ACCUMULATION OF PHOSPHORUS IN AN ORGANIC FARMING SYSTEM FOLLOWING SEVEN YEARS OF ORGANIC AMENDMENT AND CONSERVATION PRACTICES

SAID HAMIDO* and K. KPOMBLEKOU-A.

Department of Agricultural and Environmental Sciences

College of Agricultural, Environmental and Natural Sciences

Tuskegee University, Tuskegee, Alabama 36088

ABSTRACT

Application of animal waste to agricultural soil has resulted in accumulation of phosphorus (P) in topsoil with potential export of the soluble P into surface waters. We investigated accumulation of P in an organic farming system at the George Washington Carver Agricultural Experiment Station at Tuskegee University. The experimental design was a randomized-complete-block design with four replications and four treatments. Each year late in fall, crimson clover inoculated with *Rhizobium* was planted (34 kg ha^{-1}) with the exception of the control. In spring, the cover crop was cut and left in the field and commercial NPK fertilizers (NPK-treatment) were applied as triple super phosphate (180 kg P_2O_5 ha^{-1}), potassium chloride (120 kg K_2O ha^{-1}), and urea (110 kg N ha^{-1}). Broiler litter (broiler litter-treatment) was applied (4.6 Mg ha^{-1}). The crimson clover alone did not receive any fertilizer. Sweet potato slits were transplanted and grown for 120 days. Each year after harvest, soil samples were collected at 0-15 cm depth. The samples were air-dried, sieved to pass through a <2-mm mesh sieve. Total P was determined by the perchloric acid method and water-soluble P, Bray P-1, Mehlich, and Olsen-P were extracted from the samples. Results showed that application of NPK or broiler litter did not affect water-soluble P concentration in the treatments between 2002 and 2007 (54.4 mg P kg^{-1} on average). However, the Bray P-1 extracted increased significantly (P < 0.05) in the NPK and broiler litter plots as compared with the control weed plot or the crimson clover plot alone. In the NPK plots, Bray P-1 increased from ≈ 57 mg P kg^{-1} in 2002 to 99.4 mg P kg^{-1} in 2007. No significant (P < 0.05) build-up P was observed in the broiler litter plot between 2002 (47.8 mg P kg^{-1}) and 2007 (70.9 mg P kg^{-1}).

BACKGROUND

Application of broiler litter on cropland has long been practiced as a disposal method. Broiler production is the top farm commodity in many states in the Southeastern region of the United States. The quantity of broiler litter produced as a by-product of the broiler industry is substantial. Poultry producers must periodically clean poultry houses to promote bird health and limit build up of wet manure. After eight to ten flocks poultry houses are cleaned to ground level. The broiler litter removed from broiler houses are a combination of chicken manure, bedding materials (wood shavings, pine needles, or peanut hulls), and spilled feed. The litter removed is directly applied to croplands, stored for later application to soil, or composted. About 30-50% of total nitrogen (N) in broiler litter is plant available in the first year compared with the 10% in the composted litter (Tyson 1994). Broiler litter improves soil aeration, soil structure, water infiltration rate, water-holding capacity, and reduces soil erosion and compaction. Broiler litter also improves soil biological activity and increases productivity. It supplies important macronutrients such as nitrogen (N), phosphorous (P), potassium (K), sodium (Na), calcium (Ca), magnesium (Mg), and sulfur (S); and micronutrients boron (B), copper (Cu), and manganese (Mn). About 90% of broiler litter produced ends up in agricultural farmland and serves as a cheap source of fertilizer. Little attention has been given to phosphorus (P) application rates of broiler litter because application of animal waste on farmland is usually regulated according to N requirements of crops. In areas where broiler litter is produced in large quantities, applications are considerably in excess of crop requirements, resulting in greater accumulation of P in the soil. Perkins et al. (1964) showed that accumulation of P in soil increases with increasing broiler litter application rates. Long-term applications of pig and poultry manures increased nitrogen (N) and P levels in the top 50 cm of soil by four and five times, respectively (Daniel et al., 1993). Land spreading of cattle slurry also was reported to increase NPK levels in the 0-15 cm depth by Canadian workers (Culley et al., 1993). Recent surveys revealed that 270,000 ha of sandy soils in the middle, eastern and southern parts of the Netherlands are saturated with P resulting from an excessive application of livestock wastes (Uunk, 1991). These accumulations of P are raising environmental concerns because they often promote eutrophication of surface waters. One of the major concerns associated with broiler litter application is the buildup of P in soils and the impact that P would have on water quality if it reached surface waters causing contamination that leads to eutrophication.

