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LONG-TERM CORN PRODUCTIVITY AND COMPOSITION AS A FUNCTION OF PHOSPHORUS FERTILIZER AND RESIDUE REMOVAL

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ABSTRACT

Sonmez O, Pierzynski GM (2015) Long-term corn productivity and composition as a function of phosphorus fertilizer and residue removal. *J. Soil Nature* 8(2), 18-23.

Management factors are extremely important for crop production. A long-term field study was established to determine the effect of crop residue removal and P applications on crop productivity and composition. Stover and grain yields were not affected by P applications until seventh year of the study. In that year, stover yields were significantly greater at 7.3 kg P/ ha compared to 0 or 29.4 kg P/ ha, while grain yields at the non-zero P rates were significantly higher than yield at the zero P treatment. In last three years of the study, significant differences occurred in whole plant (V6) dry matter yields with increasing V6 yields with increasing P rates. Total P uptake also increased with increasing P rates when significant differences were observed in total P uptake. Total C and N were not influenced by P rates at either soil depth. Residue treatments did not affect stover, and grain yields while the effect on V6 dry matter yields and total P uptake was variable. At 0-15 cm organic C content in last two years was significantly higher for residue retained. Six years of residue removal significantly decreased soil organic C content at 0-15 cm soil depth, but organic C did not differ between residue treatments at 15-30 cm. Total N content was not affected by residue treatments except in seventh year. In this year a higher total N content was observed with residue retained compared to residue removed.

Key words: *crop residue, phosphorus, corn yield, total P uptake, total C and N*

INTRODUCTION

Phosphorus (P) is a key nutrient for plants as well as animals due to its role in many physiological processes. Phosphorus encourages the development of an extensive root system and photosynthesis in plants and also plays a role in energy transformation systems in all forms of life. Moreover, P is crucial for sustaining and building up of soil fertility, especially under intensive agriculture systems. The amount of P in soil solution at any time is very small in most soils. Therefore, soil solution must be replenished with soluble P to prevent declines in crop yields due to low organic P reserves, low P parent material or intensive cropping (Pierzynski *et al.* 2005). Addition of P to soil is mostly accomplished by inorganic P fertilizer.

Crop residue addition is vital for increasing soil organic matter. Fertility of soil is closely related to the content of soil organic fraction (Doran 2002) because organic matter influences numerous characteristics of soil such as bulk density, penetration resistance, water holding capacity and infiltration of water to soil (Carter 2002). Incorporation of crop residue develops soil structure and enhances nutrient availability, buffering and ion exchange capacities of soil (Perucci *et al.* 1997). Residues contain an important reservoir of essential macro and micronutrient pools and keeping crop residues on the soil surface reduces surfaces runoff, improves infiltration rates, and cut down evaporation rates (Blanco-Canqui and Lal, 2009), enhances plant available P and decreases surface temperature (Buerkert *et al.* 2000).

Our objectives are to determine the effect of P applications and crop residue removal on crop productivity and composition.

MATERIAL AND METHODS

Experimental design and treatment applications

Four replications of four P rates (0, 7.3, 14.7, and 29.4 kg P/ ha as triple super phosphate (TSP) and two crop residue treatments (residue removal and keeping) were investigated during the years 1991-1998 at the Kansas State University North Agronomy Farm in Manhattan, Kansas in USA on an area mapped as a Kahola silt loam. The study design was a randomized complete block with split plot. The P rate was main plot factor. The non-zero P rates represent one-half, one, and two times the recommended P fertilizer rates for corn based on the Bray P_1 extractable P concentration at the beginning of the study. The corn residue removal of grain (residue retained) or removal of grain and stover (residue removed) was subplot factor. Corn was planted in 15 x 6 m with in rows 0.76 m apart.

To prepare the seed bed a chisel disk was used as tillage method. In the middle of April corn (first 4 years Pioneer variety 3751 and the second 4 years Dekalb variety 591) was planted at 66,667 seeds/ha each year. Phosphorus fertilizer was applied as broadcast by hand to each plot before planting. The P applications were followed by at least two disking operations. Ammonium nitrate (135 kg N/ ha) was also broadcast on each plot after planting. No other fertilizers were used during the study periods. For the subtreatments the crop residue was removed by hand after harvest. Prior to tillage in the spring any residue that had been blown onto the residue removed subtreatments was removed.

