PHOSPHORUS PLACEMENT AND TILLAGE EFFECTS ON CORN AND SOIL P LEVELS[1]

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ABSTRACT

Increasing crop production costs have producers scrambling to gain the greatest efficiency possible from added fertilizers. A field study was conducted at two locations in southern Illinois is assess the effect of phosphorus (P) rates and placement methods on yield and P uptake by corn under no-till (NT) and conventional (chisel and disk) tillage (CT) systems. Phosphorus rates consisted of 0, 20, and 40 pounds P_2O_5/Ac with placement methods of surface broadcast, dribble and 2x2 at planting. After three years (1987-89) of a corn-soybean rotation where P treatments were applied to each crop each year, an intensive sampling of soil to an eight-inch depth across two rows in 2-inch increments was completed at one location.

In most years and locations, corn yields from CT were greater than those of NT. Phosphorus rate in general increased grain P concentrations but placement method had little effect. Greater P uptake and accumulation in the grain was observed with dribble and 2x2 (with K) placement of P under CT at Dixon Springs. For NT, however, greatest uptake occurred with broadcast placement. At Millstadt, placement had no effect on grain P uptake, regardless of tillage. Grain yields were not affected by P rate or placement at either location.

Soil P distribution was dramatically affected by both tillage and placement method. A definite zone of P depletion was observed near the corn rows with the broadcast placement. The most pronounced depletion occurred with NT where the fertilizer was not mixed to redistribute the P within the soil. For the dribble treatment, final tillage for seedbed preparation under CT essentially leveled out any gradient effects of dribble placement; however, large "spikes" of P concentrations were observed near the rows under NT in the 0-2 inch depth increment. Large P concentration increases were observed under both tillage systems with the 2x2 placement method, but the increases were mostly in the 2-4 inch increment. Results indicate that movement toward dribble or 2x2 placement designed to increase fertilizer efficiently may not always provide yield benefits, but would create a soil sampling dilemma in correctly assessing the true soil fertility in a field.

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INTRODUCTION

Optimizing the crop utilization of applied P fertilizers has been a long-sought goal of both producers and agronomists. It has been well established that only about 10 to 30 percent of applied fertilizer P is taken up and used by most crops during the season of its application. The extreme low mobility of P in soils and the fractional root contact with soil particle surfaces interact to result in low P utilization. Likewise, fixation of the applied P can be significant in many soils, reducing the soluble fraction that is useable by crops.

The ever-increasing use by growers of reduced tillage and no-tillage practices in Midwestern crop management systems has spurred re-evaluation of P placement methods in relation to tillage. Work reported by Barber and Kovar (1985) suggested that there is an optimum soil volume that should be fertilized in relation to the soil type (soil buffer capacity), tillage method used, and the cropping practices followed. Using their approach, the idealized outcome would be P fertilization that resulted in maximum root contact and plant utilization, yet with minimum fixation and tie-up by the soil.

The objectives of the research reported in this paper were as follows:

1. Determine the effect of P rates and broadcast, dribble, and 2x2 starter placement on yield and P uptake by corn under no-till and conventional (chisel and disk) tillage systems.

2. Evaluate the changes in plant-available P that occurred in soils after P fertilization using the three placement methods.

EXPERIMENTAL DETAILS

Two locations in southern Illinois were utilized for the studies during the 3-year period of 1987-1989. One location was at the Southern Illinois University Henry White Research Farm near Millstadt in St. Clair County on a Herrick silt loam soil (fine, montmorillonitic, mesic, Typic Hapludalfs). The other location was at the University of Illinois Dixon Springs Agricultural Center (DSAC) in Pope County on a Grantsburg silt loam soil (fine-silty, mixed, mesic, Typic Fragiudalfs). At each location, two sites were selected contiguous with each other, cropped to corn and soybeans, respectively, and rotated each year of the study. At Millstadt, pre-experimental soil test levels were: pH = 6.8; Bray P_1 = 32 lbs P/Ac; exchangeable K = 193 lbs K/Ac, and organic matter = 2.1 percent. At the DSAC, soil test levels were: pH = 6.3; Bray P_1 = 29 lbs P/Ac; exchangeable K = 135 lbs K/Ac, and organic matter = 2.9 percent. Soybeans were the previous crop at Millstadt while tall fescue sod was the preceding crop at Dixon Springs.

A split-plot design with four replications was used with no-tillage (NT) and conventional (chisel-disk) tillage (CT) being main plots. Subplots consisted of three P rates, including the highest P rate applied without and with nitrapyrin added to the sidedressed N, and 3 placements (broadcast, dribble, and 2x2 at planting). Phosphorus rates were 0, 20, and 40 lbs P_2O_5/Ac applied as ammonium polyphosphate, 10-34-0. Potassium was broadcast-applied at the rate of 200 lbs K_2O/Ac at Dixon Springs and 160 lbs K_2O/Ac at Millstadt each year of the study with selected treatments receiving 20 lbs of K_2O/Ac at the time of P treatment application. Nitrogen was applied with all P treatments at 50 lbs N/Ac. A check treatment (no N, P_2O_5, or K_2O) and a N-only check were also included in the experiment. Total N applied was 200 lbs N/Ac to all treatments (except check) and it included 50 lbs N/Ac applied with P treatments. A complete listing of experimental treatments for corn is given in Table 1.

