# CHAPTER 5

# EFFECT OF POULTRY LITTER-YARD WASTE COMPOST ON CORN GROWTH AND P UPTAKE IN GREENHOUSE STUDIES

## ABSTRACT

Application of animal waste compost to soil can be a valuable source of P for crop production. Use of animal waste to meet crop N requirements often results in an over application of P. Attention is currently being focused on nonpoint pollution sources of P due to agricultural runoff from high application of organic amendments such as poultry litter (PL) or poultry manure. Therefore, there is a need to develop sound environmental methods for PL utilization. A new approach investigated in this research was to develop a poultry litter-yard waste compost (PYC) for use as a soil conditioner and an organic fertilizer.

Greenhouse studies were conducted on four soils [Vance topsoil and subsoil, Starr (mixture of Ap and upper B horizons), and mine tailings] to determine the effect of PYC from 15:1, 20:1, and 25:1 C:N ratio substrates on P availability and to evaluate the influence of triple superphosphate (TSP) and PYC on corn (*Zea mays* L.) growth. The rate of PYC application was based on P recommendations from Mehlich-1 extractable P data for corn growth on soils with low to high P adsorption capacities. These soils were treated with three levels of TSP, PL, and PYC from 15:1, 20:1, and 25:1 C:N ratio substrates. The organic and inorganic amendments increased ($P<0.05$) dry weight production and P uptake. The magnitude of the response varied with P adsorption capacity of the soils and with rate of amendment application. A rate of 26.2 mg P $kg^{-1}$ from TSP increased the dry weight by 103.7%, whereas, the same rate, PYC (from a 15:1 C:N ratio substrate) increased the dry weight by 192.6% on Vance topsoil. A similar P rate on Vance subsoil increased the dry weight by 100% for TSP, 110% for PYC from 20:1 C:N ratio substrate, and 280% from PL. Overall, at the same rate of P application, PL and PYC supplied more P to corn than TSP which was attributed to the slow P release from the PL and PYC and, thereafter,

to slow P adsorption by soil. No differences ($P<0.05$) were observed among PYC from differ C:N ratio substrates with respect to the dry weight and P uptake. Nevertheless, the PYC from 20:1 and 25:1 C:N ratio substrates were superior to PYC from 15:1 C:N ratio substrate based on completion of the composting procedure. From a practical standpoint, slow release of P from the PYC, combined with appropriate management would decrease P in groundwater and runoff , and would increase P uptake by decreasing the rate of P fixation in an available forms.

## 5-1 INTRODUCTION

Poultry or yard waste used as a soil amendment has improved crop yield but has also caused environmental concern (Liebhardt, 1976; Edwards and Daniel, 1992; Dick and McCoy, 1993). Yield increases of horticultural and agronomic crops from poultry manure or composted waste application reflect a combination of improved physical and chemical soil properties. Such benefits may justify the use of these organic wastes as an amendment for crop production. However, environmental concerns with N and P have prompted a reduction in waste application on agricultural soils. Composting carbonaceous and nitrogenous materials together has a suppressive effect on N leaching due to N immobilization by microorganisms or N loss by volatilization. Therefore, the compost process has become more widely used to recycle organic waste. Furthermore, the loss of N by leaching could also be decreased with recommended application rates of poultry waste based on plant N requirement. Phosphorus is applied in excess of crop demands when application is based on N requirement, and the excess P may be removed by the fixation, runoff, and fixation processes. To minimize P losses through erosion and runoff, the application of PYC was based on plant P requirement while maintaining adequate N by adding $NH_4NO_3$ to soil. Currently there is a lack of information on P availability in soils that received composted wastes.

The objectives of the greenhouse study were as follows: 1) to determine the P availability in compost from PYC digested at three different substrate C:N ratios (15:1, 20:1, and 25:1), and 2) to evaluate the response of corn to P application from triple superphosphate and PYC.

## 5-2 MATERIALS AND METHODS

### 5-2.1 Soils characteristics

Two greenhouse studies were conducted in this experiment. Selection of the soil materials was based on previously described adsorption isotherms (Table 3.3). The goal was to select soils with low to relatively high P adsorption capacities to facilitate use of a wide range in levels of compost application. Based on this criteria the selected soils were Starr (fine loamy mixed, thermic Fluventic Dystrochrepts),Vance (clayey kaolinitic, thermic Typic Kanhapludults), and mine sand tailings (fine loamy siliceous, thermic Typic Udorthents). Relevant physical and chemical properties of these soils are given in Table 5.1.

### 5-2.2 Greenhouse Investigation

#### *5-2.2.1 Greenhouse Study 1- Vance (Ap horizon) and Starr( mixture of Ap and upper B horizons) soils*

These experiments were conducted with a mixture of Ap and upper B sample from a Starr soil and with an Ap horizon sample from a Vance soil. The Starr soil did not receive P fertilization during the past 10 years, and the Vance soil did not receive P fertilizer during the past 30 years. These soils were air dried, ground, sieved to pass a 4-mm sieve, and mixed in preparation for the experiments.

Thirteen treatments on the Vance soil (Ap horizon) were a control and 8.7, 13.1 26.5 mg P $kg^{-1}$ as $Ca(H_2PO_4)_2.H_2O$ and as compost from 15:1, 20:1, and 25:1 substrate C:N ratios (Table 5-2). The same 13 treatments were used on the Starr soil, except that P levels were 8.7, 17.4 and 26.5 mg $kg^{-1}$. Each pot received a basal fertilization of 40 mg N $kg^{-1}$ as $NH_4NO_3$, 30 mg K $kg^{-1}$ as KCl, 25 mg Mg $kg^{-1}$ as $MgSO_4.7H_2O$, 5 mg Mn $kg^{-1}$ as $MnSO_4.H_2O$, 5 mg Zn $kg^{-1}$ as $ZnSO_4.7H_2O$, 2.5 mg Cu $kg^{-1}$ as $CuSO_4.5H_2O$, and 1 mg B $kg^{-1}$ as $Na_2B_4O_7.10H_2O$. This basal fertilization ensured that the growth of the corn plant was limited by P only. A level of 1000 mg $CaMg(CO_3)_2$ $kg^{-1}$ was mixed with the Starr soil and of 1100 mg $CaMg(CO_3)_2$ $kg^{-1}$ with the Vance soil to decrease soil acidity. The rate of P application was approximatively one, two, or three times the Virginia fertilizer recommendation for corn (Donohue, 1994) because of the high buffering capacity of the soils.

**Table 5-1. Selected physical and chemical properties of three soils used in the greenhouse studies.**

| | | Mehlich-1 extractable | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Soil Series | pH | Ca | Mg | K | H | Al | Sand | Silt | Clay | Organic Matter | Mehlich-1 Extr. P |
| | | mg $kg^{-1}$ | | | | | % | | | | mg $kg^{-1}$ |
| Vance (Ap) | 5.3 | 372 | 63 | 64 | -- | -- | 67.8 | 17.8 | 14.5 | 1.5 | 3.0 |
| Vance (Bt) | 4.9 | 132 | 68 | 44 | 13.1 | 1.8 | 23.9 | 15.2 | 60.9 | 0.6 | 1.0 |
| Mine tailings | 4.7 | 42 | 20 | 37 | 4.7 | 0.8 | 74.6 | 5.6 | 19.8 | <0.5 | 1.6 |
| Starr (Ap+B) | 5.4 | 600 | 120 | 106 | -- | -- | -- | -- | -- | 3.7 | 7.0 |

The treatments and basal fertilizers were mixed with 1.25 kg of soil, the mixture was placed in plastic-lined pots, and the pots were arranged in a randomized complete block design with three replicates. Eight corn (*Zea mays* L. Cultivar Pioneer 3394) seeds were planted in each pot, and thinned to four plants per pot after emergence and, a few days later, thinned to two plants per pot. Pots were placed on greenhouse benches and rotated within a block when watered either once or twice per day. Fifty mg $kg^{-1}$ of N as $NH_4NO_3$ and 50 mg $kg^{-1}$ of K as KCl were added to each pot during the growth period to prevent deficiencies of these elements. Plants were harvested after a 5-week growing period, and were oven-dried at $70^o$ C to constant weight.

#### *5-2.2.2 Greenhouse Study 2- Mine tailings and Vance (subsoil)*

The second greenhouse study was conducted in a manner similar to the first greenhouse study. Sandy mine tailings and Vance subsoil (B horizon) were used in this study. The soils were air-dried, ground to pass a 4-mm sieve and mixed in preparation for the experiments. Fifteen treatments were applied on the Vance subsoil as follows: a control; 13.1, 26.2, 52.4, and 78.6 mg P $kg^{-1}$ as $Ca(H_2PO_4)_2.H_2O$; 13.1, 26.2, and 52.4 mg P $kg^{-1}$ as PL and as PYC from the 20:1 and 25:1 C:N ratio substrate; and 52.4 mg P $kg^{-1}$ as compost from the 15:1 C:N ratio substrate. Seventeen treatments applied to the mine tailings were a control, 15.3, 30.6, 61.2, and 91.8 mg P $kg^{-1}$ as $Ca(H_2PO_4)_2.H_2O$, and 15.3, 30.6, and 61.2 mg P $kg^{-1}$ as compost from 15:1, 20:1, and 25:1 C:N ratio substrates and as PL (Table 5.2). Basal levels of nutrients applied in both soils were: 75 mg N $kg^{-1}$ as $NH_4NO_3$, 75 mg K $kg^{-1}$ as KCl, 25 mg Mg $kg^{-1}$ as $MgSO_4.7H_2O$, 5 mg Mn $kg^{-1}$ as $MnSO_4.H_2O$, 5 mg Zn $kg^{-1}$ as $ZnSO_4.7H_2O$, 2.5 mg Cu $kg^{-1}$ as $CuSO_4.5H_2O$, and 1 mg B $kg^{-1}$ as $Na_2B_4O_7.10H_2O$. A level of 1900 mg $CaMg(CO_3)_2$ $kg^{-1}$ was applied to the Vance subsoil and of 1250 mg $CaMg(CO_3)_2$ $kg^{-1}$ to the mine soil to increase the soil pH.

**Table 5-2. Compost rates and inorganic sources used in the greenhouse studies.**

| | Soils | | |
|---|---|---|---|
| Treatment | Vance topsoil and Starr‡ | Vance subsoil | Mine tailings |
| | ------------------------------mg $kg^{-1}$------------------------------- | | |
| Control | -- | -- | -- |
| **Inorganic fertilizer ($Ca(H_2PO_4)_2.H_2O$)** | | | |
| | 44 | 57 | 177 |
| | 67 | 114 | 354 |
| | 134 | 229 | 708 |
| | --- | 344 | 1063 |
| **Organic Amendment (Yard waste-poultry litter compost)** | | | |
| C:N (15:1) | 1162† | -- | 610 |
| C:N (15:1) | 1744 | -- | 1220 |
| C:N (15:1) | 3488 | 1100 | 2400 |
| C:N (20:1) | 1176 | 540 | 620 |
| C:N (20:1) | 1768 | 1100 | 1240 |
| C:N (20:1) | 3528 | 2200 | 2480 |
| C:N (25:1) | 2072 | 950 | 1090 |
| C:N (25:1) | 3112 | 1900 | 2180 |
| C:N (25:1) | 6232 | 3800 | 4370 |
| Poultry litter | -- | 1100 | 1270 |
| Poultry litter | -- | 2200 | 2550 |
| Poultry litter | -- | 4400 | 5100 |

†Based on an estimated P mineralization rate of 45%.
‡Starr soil is a mixture of the Ap and upper B horizon.

The treatments and basal fertilizer were mixed with 1.075 kg of Vance subsoil and with 2.85 kg of mine tailings, the mixtures were placed in plastic-lined pots, and the pots were arranged in a randomized complete block design with three replicates. Eight corn (*Zea mays* L. Cultivar Pioneer 3394) seeds were planted in each pot, thinned to four plants per pot after emergence and, a few days later, thinned to two plants per pot. Pots were placed on greenhouse benches and rotated within a block when watered either once or twice per day. Plants were harvested after a 7-week growing period, and were oven-dried at 70$^o$ C to constant weight.

## 5-2.3 Laboratory Analyses

### *5-2.3.1 Plant tissue P analysis*

Dried plant tissue was ground to pass a 20-mesh sieve in preparation for P analyses. A 1-g subsample of ground tissue weighed into a Folin-Wu tube was digested in a $HNO_3$-$HClO_4$ mixture (Gaines and Mitchell, 1979). The digests were diluted to 50 ml with 1.2 M HCl, mixed, and filtered through Whatman no. 42 filter paper, and the filtrate was stored at 4$^o$C. Phosphorus in the filtrate was determined colorimetrically by a molybdate-vanadate method (Jackson, 1958) with a Hitachi model 200-20 spectrophotometer. Calcium, K, Mg, and Mn in the $HNO_3$-$HClO_4$ digests were determined by inductively coupled plasma emission spectrometry, and Cu and Zn in the digests were determined by atomic adsorption spectrophotometry. Total N in the plant tissue was measured by a Kjeldahl method (Bremner and Mulvaney, 1982).

### *5-2.3.2 Compost analysis*

Percent moisture, and the elemental components of the finished compost were determined by the same procedures as those used for the plant tissue. The total N and C for C:N measurement were determined on a Leco Analyzer (USDA, 1979). Ammonium was extracted from compost with 2 M KCl, and determined by an indophenol-blue procedure (USDA, 1979). Data from compost samples analyses are reported on the dry weight (Table 5-3). The pH of each sample was determined at a 1:1 soil-to-water ratio after a 30-min equilibration period. The suspension pH of PL, YW, and PYC from 15:1, 20:1, and 25:1 C:N ratio substrates were 8.83, 7.94, 9.1, and 6.93 respectively.