Stand count, plant, grain, and stover sampling

Biomass yields were measured at the V6 (approximately) growth stage by conducting stand counts and then randomly selecting 20 plants per plot from two outside rows with 1.5 m apart. Stand counts were done by counting plants from two selected 10 m lengths of row in each plot. Grain harvest was generally done in mid-September. Corn was also harvested by hand from 7.5 m in each of the center two rows. Grain yields were adjusted to 155 g/ kg moisture. After harvest stover samples were taken by cutting the plants at the soil surface for 5 m from one of the two harvested rows. Stover samples were chopped with a German made Hohebuch model 1968 plant chopper, weighed, and a subsample was taken for moisture content. All plant samples were dried in a forced-air oven at 60^{o}C and ground to pass through 2 mm sieve for further laboratory analysis.

The V6, stover, and grain samples were digested with a sulfuric acid / hydrogen peroxide digest in preparation for analyses of P, K, Ca, Cu, Zn, Fe, Mn, Mg, and Na. Analysis was done by using inductively coupled plasma (ICP) spectrometer. Total P uptake was calculated each year as the sum of grain and stover P uptake for residue removed plots but only grain uptake for residue retained since stover was retained in plots.

Soil sampling and analysis methods

Prior to planting, soils from two different depths (0-15 and 15-30 cm) were annually sampled. Soil was air-dried, crushed and sieved to pass through a 2 mm sieve. All soil samples were stored at room temperature.

Extraction of soil P was determined using the Bray-l extraction method as described by Bray and Kurtz (1945). Total carbon (C) and nitrogen (N) by dry combustion method was determined in soil samples collected in first, sixth, seventh and eighth years of study (LECO CN 2000, LECO Corp., St. Joseph, MO). Soil pH was determined in a 1:1 soil-water slurry.

Statistical analysis

The analysis of variance procedure (ANOVA) of the Statistical Analysis System (SAS Inst. Inc., 1987) was used for data analysis. When significant interactions were present Proc Mix was used for mean separation ($p \leq 0.05$). Main effects were compared using least significant differences.

RESULTS AND DISCUSSION

Whole plant above ground dry matter yield and P concentration

No significant response to P rate was observed in V6 yields from first to fourth year of study ($P \leq 0.05$); however, significant differences occurred in last three years of the study (Table 1). Dry matter yields increased significantly with increasing P rates in these years. No significant differences were found between residue treatments in second, sixth, and seventh years (Table 1). In third year V6 dry matter yields were higher where the residue was removed whereas in fourth and fifth years the yield was higher where the residue was retained.

In literature, there are controversial results on this topic. Ashraf (1997) found that the V6 dry matter yields significantly increased with P additions. Wilber (1993) reported that of the seven site-years significant increases in V6 dry matter yield were found twice at the same location (ISTP:23.5 mg P/kg). One year 20 kg P/ ha produced significantly higher V6 yields than 0 kg P/ ha and the other year 10 and 20 kg P/ ha had significantly higher yields than 0 kg P/ ha.

Phosphorus concentrations in whole plants were significantly influenced by P rates in fourth, fifth and sixth years of the study period (data not shown). Phosphorus concentration increased with increasing P rate. The significant differences in fifth and sixth years corresponded to two of the three years in which significant differences in V6 dry matter yields were found. Residue treatments did not influence V6 P concentrations. Ashraf (1997) reported that there was a significant response to P rates for P concentration in whole plant dry matter at one location in 1993. It was significantly higher at 30 and 45 kg P/ ha compared to no P. There was no significant difference between 15 and 30 kg P/ha and between 0 and 15 kg P/ ha. At a second location P concentrations in whole plant at the non-zero P rates were significantly higher than those at 0 kg P/ ha. Wilber (1993) found that whole plant tissue P concentration was affected by P fertilizer rate with the highest P concentration occurring at the highest P rate (20 kg P/ ha) for corn at several locations over a two year study**.**

