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Deep Placement of Phosphorus into Established Alfalfa[1]

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ABSTRACT

Previous attempts to place phosphorus (P) fertilizer below the soil surface in established alfalfa [*Medicago sativa (L.)*] have not been successful because of stand disturbance and subsequent yield reduction. Three dryland experiments were conducted in western North Dakota on Pachic and Typic Haploborolls comparing surface applications of granular concentrated superphosphate to deep applications of liquid ammonium polyphosphate. The phosphorus rates were 0, 20, 40 and 80 lb P_2O_5/ac (0, 10, 20, 40 kg P/ha). The liquid fertilizer was injected on 12-inch (30 cm) centers at a depth of 4 inches (10 cm) using modified thin profile anhydrous ammonia knives. Results indicate that the deleterious effects of the knifing operation on alfalfa yield were negligible at two of the three sites. The knifing operations decreased yield approximately 7% at the third site. Deep placed P promoted significantly higher yields and recoveries of fertilizer P than surface P at two of the three locations. Deep placed P was 3.4, 1.8, and 1.2 times as effective as surface P for the three sites, as estimated by plant uptake data. Procedures for knifing P into established alfalfa with minimal stand damage are discussed.

Additional index word: Medicago sativa.

THERE is great current interest in methods of phosphorus (P) fertilizer application. Much of this interest has been sparked by the successful deep placement trials of Leikam, *et al.* (1979, 1983).The wide publicity that these trials have received has prompted renewed research in P placement methods. Most of the trials to date have been with annual crops.

Past trials with subsurface application of P fertilizers in established grass or alfalfa [*Medicago sativa (L.)*] have not produced encouraging results. Leyshon (1982) applied granular P fertilizers to established alfalfa in southwest Saskatchewan with a "hoe drill" type implement. In this study, the stand damage inflicted by the application process caused a yield reduction. He concluded surface application was the only recommendable method for P fertilizer application on established alfalfa. This paper reports on the results obtained with another method of P fertilizer injection into established alfalfa.

MATERIALS AND METHODS

Four dryland experiments were established in western North Dakota in October of 1982. The sites were in either common or 'Vernal' alfalfa. All stands were over four years old. One site was lost to winterkill. The "surface P" treatments consisted of a topdressing of concentrated superphosphate at 0, 20, 40 and 80 lb P_2O_5/ac. The "deep P" treatments consisted of an injected application of liquid ammonium polyphosphate at 0, 20, 40 and 80 lb P_2O_5/ac. The 0 lb/ac "deep P" treatment was shanked identically as the 20, 40, and 80 lb treatments, only without fertilizer addition. The "surface P" treatments were not shanked. The liquid fertilizer was metered with a ground driven John Blue[3] fertilizer pump, through a John Blue flow divider, to knives mounted on DMI spring shanks on 12 inch centers on a 3 rank tool bar. The knives were Harlan thin-profile anhydrous ammonia knives, modified for liquid fertilizer delivery (Figure 1). The knives, as modified, operated without plugging. The operation depth of the point of each knife was 4 inches, with fertilizer delivery at a depth of 3 inches. At the time of fertilizer application,the fields were moist, the stands were dormant, and no problem with crown uprooting was noted.

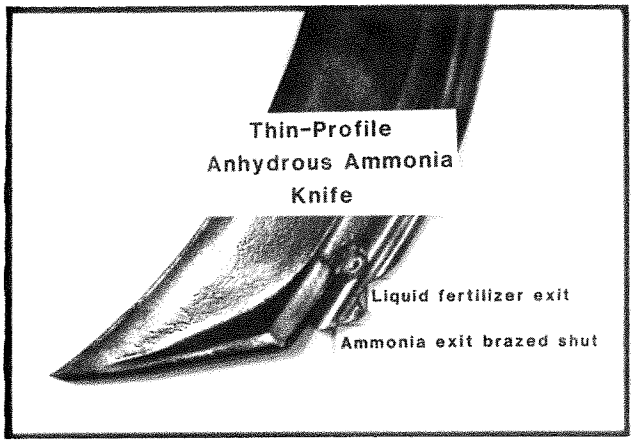

Figure 1. Modified thin-profile anhydrous knife as used in this study.

Preliminary experiences with deep placement into alfalfa have shown that if stands are not totally denuded of leaves and dormant, there will be enough intertwining of stems to promote uprooting of crowns

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[3] Use of trade names is only intended for reader convenience and does not imply an endorsement by North Dakota State University.

and subsequent stand reduction. Typically, this is not a problem in semi-arid regions, as regrowth after the second cutting is minimal.