#### *5-2.3.3 Soil analysis*

One core per pot was sampled from the surface 15-cm after the plants were harvested. Mehlich-1 extractable P, K, Ca, Mg, Zn, and Mn were determined as described by Sims (1989). Soil texture was determined by the hydrometer method (Day, 1965). The soil pH of each sample was determined at a 1:1 soil-to-water ratio after a 30-min equilibration period.

### 5-2.4 Statistics analysis

Phosphorus uptake, dry matter yield, soil pH, and N uptake data were evaluated by analyses of variance (Myers, 1992). The Tukey's mean separation procedure was used to obtain mean differences where F-values were significant at the 0.05 level. A Tukey test was used to evaluate mean differences in plant response to PYC from three substrates with three different C:N ratios and to $Ca(H_2PO_4)_2.H_2O$ application. The relationships between rate of application from different sources and dry weight of plant tissue, tissue N and P, and N and P uptake were analysed 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 and the 0.01 probability level (Steel and Torrie, 1980).

**Table 5-3. Composition of compost used in the greenhouse studies†.**

| Initial C:N | Final C:N | N | $NH_4$-N | P | K | Ca | Mg | S | B | Cu | Fe | Mn | Zn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ------------------------------%------------------------------ | | | | | | | ---------------------ppm------------------ | | | | |
| 15:1 | 7.6 | 2.8 | 0.38 | 2.5 | 2.7 | 2.8 | 0.69 | 0.95 | 70 | 847 | 3020 | 827 | 625 |
| 20:1 | 10.5 | 2.5 | 0.12 | 2.5 | 2.3 | 2.6 | 0.60 | 0.79 | 69 | 736 | 3545 | 775 | 600 |
| 25:1 | 13.8 | 1.9 | 0.02 | 1.4 | 1.7 | 2.4 | 0.52 | 0.55 | 64 | 558 | 3745 | 743 | 474 |

†All data are reported on a dry weight basis.

## 5-3 RESULTS AND DISCUSSION

### 5-3.1 Dry matter production of corn

#### *5-3.1.1 Greenhouse study 1 - dry weights of corn plants*

Application of both PYC and TSP increased dry matter weights ($P<0.05$) of corn plants grown in the greenhouse on Vance topsoil (Fig. 5.1; Appendix Fig.1 and Table 5.1) and on Starr mixed horizon soil (Fig. 5.2; Appendix Fig. 2 and Table 5.2). The increase in dry matter is attributed to correction of P deficiency because the two soils contained amounts of Mehlich-1 extractable P (Table 5.1) in the deficiency range (Olsen and Sommers, 1982), the P concentrations in plants grown on the control treatment of both soils were <0.25% (Fig. 5.3 and 5.4), i.e., the low end of the range for adequate P levels in young corn plants (Jones et al., 1996), and P application increased dry matter weights on the soils. Application of 13.1 and 26.2 mg P kg $^{-1}$, as either PYC or TSP increased P levels into the adequate range on the Vance topsoil (Fig. 5.3; Appendix Fig. 3 and Table 5.1), but not on the Starr mixed horizon soil (Fig. 5.4; Appendix Fig. 4 and Table 5.2). These data indicate P deficiency was not completely corrected by the P application on the Starr mixed horizon soil, which had a higher P fixation capacity than the Vance topsoil (Table 3.3).

Dry matter yields increased linearly with rates of TPS and curvilinearly with rates of PYC from substrates with three different C:N ratios on both soils (Fig. 5.1 and 5.2). Large increases in dry weights of corn occurred from incorporation of either PYC or TSP over the five-week growth period. For example, at the 26.2 mg P kg$^{-1}$ rate, dry weights were increased by 2.7 to 5.5 g pot$^{-1}$ (i.e., 103.7%) from TSP application and from 2.7 to 7.9 g pot$^{-1}$ (i.e., 192.6%) from PYC produced from 15:1 C:N ratio substrate on the Vance topsoil (Fig. 5.1; Appendix Fig. 1 and

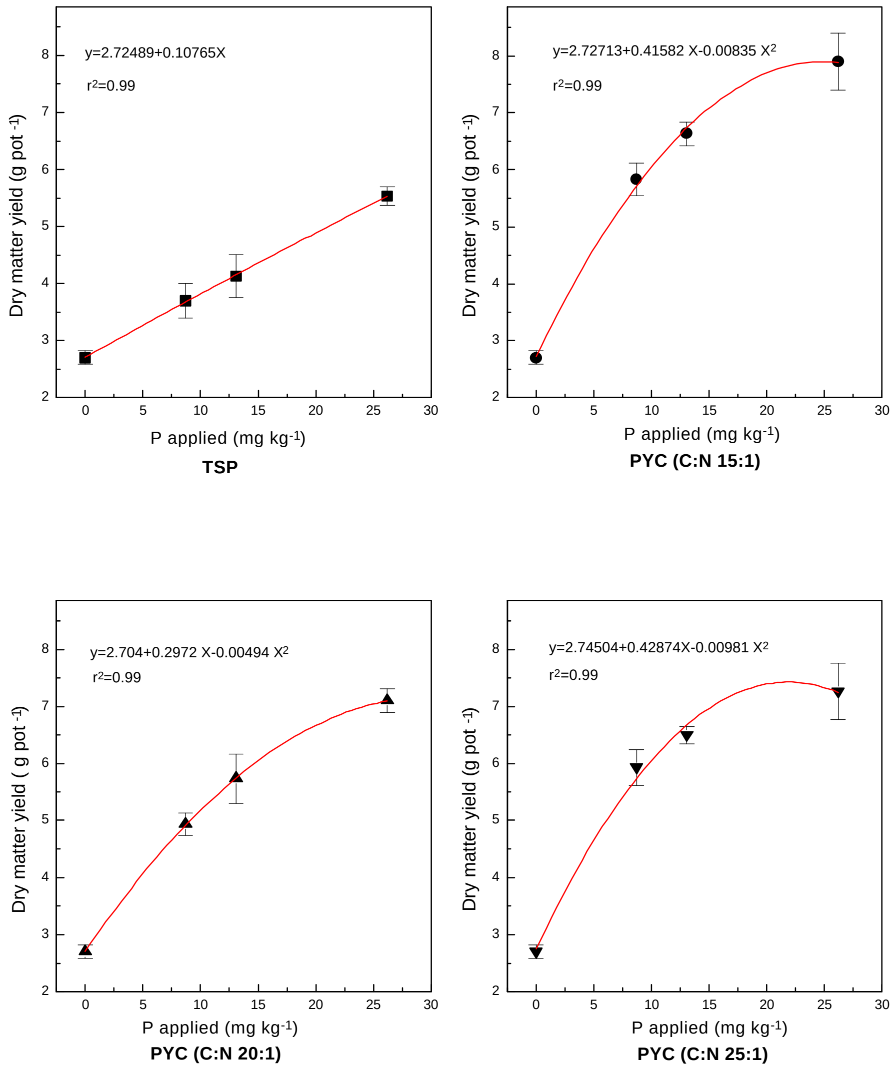


Fig. 5-1. Dry matter yield of corn plants as affected by the rate of P applied as PYC and TSP on Vance topsoil.

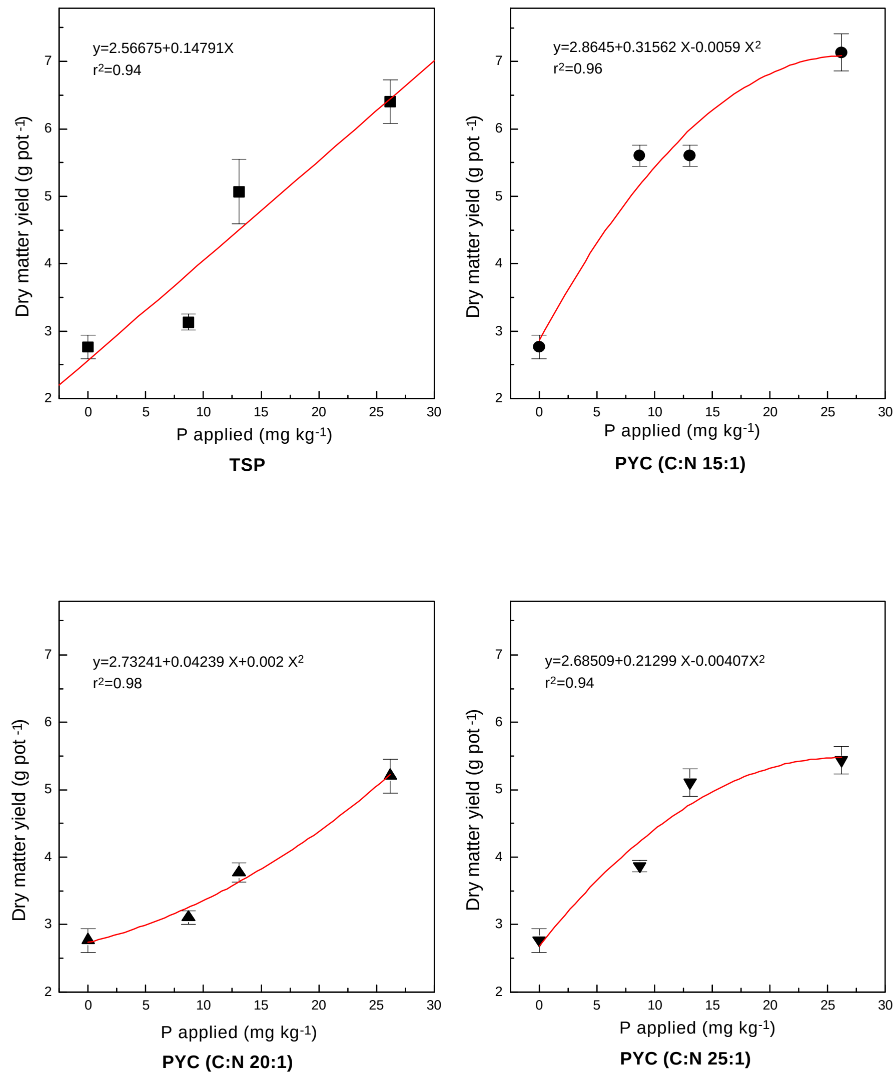


Fig. 5-2. Dry matter yield of corn plants as affected by rate of P applied as PYC and TSP on Starr mixed horizon soil.

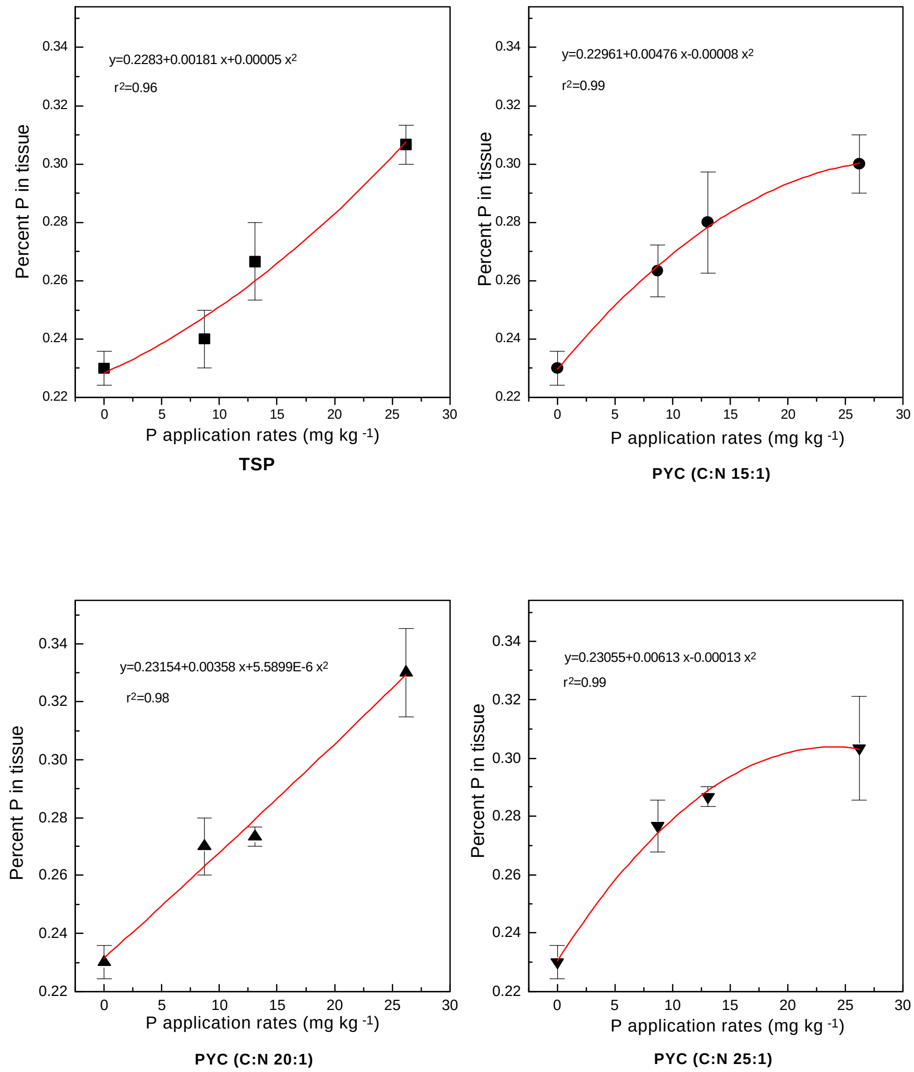


Fig. 5-3. Percent P in corn tissue as affected by rate of PYC and TSP on Vance topsoil.

