Influence of Tillage Method on Incorporation of Fertilizer Phosphorus

Armand Bauer and Henry L. Kucera

Tillage is performed for various reasons. One is to incorporate fertilizers and other soil amendments. Depth of placement and extent of incorporation of these materials is affected by the tillage implement used. Placement of phosphorus and other immobile nutrients in the soil in a position to facilitate contact with plant roots is necessary if benefits are to be derived from the application.

Data from two North Dakota locations, where **four** different tillage treatments were imposed following the uniform application of phosphorus fertilizer on each site, show that turning the soil with a **moldboard plow** placed more of the fertilizer phosphorus in the 3 to 6-inch depth than where the soil was **not tilled** or where tillage was done with a **double disk** or **Noble blade.** Concomitantly, less of the applied phosphorus was removed by extraction with a sodium bicarbonate solution from the 0 to 3-inch depth of the moldboard plow treatment than from this depth following the other three tillage treatments. Also, the data show that the amount of phosphorus extracted from the 0 to 3-inch depth following double disking was less than where no tillage was performed, but there was no difference in extractable amounts from these two treatments at the 3 to 6-inch depth. Furthermore, the data show that at one of the locations the amount of phosphorus extracted from both the 0 to 3 and 3 to

Dr. Bauer is professor, Department of Soils, and Kucera is associate professor, Department of Agricultural Engineering.

6-inch depths was the same for the Noble blade as the no tillage treatment, but at the other location less was extracted from the 0 to 3-inch depth after tilling with the Noble blade than not tilling.

METHODS

Phosphorus-containing fertilizers were applied broadcast in the fall and by drill attachment in the spring at two locations. At the Carrington Station on a Kief silt loam fall applications were made in 1965, 1966, and 1967 and in the spring of 1966 and 1967. At the Dalrymple Experimental Plot at Casselton on a Fargo silty clay, fall applications were made in 1966 and 1967 and spring applications in 1967. The source and approximate amount of phosphorus at each time of application are shown in Table 1.

Table 1. Source and Amount of Phosphorus (P) Applied in Fall and Spring.

		Casselton		Carrington	
		Source and Pounds P[1] Per Acre			
Year	Time	CSP[2]	MAP[3]	CSP[2]	MAP[3]
1965	Fall[4]/	-	-	44	0
1966	Spring[5]	-	-	15	10
1966	Fall[5]	42	21	30	15
1967	Spring[5]	7	3	7	3
1967	Fall[5]	38	20	38	20

[1]To convert to P_2O_5, multiply by 2.29.
[2]Concentrated superphosphate (0-46-0 as N-P_2O_5-K_2O).
[3]Mono-ammonium phosphate (11-55-0 as N-P_2O_5-K_2O).
[4]Source was 0-45-0 (N-P_2O_5-K_2O).
[5]Fertilizer material applied was 12-24-12 (N-P_2O_5-K_2O). About 2/3 of the phosphorus was from 0-46-0 and the remainder from 11-55-0.

After each fall broadcast application of fertilizer, four fall tillage treatments were imposed, each repeated six times. The treatments and the estimated depth of penetration were:

Treatment	Estimated Depth
1. No fall tillage	
2. Moldboard plow	7 inches
3. Double disk	2 to 3 inches
4. Noble blade	4 inches

Except for the soil disturbance by a press drill to seed wheat, no spring tillage was performed on the plots sampled. Each fall tillage treatment was always in the same position in the site area over the time period considered. Depth of seeding and spring fertilizer placement depth did not exceed two inches.

A composite of 4 samples was taken from each plot of each treatment. Samples were taken from the 0 to 3, 3 to 6, 6 to 9, 9 to 12 and 12 to 18-inch depth with a cylindrical tube 1.4 inches in diameter shortly after fall tillage treatments were imposed in 1967. After air-drying, phosphorus extractable with 0.5 **M** sodium bicarbonate ($NaHCO_3$) was measured by the Soil Testing Laboratory at North Dakota State University (1).

To evaluate the $NaHCO_3$-extractable phosphorus already in the soil before application of phosphorus fertilizer, samples were taken from the periphery of the trial sites in the fall of 1967 where broadcast application of phosphorus fertilizer had not been made. Data which show the levels of $NaHCO_3$-extractable phosphorus (P) found in the peripheral areas are presented in Table 2.

Table 2. Distribution of Sodium Bicarbonate Soluble Phosphorus in Soil Adjacent to Experimental Sites.[1]

	Pounds $NaHCO_3$ Soluble Phosphorous (P)[2] -					
	Soil Depth (inches)					
Location	0-3	3-6	6-9	9-12	12-18	Total
Casselton	17	8	2	1	<1	28
Carrington	12	6	4	2	2	26

[1]Sampled fall of 1967. Samples taken from periphery of each site where broadcast application had not been made.
[2]Pounds of phosphorus (P) per sampled depth, corrected for soil bulk density.

