CHAPTER 6

EFFECT OF POULTRY LITTER-YARD WASTE COMPOST ON CORN GROWTH IN A FIELD STUDY

ABSTRACT

To decrease the potential for adverse environmental impact of N and P in groundwater, a new approach developed in this research was to compost a mixture of poultry litter and yard waste for use as a soil amendment. A field study was conducted on Vance sandy loam (clayey, kaolinitic, thermic Typic Kanhapludults) to determine the effectiveness of poultry litter-yard waste compost (PYC) from 15:1, 20:1, and 25:1 C:N ratio substrates on P availability and to compare the composts with triple superphosphate (TSP) as sources of P for corn grown on acidic soil. Treatments included three levels of TSP and PYC from 15:1, 20:1, and 25:1 C:N ratio substrates, and one level of poultry litter (PL) based on P fertilization recommendations. Without P additions, severe growth restrictions (low dry matter production and tissue P concentration <0.25) indicated that P deficiency was limited on corn plant growth on the Vance sandy loam. Application of all rates of PL, PYC, and TSP increased corn grain yields as compared with control. Soil variability may have masked differences in P availability from rate of amendment application. A maximum of 1.95 and 0.75 kg ha^{-1} of the P applied as PYC and TSP, respectively, was taken up by the corn plants. Corn grain yields increased (up to 85% over the control) with PYC application. Increases in corn yield may reflect the relatively high P availability of PYC and the higher pH which increased availability of indigenous and applied soil P for corn plants. These data also suggested that P mineralization from PYC and PL had a dominant effect on increasing P availability in the Vance soil.

6-1 INTRODUCTION

Assimilation of P is a process that affects the photosynthesis and the energy transformation in all plants. Therefore, P deficiency is a major constraint to crop production on highly acidic soils. In order to develop efficient P management procedures, many researchers have investigated procedures to minimize P adsorption by soil. One way to increase total and available P in surface and subsurface soil (Sharpley et al., 1984; Meek et al., 1979) and to decrease the P adsorption (Fox and Kamprath, 1970; Reddy et al., 1980) is to apply animal waste. Cropland application of PL is widely used and the rate of application has been long determined by the N need of a crop perhaps because of the well known detrimental effect of N on groundwater.

Bitzer and Sims (1988) found that the N availability in compost was lower than in conventional fertilizer. Thus, the tendency will be to apply more waste to fulfill the N fertilization goal. As a consequence, application of the waste can result in accumulation of large amounts of P in the soil surface (Sharpey et al., 1993; Chang et al., 1991). Their study and current manure application guidelines indicated that the availability of P in manure was similar to that of fertilizer P. Furthermore, the P availability from manure application can only be reduced by adsorption or precipitation reactions in soils (Moore and Miller, 1994; Shreve et al., 1995; Sharpley, 1996). Reliable manure management is needed to control the environmental and agronomic fate of P. The objective of the present study was to determine the P response of corn plants to PYC and PL application based on the P requirement for corn production. The P uptake was related to three C:N ratios of substrates used for production of the PYC.

6-2 MATERIALS AND METHODS

6-2.1 Field experimentation

A field study was carried out on a Vance sandy loam soil located on the Southern Piedmont Agricultural Experimental Station, Blackstone. The Vance soil is acidic, has a low organic matter content, and has a high P adsorption capacity (Table 3.2). Experimental finding from the greenhouse studies with the Vance soil as well as with the Starr and mine tailings with similar characteristics (Tables 3.2 and 5.1) were used to design this field study.

6-2.1.1 Treatment and experimental design

The compost used in this study was collected and prepared by procedures used for the mineralization and the greenhouse experiments. Composts were analyzed before the field application and properties of sources of PYC from digestion of PL and YW at C:N ratios of 15:1, 20:1, and 25:1 are given in Table 6.1. Fourteen treatments applied in the field experiment were as follows: a control; 19.6, 39.2, and 58.8 kg P ha^{-1} as triple superphosphate, 43.6, 87.2, and 130.2 kg P ha^{-1} as three sources of PYC; and 39.2 kg P ha^{-1} as PL. A mineralization rates of 45% were considered for the nine PYC treatments and for the PL treatment (i.e., 43.6 kg P ha^{-1} times 0.45 = 19.6 kg P ha^{-1}). Mozaffari and Sims (1996) found that 33 to 53 % of cumulative net P was released during 60-to-110 days period with litter application in the Matawan loamy sand. The mineralization rate varies with the type soil. The total amount of wet PYC and PL applied for each treatment is shown in Table 6.2.