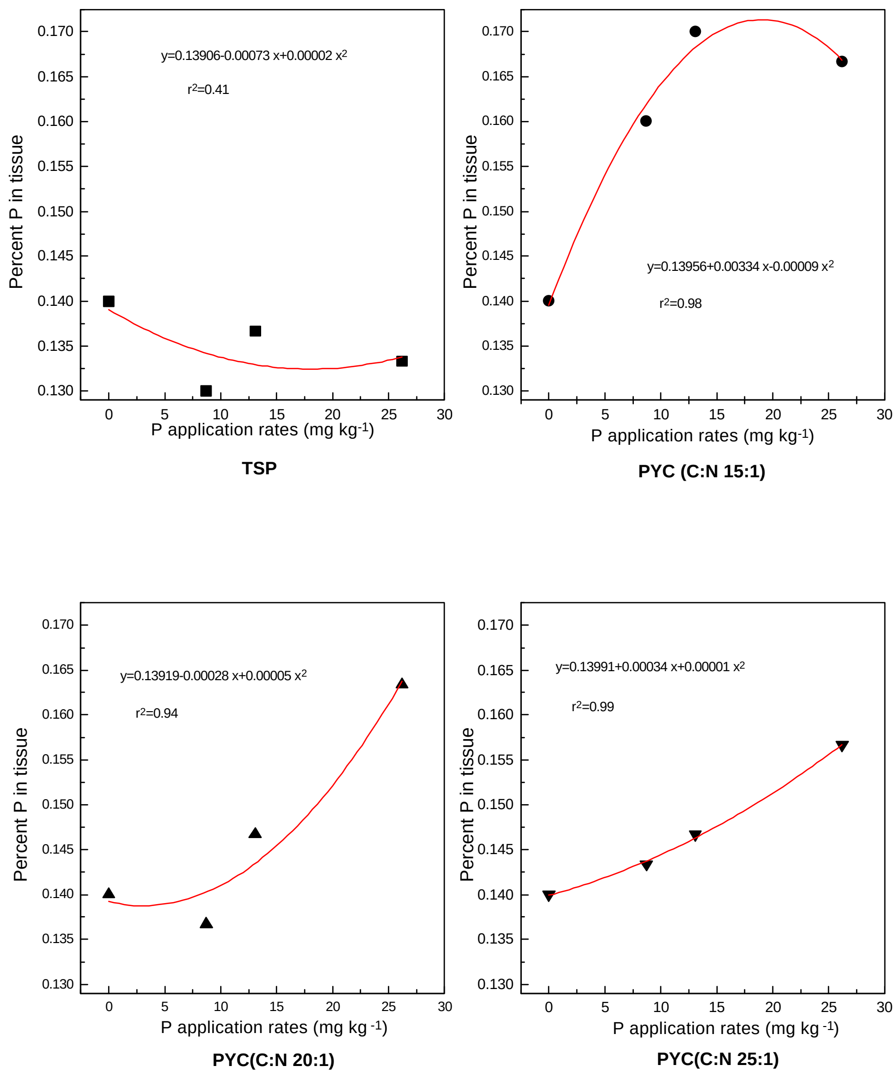


Fig. 5-4. Percent P in corn tissue as affected by rate of applied P as PYC and TSP on Starr mixed horizon soil.

Table 5.1). Dry weights of corn plants grown on the 26.2 mg P $kg^{-1}$ treatment for five weeks on the Starr mixed horizon soil were increased from 2.8 to 6.4 mg $pot^{-1}$ (i.e., 128.6%) for TSP application and from 2.8 to 7.1 g $pot^{-1}$ (i.e., 154%) for application of PYC from a 15:1 C:N ratio substrate (Fig. 5.2; Appendix Fig. 2 and Table 5.2). The increases in dry weight of corn plants indicate that the PYC would serve as a good P source for correction of P deficiency in crops grown on the Starr and Vance soils.

Relationships between dry matter weights varied with rates of application of TSP and PYC from different substrate C:N ratios for the two soils. At an equal rate of P application, the PYC from 15:1, 20:1, and 25:1 C:N ratio substrates increased dry matter weights of corn as much as or more than the inorganic P on the Vance topsoil (Fig. 5.1; Appendix Table 5.1). In contrast, at an equal rate of P application, the inorganic P increased dry weights as much as or more than the PYC from different C:N ratio substrates on the Starr mixed horizon soil (Fig. 5.2; Appendix Fig. 2 and Table 5.2). Increases in dry weights with rate of PYC and TSP application would vary with factors including rate of P mineralization from the applied PYC (Warman, 1986), level of P in soil solution and amount of fixation of P from soil solution (Taylor et al., 1978).

#### *5-3.1.2 Greenhouse study 2 - dry weights of corn plants*

Changes in experimental procedures were made in greenhouse study 2 based on findings in greenhouse experiment 1. An extra inorganic P treatment of 78.6 mg P $kg^{-1}$, which was higher than any of the P treatments in experiment 1 (Fig. 5.1 and 5.2; Appendix Fig.1 and 2, and Tables 5.1 and 5.2), was used in experiment 2 (Fig. 5.5 and 5.6; Appendix Fig. 5 and 6, and Tables 5.3 and 5.4). Poultry litter treatments were included in greenhouse experiment 2 (Fig. 5.5 and 5.6; Appendix Tables 5.3 and 5.4) so that P parameters from PYC treatments could be compared with raw PL, a component of the PYC, as well as with inorganic P treatments. Another treatment change was necessitated by the lack of Vance subsoil for all of the desired treatments. One rather than three rates of PYC from the 15:1 C:N ratio substrate was used in greenhouse experiment 2. Deletion of treatments from the PYC from the 15:1 C:N ratio substrate was based on the less

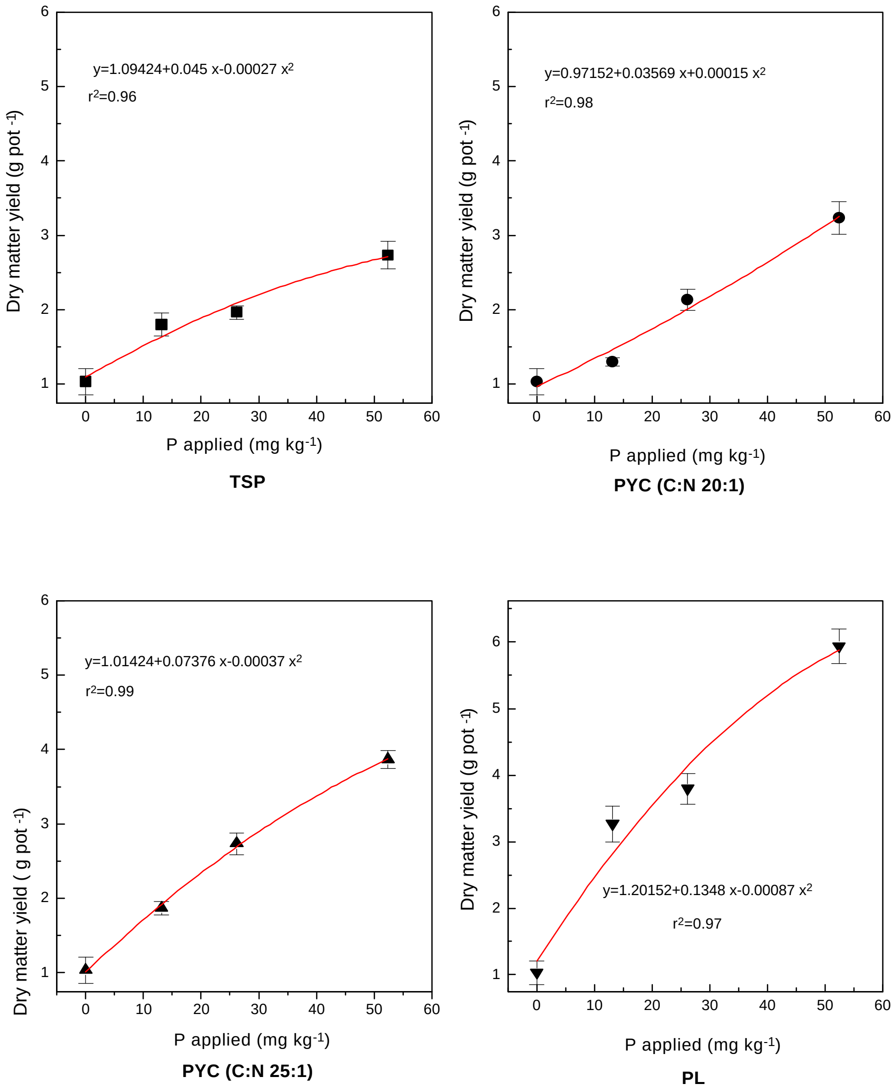


Fig. 5-5. Dry matter yield of corn plants as affected by the rate of P applied as PYC, TSP, and PL on Vance subsoil.

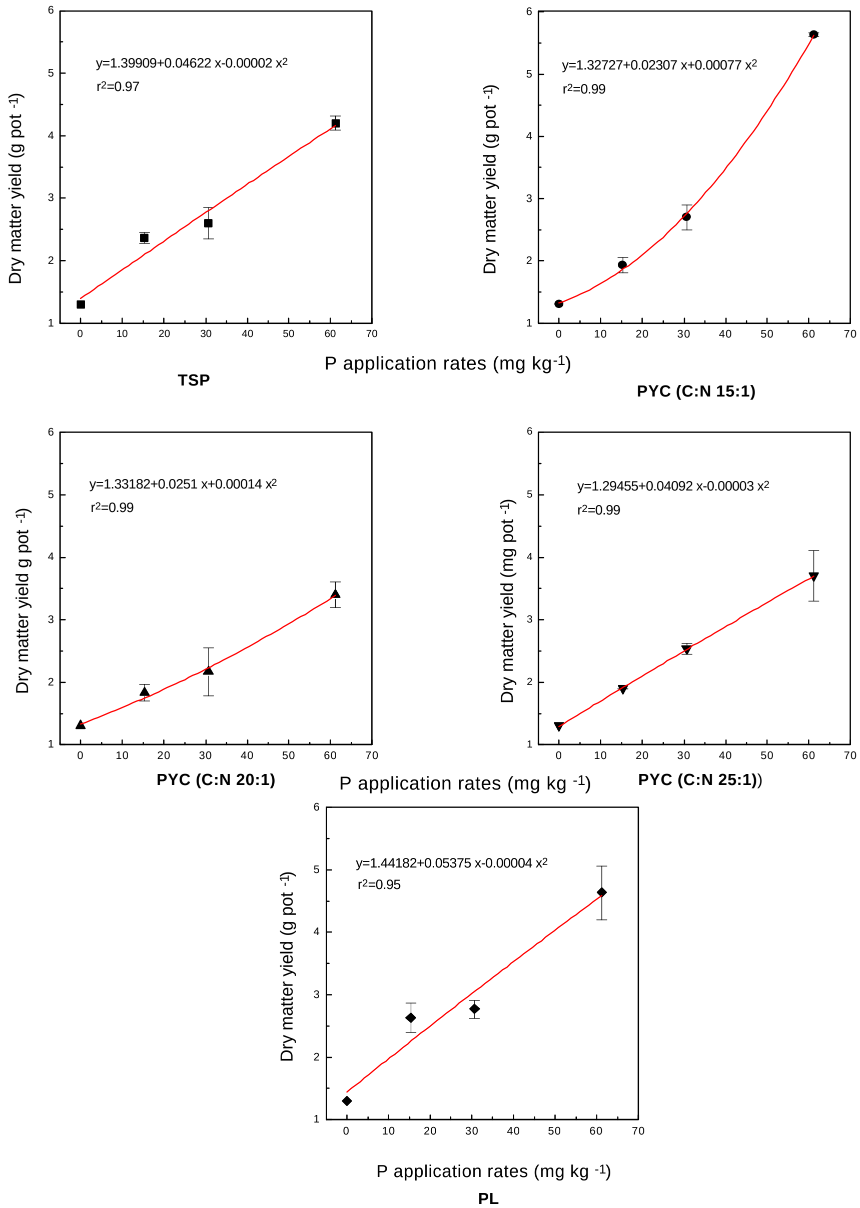


Fig. 5-6. Dry matter yield as affected by the rate of P applied as PYC, TSP, and PL on mine tailings.

desirable field application properties of this PYC as compared with that from the 20:1 and 25:1 C:N ratio substrates.Application of higher levels of PYC and TSP and of all levels of PL increased dry matter weights ($P<0.05$) of corn plants grown in the greenhouse on Vance subsoil (Fig. 5.5; Appendix Fig.5, and Table 5.3) and on mine tailings (Fig. 5.6; Appendix Fig.6, and Table 5.4). The increase in dry matter is attributed to correction of P deficiency because the two soils contained amounts of Mehlich-1 extractable P (Table 5.1) in the deficiency range (Olsen and Sommers, 1982), the P concentrations in plants grown on the control treatment of both soils were <0.25% (Fig. 5.7 and 5.8) which indicates an inadequate P level in young plants (Jones et al., 1996), and P application increased dry matter weights on the soils. Application of as high as 91.8 mg P $kg^{-1}$ as inorganic P and of as high as 61.2 mg P $kg^{-1}$ as PYC or PL did not increase P levels in corn plants to a sufficient level of above 0.24 mg P $kg^{-1}$ (Jones et al., 1996) on either the Vance subsoil or the mine tailings (Fig. 5.7 and 5.8; Appendix Fig. 7 and 8, and Table 5.3 and 5.4). This lack of complete correction of P deficiency by the high level of P application indicated severe P deficiency in the Vance subsoil and the mine tailings.