All P treatments that were broadcast or dribble placed for CT were applied prior to final seedbed tillage preparation and worked into the soil. Broadcast and dribbled P treatments for NT were applied prior to planting. All 2x2 placement treatments were applied at planting. Pioneer 3295 was the corn hybrid planted at both locations during all 3 years of the study. Sidedressing of supplemental N was as a knifed urea-ammonium nitrate solution (28-0-0) with selected treatments receiving nitrapyrin at 0.5 lb/Ac. Measurements taken included ear leaf samples at silking, grain samples at harvest (for P composition and uptake), and grain yields.

At the conclusion of the study, intensive soil sampling of the surface 8-inches of soil was completed at Millstadt in April 1990 on treatments 9, 10, and 11 (see Table 1) to study the partitioning effects of fertilizer placement on P distribution in the soil. Increments of 0-2, 2-4, and 4-8 inches were collected along a 60-inch line perpendicular to the center two corn rows of each plot at 2-inch spacings. Samples were analyzed for pH and Bray P_1 phosphorus and selected results will be discussed in this paper.

RESULTS AND DISCUSSION

A. Effects of P Rates and Placement on Corn

Grain Yields. Yields of corn were not affected either by placement methods or rates of P application during the 3-year study (Table 2 and Figure 1). Large year to year variations in yield were observed at each location, and the drought of 1988 was especially severe at Dixon Springs (hence the data for that location was not included in the discussion of this report). Overall, the yields were higher with CT than NT at Millstadt but little difference was observed at Dixon Springs. At both locations in 1989, yields from NT were higher than CT, possibly resulting from the loosening of soil caused by Para-plow tillage of the experimental areas prior to planting.

The lack of a yield response to added P at Dixon Springs may have been the result of tall fescue sod being the previous crop for a number of years prior to use of the site for these experiments. Mineralization of P from the organic matter may have contributed to the available pool of P sufficiently to meet crop needs, even though the average P soil test was less than 30 pounds per acre. At Millstadt the soil test, in excess of 30 pounds per acre along with a fairly high organic matter content, was sufficiently high to provide for optimum yields even when no P fertilizer was applied.

Corn yields from the "no K" check treatment (No. 17) were significantly lower than the other fertilized treatments, which received blanket K applications. Potassium soil test levels at both locations were less than 200 pounds per acre at the time of experiment initiation, probably resulting in the observed response to applied K.

The addition of nitrapyrin to the sidedressed UAN had a variable but generally beneficial effect on yields (Figure 2). Response to nitrapyrin was most frequently observed at Millstadt on the NT treatments. Apparently, the benefits of nitrapyrin in reducing N losses or promoting a greater ammonium nutrition were involved in the observed effects.

Grain P Concentration and Uptake. Higher grain P concentrations were observed under NT compared to CT at Dixon Springs but were not affected by tillage at Millstadt (Table 3). Phosphorus placement method within tillage had no effect on grain P concentration at either location. There was, however, a trend for greater P in the grain with increasing rate of P application (Figure 3). This increased concentration with rate was most apparent at Millstadt and was independent of the tillage method used. Even though a greater P concentration was found in the grain with added P fertilizer, yields were not affected at either location.

Greater P uptake and accumulation in the grain was observed with dribble and 2x2 (with K) placement of P using CT at Dixon Spring (Table 4). For NT, however, greatest uptake of P occurred with broadcast placement of P. This suggested that the mulch residue, consisting initially of the fescue sod, served to enhance a rooting media for the corn that favored prolific root development for moisture and nutrient extraction. Likewise, it was reported that organic residues serve in a synergistic manner in the presence of applied P to maintain its solubility in the soil (Olsen and Barber, 1977). At Millstadt, no clear-cut relationship was observed between placement of P and uptake of P in the grain regardless of tillage method used. However, there was an enhanced crop content of P with increasing rate of applied P at the Millstadt location (Figure 4). This paralleled the observed effect of P rate on the enhancement of P concentration in the grain.

B. Effects of Phosphorus Placement on P Distribution and Acidity in the Surface Soil.

Pronounced P variability was observed in the surface soil as related to placement method and tillage system (Figures 5, 6, and 7). When the P was broadcast-applied (Figure 5) relatively uniform concentrations of P were found across corn rows in the 2-4 and 4-8 inch depths of sampling. However, after 3 consecutive years of cropping, with rows always being positionally in the same location, definite zones of P depletion by the previous crops can be observed in the 0-2 inch increment. For no-till the variability associated with uptake was accentuated because the P fertilizer was always surface-applied with no mixing to redistribute the P within the soil.

The differences in soil P distribution as affected by dribble placement and tillage were dramatic (Figure 6). Seedbed preparation tillage for the CT treatment essentially "leveled" any gradient effects caused by dribble P placement near the intended rows. However, for NT large "spikes" of increased P concentration were noted at 0-2 inches in the vicinity of the rows. Elevated P concentrations were also noted to some extent at 2-4 inches in the NT plots.

For the 2x2 placement, large soil P concentration differences were primarily observed in the 2-4 inch increment for both tillage methods (Figure 7). However, P concentration was also influenced by 2x2 placement at the 4-8 inch depth, with the effect primarily noted on the CT treatment. This probably was the result of deeper P placement in the less compacted CT treatment. The double "spike" observed on each side of the row for both tillage methods was probably the result of the planter traveling in different directions during the 3-year study.