MATERIALS AND METHODS

Site Description and Field Layout

The site investigated is located at the George Washington Carver Agricultural Experimental Station located at Tuskegee, Alabama (32° 25.96' N, 85° 42.84'W). The soil at the experimental site is a Marvyn sandy loam (fine, siliceous, thermic, typic Paleudult) with less than 5% slope. To homogenize the soil in the experimental field, Crimson clover was planted in December 2001, harvested and incorporated into soil in all plots including the control plots in May 2002. Prior to establishment of the experimental plots of 20' x 12' (6.1 m x 3.6 m), twelve soil core samples were taken randomly at 0-15 cm depth. The soil samples were mixed together, homogenized, air-dried and ground to pass through a 20–mesh sieve. A sub-sample of the 20-mesh sieved sample was analyzed (CEC, 4.64 cmol kg^{-1}; pH, 5.40; extractable P, 8.00 mg kg^{-1}; extractable K, 23.1 mg kg^{-1}; sand 76.23%; clay, 5.00%; silt, 18.8%).

The experimental design includes factorial arrangement in a randomized-complete-block examining four soil amendments on main plots (control, no cover crop; crimson clover alone, crimson clover + broiler litter; crimson clover + NPK) plots (Fig. 1). Each main plot of 54' x 20' (16.5 m x 6.1 m) was split into three equal subplots of 20' x 12' (6.1 m x 3.6 m) to examine the effect of the treatments on three sweetpotato cultivars. The spaces between two adjacent blocks were 50' (15.2 m) or 40' (12.2 m). Each block has an area of 54' x 170'(16.5 m x 51.8 m) with 50' (15.2 m) spacing between them. The main plots within a block were separated by 30' (9.1 m) from each other. Each main plot was replicated four times to give four blocks containing 48 experimental units (Fig. 1).