Large increases in dry weights of corn plant, occurred from incorporation of either PYC or TSP over the 7-week growth period. For example, at the 52.4 mg P $kg^{-1}$ rate, dry weights were increased by 1.0 to 2.7 g $pot^{-1}$ (i.e., 170%) from TSP application and by 1.0 to 5.9 g $pot^{-1}$ (i.e., 490%) from PL application on the Vance subsoil (Fig. 5.5; Appendix Fig. 5, and Table 5.3). Dry weights of corn plants grown on the 61.2 mg P $kg^{-1}$ treatment for 7 weeks on the mine tailings increased from 1.3 to 4.2 mg $pot^{-1}$ (i.e., 223.1%) for TSP application and from 1.3 to 5.6 g $pot^{-1}$ (i.e., 330.1%) for application of PYC from a 15:1 C:N ratio substrate (Fig. 5.6; Appendix Table 5.4). The dry weight of corn plants grown in the greenhouse indicated that the PYC and PL would serve as a good P source for correction of P deficiency in crops grown on the Vance subsoil and mine tailings.

Relationships between dry matter weights varied with rates of application of TSP, poultry litter, and PYC from different substrate C:N ratios for the two soils. At an equal rate of P application, greater increases in dry weights of corn occurred from PL treatments than from the

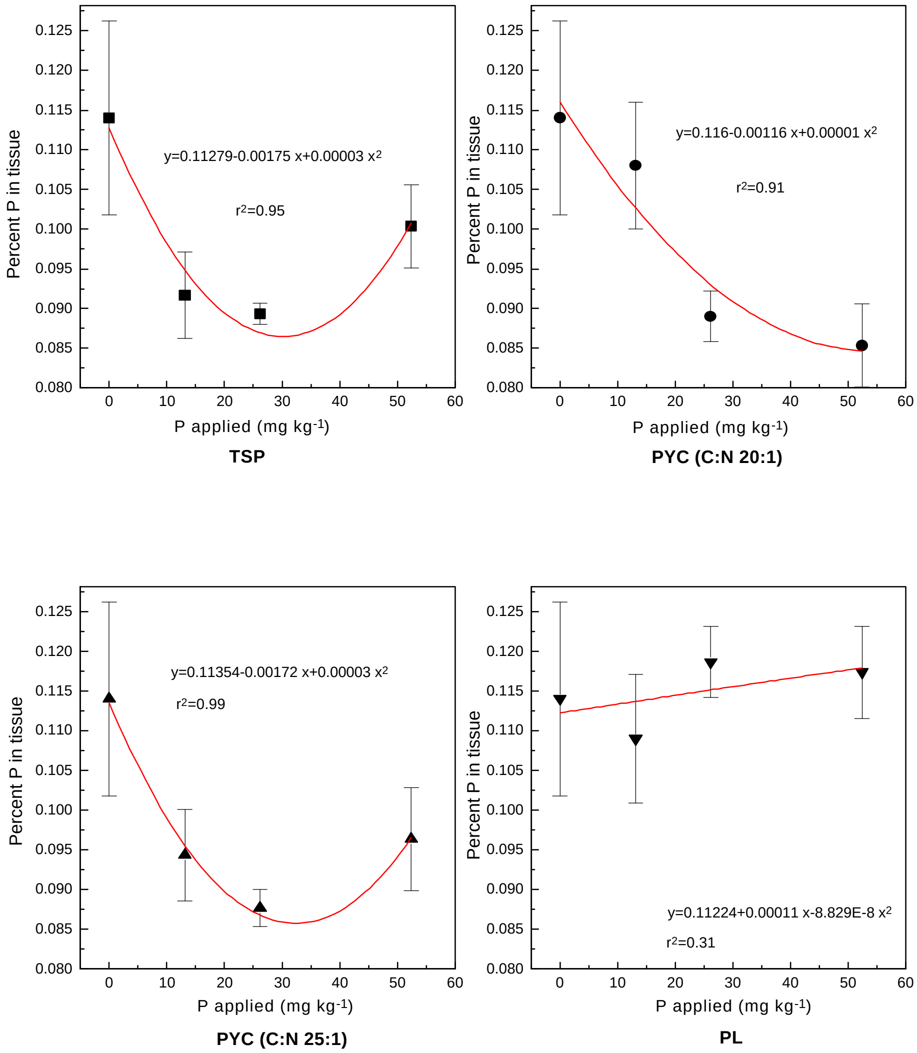


Fig. 5-7. Percent P in corn plant tissue as affected by rate of applied P as PYC, TSP, and PL on Vance subsoil.

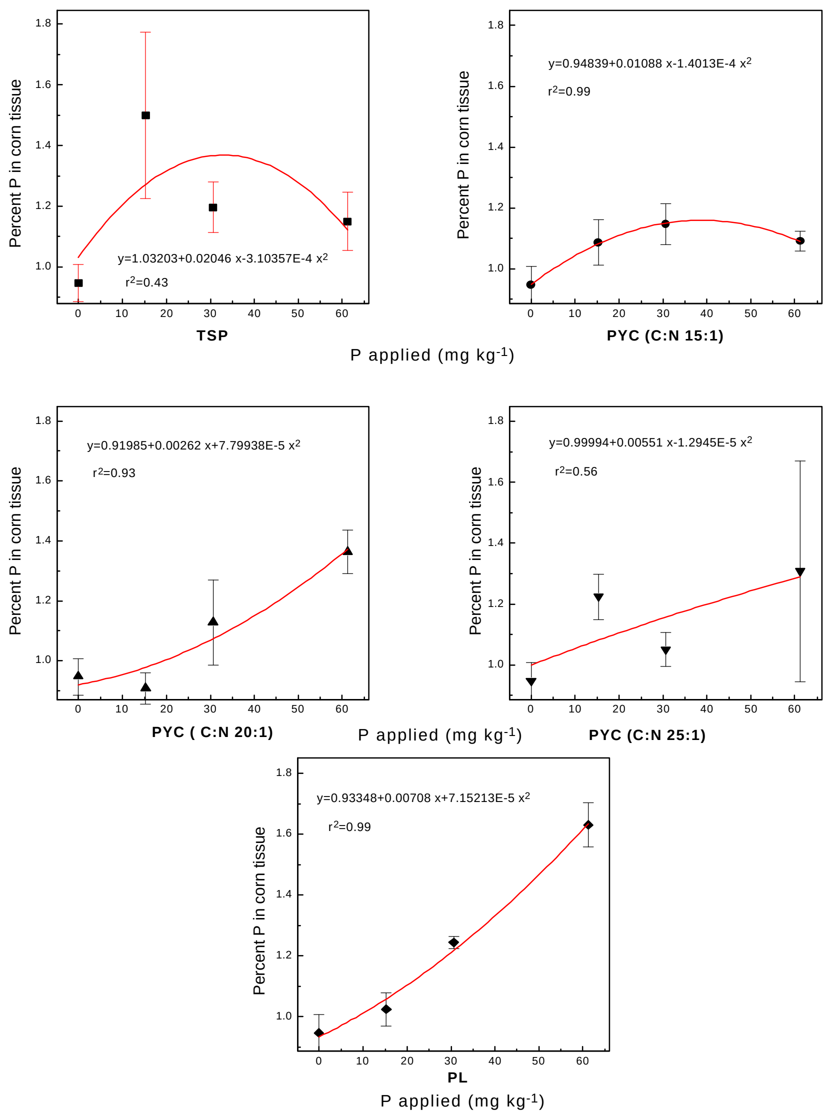


Fig. 5-8. Percent P in corn plant tissue as affected by rate of P as PYC, TSP, and PL on mine tailings.

inorganic P and PYC treatments on the Vance subsoil. Increases in dry weights were equivalent for inorganic P application and for PYC from 15:1, 20:1, and 25:1 C:N ratios of substrates on the soil (Fig. 5.5; Appendix Fig. 5, and Table 5.3). Dry weights of the corn plants were equivalent at equal rates of P application to the mine tailings, except the highest dry weight occurred on this soil with the highest rate of P application as PYC from the 15:1 C:N ratio substrate (Fig. 5.6; Appendix Fig. 6, and Table 5.4). It has been established that increases in dry weights with rate of PYC, PL, and inorganic P would vary with factors including rate of P mineralization from the applied PYC (Reddy et al., 1978), level of P from soil solution for soils under study, and amount of fixation of P from soil solution (Edwards and Daniels, 1992, Reddy et al., 1980a).

### 5-3.2 Phosphorus uptake by corn plants

#### *5-3.2.1 Greenhouse study 1 - Phosphorus uptake by corn plants*

Relationships between plant dry matter and P uptake by young corn plants are given for the Vance topsoil (Fig. 5.9; Appendix Table 5.1) and for the Starr mixed horizon Fig. 5.10; Appendix Table 5.2). A curvilinear correlation between dry matter yield and P uptake of $r^2$=0.99 was obtained on the Vance topsoil. A linear correlation between dry matter yield and P uptake of $r^2$=0.99 was obtained on the Starr mixed horizon soil for $Ca(H_2PO_4)_2.H_2O$, and PYC f rom the 15:1 C:N ratio and PYC substrate application, whereas a curvilinear relationship was obtained for PYC from the 20:1 and 25:1 C:N ratio substrates. These relationships indicate that, on the average, P uptake accounts for 99% of the variation in the dry matter weight on the Vance topsoil and on the Starr mixed horizon soil.

Based on the P uptake values, P availability increased with rate of inorganic P and compost application on the Vance topsoil. At an equal level of P application, there was higher P availability from application of the compost than from inorganic P application on Vance topsoil (Fig. 5.11; Appendix Table 5.1). Slow adsorption of mineralized P from the compost P would account for the higher P availability from the compost application than from the inorganic P

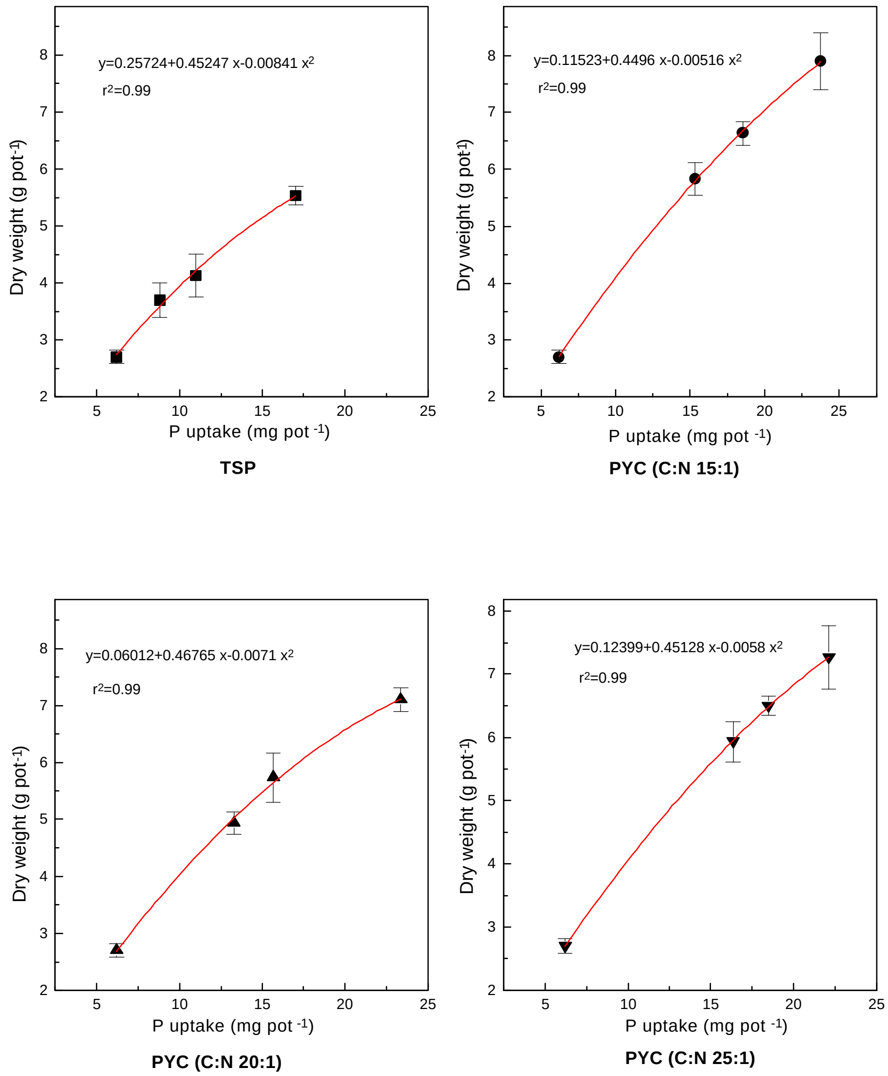


Fig. 5-9. Relationship between dry weight and P uptake by corn plant on the Vance topsoil.