The 14 treatments were arranged in a randomized complete block design with four blocks. Treatments, were applied to 3.64 by 6.08 m plots with a border of 1.2 to 1.5 m. An amount of 67.2 kg N ha^{-1} as NH_4NO_3 was broadcast on the experimental area prior to planting 67.2 kg N ha^{-1} were sidedressed applied on the experimental area six weeks after planting. Before planting, 65.1 kg K ha^{-1} as KCl was applied over the experimental area. The soil pH was maintained near 6.5 by application of dolomite limestone at a rate of 2 t ha^{-1}. The NH_4NO_3 for starter N and KCl were incorporated into soil by disking prior to planting. Corn Cultivar Pioneer 3394 was grown at a final population of 51,666 plants ha^{-1}. A recommended rate of and preemergent herbicide was applied to the entire experimental area.

6-2.2 Laboratory Analyses

Table 6-1. Elemental composition of compost used in the field study.

Initial C:N	Final C:N	Moisture content	N	NH_4-H	P	K	Ca	Mg	B	Cu	Fe	Mn	Zn
		--------------------------------------%-------------------------------------							--------------------mg kg^{-1}----------------				
15:1	8.4:1	56.6	1.5	0.17	0.17	1.3	1.7	0.41	37	502	2147	476	390
20:1	10.8:1	53.2	1.0	0.06	0.15	1.0	1.5	0.33	28	350	1863	407	312
25:1	9.6:1	50.5	1.3	0.02	0.11	0.7	1.1	0.22	26	202	1587	286	195

Table 6-2. Rates of poultry litter-yard waste compost and poultry litter application for the field investigation.

Amendment †	Rates
	--kg ha^{-1}--
Poultry litter..	5034
Poultry litter-yard waste (C:N 15:1)......................	2850
Poultry litter-yard waste (C:N 15:1)......................	5700
Poultry litter-yard waste (C:N 15:1)......................	8850
Poultry litter-yard waste (C:N 20:1)......................	3220
Poultry litter-yard waste (C:N 20:1)......................	6440
Poultry litter-yard waste (C:N 20:1)......................	9660
Poultry litter-yard waste (C:N 25:1)......................	4840
Poultry litter-yard waste (C:N 25:1)......................	9670
Poultry litter-yard waste (C:N 25:1)......................	14500

† Wet rate of amendment application.

6-2.2.1 Plant tissue sampling and analysis

Eight whole plants were collected from each plot six weeks after planting, the samples were oven dried (70^{o} C) to constant weight (for at least 48 hours) to determine the initial dry weight, and the dry sample was ground to pass a 20 mesh stainless steel sieve. One gram of each dry samples was digested in HNO_3-$HClO_4$ mixture in preparation for P analyses. Phosphorus in the filtrate was determined colorimetrically by a molybdate-vanadate yellow color method (Jackson, 1958) with a Hitachi model 200-20 spectrophotometer. Corn grain was harvested from 2.3 to 4.6 m of the three center rows at plant maturity. Grain yields were reported at kg ha^{-1} as 15.5 % moisture content. The corn plant heights were measured at seven weeks after fourteen leaves were fully emerged.

6-2.2.2 Soil sampling and analysis

Soil surface samples were taken from 0 to 15-cm depth of the entire experimental area prior to initiation of the field study, mixed, and ground to pass a 2-mm sieve. Levels of soil Mehlich-1 extractable P, K, Ca, Mg, Zn, and Mn (Nelson et al., 1953); pH (1:1 water/soil), organic matter (Walkley Black, 1934), and CEC (extraction by 1M NH_4OAc at pH 7) in the soil samples are shown on Table 5-1. A composite of 10 cores per plot also were taken from the top 15-cm surface layer seven weeks after amendment application to determine the effect of compost treatments on pH and extractable P content. Soil samples were air dried, and ground to pass a 2-mm sieve. The amount of extractable P in the soil samples was determined by the Mehlich-1 procedure and soil pH was determined at a 1:1 soil-to-water ratio after a 30 min. equilibration period.

6.2.3 Statistics analysis

Dry matter and corn grain yields, plant tissue P content, plant heights, and plant P and N uptake data were evaluated statistically by analyses of variance. Mean separations were performed by the Tukey test (Myers, 1993) where F-values were significant at the 0.05 level. The relationships between extractable P and the uptake, dry matter and P uptake, dry matter and extractable P for each treatment were evaluated by simple regression analyses. The relationships between rate of amendment application from different sources and dry weight of plant tissue, tissue N and P, and N and P uptake were analyzed by linear and curvilinear simple regression. For these analyses with four observations, an r-value of 0.95 is significant at the 0.05 probability level and of 0.99 is significant as the 0.01 probability level (Steel and Torrie, 1980).