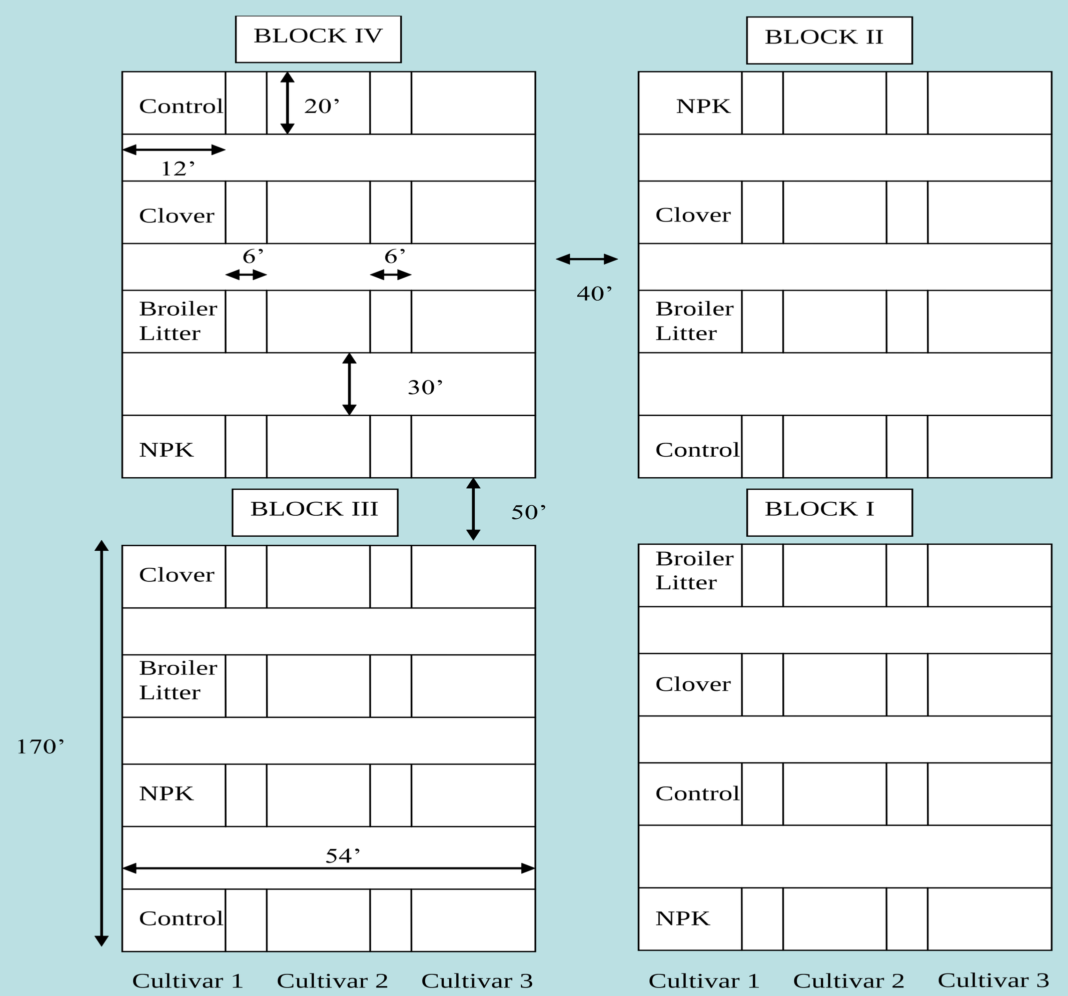

Fig. 1. Experimental field layout

The experimental results showed that tillage systems have a profound effect on

Phosphorus Analyses

A soil of each experimental unit was sampled (0-15 cm) in 2002, 2003, and 2007 to analyze for total and extractable P. The soil was air-dried and a subsample was ground to pass through a 100-mesh sieve for determination of total P after $HClO_4$ digestion as described by Olsen and Sommers (1982). Another portion was ground to pass through a 2-mm sieve for Water-soluble P, Bray-1 P (Bray and Kurtz, 1945), Mehlich-P (Nelson and Mehlich, 1953), and sodium bicarbonate-soluble P (Olsen et al., 1954). Phosphorus concentration in the digest and the various extraction methods was determined by the heteropoly blue colorimetric method described by Murphy and Riley (1962) after neutralization with 5 *M* NaOH or H_2SO_4 using *p*-nitrophenol as indicator.

RESULTS AND DISCUSSION

With no exception, total P accumulated under all treatments. The total P (Fig. 2) was less than 600 mg kg^{-1} in the control weed treatment in 2002 and did not change must at the end of 2007. In contrast, by the end of 2007, the total P was greater than 1000 mg kg^{-1} in the broiler litter treatment following seven years of broiler litter applications. Thus, repeated applications of broiler litter in an organic farming system that includes crimson clover as cover crop has the potential to increase total P. In the NPK treatment, an increased in total P was also observed. However, P in triple super phosphate contains 80-90% of plant available P that will be used by growing crops. Statistically, there was no significant differences (P<0.05) between total P in the NPK and broiler litter plots at the end of 2007;

In general, the water soluble-P (Fig. 3) was very low (<4 mg P kg^{-1}) in the soils. The crimson clover alone system was relatively high in 2002 but decreased over the years due to crop removal. In the NPK treatment, the water soluble-P increased from 0.75 mg in 2002 to 2.30 mg P mg kg^{-1} in 2007; the differences observed were not, however, statistically significant. The broiler litter treatment on the other hand was less than 1 mg P kg^{-1} in 2007; The Bray 1-P (Fig. 4) substantially increased in the NPK treatment and reached 100 mg P kg^{-1} in 2007. The build-up of Bray 1-P in the soil is of a major concern because it can move through the profile soil is of a major concern because it can move through the profile or to surface waters to cause eutrophication. In the broiler litter treatment, the Bray P increased from 2002 to 2003 but decreased in 2007 due to heavy crop removal (observed sweet potato yields were always better under the broiler litter treatment);