Bulk density measurements to the 18-inch depth were made in the fall of 1965 and 1966 at Carrington and Casselton, respectively. Samples

Table 3. Approximate Soil Bulk Density and Weight as Influenced by Depth and Tillage Method at Casselton and Carrington.

		Casselton		Carrington	
Fall Tillage Method	Soil Depth	Bulk[1] Density	Weight of[2] 3 inches soil	Bulk[1] Density	Weight of[2] 3 inches soil
	(Inches)	(grams/cc)	(pounds x 10^5)	(grams/cc)	(pounds x 10^5)
None	0-6	1.00	6.80	1.04	7.02
	6-12	1.27	8.63	1.22	8.30
	12-18	1.33	9.03	1.24	8.42
Moldboard Plow	0-6	0.76	5.17	0.95	6.46
	6-12	1.21	8.23	1.23	8.35
	12-18	1.31	8.90	1.32	8.97
Double Disk	0-6	0.93	6.33	1.03	7.01
	6-12	1.23	8.35	1.21	8.23
	12-18	1.35	9.18	1.24	8.42
Noble Blade	0-6	0.86	5.85	0.99	6.73
	6-12	1.22	8.30	1.22	8.30
	12-18	1.33	9.03	1.25	8.45

[1]Bulk density 0-6 inch depth based on spring and fall measurements and of 6-12 and 12-18 inch depth on fall measurements (average of 4 to 6 replicates). Bulk density of 2,000,000 pounds to 6-inch depth over an acre is about 1.47.
[2]Based on assumption that bulk density within each 6-inch increment is uniform. (6.80 x 10^5 is 680,000 pounds, etc.)

were taken with a tube 1.4 inches in diameter. Samples from the 0 to 6-inch depth were also taken in the spring after seeding, with cans 6 inches long and 2.5 inches in diameter pushed into the soil with a hydraulically-operated soil probe. Bulk density data and weight of 3 inches of soil over an acre are presented in Table 3.

Total precipitation at Carrington after fall application of fertilizer in 1965 to the sampling date in 1967 was about 31 inches; at Casselton total precipitation was about 15 inches from the fall of 1966 to fall sampling in 1967.

Total wheat yield for the 1966 and 1967 seasons at Carrington ranged from about 21 bushels per acre on the no fall tillage treatment to 45 bushels on the moldboard plow treatment. At Casselton the yields in 1967 ranged from about 12 bushels per acre on the no fall tillage treatment to 29 bushels per acre on the moldboard plow treatment.

RESULTS

A summary of the significance of the variables tested in the experiment, as determined by statistical analysis, is shown in Table 4. The total amount of phosphorus extracted to the 18-inch depth was not affected by tillage treatment. (Treatment was not significant). However, the amount of phosphorus extracted was not the same at all sampled depths. (Depth was statistically significant). Also, the amount of phosphorus extracted from the sampled depths was not the same under all tillage treatments. (The treatment x depth interaction was significant).

The data in Table 5 show the amount of phosphorus, in pounds of phosphorus (P) over an area of an acre, extracted from each depth. These show that the largest amount extractable was in the 0 to 3-inch depth, irrespective of tillage treatment. The largest amount in the 0 to 3-inch depth was present or tended to be present on the no fall tillage treatment and the least in the moldboard plow treatment; the double disk and Noble blade treatment did not differ from each other, but both had larger amounts than the moldboard plow treatment. At the 3 to 6-inch depth, the largest quantity extractable was on the moldboard plow treatment; the others did not differ from each other. At depths greater than 6 inches, the amount of phosphorus extracted did not vary significantly with depth or with tillage treatment.

Table 4. Summary of Significance of Variance Sources.

Location	Source of Variance: Tillage Treatment	Depth	Treatment x Depth
Casselton	N.S.[1]/	**[2]/	**[3]/
Carrington	N.S.	**	**

[1]Not Significant. The odds are less than 95 out of 100 that total average differences in amounts of phosphorus extracted to 18 inches are due to tillage treatment rather than to chance.
[2]Used to indicate that the odds are greater than 99 out of 100 that average differences in amounts of phosphorus extracted among sampled depths are due to tillage treatment rather than chance.
[3]Used to indicate that odds are greater than 99 out of 100 that average differences in amounts of phosphorus extracted from a given soil depth was not the same for all tillage treatments.

DISCUSSION

Incorporation of fertilizers supplying nutrients that are immobile in soil is necessary in order to position the material for root contact. The depth to which placement is desired will depend upon the crop grown — its rooting habits and period of its life cycle when maximum uptake of the nutrient occurs. Immobile nutrients must be placed in the rooting zone of nearly all crops in order to be taken up. Expected rainfall distribution is another con-

Table 5. Distribution of Sodium Bicarbonate Soluble Phosphorus as Influenced by Incorporation Method of Broadcast Phosphorus Fertilizer.[1] [2]