6-3 RESULTS AND DISCUSSION

6-3.1 Dry matter production and plant height

Application of PYC, TSP and PL increased the dry weight ($P \leq 0.05$) of young corn plants grown in the field on the Vance soil (Fig.6.1; Appendix Table 6.1). The increase in dry weight is attributed to correction of P deficiency for the following reasons: levels of Mehlich-1 extractable P (Table 5.1) were in the deficiency range of 40-60 mg P dm^3 (Donohue, 1994); the P concentration in plants grown on the control treatment was <0.25% (Fig.6.1; Appendix Table 6.1), which is the low end of range for adequate P levels in young corn plants reported by (Jones et al., 1996); and application of PYC, TSP, and PL increased P levels into the adequate range (Fig. 6.1). These data indicate that P limited corn growth on the Vance soil, which is desirable for this study to evaluate the availability of P in PYC, PL, and TSP.

There was a linear increase in of dry weight produced with increasing P rate from TSP and PYC from 15:1, and 20:1 C:N ratio substrates and a curvilinear increase for the 25:1 C:N ratio substrate (Fig. 6.1; Appendix 6.1). Large increases in dry weight of corn occurred from incorporation of either PYC, TSP or PL. At the 87.2 kg P ha^{-1} rate, dry weights were increased from 64.5 to 132.8 kg ha^{-1} (i.e., 105.9 %) from TSP application and from 64.5 to 186.5 kg ha^{-1} (i.e., 189 %) from PL application. Dry matter was increased by 64.5 to 288.3 kg ha^{-1} (i.e., 347 %) from PYC from 15:1 C:N ratio substrate, by 64.5 to 312 kg ha^{-1} (i.e., 384 %) from PYC from 20:1 C:N ratio substrate, and by 64.5 to 250.7 kg ha^{-1} (i.e., 289 %) from PYC from the

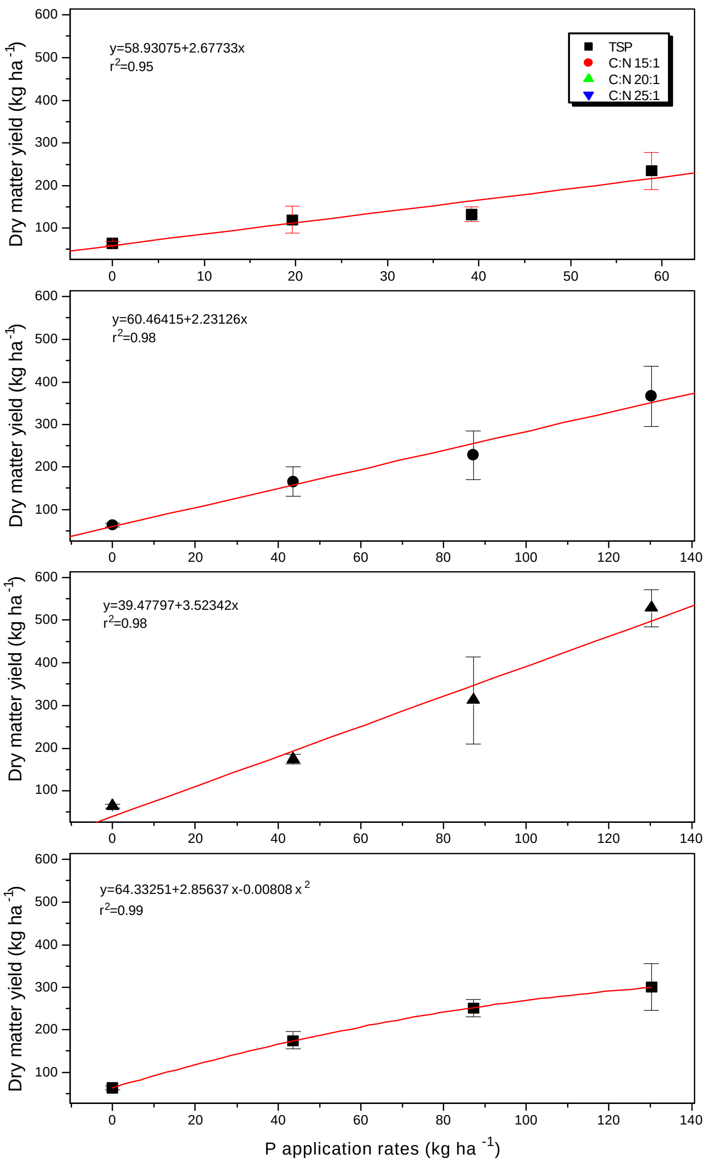

Fig. 6-1. Dry matter yield of corn as affected by rate of applied P as PYC and TSP.