The Mehlich P (Fig. 5) accumulated in the NPK and broiler litter treatment plots; the increase was greater in the NPK plots than the broiler litter plot. However, this increase was not statistically different (P<0.05). Because plants fed with broiler litter grew more vigorously, they were able to remove more P than plants fed with NPK. In the weed control plot, Mehlich P decreased slightly indicating that years of cropping have removed most of the available P and significantly reduced crop yield (data not shown). In crimson clover alone plot, Mehlich P also decreased in 2007 to 3 mg P kg^{-1};

Olsen P (Fig. 6) build-up was observed in the crimson clover alone and NPK treatments. The Olsen P level the NPK plot has more than double between 2002 and 2007. Although there was an increase in Olsen P in 2003 as compare with 2002, the level dropped slightly in 2007 in the broiler litter treatment plot;

Although we observed significant P build-up in the NPK and broiler litter treatment plots, the levels of extractable P was slower in the broiler litter plot than in the NPK plot. This could be attributed to heavy P removal by sweet potato that developed more fibrous roots that grew deep into the soil to scavenge the available P.

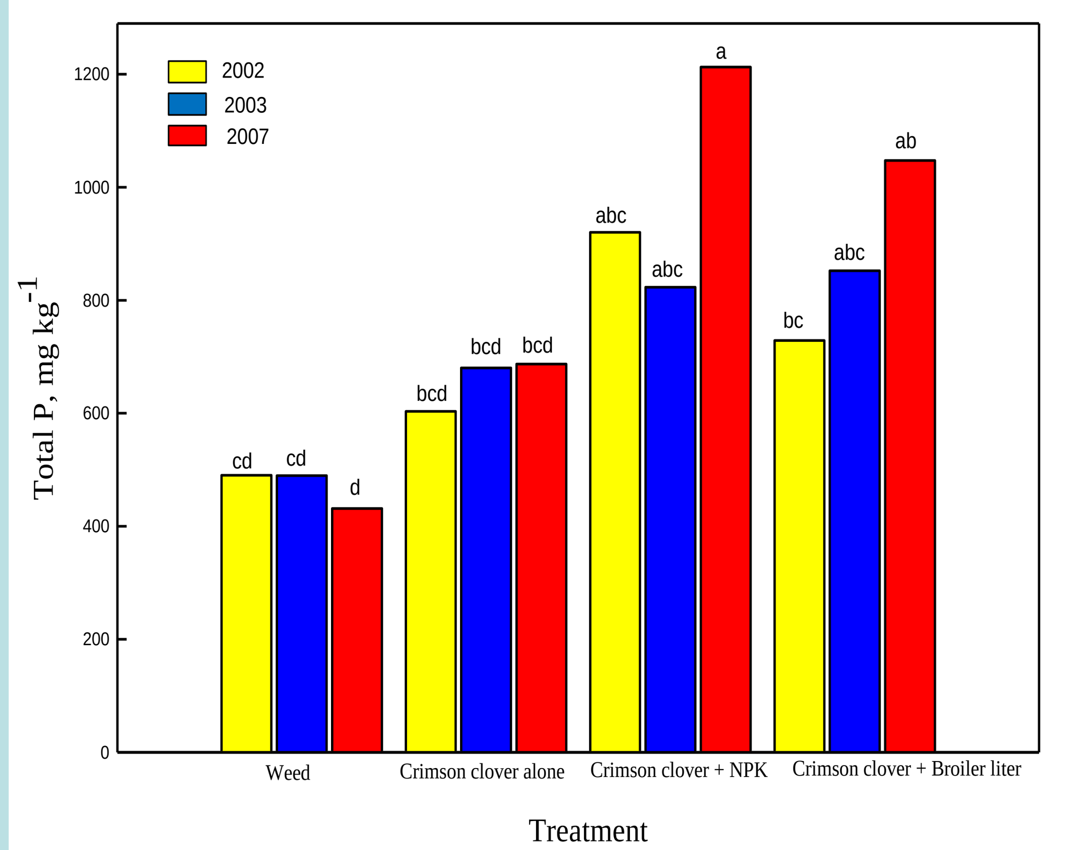

Fig. 2. Accumulation of total P in topsoil following applications of broiler litter or NPK in an organic farming system.