Acidity changes in the soil from selected treatments are shown in Figure 8. The most pronounced effect on acidity from broadcast-applied P using CT was the between-row acidity caused by the sidedress N application. Only minimal effects were observed from the P fertilizer treatment that contained 50 lbs N/ac. However, for dribble placement on NT, substantial surface acidity associated with the near-row fertilizer treatment was evident, as well as the acidity from the sidedressed N application.

In conclusion, implications of soil P and acidity results suggest that more intensive soil sampling may be required to more adequately and correctly assess the true average soil fertility that occurs in the field.

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Table 1. Treatments applied to corn within each tillage group[1]

Treatment No.	Placement	Fertilizer Rates (lbs/Ac) Treatment $N-P_2O_5-K_2O$	Broadcast K_2O[2]	Sidedress N[3]	Nitrapyrin[4]
1	Broadcast	50-0-0	200 (160)	150	-
2	Dribble	50-0-0	200 (160)	150	-
3	2 x 2	50-0-0	200 (160)	150	-
4	2 x 2	50-0-20	180 (140)	150	-
5	Broadcast	50-20-0	200 (160)	150	-
6	Dribble	50-20-0	200 (160)	150	-
7	2 x 2	50-20-0	200 (160)	150	-
8	2 x 2	50-20-20	180 (140)	150	-
9	Broadcast	50-40-0	200 (160)	150	-
10	Dribble	50-40-0	200 (160)	150	-
11	2 x 2	50-40-0	200 (160)	150	-
12	2 x 2	50-40-20	180 (140)	150	-
13	Broadcast	50-40-0	200 (160)	150	+
14	Dribble	50-40-0	200 (160)	150	+
15	2 x 2	50-40-0	200 (160)	150	+
16	2 x 2	50-40-20	180 (140)	150	+
17	Broadcast	50-0-0	0	150	-
18	--	0-0-0	0	0	0

[1]All treatments same for no-tillage and conventional tillage systems and for both Dixon Springs and Millstadt sites.

[2]Figures in parentheses are rates of K_2O applied at Millstadt.

[3]Sidedress knife application using UAN only.

[4]Nitrapyrin (0.5 lb/ac) added (+) or not added (-) to the UAN sidedress application only.

Table 2. The effect of different phosphorus placements and tillage on corn yields at Millstadt and Dixon Springs, 1987-1989.

Placement	1987		1988		1989	
	CT	NT	CT	NT	CT	NT
	bushels/ac					
Millstadt						
Broadcast	181	156	141	125	160	174
Dribble	176	148	140	129	154	178
2 x 2	179	151	146	119	156	174
2 x 2 w/K	182	154	145	128	161	175
Check (no K)	166	136	135	119	135	151
Check	125	100	110	96	65	103
Dixon Springs						
Broadcast	152	146	65	65	170	177
Dribble	155	143	61	62	166	171
2 x 2	148	144	67	64	168	173
2 x 2 w/K	152	142	66	69	168	172
Check (no K)	128	129	73	58	162	166
Check	115	121	67	63	138	156

CT = Conventional Tillage NT = No-Tillage

Table 3. The effect of different phosphorus placements and tillage on grain P concentration at Millstadt and Dixon Springs, 1987-1989.

Placement	1987		1988		1989	
	CT	NT	CT	NT	CT	NT
	percent P					
Millstadt						
Broadcast	.233	.228	.257	.248	.238	.241
Dribble	.223	.238	.249	.253	.242	.237
2 x 2	.228	.236	.254	.256	.241	.235
2 x 2 w/K	.218	.238	.259	.254	.246	.246
Check (no K)	.210	.223	.248	.249	.257	.276
Check	.258	.278	.257	.281	.248	.253
Dixon Springs						
Broadcast	.242	.267	.243	.245	.250	.275
Dribble	.241	.260	.218	.245	.272	.265
2 x 2	.247	.262	.245	.235	.256	.257
2 x 2 w/K	.245	.266	.225	.244	.267	.266
Check (no K)	.248	.258	.251	.234	.260	.263
Check	.235	.255	.256	.232	.267	.262

CT = Conventional Tillage NT = No-Tillage

Table 4. The effect of different phosphorus placements and tillage on grain P uptake at Millstadt and Dixon Springs, 1987-1989.

Placement	1987 CT	1987 NT	1988 CT	1988 NT	1989 CT	1989 NT
	pounds P/ac					
Millstadt						
Broadcast	20.7	17.6	19.2	16.0	18.0	19.9
Dribble	19.9	18.6	17.8	15.9	17.6	20.1
2 x 2	21.0	17.2	18.6	16.1	17.9	19.5
2 x 2 w/K	21.4	17.9	17.9	16.6	18.7	20.4
Check (no K)	19.1	16.8	15.8	13.7	16.5	19.7
Check	16.0	15.3	14.6	12.6	8.1	12.1
Dixon Springs						
Broadcast	17.6	19.7	7.8	7.1	20.1	23.0
Dribble	18.0	17.8	6.8	7.3	21.4	21.4
2 x 2	17.5	18.1	7.8	7.2	20.4	21.1
2 x 2 w/K	17.8	18.1	6.9	8.1	21.2	21.6
Check (no K)	15.2	15.9	9.7	6.0	19.9	20.6
Check	13.0	14.8	8.3	7.0	17.4	19.5