Ammonium nitrate was topdressed as appropriate so that all plots received a total of 23 lb N/ac. This was to compensate for the N additions from the liquid fertilizer. A randomized complete block design with four replications was employed. One replication was abandoned at the Hettinger location because of badger damage and other soil variability. Individual plot size was 6 x 30 ft. Two harvests were made. The first harvest was at first bloom to 10% bloom and the second harvest was made at 50-75% bloom. An area of 3 x 24 feet was harvested from individual plots with a flail-type plot harvester, weighed, and sub-samples taken for moisture and phosphorus analysis. Forage samples were dried, ground finely, and analyzed for total P by sulfuric acid digestion and colorimetric determination. Initial soil samples were taken from control plots to a depth of 4 feet and analyzed for standard soil test parameters (Dahnke, 1980).

RESULTS AND DISCUSSION

Pertinent soil test data, climatic data, and dates of significant field operations are found in Table 1. The Dickinson and Hettinger locations tested "low" in Olsen P and the Mandan location tested "medium," by present interpretation criteria (Dahnke *et al.* 1981). All sites had very low levels of available P below 6 inches. Initial stored soil moisture was above normal and growing season precipitation was near normal for western North Dakota. In general, the air temperatures were below normal from April 20 to July 1 and above normal July 1 to Aug. 1.

Table 1. Characteristics of the experimental locations.

Measurement	Soil Depth	Site		
		Dickinson	Hettinger	Mandan
	inch			
Olsen P, lb/ac	0-6	8	5	12
	6-12	2	3	3
pH	6-6	7.1	7.2	7.4
Exch. K, lb/ac	0-6	300	450	610
	6-12	180	270	620
Organic Matter, %	0-6	1.3	2.0	3.8
	6-12	1.0	1.2	2.6
Soil Series	—	Parshall	Stady	Bowdle
Classification	—	Pachic Haploboroll	Typic Haploboroll	Pachic Haploboroll
Growing season precipitation, in ‡	—	6.5	7.0	6.0
Date of fertilization	—	10-20-82	10-19-82	10-18-82
Harvest dates	—	6-15-83	6-14-83	6-13-83
	—	7-26-83	7-25-83	7-25-83

‡April 20 (date of spring soil sampling) to date of second harvest.

The effect of P rate and placement at the Dickinson site is shown in Table 2. First cutting yields were significantly increased by added P, and deep placed P was superior to surface P. For example, dry matter yields at 20 lb P_2O_5/ac deep placed were similar to those observed at 40 lb P_2O_5/ac surface placed (2110 vs. 2080 lb/ac), and yields at 40 lb P_2O_5/ac deep placed were similar to observed at 80 lb P_2O_5/ac surface placed (2430 vs. 2370 lb/ac), suggesting that the deep applications were at least twice as effective as surface P in increasing yield at this site.

Table 2. Effect of phosphorus rate and placement on alfalfa yield and P uptake. Dickinson site, 1983.

Phosphorus rate	Placement	First cutting		Second cutting	
		Dry matter	P uptake	Dry matter	P uptake
lb P_2O_5/ac		lb/ac			
0	Surface	1890	2.5	1700	2.3
20		2070	2.8	1700	2.4
40		2080	2.7	1700	2.5
80		2370	3.2	1720	2.5
0	Deep	1880	2.4	1650	2.2
20		2110	3.0	1840	2.5
40		2430	3.6	1770	2.6
80		2650	4.6	1790	3.0
Significance of F					
P rate		**	**	NS	**
P placement		*	**	NS	NS
Rate x Placement		NS	**	NS	NS
C.V., %		8.0	12.0	5.2	8.8

*,**F significant at 0.05, 0.01, respectively.

First cutting P uptake was increased by P fertilization, and again deep applied P was superior to surface P. Simple linear regressions were performed on the first cutting P uptake data to further compare the two placement methods. The ratio of the linear regression slopes is an estimate of relative placement effectiveness. Results of this analysis are shown in Table 5. Deep placed P was approximately 3.4 times as effective, in terms of uptake, as equal rates of surface P at this site.

Second cut yields and P uptake were not significantly affected by P placement at the Dickinson site. This is perhaps due to the warmer than normal temperatures that prevailed after July 1.

The effects of P rate and placement at the Hettinger site are summarized in Table 3. Although the first cutting data are more erratic than for the Dickinson site, there is a significant advantage of deep placement over surface placement in both yield and P uptake. The P

uptake data for the first cutting also shows a decided superiority for deep placement. For the first cutting, deep P was 1.8 times as effective as surface P (Table 5). Second cut yields and P uptake were not significantly affected by treatment at Hettinger (Table 3) although the data tends to support a superiority of deep placement.