Location and Soil Type	Fall Tillage Method	Pounds $NaHCO_3$- Soluble Phosphorus (P)[3] — Soil Depth (inches): 0-3	3-6	6-9	9-12	12-18	Total
Casselton (Fargo SiC)	None	47 f[4]	3 ab	2 a	1 a	<1 a	53
	Moldboard Plow	23 d	15 c	5 ab	3 ab	4 ab	50
	Double Disk	34 e	6 ab	4 ab	3 ab	3 ab	50
	Noble Blade	37 e	5 ab	4 ab	3 ab	3 ab	52
Carrington (Kief SiL)	None	56 e	6 a	1 a	<1 a	<1 a	63
	Moldboard Plow	29 c	16 b	4 a	1 a	<1 a	50
	Double Disk	45 d	4 a	1 a	<1 a	<1 a	50
	Noble Blade	50 de	5 a	1 a	<1 a	1 a	57

[1]Source was concentrated superphosphate (0-46-0) and mono-ammonium phosphate (11-55-0). (Expressed in terms of N-P_2O_5-K_2O).
[2]Application rate at Casselton was 300 pounds P_2O_5 (131 pounds P) and 415 pounds P_2O_5 (182 pounds P) at Carrington.
[3]Pounds of phosphorus (P) per sampled depth, corrected for soil bulk density. Average of 6 replications.
[4]Within each location, numbers followed by the same letter are not significantly different at the 5% confidence level.

sideration in determining incorporation depth. Placement of the immobile nutrient at a depth where the soil is dry during much of the growing season may produce limited, if any, benefits because of inactivity of roots in dry soil.

The need for incorporating broadcast-applied fertilizers into the soil is not limited to those supplying immobile nutrients. Soil incorporation is required to prevent volatilization losses of nitrogen from sources such as the pressure liquids, and from ammonium-containing or ammonium-forming materials especially when applied to soils calcareous to the surface. Frequently, incorporation depth is important in preventing loss.

Incorporation of fertilizer into soil also may be desirable on sloping land where water runoff may occur carrying the fertilizer with it. Under such conditions any nutrient could be involved.

Several of the soil-derived nutrients essential for plant growth are immobile in soil, but the cause of the immobility is not the same for all nutrients. Those which form positive ions (cations), and are taken up by plants as such, are subject to adsorption by the negatively charged colloidal substances (clay and humus) in soil. When adsorbed, positive ions are not free to move with water. Since clay and humus content varies in soils, degree of immobility also varies with soils.

Nutrients taken up by plants as positive ions are not equally immobile in a given soil. The degree of immobility is associated with the ease with which the ion species is replaced on the adsorption site of the colloidal substances by other ions. Potassium, adsorbed as K^+, is more mobile in soil than either zinc (Zn^{++}) or copper (Cu^{++}), both of which are very immobile in soil and also strongly adsorbed to clay and humus.

Nutrients taken up by plants as negative ions (anions) can also be immobile in soil, even though negative ions are repelled rather than adsorbed by soil colloidal substances. Phosphorus, taken up by plants as a negative ion H_2PO_4 and/or HPO_4[a]/ is considered very immobile in soils, except those of very low adsorption capacity (3). Immobility of phosphorus results from very rapid formation of phosphorus compounds of low water solubility; only very small amounts of phosphorus are in solution at any one time. Thus, when fertilizer containing phosphorus is added to soil, specific compounds form, dependent upon the fertilizer composition and acidity of the solution formed by the dissolving fertilizer, the soil reaction, and the nature of the substances in the soil surrounding the dissolving fertilizer (4). The compounds formed in the initial reaction are unstable, even though they may persist for one or more growing seasons in the fertilizer band. Eventually these revert to more stable compounds of lower availability. In acid soils the stable compounds formed are iron or aluminum phosphates and in neutral to alkaline soils calcium phosphates (5). Immobility is a characteristic of phosphorus in soil, irrespective of the source or form (liquid or solid) of fertilizer applied.

An exception to the necessity of incorporating phosphorus fertilizer in order to facilitate uptake is associated with alfalfa (2). Uptake likely occurs when the soil surface is moist.

This study illustrates the immobility of phosphorus inasmuch as the amount of extractable phosphorus in the 6 to 9-inch depth in the experimental site was essentially the same as in the area adjacent to the experimental site.

a)H_2PO_4 is present in largest proportion in soils of less than pH 7.2 and HPO_4 at pH greater than 7.2.

SUMMARY

Based on extraction with 0.5 **M** $NaHCO_3$, phosphorus fertilizer applied broadcast, together with a lesser amount by drill attachment, was incorporated into soil to at least 6 inches with a moldboard plow. Less $NaHCO_3$-extractable phosphorus was found in the 0 to 3-inch soil depth after moldboard plowing than after tilling with the double disk or Noble blade, or with no tillage. A double disk or Noble blade did not achieve incorporation beyond 3 inches.

The amount of phosphorus extracted with $NaHCO_3$ from the 0 to 3-inch soil depth was less after double disking than after no tillage. Likewise, less $NaHCO_3$-extractable phosphorus was found in the 0 to 3-inch soil depth in plots tilled with the Noble blade than in no tillage plots in one of two trials.

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