25:1 C:N ratio substrate (Fig. 6.1; Appendix 6.1).

Dry weights varied with rates of application of either TSP or PYC from different substrate C:N ratios, (Fig. 6.1; Appendix Table 6.1). Differences in dry weight among C:N often were smaller than differences among P rates within substrate C:N ratios. At an equal rate of P application, the PYC from 20:1 C:N ratios of substrate increased dry weight as much as or more than inorganic P or P from PYC from 15:1 and 25:1 C:N ratio substrates. Increases in dry weighs with rate of PYC, PL, and inorganic P would vary with factors such as the rate of P mineralization from the applied PYC, the level of P in soil solution, and the amount of fixation of P from soil solution (Edwards and Daniels, 1992)

Treatment effects were similar for plant height and dry weight (Appendix Table 6.2). The plant height was lower for the control than for TSP, PL, and compost treatments. These data suggest that application of fertilizer P, PL and PYC have a greater effect on corn height during periods of rapid plant growth. The plant height increased with increasing rates of P application. Thus, plant height data may be a good substitute for dry matter as a indicator of P availability from incorporation of inorganic and organic P compounds into the Vance soil.

6-3.2 Phosphorus uptake in young corn and soil extractable P

Effects of P source and rate on dry matter and P levels in young corn plants, P uptake by young corn plants, Mehlich-1 extractable P, and grain yield are presented in Appendix Table 6.1. Relationships between amount of extractable soil P and P uptake by corn young plants are given in Fig. 6.2. Phosphorus uptake increased linearly with the rate of TSP and PYC from 15:1 C:N ratio substrate and curvilinearly with rate of PYC from substrate with C:N ratio substrates of 20:1, and 25:1. The coefficients of variation, r^2, were 0.87, 0.99, 0.99 and 0.89 for TSP and PYC from substrate with C:N ratios of 15:1, 20:1, and 25:1, respectively. This relationship indicates that, on the average, Mehlich-1 extractable P accounted for 89 to 99 % of the variation in P uptake on the compost amended soil and for 87 % of this variation on the soil fertilized with TSP. The high correlation supported the earlier contention that PYC contained a large amount of P that

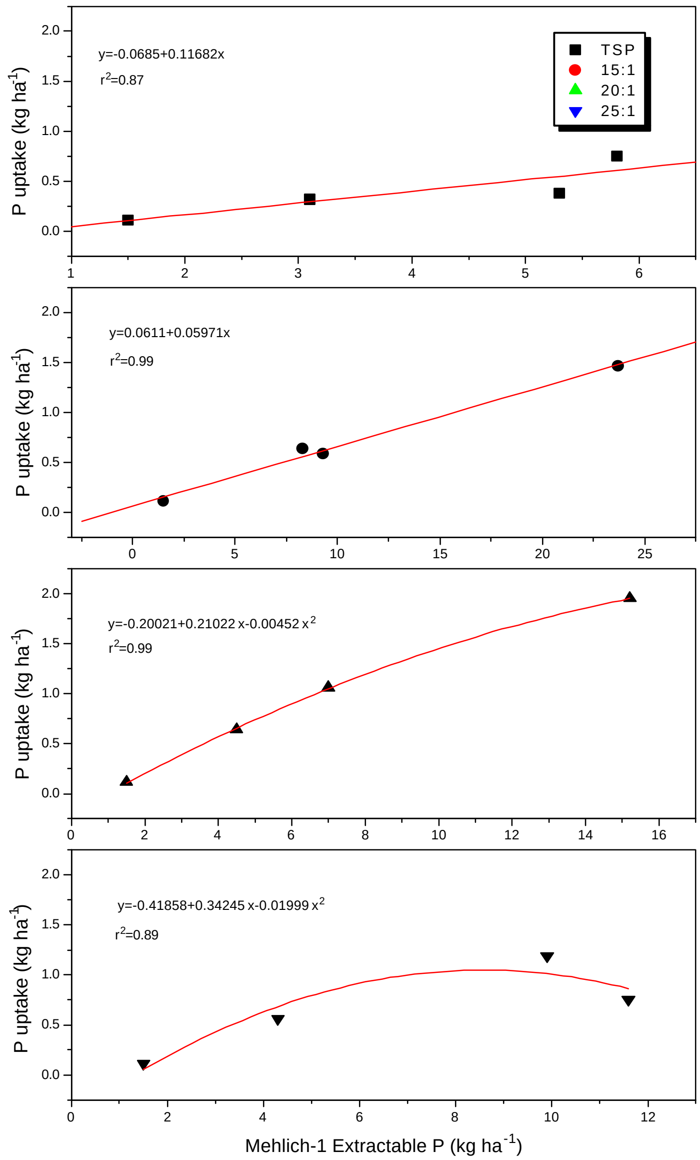

Fig. 6-2. Relationship between P uptake and Mehlich-1 extractable P in the Vance sandy loam.