Grain yield and P concentration

Phosphorus rate did not significantly affect grain yields until seventh year (Table 2). The nonzero P rates had significantly higher yields than 0 kg P/ha, with no significant differences between them. Residue treatments did not significantly influence grain yields during the study period. Mallarino *et al.* (1991) reported that there was no significant difference in mean yields of corn and soybean by either P or K fertilization over 11 years, but ISTP was increased by the highest fertilizer rates (44.8 kg P/ ha, 134.4 kg K/ ha, respectively) while it decreased with no P and K. Ashraf (1997) reported that there was no significant effect of P starter fertilizers on corn grain yields at one location in 1993, but found 18% higher grain yields at non-zero P rates compared to no P in 1994 at the same location.

Crop production is clearly affected by crop residues. Blanco-Canqui and Lal (2007) found 20% reduction in corn grain with 50% stover removal and 30% with complete removal. Linden *et al.* (2000) reported that stover removal reduced grain yield of corn by 0.5-2.0 Mg/ha depending on tillage types. Burgess *et al.* (1996) reported that the application of high rates of surface residues delayed or reduced seedling emergence and resulted in lower yields for corn. However, Maskina *et al.* (1993) found that addition of residue increased corn grain and residue yields. That was attributed to improved water relations in the soil for plant growth and microbial activity. Swan *et al.* (1994) reported that average corn yields for retention of residue produced were higher than with the residues removed. Similar greater production was reported by Power *et al.* (1998) due to improved soil organic matter and N cycling. However, Barber (1979) found that corn yield as a result of 6 year of fallow, residue removal or residue returned, or double residue returned was not influenced by residue treatments.

Generally, P concentration in the grain was not influenced by P rates. The effect of residue treatments on grain P concentration was more varied (data not shown). The grain P concentration was higher when the residue was retained in second year while the opposite was true in third and fourth years. Ashraf (1997) reported that P rate affected grain P concentration in a two year study (ISTP: first year13 mg P/kg; second year 9.6 mg P/ kg). Phosphorus concentrations in grain were significantly higher at non-zero P rates compared to no P. Wilber (1993) reported that P concentration in the grain at 20 kg P/ ha was significantly higher than the 0 kg P/ ha for three site-years out of seven in a two year study.

Stover dry matter yield and P concentration

In general, stover yields in our study were not influenced by P rate or residue treatments. However, Bauder *et al.* (1997) reported that sorghum- sudan grass cumulative dry matter yields increased with increasing P fertilizer applied throughout the entire soil test P range. The response to P fertilizer was linear up to 30 mg P/ kg of soil test P but curvilinear above this value. Wilber (1993) reported that generally corn stover yields were higher at nonzero P rates compared to no P but they were not significant in three locations (ISTP: 23.5, 13, and 25.5 mg P/kg). Ashraf (1997) found that corn stover yield response to P rates was not significant for two site years while for one site year he found significantly higher stover yields for the nonzero P rates compared to 0 kg P/ ha. Blanco-Canqui and Lal (2007) reported that stover yield was decreased consistently every year by increasing residue removal.

Phosphorus rates did not significantly affect P concentration in stover except in sixth year (data not shown). The residue retained had higher stover P concentrations compared to the residue removed when statistical differences were occured. Bauder *et al.* (1997) also reported that the P content of sorghum-sudangrass was the highest at the highest P rate (40 mg P/ kg) which was significantly different from all other P rates (0, 5, 10, and 20 mg P/ kg) on one site and from all rates except 20 mg P/ kg on another site. However, Ashraf (1997) found that there was no difference among P rates for P concentrations in stover at two locations in one year. A significant difference occurred at one location another year where stover P concentrations were significantly higher at 45 kg P/ ha compare to 0 and 15 kg P/ ha. Wilber (1993) reported that although stover P concentrations increased with an increase in P rates, these increases were not significant.