Different letters within a given year represent significantdifferences in means according to Tukey's honestly significant difference (α = 0.05).

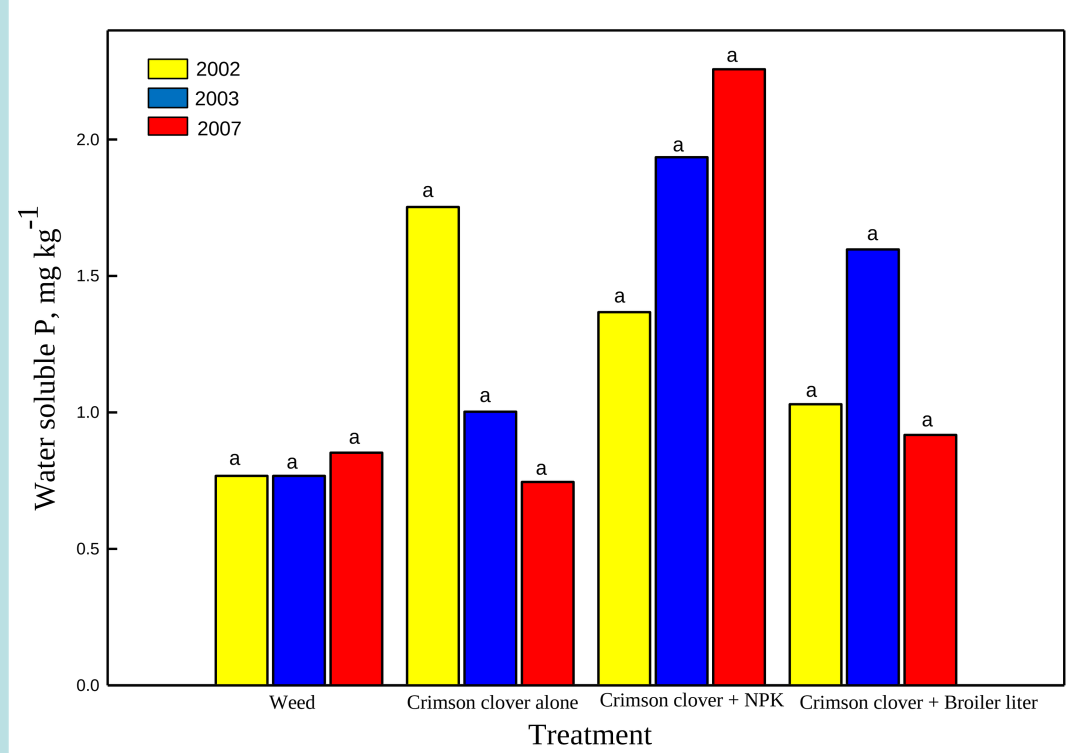

Fig. 3. Accumulation of water soluble P in topsoil following applications of broiler litter or NPK in an organic farming system.

Different letters within a given year represent significant differences in means according to Tukey's honestly significant difference (α = 0.05).