Table 3. Effect of phosphorus rate and placement on alfalfa yield and P uptake. Hettinger site, 1983.

Phosphorus rate	Placement	First cutting		Second cutting	
		Dry matter	P uptake	Dry matter	P uptake
lb P_2O_5/ac		lb/ac			
0	Surface	2450	4.7	2200	3.6
20		2330	4.3	2110	3.4
40		2490	4.9	2100	3.6
80		2670	5.9	2160	3.9
0	Deep	2350	4.1	2120	3.1
20		2710	5.5	2330	3.8
40		2710	5.8	2190	3.8
80		2830	6.8	2230	4.3
Significance of F					
P rate		*	**	NS	*
P placement		*	**	NS	NS
Rate x Placement		+	+	NS	NS
C.V., %		6.1	8.0	6.4	11.0

+,*,**F significant at 0.1, 0.05, 0.01, respectively.

The Mandan site gave results at variance with the other two sites (Table 4). First cutting yields were significantly lower for deep placement, although both forms of placement promoted an overall P response. Averaged across P rate, the magnitude of the yield reduction was approximately 7%. This overall yield reduction is due to the tillage aspect of the deep placement and not due to a lesser availability of the deep applied P. This contention is supported by Table 5, which shows approximately equal effectiveness of these two placement methods as measured by plant P uptake. The magnitude of the tillage induced yield decreases observed at this site are less than the decreases reported by Leyshon (1982), who observed a 20% yield decrease when alfalfa was disturbed to a one-inch depth by a "hoe drill" type implement. In this present study, the soil was disturbed to 4 inches with a 7% decrease at the Mandan site and negligible decreases at the other two sites. It is not known why the alfalfa was adversely affected at only the Mandan site. This site had the oldest and thinnest overall stand of the three sites, and thus may have been more affected by the tillage operation. These yield decreases were not observed at the second cutting, however (Table 4). There were no placement differences in second cutting P uptake.

Table 4. Effect of phosphorus rate and placement on alfalfa yield and P uptake. Mandan site, 1983.

Phosphorus rate	Placement	First cutting		Second cutting	
		Dry matter	P uptake	Dry matter	P uptake
lb P_2O_5/ac		lb/ac			
0	Surface	2220	3.4	980	1.4
20		2450	4.0	1150	1.8
40		2470	3.9	1040	1.6
80		2450	4.0	1140	1.8
0	Deep	2030	3.4	1090	1.6
20		2260	3.6	1090	1.7
40		2330	3.7	1140	1.8
80		2340	4.0	1020	1.7
Significance of F					
P rate		*	**	NS	+
P placement		*	NS	NS	NS
Rate x Placement		NS	NS	NS	+
C.V., %		7.8	9.2	9.9	10.8

+,*,**F significant at 0.1, 0.05, 0.01, respectively.

Table 5. Effectiveness ratio calculation for deep vs. surface applied P. First cutting P uptake data, 1983.

Site	P surface+			P deep+			Effectivess ratio
	Intercept	Slope 1	r^2	Intercept	Slope 2	r^2	(Slope 2/Slope 1)
		-	%		-	%	-
Dickinson	2.5	0.008	.86	2.4	0.027	.99	3.4
Hettinger	4.3	0.017	.76	4.5	0.031	.91	1.8
Mandan	3.6	0.006	.49	3.4	0.007	.99	1.2

+P uptake data fitted to a simple linear regression model: P uptake, lb/ac = Intercept + slope (P rate, lb P_2O_5/ac).

CONCLUSIONS

Deep placement of liquid P fertilizer into standing alfalfa was superior to surface broadcast application of granular fertilizer at two of the three locations. At these two sites, there were negligable deleterious effects of the knifing operation on the alfalfa stand. Deep applied P was 1.8-3.4 times more effective than surface P at these two sites, as measured by first cutting plant P uptake. At a third site, a significant yield reduction (7%) from the knifing operation was observed at the first cutting, but not at the second cutting. Equal plant uptake of surface P vs. deep P was observed at this site.

The conclusion of this paper is that deep-applied P to established alfalfa using modified thin profile anhydrous ammonia knives can be a very practical application technique, especially on soils testing quite low in available P. Such applications should be made

in late fall or early spring when stands are dormant and very little remains of the previous year's growth. This study is being continued and results will be reported after termination of the experiment.

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