Total Phosphorus Uptake

Phosphorus rates had a significant effect on total P uptake (Table 3). When significant differences occurred in total P uptake, uptake increased with increasing P rates. This occurred in third, sixth and seventh years. The highest total P uptake was at the highest P rate while the lowest was with no P. Residue treatment effects on total P uptake were variable (Table 3). Most years there was no significant effect. In second year uptake was higher for residue removal compared to residue retained while the opposite was true in fourth year. Similar result was found by Bauder *et al.* (1997) that with increasing P fertilizer rate or ISTP, P uptake increased. Ashraf (1997) reported that total P uptake was significantly affected by P applications at one location over two years (ISTP: first year 13 and second year 9.6 mg P/kg). Phosphorus uptake increased with increasing P rates although this increase corresponded to increased grain yields for only one year. Phosphorus applications did not affect total P uptake at a second location (ISTP: 15 mg P/kg). Wilber (1993) reported that P uptake in an early corn study in Kansas did not differ between P rates.

Total Carbon and Total Nitrogen

Total C and N were determined in first and last three years of study. Phosphorus rate did not influence soil organic C content at 0-15 cm and 15-30 cm. This is an agreement with stover production which was not influenced by P rate. At 0-15 cm organic C content was significantly higher for the residue retention treatments in last two years of study (Table 4). Six years of residue removal was required to significantly reduce soil organic C concentrations. At 15-30 cm there was no significant difference between residue treatments.

Buerkert *et al*. (2000) reported that organic C concentrations as a function of depth and P level were higher with mulching compared to unmulched plots. Campbell and Zentner (1993) reported that well fertilized annually cropped rotations increased the soil organic matter content in the 0-15 cm soil depth.

Phosphorus rate did not significantly affect total N content in both 0-15 cm and 15-30 cm soil depths in all years. Generally total N was also not influenced by residue treatments except in seventh year (0-15 cm). In that year higher total N content was found with residue retained compared to residue removed (data not shown).

As discussed above, response of corn compositions (grain and stover) and selected soil properties to fertilizer and residue treatments varied among the studies. These different results could be attributed to residue management variations and tillage techniques affecting crop performance directly or indirectly by creating a complex association of soil and surface conditions. Swan *et al.* (1994) reported that residue coverage decreased crop yields due to poor seed placement and stand, wet and cold soils, and poor weed control. However, residue could improve yields through conservation of soil water, preventing raindrop crusting and retention of nutrients (Blanco-Canqui and Lal, 2009). Effects of residue treatments are influenced by climate and weather conditions as well as time (Wilhelm *et al*. 2004). That is why there are controversial results in literature.

Logical expectation was a reduction in soil organic C by residue removal because soil organic C are related to the amount of crop residue returned to soil. That reduction in our study occurred after six years of residue removal. However, soil organic C content not only depends on residue returned to soil but also decomposition and other loss processes affected by tillage system (Wilhelm *et al.* 2004).

Table 1. Phosphorus rate and residue treatment effects on whole plant (V6) above ground dry matter yields

Treatments	Years 1	2	3	4	5	6	7
kg P / ha	kg / ha						
0	334a[†]	567a	504a	228a	425c	350b	246b
7.3	430a	584a	562a	242a	473cb	396ab	262b
14.7	410a	572a	583a	295a	529b	430a	308ab
29.4	392a	613a	647a	343a	622 a	441a	
P >F	0.34	0.71	0.10	0.16	<0.01	0.05	0.04
Sub treatments	Years 1	2	3	4	5	6	7
	kg / ha						
R.Removed	na [§]	593a	622a	252b	492b	415a	309a
R.Retained	na	575a	526b	302a	533a	393a	292a
P> F		0.41	0.01	<0.01	0.04	0.14	0.42

† Means within a column followed by the same letter are not significantly different at P≤0.05 by LSD