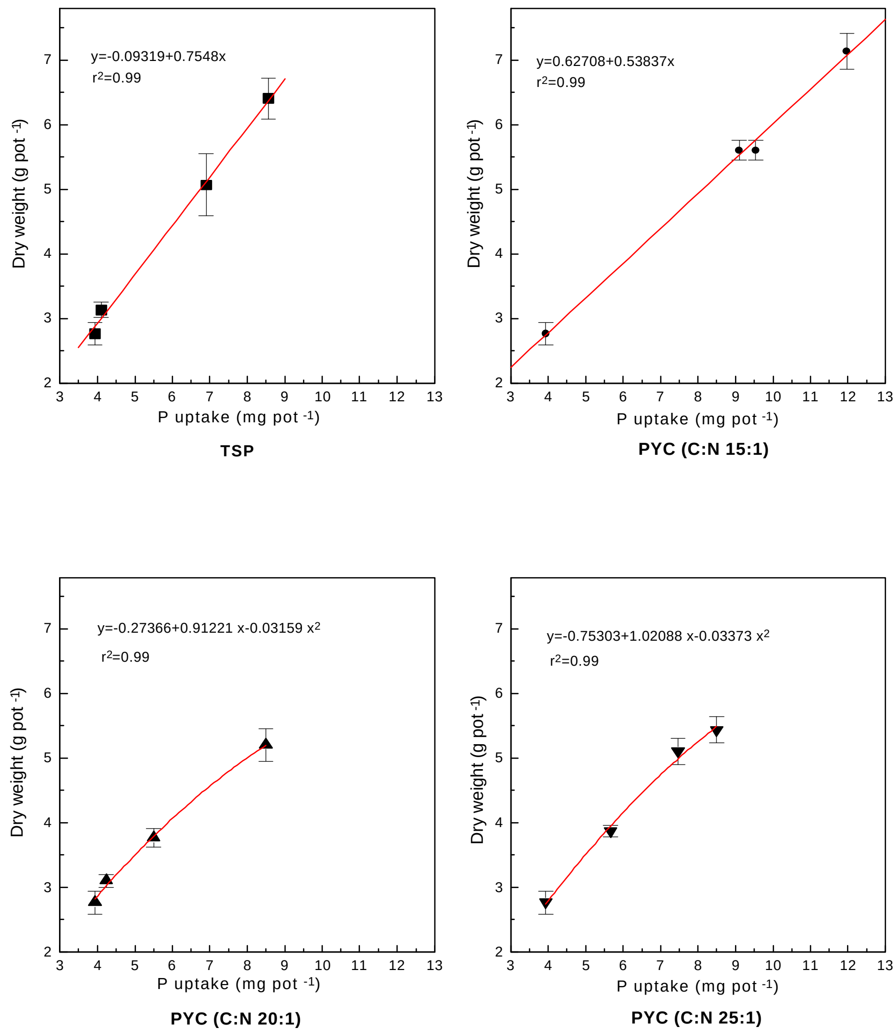


Fig. 5-10. Relationship between dry weight and P uptake by corn plant on the Starr soil.

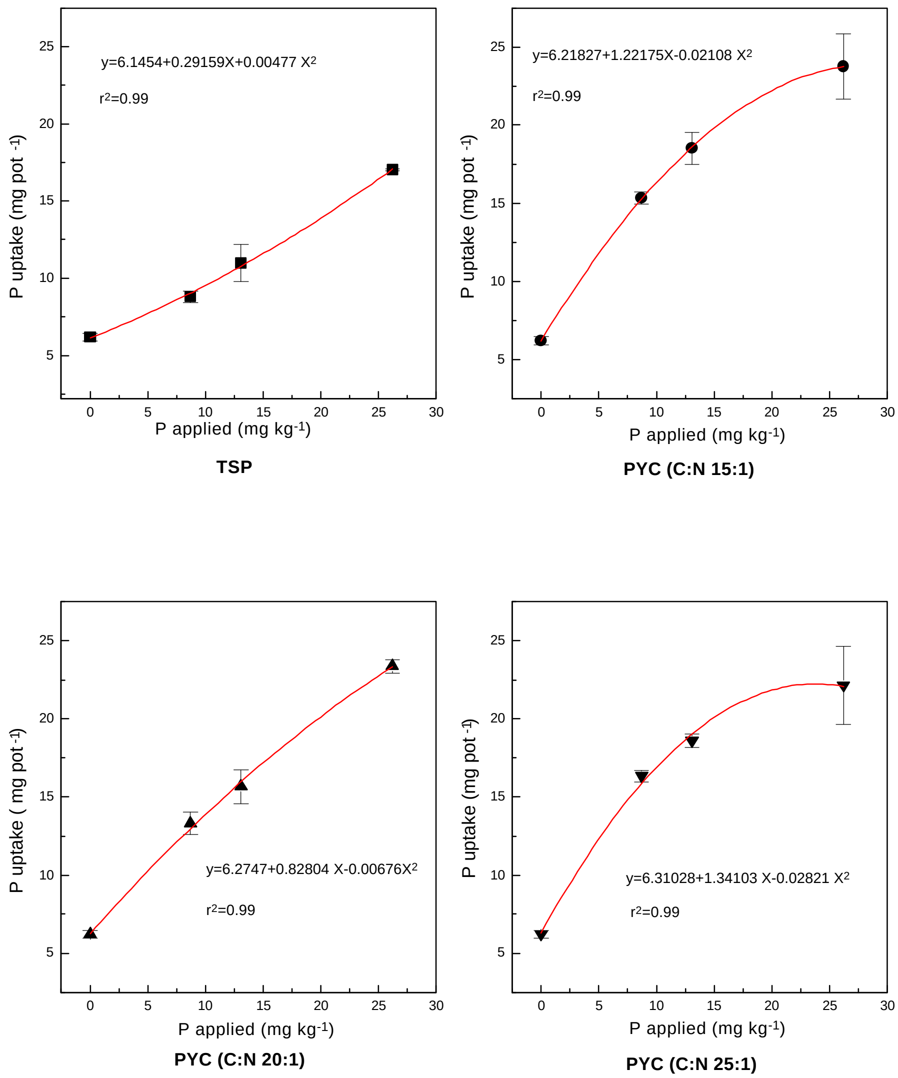


Fig. 5-11. Phosphorus uptake by corn plants as affected by rate of P applied as PYC and TSP on Vance topsoil.

application. These data indicate that the three composts mimic a slow release P fertilizer in the Vance topsoil, which has a relatively low P fixation capacity (Table 3.3).

Based on the P uptake values, P availability increased with rate of inorganic P and compost application on the Starr mixed horizon soil. At an equal level of P application, P availability was higher for application of compost from a 15:1 C:N ratio substrate than for application of compost from the substrates with 20:1 and 25:1 C:N ratios and for application of inorganic P for the Starr mixed horizon soil (Fig. 5.12; Appendix Table 5.2). A faster rate of P mineralization would account for the greater P uptake for compost from 15:1 C:N substrate ratio than for compost from the 20:1 and 25:1 C:N substrate ratios. Less P sorption by oxides of Al and Fe and layer silicates would account for the higher P availability from application of 15:1 C:N ratio substrate than from application of inorganic fertilizer.

***5-3.2.2 Greenhouse study 2 - Phosphorus uptake by corn plants***

Relationships between quantities of dry matter and P uptake by young corn plants are given for the Vance subsoil (Fig. 5.13; Appendix Table 5.3) and for the mine tailings (Fig. 5.14; Appendix Table 5.4). Dry matter yield and P uptake on the Vance subsoil correlated linearly ($r^2$=0.99) on the PYC (substrate 20:1 C:N ratio) and PL treatment, and curvilinearly ($r^2$=0.99) on the PYC (substrate 25:1 C:N ratio) and inorganic P treatments (Fig. 5.13). A linear correlation between dry matter yield and P uptake of $r^2$=0.98 was obtained on the mine tailings for PYC from the 25:1 C:N ratio substrate application, whereas curvilinear relationships ( $r^2$=0.94 to 0.99) were obtained for TSP, PL and PYC from the 15:1 and 20:1 C:N ratio substrates (Fig. 5.14). These relationships indicate that, on the average, P uptake accounted for 99 % of the variation in the dry matter weight on the Vance subsoil and for 94 to 99% of this variation on the mine tailings.

Based on the P uptake values P availability increased with rate of inorganic P, PL and compost application on the Vance subsoil. At an equal level of P application, P availability was higher for application of PL than for application of inorganic P or composts from substrates with

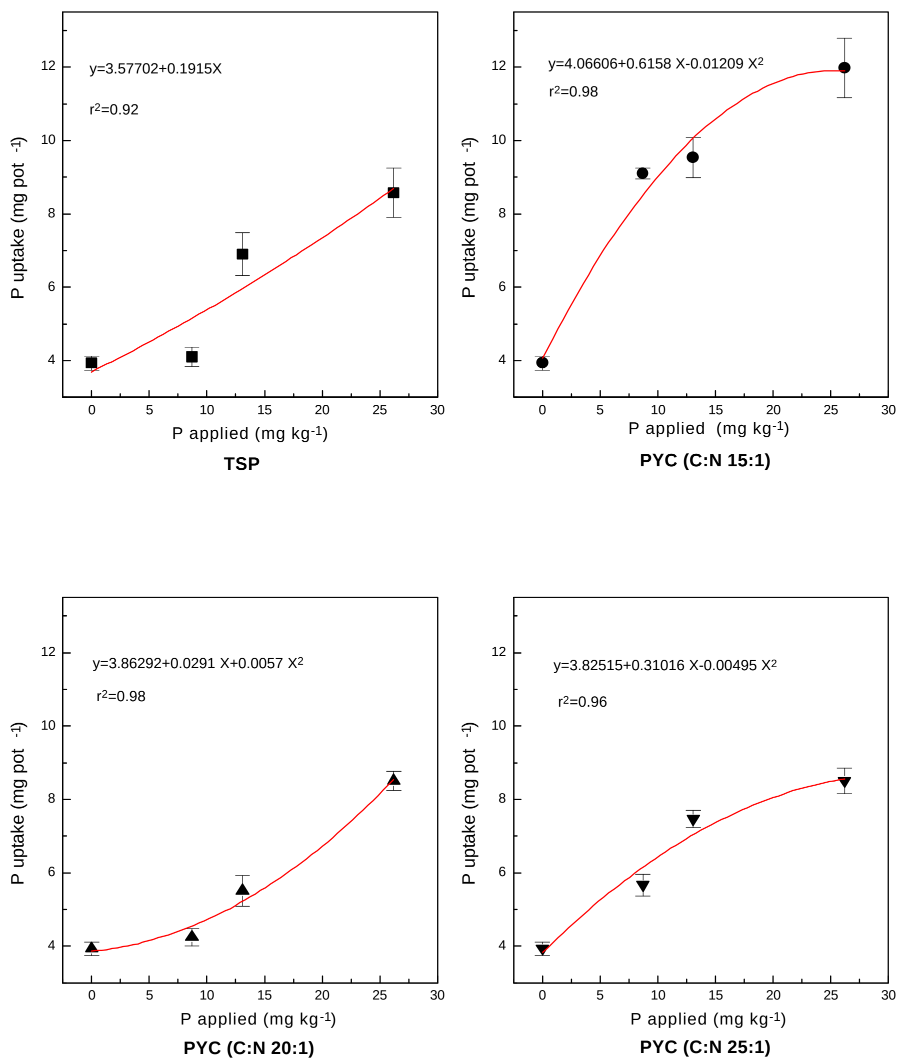


Fig. 5-12. Phosphorus uptake by corn plants as affected by rate of P as TSP and PYC on Starr soil.

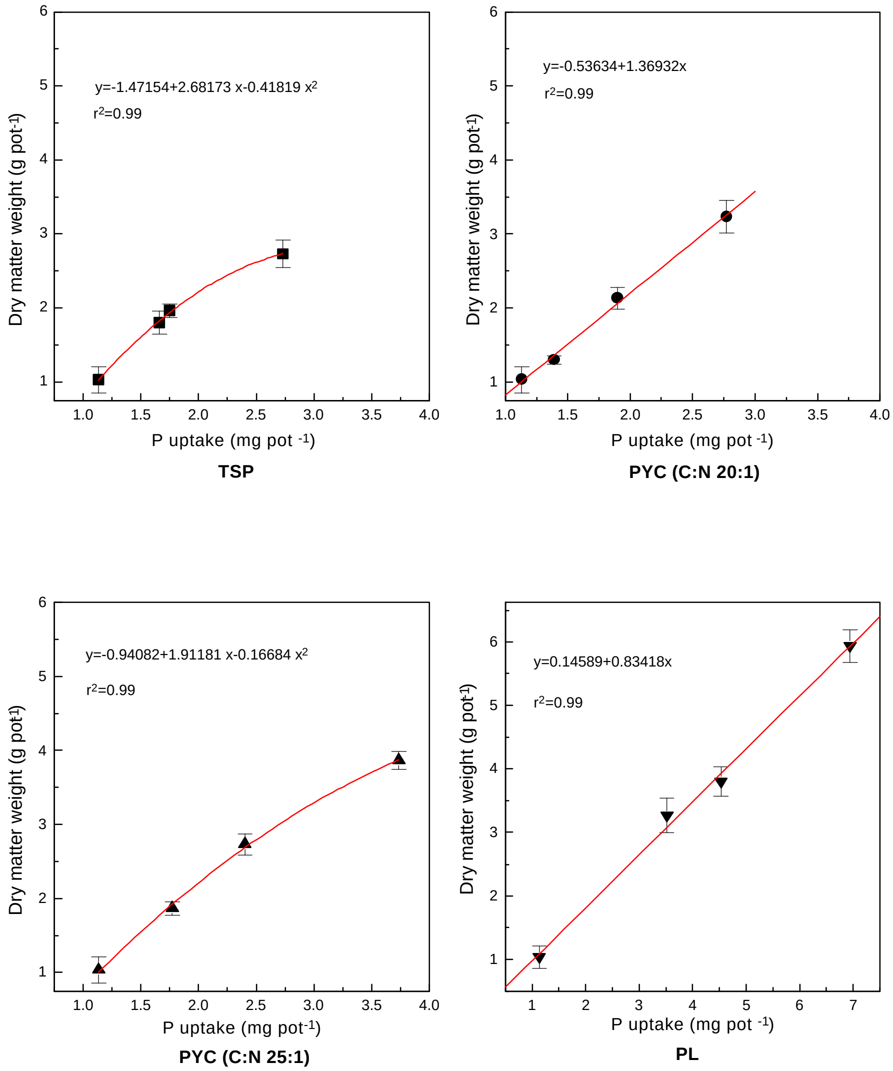


Fig. 5-13. Relationship between dry weight and P uptake by corn plant on the Vance subsoil.

