	Water-run	100	1.73	1.31	2.19	1.94	1.91	0.75	1.09	1.65	12.6
11-52-0	Broadcast	20	1.45	1.25	2.03	2.02	1.91	0.72	1.04	1.57	12.0
11-52-0	Broadcast	40	1.65	1.22	2.11	2.02	1.92	0.72	1.06	1.56	12.2
11-52-0	Broadcast	60	1.69	1.29	2.20	2.12	2.01	0.73	1.03	1.56	12.6
11-52-0	Broadcast	100	1.78	1.28	2.13	2.05	1.93	0.75	1.08	1.54	12.5
11-52-0	Broadcast	150	1.77	1.29	2.12	2.10	1.95	0.74	1.09	1.58	12.6
10-34-0	Sprayed	40	1.54	1.26	2.10	2.02	1.95	0.75	1.07	1.53	12.2
10-34-0	Sprayed	100	1.73	1.27	2.15	2.12	1.89	0.70	1.06	1.54	12.5
	LSD(5%)†		0.21	NS	NS	NS	NS	NS	NS	NS	NS
10-34-0	Water-run	20,40,60,100	1.62	1.27	2.10	2.04	1.90	0.72	1.06	1.60	12.3
11-52-0	Broadcast	20,40,60,100	1.64	1.26	2.11	2.05	1.94	0.73	1.05	1.56	12.3
10-34-0 vs. 11-52-0			NS	NS	NS	NS	NS	NS	NS	NS	NS
10-34-0	Water-run	40, 100	1.63	1.27	2.13	2.07	1.92	0.72	1.07	1.53	12.3
10-34-0	Sprayed	40, 100	1.68	1.29	2.18	2.00	1.92	0.74	1.07	1.63	12.5
Water-run vs. sprayed			NS	NS	NS	NS	NS	NS	NS	NS	NS

†NS = not significant at P = 0.05.

Table 2c. Hay yields in 1999 as affected by phosphorus fertilizer form, method of application, and rate.

Fertilizer Form	Method of Application	P Rate	Hay Yield in 1999 (0% moisture)									97-99 Sum
			3/4	4/15	5/20	6/17	7/22	8/26	9/30	12/2	Sum	
		lbs P_2O_5/A	tons/A									
Control	N/A	0	1.33	1.72	1.96	2.11	1.32	1.13	0.87	0.95	10.4	32.7
10-34-0	Water-run	20	1.58	1.81	2.03	2.12	1.26	1.08	0.85	0.89	10.7	33.4
10-34-0	Water-run	40	1.77	1.97	2.19	2.21	1.37	1.12	0.89	0.91	11.5	35.4
10-34-0	Water-run	60	1.75	1.92	2.13	2.17	1.40	1.08	0.79	0.88	11.2	35.0
10-34-0	Water-run	100	1.91	1.95	2.26	2.22	1.34	1.07	0.81	0.96	11.6	35.8
11-52-0	Broadcast	20	1.48	1.83	2.15	2.11	1.19	1.04	0.78	0.85	10.5	33.7
11-52-0	Broadcast	40	1.78	1.87	2.21	2.18	1.32	1.04	0.81	0.90	11.2	35.4
11-52-0	Broadcast	60	1.73	1.96	2.22	2.24	1.34	1.16	0.88	0.92	11.5	36.8
11-52-0	Broadcast	100	2.03	1.99	2.24	2.27	1.28	1.06	0.84	0.93	11.7	36.1
11-52-0	Broadcast	150	2.03	1.96	2.24	2.31	1.31	1.12	0.82	0.90	11.8	36.8
10-34-0	Sprayed	40	1.67	1.89	2.12	2.20	1.27	1.07	0.82	0.89	11.0	34.8
10-34-0	Sprayed	100	1.74	1.96	2.20	2.19	1.34	1.09	0.80	0.88	11.3	35.7
	LSD(5%)†		0.15	0.15	0.16	NS	NS	NS	NS	NS	0.73	1.6
10-34-0	Water-run	20,40,60,100	1.75	1.91	2.15	2.18	1.34	1.08	0.83	0.91	11.2	34.9
11-52-0	Broadcast	20,40,60,100	1.75	1.91	2.16	2.20	1.28	1.07	0.83	0.89	11.2	35.4
10-34-0 vs. 11-52-0			NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
10-34-0	Water-run	40, 100	1.70	1.92	2.16	2.20	1.30	1.08	0.81	0.88	11.2	35.2
10-34-0	Sprayed	40, 100	1.83	1.96	2.22	2.21	1.35	1.09	0.85	0.94	11.5	35.6
Water-run vs. sprayed			*	NS	NS	NS	NS	NS	NS	NS	NS	NS

†NS = not significant at P = 0.05 and * = significant at P=0.05.

Table 3. Total plant phosphorus as affected by phosphorus fertilizer form, method of application, and rate.