CT = Conventional Tillage NT = No-Tillage

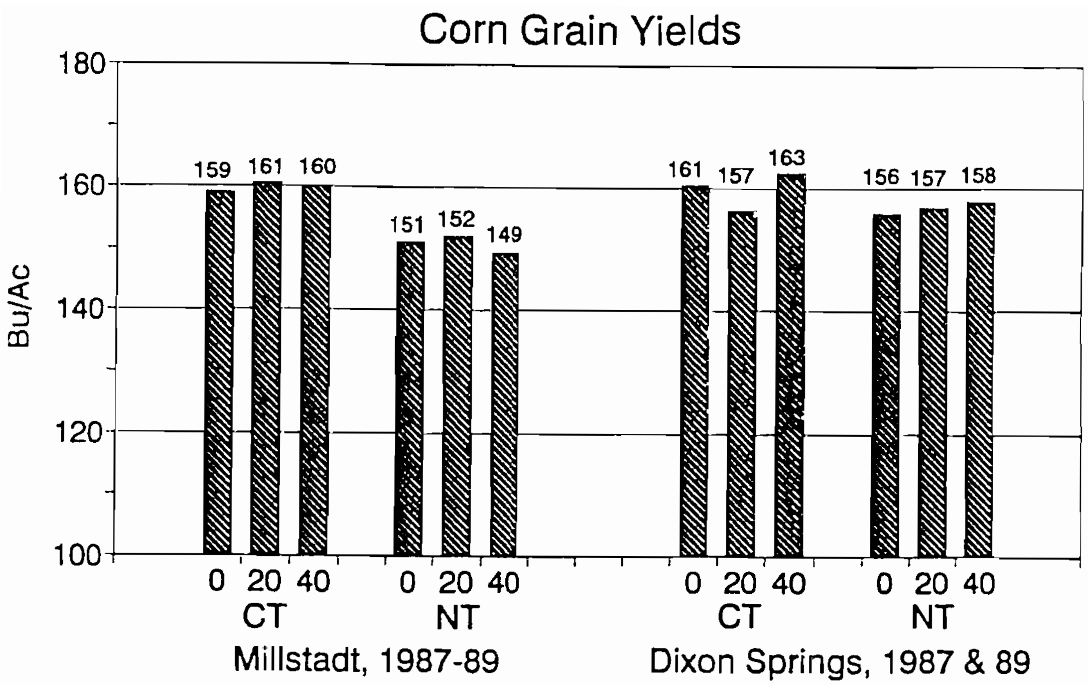

Figure 1. The effect of phosphorus rates (lbs P2O5/ ac) on corn grain yields at Millstadt and Dixon Springs as affected by tillage (CT = conv. till, NT = no-till).

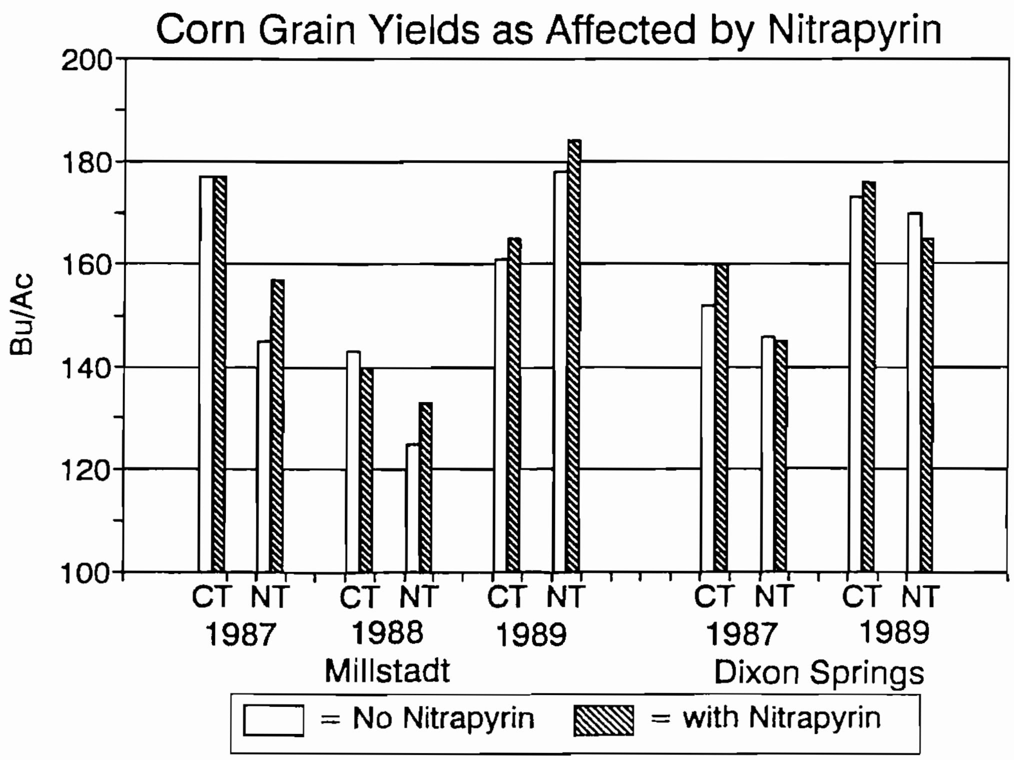

Figure 2. The effect of nitrapyrin added to sidedressed UAN solution on corn grain yields as influenced by tillage method (CT = conv. till, NT = no-till).