‡ Phosphorus by residue treatments interaction significant. § Not available

Table 2. Phosphorus rate and residue treatment effects on grain yields

Treatments	Years 1	2	3	4	5	6	7
kg P / ha	kg / ha						
0	5786a[†]	10855a	5290a	8796a	4794a	4169a	5591b
7.3	6788a	11015a	5420a	9449a	4861a	5267a	7098a
14.7	7242a	11117a	5564a	9420a	5067a	5215a	7092a
29.4	7372a	10837a	5645a	8964a	4871a	5199a	7410a
P >F	0.12	0.91	0.76	0.68	0.50	0.16	<0.01
Sub treatments	Years 1	2	3	4	5	6	7
	kg / ha						
R.Removed	6886a	11189a	5738a	9170a	4942a	4926a	6952a
R.Retained	6708a	10723a	5221a	9145a	4855a	4999a	6643a
P> F	0.36	0.09	0.09	0.88	0.57	0.78	0.32

† Means within a column followed by the same letter are not significantly different at P≤ 0.05 by LSD

Table 3. Phosphorus rate and residue treatment effects on total P uptake

Treatments	Years 1	2	3	4	5	6	7	Total
kg P / ha	kg P / ha							
0	19.9a[†]	33.0a	18.3b	24.5a	14.1a	13.0c	14.6b	137.4
7.3	21.9a	32.6a	18.8b	27.1a	14.7a	15.5bc	17.9ab	148.6
14.7	21.7a	34.0a	19.8ab	29.6a	16.6a	18.2ab	18.4a	158.4
29.4	23.0a	34.6a	21.7a	29.2a	17.3a	20.1a	21.1a	167.0
P >F	0.58	0.44	0.01	0.11	0.10	0.01	0.02	
Sub treatments	Years 1	2	3	4	5	6	7	Total
	kg P / ha							
R.Removed	21.8a	35.0a	19.4a	26.9b	15.8a	16.0a	17.7a	152.6
R.Retained	21.5a	32.2b	20.0a	28.3a	15.8a	17.4a	18.3a	153.5
P> F	0.66	0.01	0.48	0.02	0.75	0.30	0.43	

† Means within a column followed by the same letter are not significantly different at P≤0.05 by LSD

Table 4. Phosphorus rate and residue treatment effects on total carbon in the soils (0-15 cm)

Treatments	Years			
	1	6	7	8
kg P / ha	g / kg			
0	13.1a†	12.9a	12.5a	13.0a
7.3	13.0a	13.1a	12.8a	12.7a
14.7	12.8a	13.6a	13.2a	13.2a
29.4	13.1a	13.0a	12.5a	12.7a
P >F	0.90	0.58	0.62	0.55
Sub treatments	1	6	7	8
	g / kg			
R.Removed	na‡	13.0a	12.4b	12.5b
R.Retained	na	13.2a	13.1a	13.3a
P> F		0.17	< 0.01	< 0.01

† Means within a column followed by the same letter are not significantly different at P≤ 0.05 by LSD

‡ Not available

CONCLUSION

In summary, P rate significantly affected V6 dry matter yields in last three years of study. In these years V6 dry matter yields increased significantly with increasing P rates. Residue treatment effects on V6 dry matter yields are variable. Phosphorus concentrations in the plant were not influenced by residue treatments.

Grain and stover yields did not respond significantly to P rate until seventh year. In this year, nonzero P rates had significantly higher grain yields compared to no P. Residue treatments did not significantly affect grain or stover yields. Phosphorus concentration in the grain was not affected by P rates except in fourth and sixth years while residue treatment effects on P concentrations were varied. Stover P concentration was significantly higher with residue retained than residue removed.

Phosphorus uptake increased with increasing P rates in third, sixth, and seventh years. Most years there were no significant effects of residue treatments on P uptake except in second and fourth years. Higher P uptake occurred with residue removed in second year with the opposite found in fourth year.

Total C and N were not influenced by P rates at either soil depth. At 0-15 cm organic C content in last two years was significantly higher for residue retained. Six years of residue removal significantly decreased soil organic C content at 0-15 cm soil depth, but organic C did not differ between residue treatments at 15-30 cm. Total N content was not affected by residue treatments except in seventh year. In this year a higher total N content was observed with residue retained compared to residue removed.

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