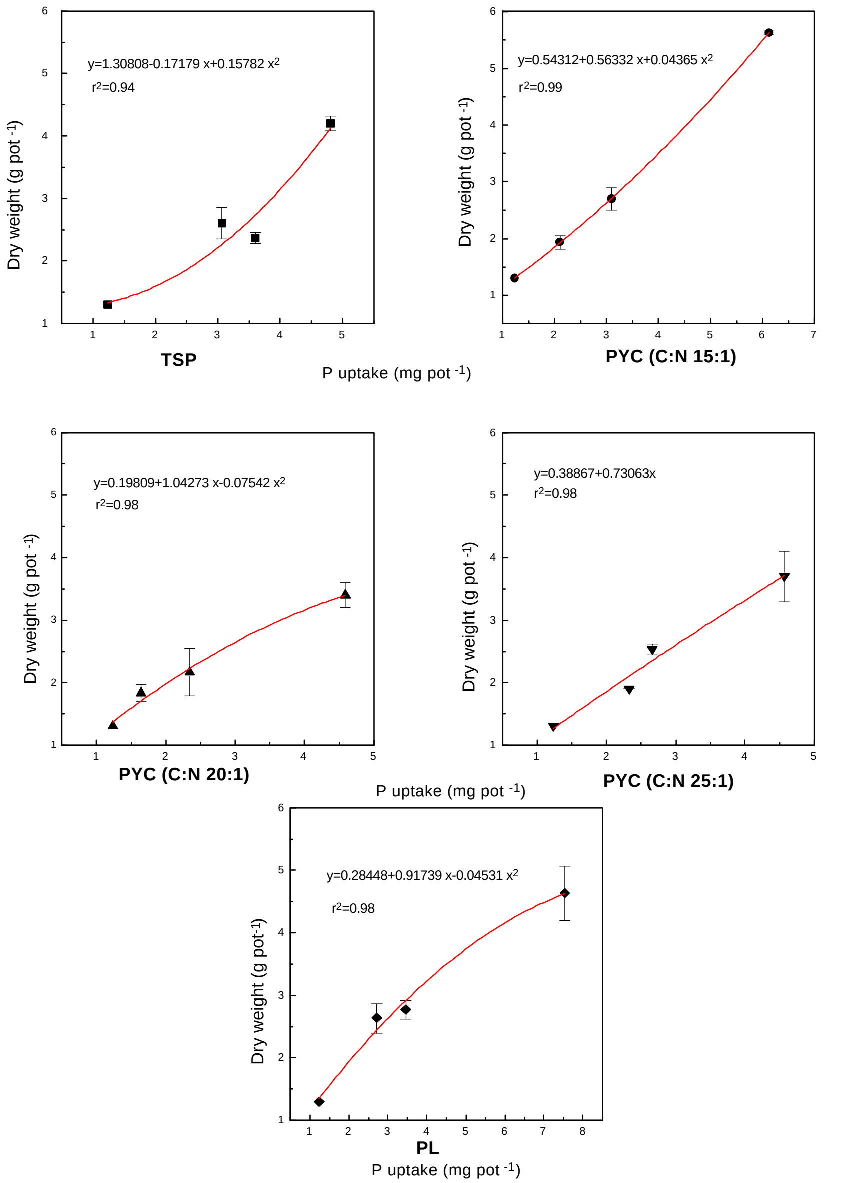


Fig. 5-14. Relationship between dry weight and P uptake by corn plant on the mine tailings.

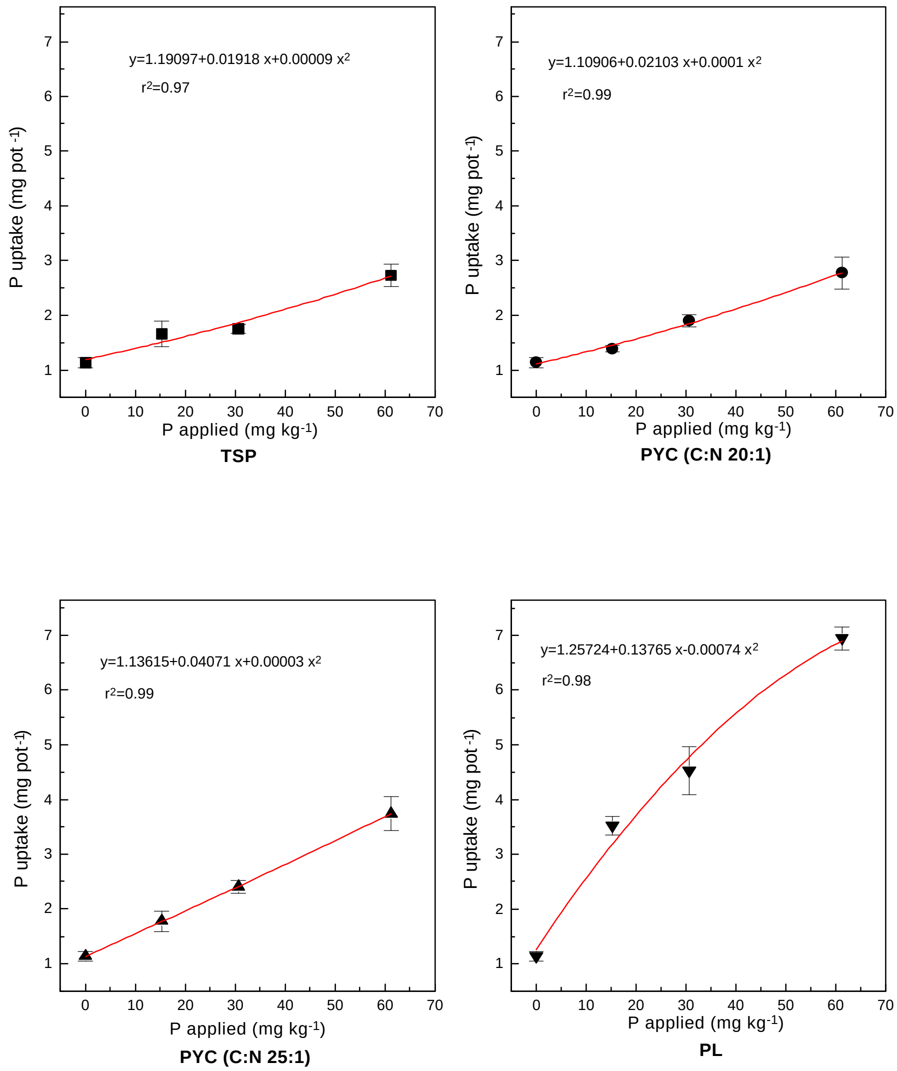


Fig. 5-15. Phosphorus uptake as affected by PYC, TSP, and PL application on Vance subsoil.

ineralization would account for the greater P uptake from PL than from composts with 15:1, 20:1, and 25:1 C:N substrate ratios. Less P sorption by oxides of Al and Fe and layer silicates would account for the higher P availability from application of PL than from application of inorganic P.

Based on the P uptake values, P availability increased with rate of inorganic P, PL, and compost application on the mine tailings. At 15.3 and 30.6 mg P $kg^{-1}$ levels P application, P availability was equivalent from application of PL, inorganic P, and composts with substrate C:N ratios of 15:1, 20:1 and 25:1 for the mine tailings (Fig. 5.16; Appendix Table 5.4). At the 61.2 mg P $kg^{-1}$ levels of P application, P availability was higher from PL than from composts with substrate C:N ratios of 15:1, 20:1, and 25:1. A faster rate of mineralization would explain the higher P availability from the PL than from the composts. Faster rates of mineralization could lead to faster P release than P uptake, which potentially without proper management could lead to P movement to ground and surface waters.

### 5-3.3 Nitrogen concentration and uptake by corn plant

Poultry litter and YW were mixed at three different initial C:N ratios for the compost used in this study. The mixture from the C:N ratio of 15:1 represented an abundant N mix as compared with mixtures from the C:N ratios of 20:1 and 25:1. Overall, the final C:N ratios (Table 5-3) of the three PYC decreased to 7.6, 10.5, and 13.8 from the substrate C:N ratios of 15:1, 20:1, and 25:1, respectively (i.e, 33.6, 34.4, and 35.6%, i.e, increments). The C:N ratio, N content, and pH measured during composting are known to influence volatile N losses (Kissel et al., 1992). The fate of C in compost depends on microbial activity, and loss as $CO_2$ occurs during microbial respiration (Edwards and Daniel, 1992).

Nitrogen concentrations in corn plants below 3.5% indicate inadequate N for normal growth (Voss, 1993). Corn plants contained less than 3.5% N on all treatments on the Vance topsoil (Fig. 5.17; Appendix Table 5.1), Starr mixed horizon soil (Fig. 5.18; Appendix Table 5.2),

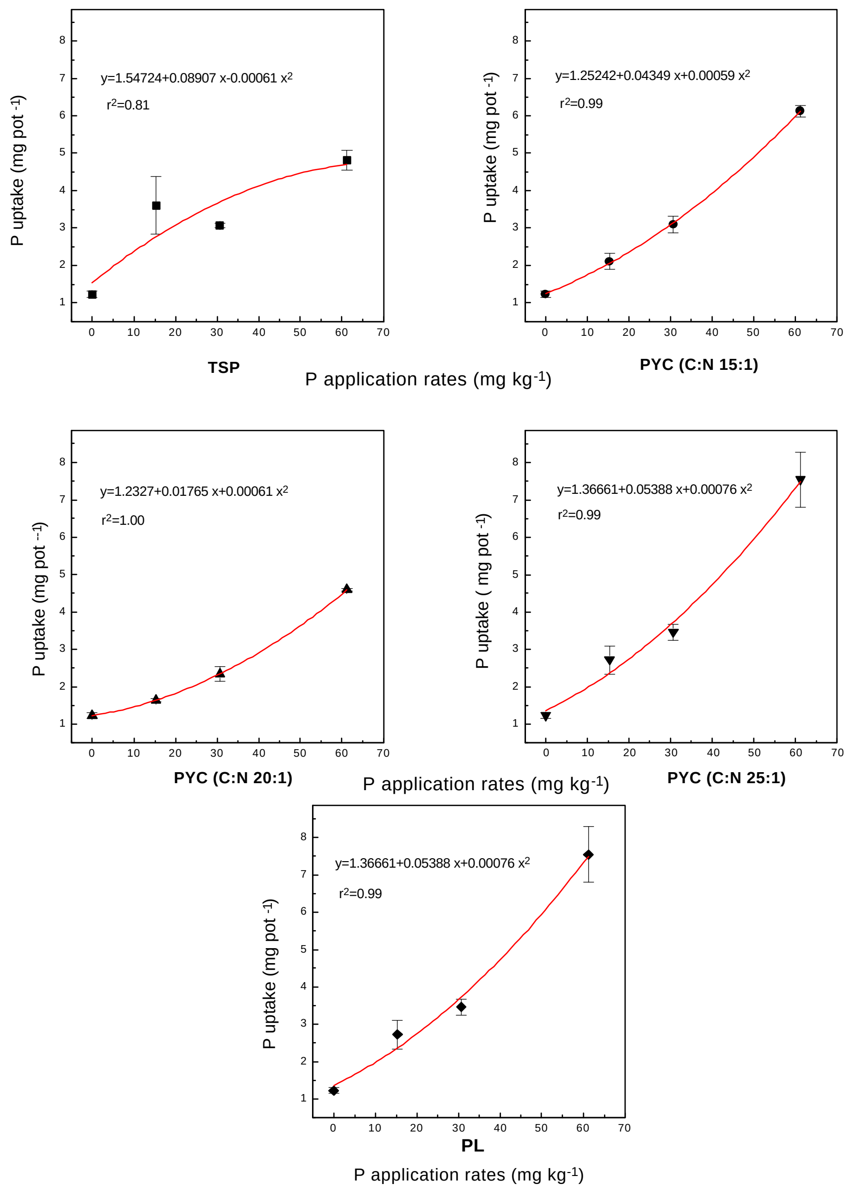


Fig. 5-16. Phosphorus uptake by corn plant as affected by PYC, TSP, and PL application on mine tailings.