could be transformed to a plant available form through microbial activity. Phosphorus levels in corn tissue of 0.27 to 0.32 % on TSP treatments and of 0.28 to 0.40 % on PYC treatments were on the medium to the high side of sufficient range of 0.25 to 0.45 % (Jones 1996).

Phosphorus uptake (Appendix Table 6.1) that indicated the availability of P to corn plants increased with rate of TSP and PYC applications. At an application rate of 130.2 kg P ha^{-1}, Mehlich-1 extractable P (Appendix Table 6.1) was higher in soil amended with compost from substrate with C:N of 15:1 than with compost from 25:1 C:N ratio substrate. Mehlich-1 extractable P was in the low range (the low range was <10 kg P ha^{-1}) for all treatments except for the highest P application rate of PYC from 15:1 and 20:1 C:N ratio substrates which fell into the medium range of extractable P (11 to 31 kg P ha^{-1}) based on calibration data for the Mehlich-1 procedure (Olsen and Sommers, 1982). Faster mineralization would account for the greater P availability from compost that originated from substrates with 15:1 and 20:1 C:N ratios. Overall, the P uptake data indicate differences in P mineralization for the three composts in the Vance soil. The inorganic P from mineralization and from TSP application could have undergone a very rapid initial reaction with soil component and, hence, the relatively low levels of extractable P could reflect the conversion of P in solution to non extractable soil forms.

6-3.3 Crop yield, P uptake and soil extractable P

Linear relationships were obtained between dry matter and P uptake of r^2= 0.99, for application of $Ca(H_2PO_4)_2.H_2O$, whereas a curvilinear relationship was obtained for the PYC from 15:1, 20:1 and 25:1 C:N ratio substrates (r^2=0.97, 0.99, and 0.98 respectively) (Fig. 6.3). The quadratic relationship for PYC from the 15:1, 20:1 and 25:1 C:N ratio substrates may indicate that the added P was more difficult to extract with Mehlich-1 at the initiation of the experiment. The difficulty in P extraction early in the growing season may reflect less P mineralization at cooler temperatures or more precipitation as less soluble P. The linear relationship for the TSP may indicate a rapid initial uptake of any available P in the soil during the first weeks of plant growth. The same trend was observed with dry matter yield and extractable P (Fig. 6.4) as with dry matter yield and P uptake (Fig. 6.3).

The corn grain yield increased ($P<0.05$) with rate of TSP and with rate of the three PYC sources (Fig 6.5; Appendix Table 6-1). A response (Table 6.1) to P application was expected because the amount of Mehlich-1 was in the deficiency range in the Vance soil (Olsen and Sommers, 1982). Therefore, the increase in corn grain yield may be attributed to correction of P deficiency. Increases in P mineralization and soil pH may have increased the availability of soil P from PYC application. An increase in soil pH causes displacement of $H_2PO_4^-$ into soil solution by reaction of layer silicates and Al and Fe oxides with OH^- (Barrow, 1984; Sanyal and De Datta, 1991; Fan et al., 1993).

Corn grain yield increased curvilinearly with rates of P application as TSP and PYC (Fig. 6.5). Fertilizer P accounted for (97 %) of the variation in corn grain yield; whereas, PYC application accounted for 84 to 99 % of the yield variation. Large increases in corn grain yield occurred from application of TSP, PL and as compared with the control. Corn grain yield was higher than the control by 50.3 %, 80.9 %, and 60.5 % with TSP, PL, and PYC (C:N 15:1 for the P rate of 43.6 or 87.2 kg P ha^{-1}) application, respectively.

6-3.4 Nitrogen concentration and uptake by corn plant

Nitrogen concentration in tissue increases up to 0.4 on TSP treatments and 0.6 % on PYC treatments (Appendix Table 6.1). Although supplemental N was applied to the PYC treatments the N concentration in tissue was below 3.5 % (Appendix 6.2) which indicates inadequate N for normal growth (Voss, 1993). These results suggest that supplemental N plus either PYC or PL did not result in over-application of N. The relatively low N concentrations in plants may reflect dilution of N in plants due to the high yields. Slow mineralization of N from PYC and PL also may have contributed to the relatively low levels of tissue N.