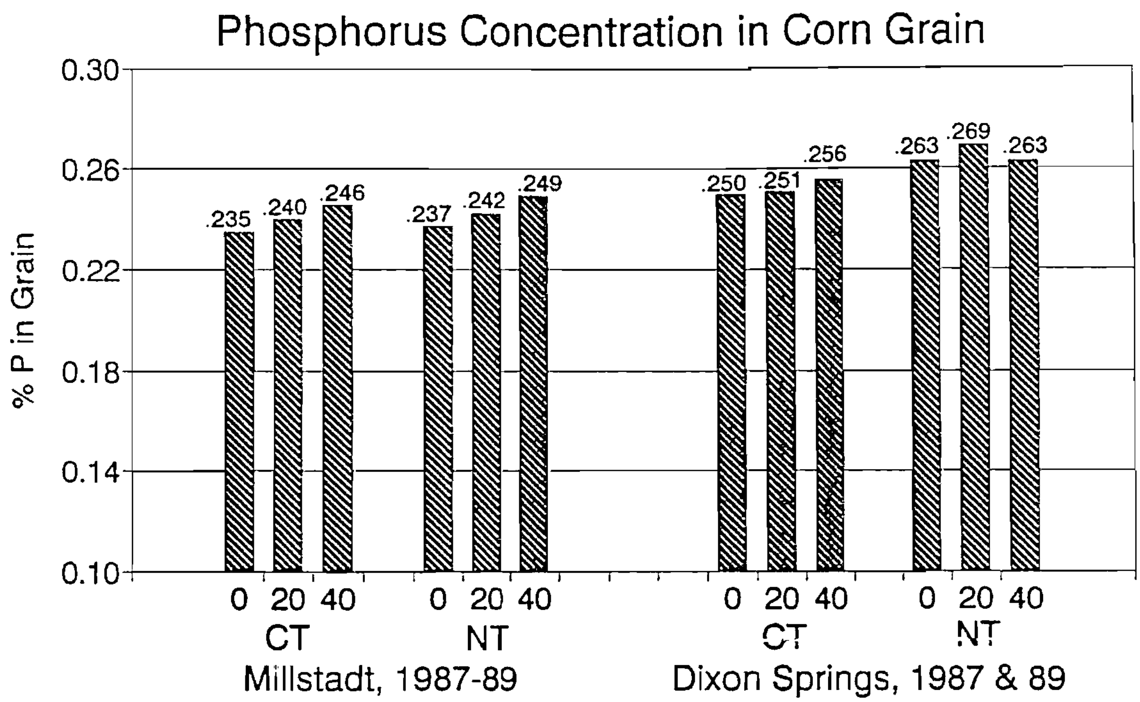

Figure 3. The effect of phosphorus rates (lbs P2O5/ ac) on P concentration in corn grain at Millstadt and Dixon Springs as affected by tillage (CT = conv. till, NT = no-till).

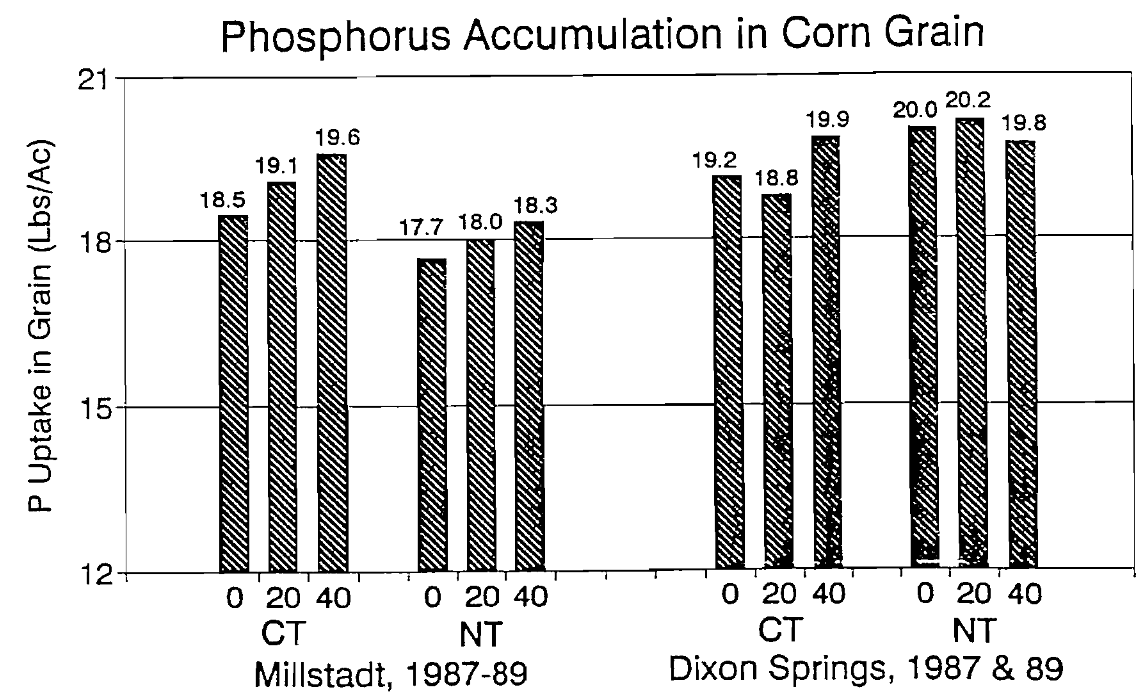

Figure 4. The effect of phosphorus rates (lbs P2O5/ ac) on P uptake in corn grain at Millstadt and Dixon Springs as affected by tillage (CT = conv. till, NT = no-till).