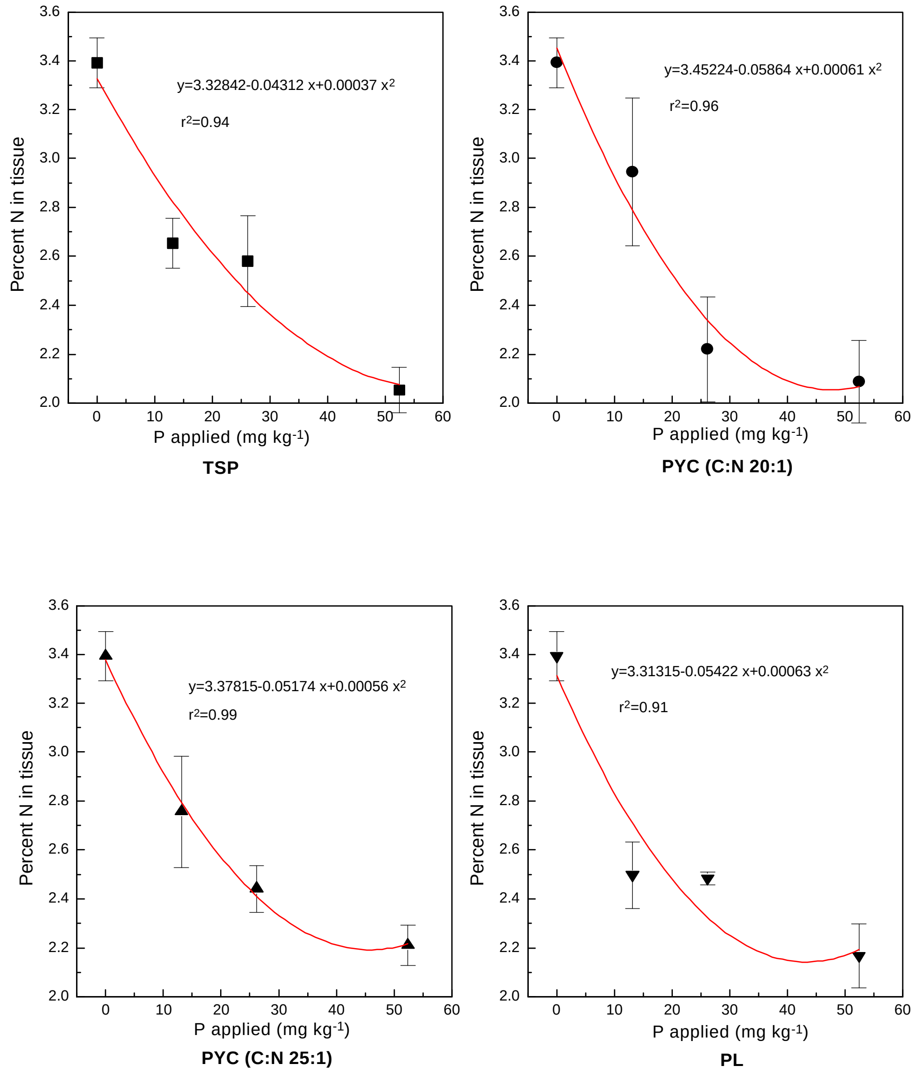


Fig. 5-17. Percent N in corn tissue as affected by rate of P applied as PYC, TSP, and PL on Vance subsoil.

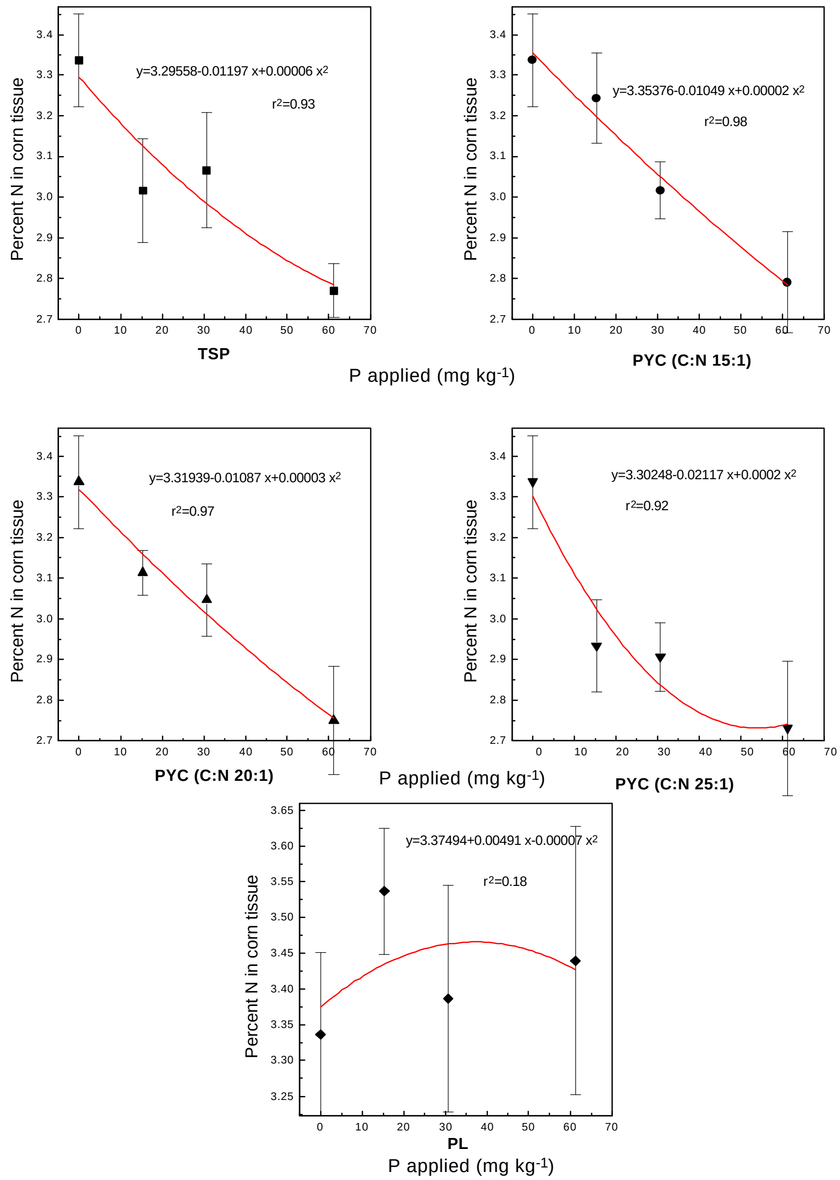


Fig. 5-18. Percent N in corn plant tissue as affected by rate of applied P as PYC, TSP, and PL on mine tailing soil.

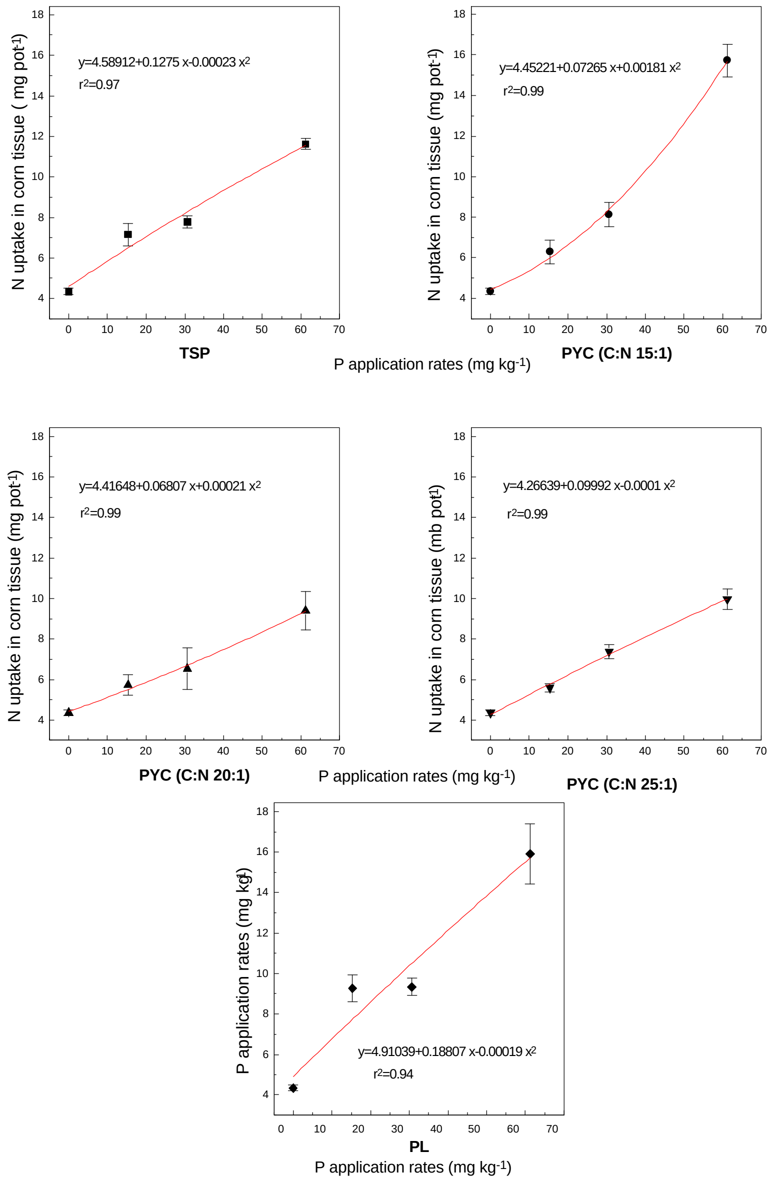


Fig. 5-19. Nitrogen uptake by corn plant as affected by PYC, TSP, and PL on mine tailings.

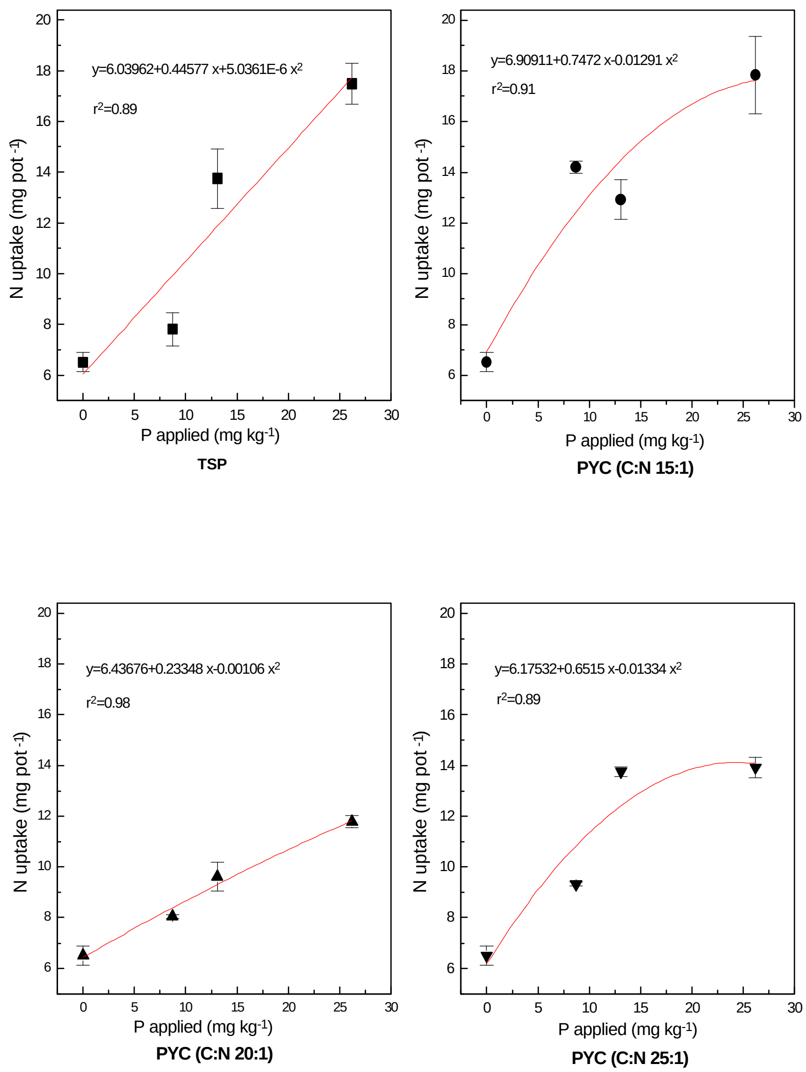


Fig. 5-20. Nitrogen uptake by corn plant as affected by the rate of applied P as PYC, and TSP on Starr soil.

ance subsoil (Fig. 5.19; Appendix Table 5.3), and mine tailings (Fig. 5.20; Appendix Table 5.7). 15.1, 20:1, and 25:1 C:N ratios on the Vance subsoil (Fig. 5.15; Appendix Table 5.3). Faster P These N concentration data indicate that over application of N did not occur during the greenhouse experiment and that higher rates of N application would have been appropriate.

Nitrogen concentrations in young corn plants were affected by rate of P application as PYC in comparison to TSP treatments on the Starr mixed horizon soil, (Fig. 5.18; Appendix Table 5.2), but not on the Vance topsoil (Fig. 5.17; Appendix Table 5.1), the Vance subsoil (Fig. 5.19; Appendix Table 5.3 ), and mine tailings (Fig. 5.20; Appendix Table 5.7). At equal rates of P application higher N concentration in young plants occurred on PL treatments, than on TSP treatments on only the mine tailings (Fig. 5.20; Appendix Table 5.7). Dilution effects from increased plant growth explain higher N concentration on the TSP treatments than on the PYC treatments on the Starr mixed horizon soil and also on PL treatments than on TSP treatments on the mine tailings. That is, as plant growth increases from correction of P deficiency plant N concentrations decreases. Furthermore, slow N mineralization at high levels of PYC application may have decreased the amount of N in soil solution that is available for plant uptake.