Nitrogen uptake was linearly related to rate of P application on the TSP and PYC (15:1 C:N ratio substrate) treatments (Fig. 6.6). Curvilinear relationships occurred between N uptake and rate of P application from the PYC 20:1 and 25:1 C:N ratio substrates (Fig. 6.6). A possible

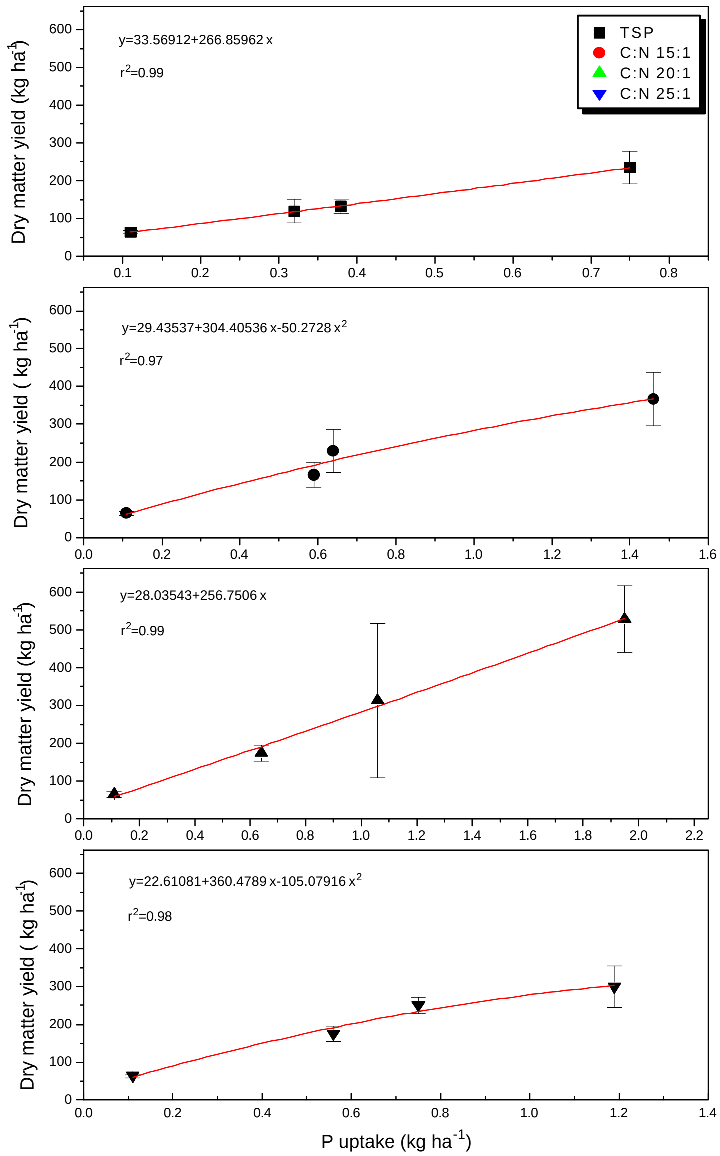

Fig. 6-3. Relationship between dry matter and P uptake as affected by TSP and PYC.