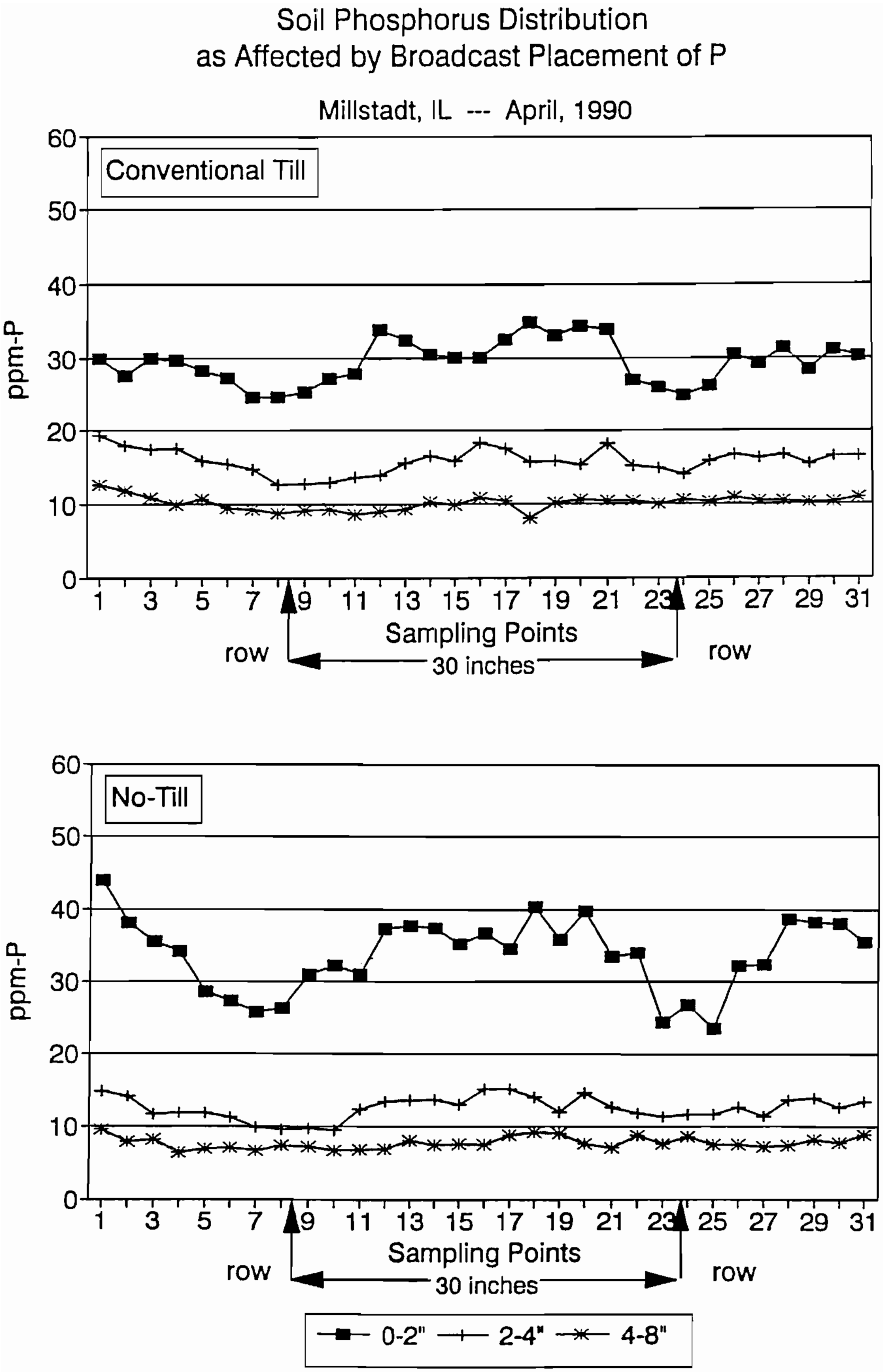

Figure 5. The effect of broadcast phosphorus placement on P distribution at varying depths in the soil as influenced by tillage method.