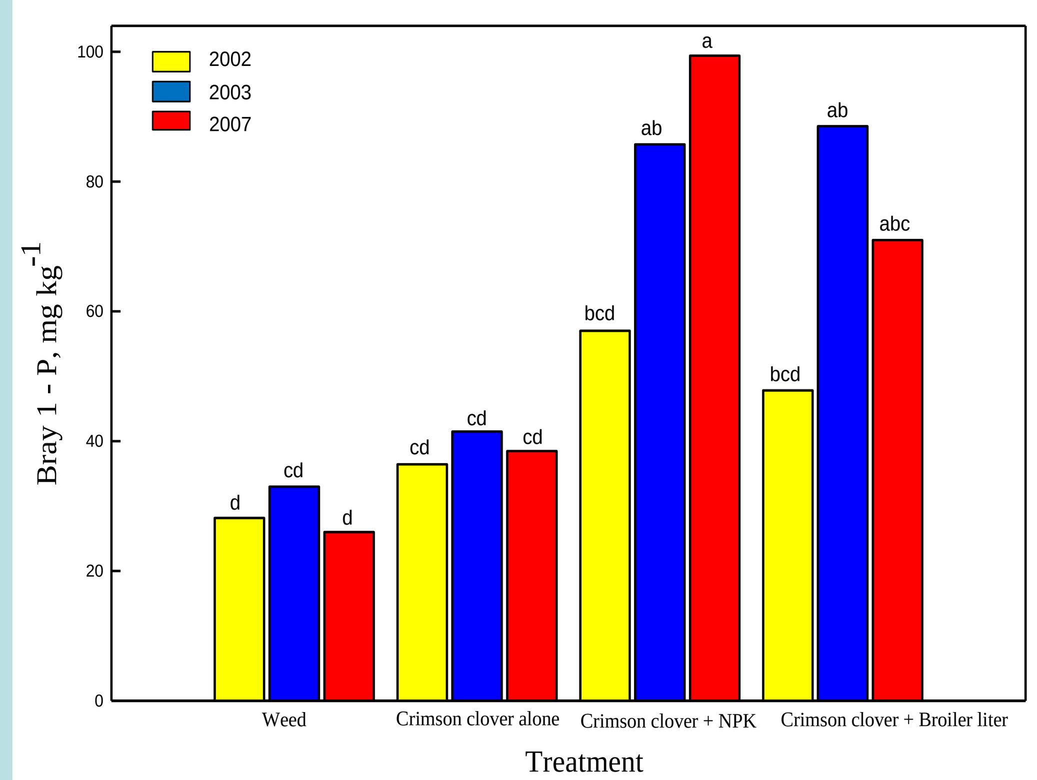

Fig. 4. Accumulation of Bray 1 - P in topsoil following applications of broiler litter or NPK in an organic farming system.

Different letters within a given year represent significant differences in means according to Tukey's honestly significant difference (α = 0.05).