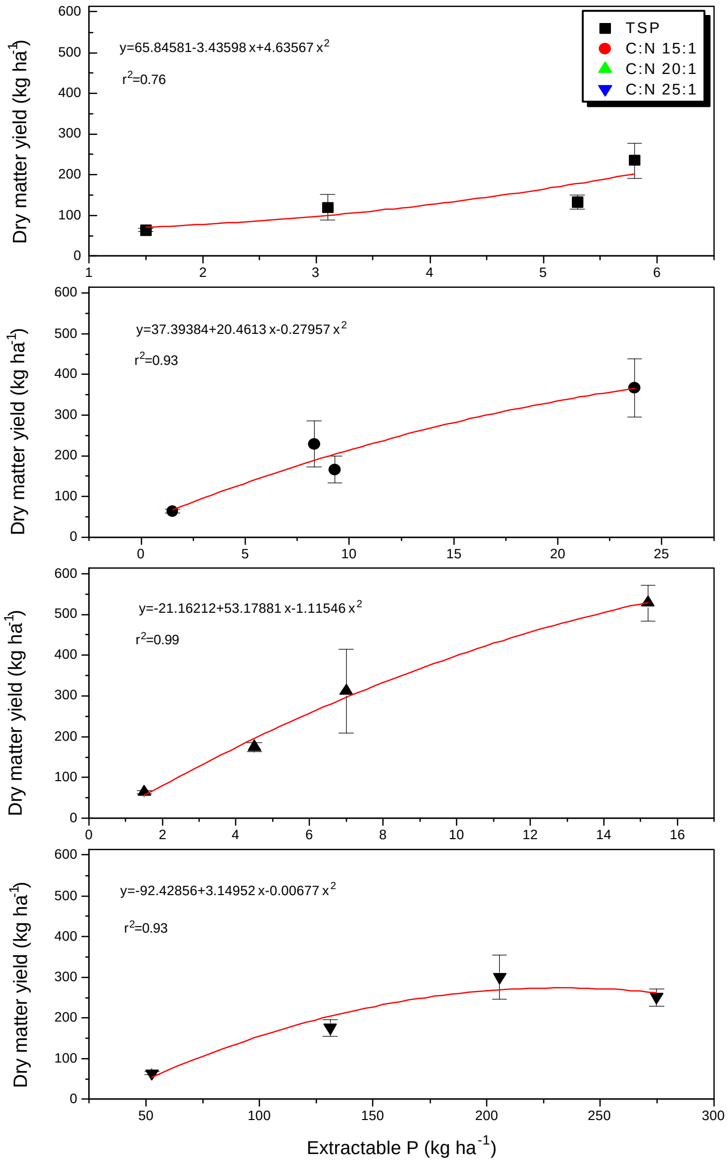

Fig. 6-4. Relationship between dry matter yield and extractable P.

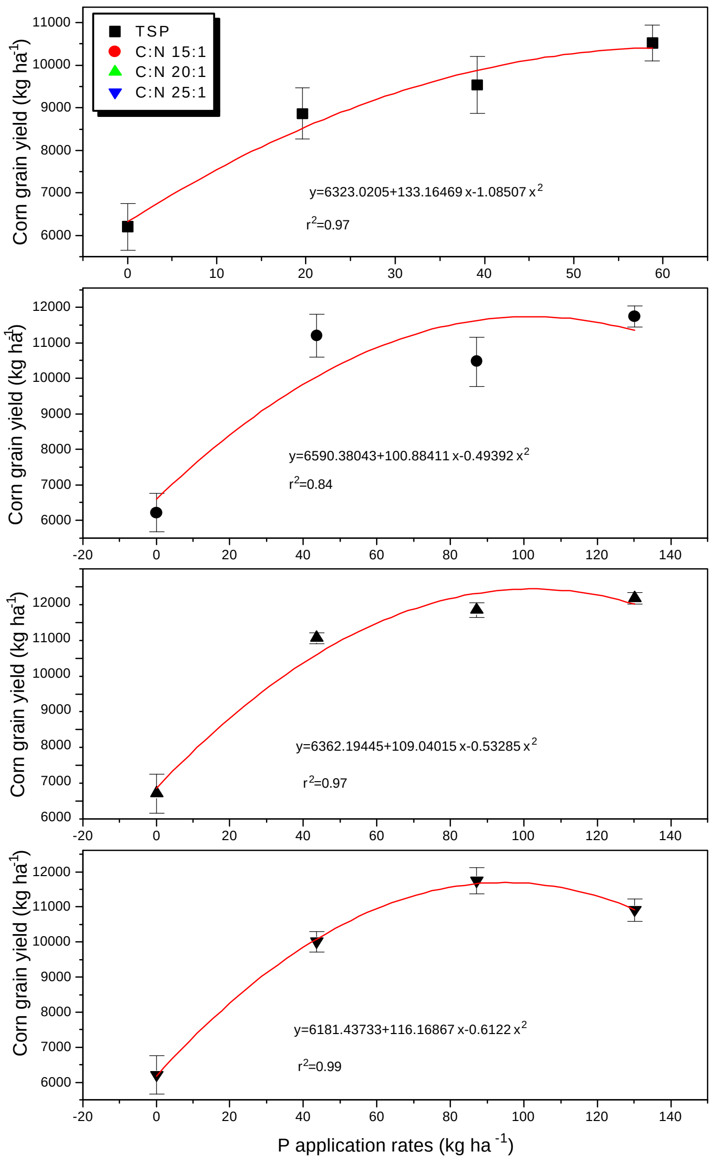

Fig. 6-5. Corn grain yield as affected by TSP and PYC from three substrate C:N ratios.

explanation for these relationships is that P application increased root and shoot growth and that the higher root volume caused higher absorption of N from soil. Mineralization of N from PYC also increased N absorption as shown by highest N uptake from the 130.2 kg P ha^{-1} treatment with PYC from the 20:1 C:N ratio substrate (Table 6.2).