Fertilizer Form	Method of Application	P Rate	Total Plant P			
			5/23/97	5/20/98	5/20/99	Avg.
		lbs P_2O_5/A	ppm P	ppm P	ppm P	ppm P
Control	N/A	0	1553	2685	1785	2008
10-34-0	Water-run	20	1573	2547	1849	1990
10-34-0	Water-run	40	1541	2872	2003	2139
10-34-0	Water-run	60	1760	2849	2015	2208
10-34-0	Water-run	100	2024	2921	2240	2395
11-52-0	Broadcast	20	1806	2603	1929	2112
11-52-0	Broadcast	40	1582	2832	1915	2110
11-52-0	Broadcast	60	1671	2924	2032	2209
11-52-0	Broadcast	100	1761	3378	2278	2473
11-52-0	Broadcast	150	2020	3169	2418	2536
10-34-0	Sprayed	40	1673	2723	2038	2145
10-34-0	Sprayed	100	1831	3254	2001	2362
	LSD(5%)†		265	422	218	172
10-34-0	Water-run	20,40,60,100	1724	2797	2027	2183
11-52-0	Broadcast	20,40,60,100	1705	2934	2038	2225
10-34-0 vs. 11-52-0			NS	NS	NS	NS
10-34-0	Water-run	40, 100	1752	2988	2020	2253
10-34-0	Sprayed	40, 100	1783	2996	2121	2267
Water-run vs. sprayed			NS	NS	NS	NS

†NS = not significant at P = 0.05.

Table 4. Surface soil (0-3") bicarbonate extractable phosphorus as affected by phosphorus fertilizer form, method of application, and rate.

Fertilizer Form	Method of Application	P Rate	Soil P (0-3")			
			1/20/98	1/20/99	1/27/00	Avg.
		lbs P_2O_5/A	ppm P	ppm P	ppm P	ppm P
Control	N/A	0	3.3	3.1	1.8	2.7
10-34-0	Water-run	20	2.7	4.5	3.1	3.4
10-34-0	Water-run	40	3.9	4.3	3.2	3.8
10-34-0	Water-run	60	6.4	5.1	3.2	4.9
10-34-0	Water-run	100	5.0	8.7	3.3	5.7
11-52-0	Broadcast	20	3.8	4.2	3.2	3.8
11-52-0	Broadcast	40	7.1	5.0	3.9	5.3
11-52-0	Broadcast	60	9.1	5.5	4.7	6.4
11-52-0	Broadcast	100	14.1	19.8	5.1	13.0
11-52-0	Broadcast	150	25.3	13.2	9.9	16.1
10-34-0	Sprayed	40	5.1	4.7	2.6	4.1
10-34-0	Sprayed	100	7.0	9.3	3.2	6.5
	LSD(5%)†		2.7	2.5	1.1	1.3
10-34-0	Water-run	20,40,60,100	4.5	5.6	3.2	4.4
11-52-0	Broadcast	20,40,60,100	8.5	8.6	4.2	7.1
10-34-0 vs. 11-52-0			**	**	**	**
10-34-0	Water-run	40, 100	6.0	7.0	2.9	5.3
10-34-0	Sprayed	40, 100	4.4	6.5	3.3	4.7
Water-run vs. sprayed			NS	NS	NS	NS

†NS = not significant at P = 0.05 and ** = significant at P=0.01.

Table 5. Bicarbonate extractable phosphorus at various depths in the soil as affected by P fertilizer form, method of application, and rate.

Sampling date	Depth	Soil phosphorus				
		Control	Water-run 10-34-0	Broadcast 11-52-0	Sprayed 10-34-0	LSD (5%)†
		---------- ppm P ----------				
1/30/97	0 to 3	4.0	13.1	9.0	16.4	2.4
	3 to 6	2.7	4.4	5.4	4.5	NS
	6 to 9	2.5	3.2	7.1	3.6	1.4
	9 to 12	3.6	2.4	3.3	3.1	NS
	12 to 24	1.9	1.9	2.7	2.1	0.6
	Avg.	3.0	5.0	5.5	5.9	0.8
1/20/98	0 to 3	3.3	5.0	14.1	7.0	2.6
	3 to 6	2.1	1.8	1.8	1.7	NS
	6 to 9	1.5	2.1	1.7	3.0	NS
	9 to 12	1.9	1.1	3.3	1.5	NS
	12 to 24	2.8	1.7	1.9	0.9	1.0
	Avg.	2.3	2.3	4.5	2.8	0.8
1/20/99	0 to 3	3.1	8.7	19.8	9.3	3.4
	3 to 6	2.6	4.1	6.6	6.2	2.5
	6 to 9	2.6	5.0	4.2	4.6	1.2
	9 to 12	2.2	4.3	3.4	4.5	NS
	12 to 24	1.8	3.4	2.9	2.8	NS
	Avg.	2.4	5.1	7.4	5.5	0.8
1/27/00	0 to 3	1.8	3.3	5.1	3.2	1.3
	3 to 6	1.2	1.1	1.1	1.1	NS
	6 to 9	1.1	1.0	1.0	1.1	NS
	9 to 12	1.1	1.0	0.9	1.0	NS
	12 to 24	1.0	1.2	1.1	0.8	NS
	Avg.	1.3	1.5	1.8	1.4	0.3
Avg.	0 to 3	3.1	7.5	12.0	9.0	1.5
	3 to 6	2.1	2.9	3.7	3.4	1.1
	6 to 9	1.9	2.8	3.5	3.1	0.5
	9 to 12	2.2	2.2	2.7	2.6	NS
	12 to 24	1.9	2.1	2.2	1.6	0.4
	Avg.	2.2	3.5	4.8	3.9	0.4

†NS = not significant at P = 0.05.