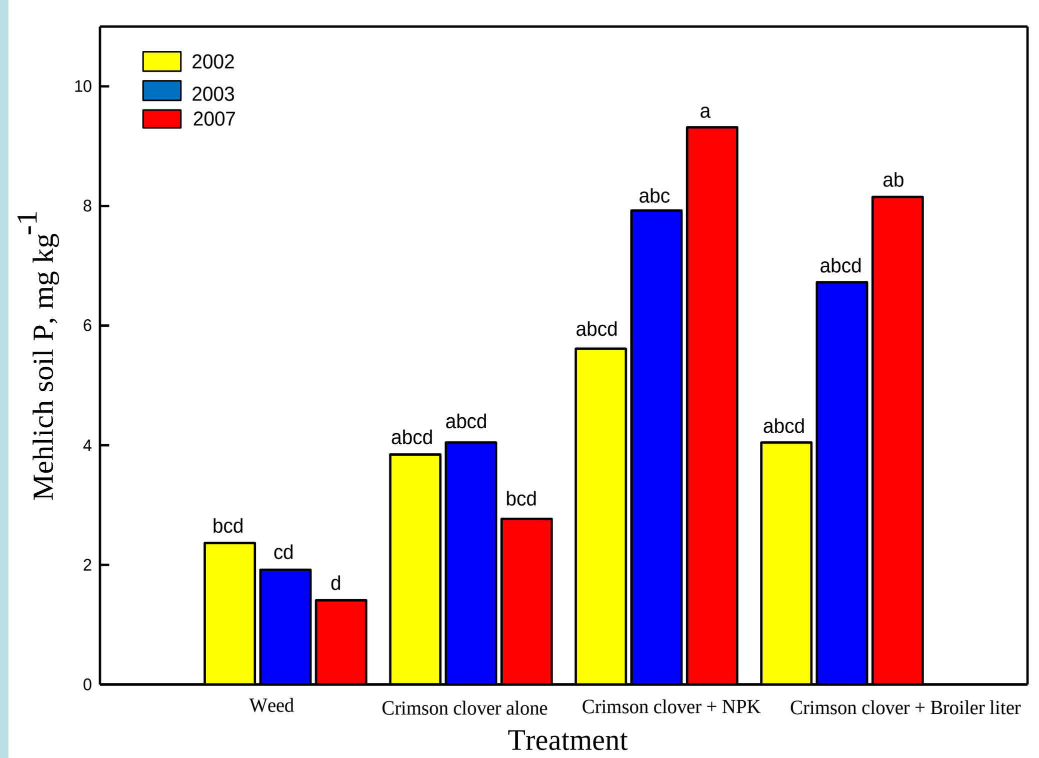

Fig. 5. Accumulation of Mehlich - P in topsoil following applications of broiler litter or NPK in an organic farming system.

Different letters within a given year represent significant differences in means according to Tukey's honestly significant difference (α = 0.05).

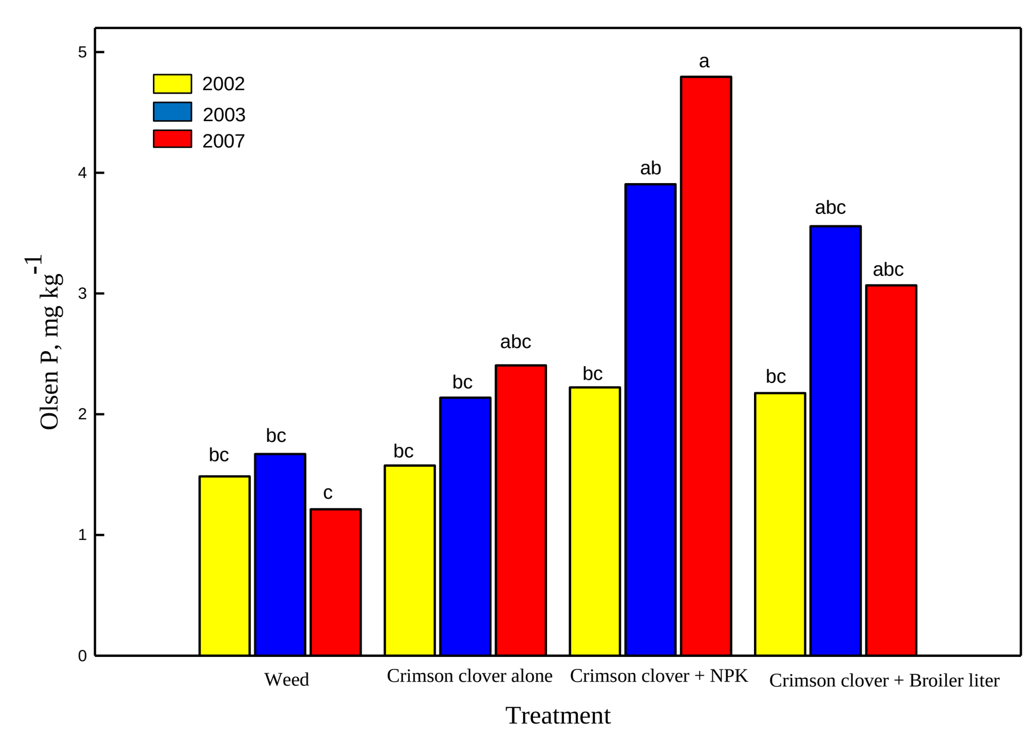

Fig. 6. Accumulation of Olsen - P in topsoil following applications of broiler litter or NPK in an organic farming system.

Different letter within a given year represent significant differences in means according to Tukey's honestly significant difference (α = 0.05).

ACKNOWLEDGEMENT

This study was funded by the George Washington Carver Agricultural Experiment Station