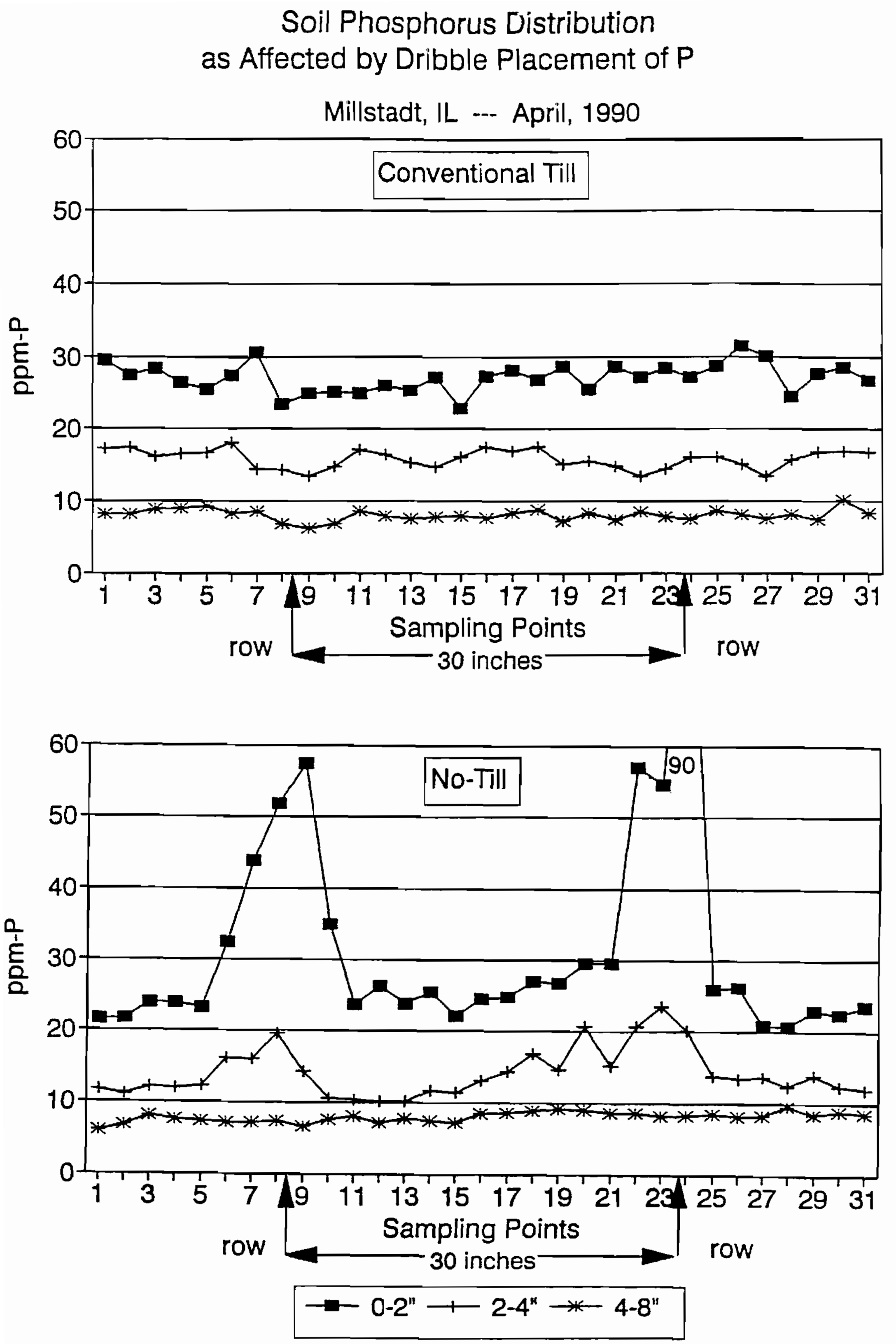

Figure 6. The effect of dribble phosphorus placement on P distribution at varying depths in the soil as influenced by tillage method.