Poultry litter application, based on P concentration may result in N deficiency on some soils. The composition of this organic waste low in N may lead to slow mineralization and therefore to low N concentrations in plant tissue. Duggan (1976) reported that high organic matter caused N deficiency in plants. Composting converted waste to a humuslike material which supplied adequate N at a high rate of application, but not at low rates of application (Sims and Wolf, 1992).

High amount of plant accumulation of N was expected on mine tailings and Vance subsoil due to the high amount of $NH_4NO_3$ applied during the experiment. Nitrogen uptake was increased ($P<0.05$) by TSP and PYC application over the control treatment. The corn N uptake closely followed the trend of dry matter yield, where N uptake increased with increased P application for all treatments. Among the treatments, high rates of PYC application did not increase N uptake beyond 10 mg $pot^{-1}$, except for Vance subsoil where N uptake ranged between

5.6 and 15.7 mg $pot^{-1}$.

The N uptake on the mine tailings and on the Starr soil follow a similar pattern, i.e., N uptake increased dramatically with level of P applied as TSP and as PYC from C:N of 15:1 and slightly with level of P applied as PYC FROM C:N substrate ratios of 20:1 and 25:1 (Fig. 5.19, 5.20). Since PYC from 20:1 and 25:1 C:N ratio substrates contained a larger amount of yard waste than PYC from the 15:1 C:N ratio substrate, it was expected that part of the N in 15:1 ratio, which was greater relative to the two others, would quickly be mineralized to increase the N availability for corn plant. Furthermore, during corn growth remineralization of immobilized N in PYC from the 20:1 and 25:1 C:N ratio substrates may have occurred to provide adequate N in soil.

Nitrogen uptake was much higher with PYC application on Vance topsoil than on Vance subsoil, and little variation in N uptake was observed among treatments on the Vance topsoil (Fig. 5.21 and 5.22). The high N uptake in the PL treatment as compared with TSP for the Vance subsoil may have resulted from a more continuous release of N through mineralization. Differences observed among Vance topsoil and subsoil can be attributed to the initial soil properties of those soils (Table 5.1). Vance topsoil contains more organic matter, which supplies N, and a higher available P content than the Vance subsoil.

### 5-5.4 Zinc and Cu concentration in the corn plant tissue

Small amounts of Cu, Zn, and other trace elements are often added to poultry feed to supply nutritional needs, to prevent diseases, and to increase the rate of gain and egg production (Tuffit and Nockels, 1991). Application of poultry waste can provide adequate levels of trace elements such as Cu and Zn, which are required for crop production. However, there is concern that long-term application of poultry waste may lead to Cu toxicity in crop plants. High application rates of poultry waste to increase P availability in soil could result in induced Zn deficiency in soils with a low level of Zn (Sims and Wolf, 1992). Conversely, high rates of animal manure can be used to correct Zn deficiencies (Payne et al., 1988a).

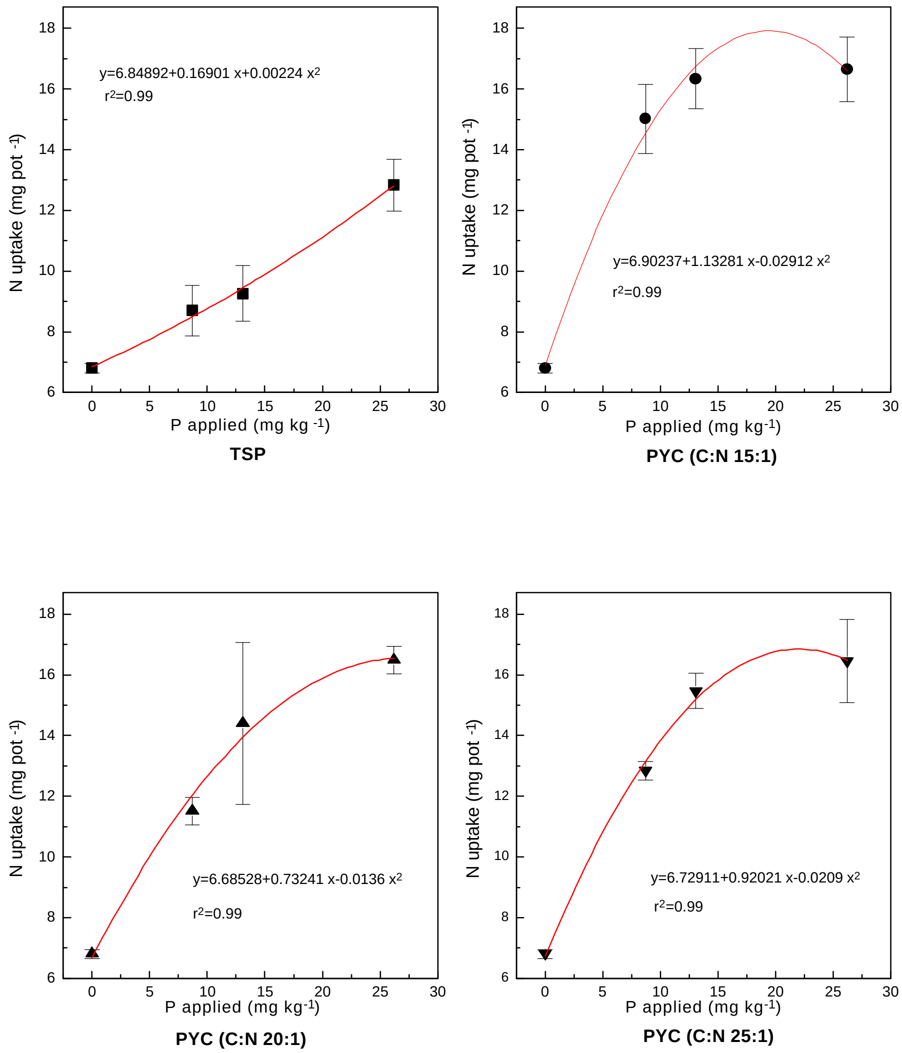


Fig. 5-21. Nitrogen uptake by corn as affected by the rate of applied P as PYC and TSP on Vance topsoil.

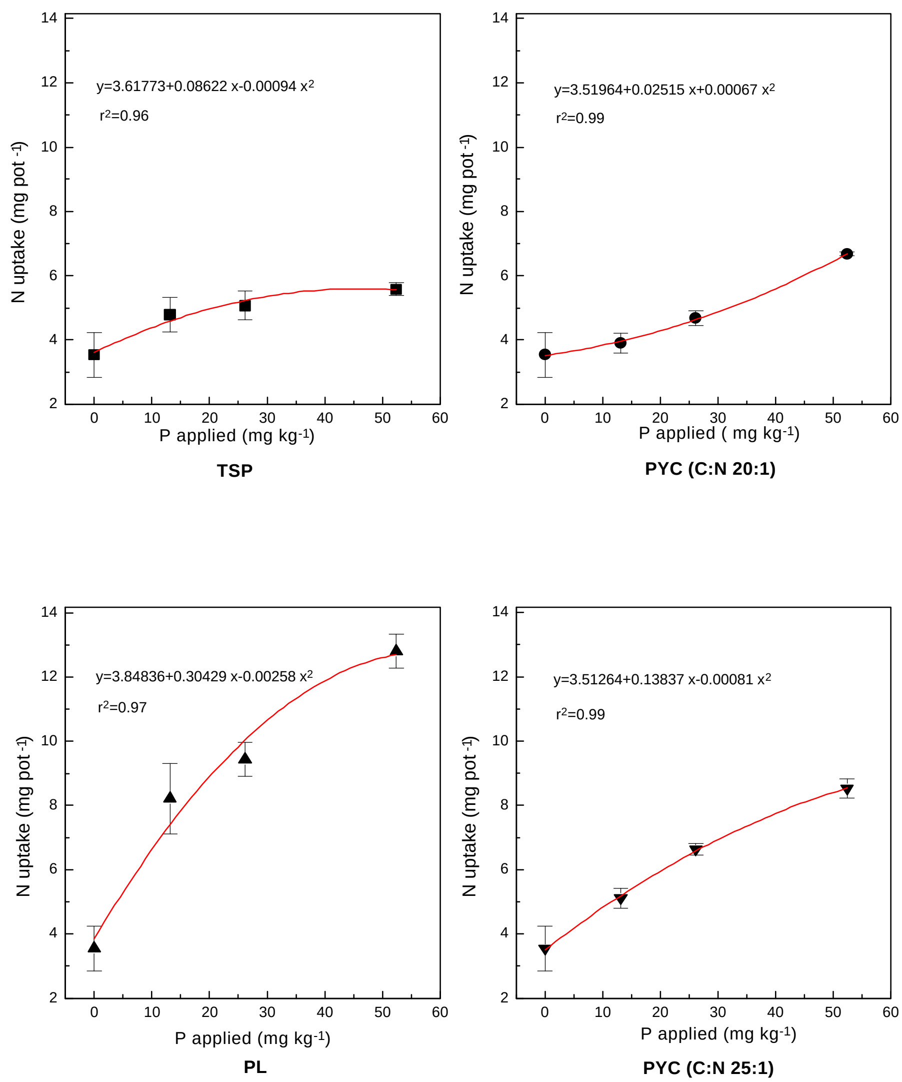


Fig. 5-22. Nitrogen uptake by corn plant as affected by the rate of P applied as PYC, TSP, and PL on Vance subsoil.

The concentrations of Zn and Cu in the corn plants for each treatment on the soils under study are given in the Appendix (Tables 5.5, 5.6 and 5.7). The statistical analysis revealed no differences ($P>0.05$) for Cu concentrations among treatments for all the soils. Slight differences among treatments were observed for Zn concentrations only the Vance soils. The highest Zn concentration for all soils were 152 to 225 mg $kg^{-1}$ on the Starr mixed horizon soil. Copper levels in young plant were within the normal range of 7 to 20 mg $kg^{-1}$ for all treatments on the soils and below the normal range for the control treatments. Zinc levels were within the normal range of 20 to 50 mg $kg^{-1}$ for all treatments on the soils except the Starr mixed horizon soil. Overall, the PL and PYC application did not increase Cu and Zn availability to inordinately high levels in the soils.

**5-3.6 Soil pH**

The application of either PYC or PL caused an increase in pH of 0.13 to 0.25 and 0.30 to 1.14 pH units on Vance subsoil and mine tailings, respectively (Table 5.4). There were treatment effects on soil pH ($P<0.05$) for all of the soils used in this study, although they had received dolomitic limestone application. Possibly there was slow neutralization of soil acidity by the applied limestone during the short plant growth period. These results are in contrast to the findings of Jackson et al. (1977), who showed that there was no change in pH with the application of PL at the rate of 22.4 Mg $ha^{-1}$. Jackson et al. (1977) found that the application of an organic waste on acid soils decreased the potential for Cu, Mn, and Zn phytotoxicity. Hue (1992) demonstrated that chicken manure could increase the pH as much as $CaOH_2$ on some acidic soils. Therefore, repeated application of either PL or PYC might increase the pH and, thereby decrease the availability of nutrients such as B, Cu, Mn, P and Zn (Jackson, 1977).

**Table 5-4. Measurement of soil pH on Vance subsoil and Mine tailings after corn harvesting.**

| Vance subsoil | | | Mine tailings | | |
|---|---|---|---|---|---|
| Treatment | P rate (mg $kg^{-1}$) | pH | Treatment | P rate (mg $kg^{-1}$) | pH |
| Control | 0 | 5.27 | Control | 0 | 4.81 |
| **Inorganic fertilizer ($Ca(H_2PO_4)_2.H_2O$** | | | | | |
| | 13.1 | 5.26 | | 15.3 | 5.78 |
| | 26.2 | 5.41 | | 30.6 | 5.76 |
| | 52.4 | 5.52 | | 61.2 | 5.62 |
| | 78.4 | 5.44 | | 91.8 | 5.11 |
| **Organic amendment (Poultry litter-yard waste compost)** | | | | | |
| C:N (15:1) | 52.4 | 5.49 | C:N (15:1) | 15.3 | 5.35 |
| | | -- | C:N (15:1) | 30.6 | 5.48 |
| | | -- | C:N (15:1) | 61.2 | 5.35 |
| C:N (20:1) | 13.2 | 5.43 | C:N (20:1) | 15.3 | 5.57 |
| C:N (20:1) | 26.2 | 5.43 | C:N (20:1) | 30.6 | 5.72 |
| C:N (20:1) | 52.4 | 5.45 | C:N (20:1) | 61.2 | 5.95 |
| C:N (25:1) | 13.1 | 5.42 | C:N (25:1) | 15.3 | 5.51 |
| C:N (25:1) | 26.2 | 5.48 | C:N (25:1) | 30.6 | 5.62 |
| C:N (25:1) | 52.4 | 5.40 | C:N (25:1) | 61.2 | 5.73 |
| Poultry litter | 13.2 | 5.48 | Poultry litter | 15.3 | 5.53 |
| Poultry litter | 26.2 | 5.52 | Poultry litter | 30.6 | 5.23 |
| Poultry litter | 52.4 | 5.60 | Poultry litter | 61.2 | 5.66 |

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