6-3.5 Zinc and Cu concentration in corn plant tissue

One of the major considerations in the use of PL products on agriculture is the soil accumulation of heavy metals such as Zn and Cu. As previously stated, Cu and Zn are added to poultry feed to supply nutritional needs to increase the rate of gain and egg production (Tuffit and Nockels, 1991). These metals can concentrate in manure as compared with feed. As Cu and Zn concentrations in wastes increase, the potential for Cu and Zn phytotoxicity increases. Results of corn tissue analyses for Cu and Zn concentrations for each treatment are given in Appendix Table 6.3. Copper levels in young plants were within the normal range of 7-20 mg kg^{-1} for all treatment on the Vance, whereas Zn levels were slightly above the normal range of 20-50 mg kg^{-1} for all treatments (Jones, 1996). The high grain yields (Table 6.1) on this Vance sandy loam with a relatively low yield potential indicate that Zn phytotoxicity was not likely.

In summary, the PYC used in this study was a good source of P for plant growth primarily because the PYC contained mineralizable P and OH^- from PYC application displaced $H_2PO_4^-$ into soil solution by reaction with layer silicates and Al and Fe oxides. Consequently, PYC can enrich the soil P status by decreasing of P adsorption capacity or by direct contribution to soil fertility. The Vance soil was more productive with addition of PYC and had higher extractable P levels than soil managed with inorganic P or without P fertilizer.

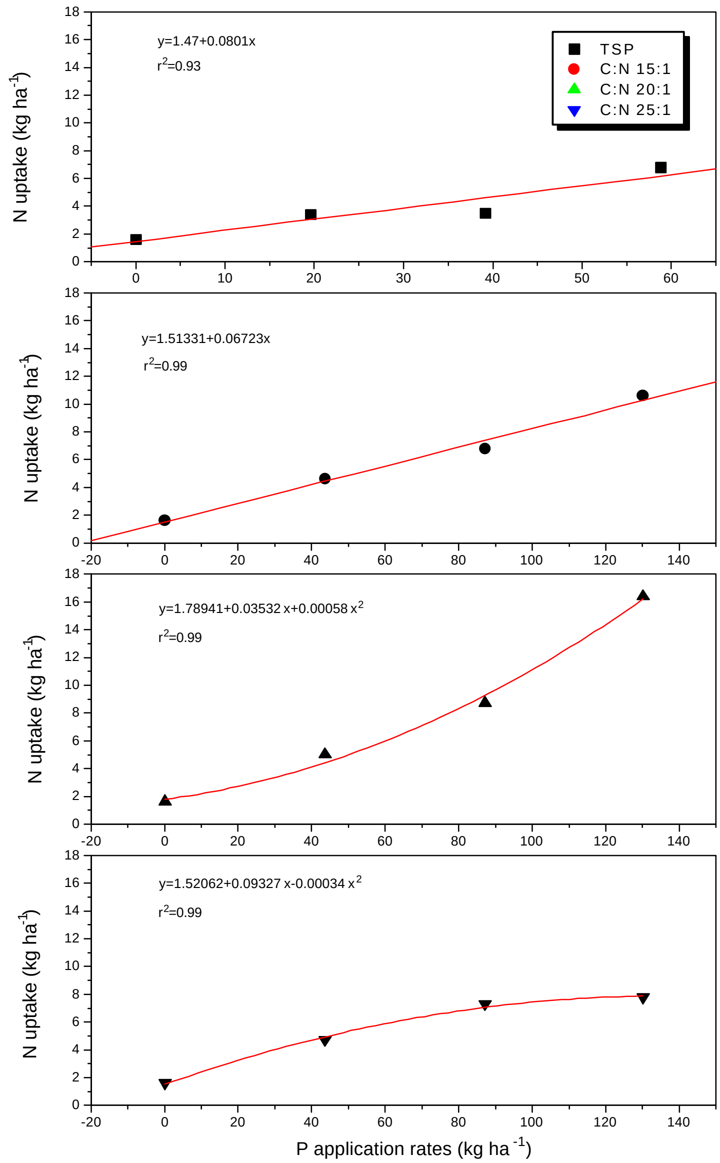

Fig. 6-6. Nitrogen uptake by corn tissue as affected by PYC and TSP.

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