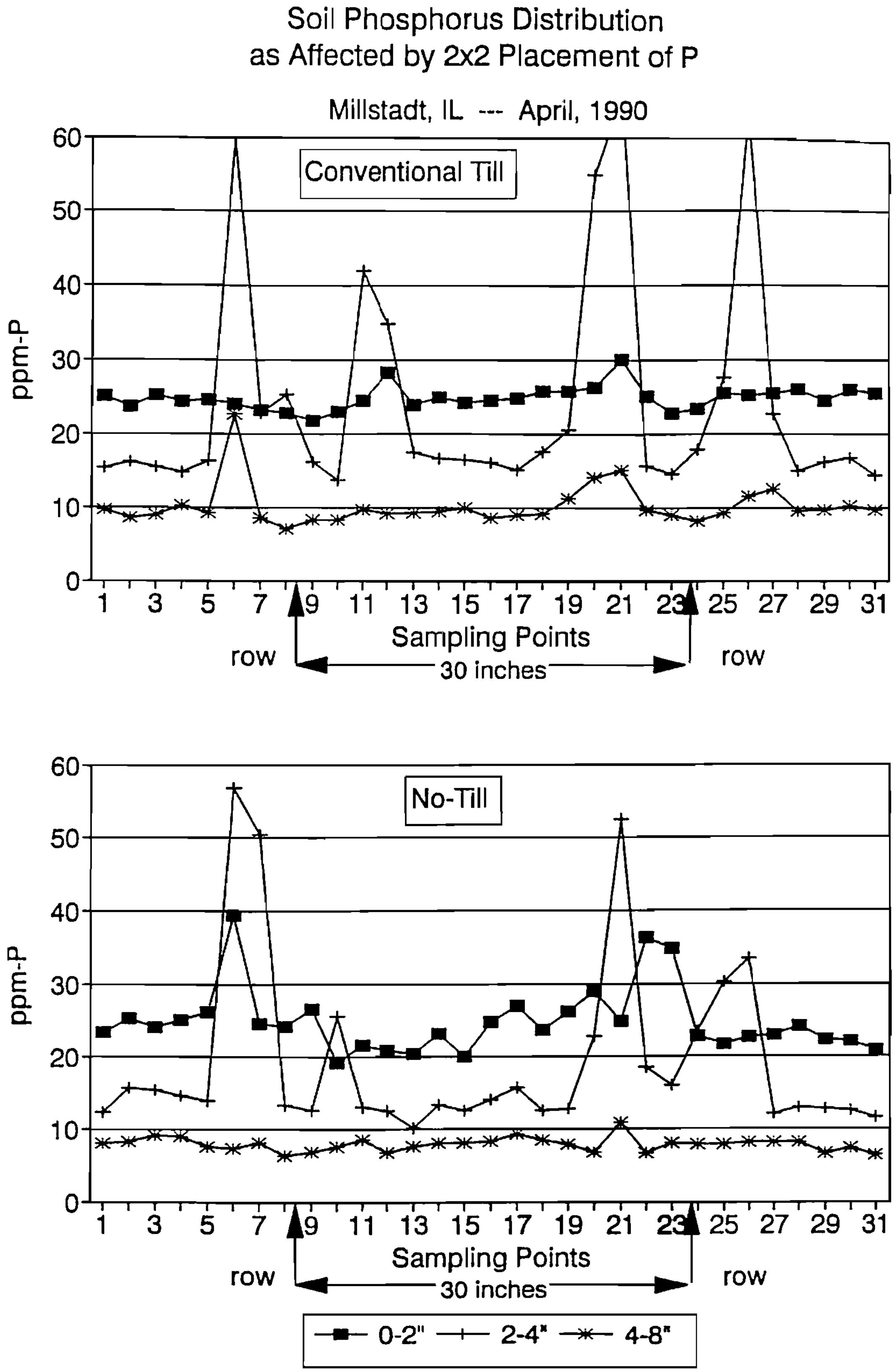

Figure 7. The effect of 2x2 phosphorus placement on P distribution at varying depths in soil as influenced by tillage method.

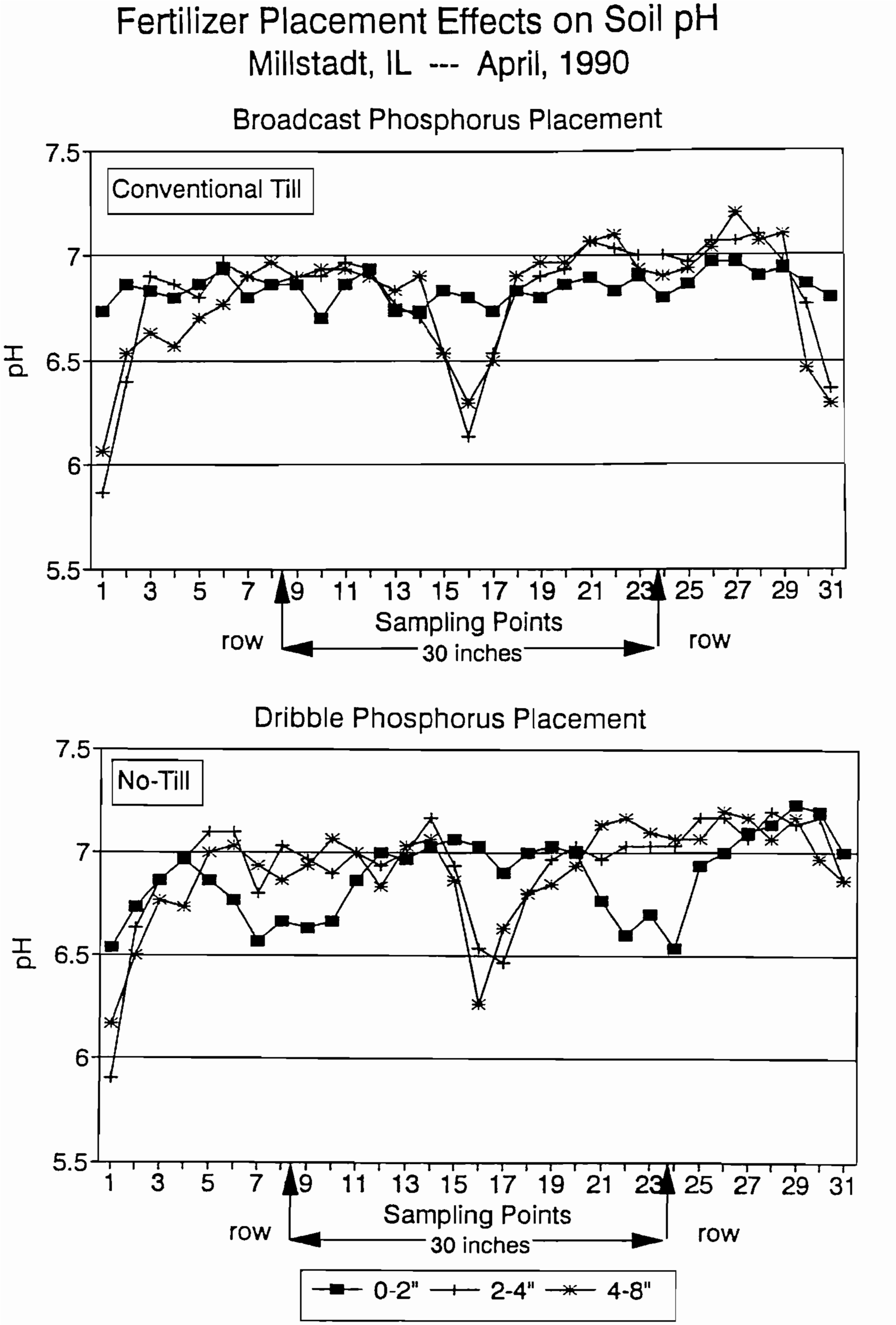

Figure 8. The effect of phosphorus placement method and sidedress N application on soil pH at varying depths as influenced by tillage method.

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