EFFECTS OF COMPOST ON THE AVAILABILITY OF NITROGEN AND PHOSPHORUS IN STRONGLY ACIDIC SOILS

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ABSTRACT

Strongly acidic soil is a major problem in Taiwan. The application of organic fertilizers is an important practice in increasing the productivity of such soils. However, the transformation and availability of phosphorus in the soil will be more complex if organic fertilizers are used in strongly acidic soils. This paper discusses the effect of using composted animal manure on the availability of nitrogen and phosphorus in strongly acidic soils in Taiwan. The development of phosphocompost and its application to strongly acidic soils are also discussed.

INTRODUCTION

Around 52% of the soil in farmland and slopeland in Taiwan is strongly acidic (pH < 5.5). This acidity is a result of the excessive leaching from ample rainfall, the low base saturated parent materials, and the long-term use of physiologically acidic chemical fertilizers. Therefore, soil acidification is a major soil problem in Taiwan (Lian 1991).

Several practices have been recommended to reclaim and upgrade the productivity of strongly acidic soils. These include the cultivation of acid-tolerant plants, covering the surface with non-acidic soil, intensive fertilization, the use of organic fertilizers, and liming. Of these practices, liming and the application of organic fertilizers are generally considered to be the best measures, because their effects are more persistent.

Livestock manure is often rich in plant nutrients. Studies have shown that about 70 - 80% of the nitrogen (N), 60 - 85% of the phosphate (P_2O_5), and 80% of the potassium (K_2O) fed to animals are excreted in the manure (Klausner *et al.* 1984). Along with nutrients, manure supplies valuable organic matter to help improve soil physical properties, and increase the activity of beneficial soil microbes.

However, the nutrient content of manure can vary, according to what has been fed to the animals, and the methods of collecting, handling and storage. In recent years, animal manure from livestock farms, and organic wastes from rural and municipal areas, have seriously contaminated the environment. In order to reduce potential pollution and minimize any damage to the crops and soil, the government is encouraging the application of composted animal manure onto croplands, and has developed regulations regarding composted manure.

Generally, the amount of organic fertilizer applied to farms is based on the nitrogen requirement of crops and the rate of N mineralization. There is little regard for the supply status of phosphate in soils (Olsen and Barber 1977). The percentage of phosphate absorbed by crops from compost annually is usually far lower than the percentage of nitrogen, while the mineralization of soil organic phosphorus (P) is strongly affected by the P fixing capacity of the soil. It is necessary to have a better understanding of the behavior of N and P in strongly acidic soils

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after composted livestock manure is applied, in order to develop a suitable management strategy. In this Bulletin, we present some results of our research on the effects of applied livestock manure on the availability of N and P in some strongly acidic soils in Taiwan. We shall also discuss the application of phosphocompost (compost with added P fertilizer) onto strongly acidic soils.

EFFECT OF APPLIED COMPOST ON THE AVAILABILITY AND MINERALIZATION OF NITROGEN IN STRONGLY ACIDIC SOILS

Changes in the availability of N, and the characteristics of mineralization or immobilization after organic fertilizers have been applied to strongly acidic soils, need to be studied as a basis for developing suitable management of organic fertilizers. Different rates of compost were applied to two strongly acidic soils. One was a clay loam (Da-Du Shan) with a pH of 4.6, and an organic carbon content of 6.9 g/kg). One was a clay soil (Kuan Chi) with a pH of 4.5, and an organic carbon content of 3.6 g/kg. Different rates of compost were applied.

The compost was made from swine manure (pH 7.1, Organic carbon: 25%, Total N: 2.89%, C/N: 9), or mushroom waste (pH 7.3, Organic carbon: 37%, Total N: 1.95%, C/N: 19). Application rates were based on the P fixation capacity of the soils (Chen and Lee 1997).

The effect of the applied compost on the availability and the mineralization potential of N in the soil was investigated at different times. Results showed that the availability of N in both soils was increased by the addition of both types of compost. However, the total nitrogen, the accumulated mineralized nitrogen and the potential N, were all higher in the soils amended with composted swine manure than in those treated with mushroom waste compost (Table 1 and Fig. 1).

This was probably because of the higher N content of swine manure compost compared to composted mushroom wastes, and the fact that N compounds in swine manure compost are more easily mineralized. Hence, as far as the mineralization potential of N is concerned, it is better to use compost with a higher N content and more easily mineralized N compounds on strongly acidic soils.

EFFECT OF APPLIED COMPOST ON THE SORPTION CHARACTERISTICS AND AVAILABILITY OF P IN STRONGLY ACIDIC SOILS

Strong phosphate retention was easily induced in strongly acidic soils rich in (crystalline and amorphous) oxides and hydroxides of Iron (Fe) and aluminum (Al) (Sample and Racz 1980, Tisdale *et al.* 1985, Kuo 1990). The more highly weathered the soil, the stronger was its adsorption capacity for phosphorus.

Chen *et al.* (1994) have investigated the effect of applied compost on the inorganic P sorption capacity of a strongly acidic soil (clay loam with a pH of 4.5), a slightly acidic soil (silty loam with a pH of 6.2) and a slightly alkaline soil (clay with a pH of 7.4).

Two of the composts used were made from swine manure or cattle manure, while the third was composted straw. The results showed that all three types of compost were effective in reducing the inorganic P sorption capacity (Fig. 2) and P sorption percentage (Fig. 3).

The composted straw was found to have the greatest ability to reduce the inorganic P sorption capacity of the soil, followed by composted cattle manure and swine manure, in that order. In general, the higher the content of inorganic P and/or organic P, and the lower the ratio of C to organic P in the compost, the more significant was the effect in reducing the inorganic P sorption capacity. Therefore, the application of compost can be expected to enhance the availability of soil P and promote the efficiency of P fertilizers.

Many suggestions have been made to explain how compost reduces the P adsorption capacity. One possibility is that the iron, aluminum or calcium combines with humic or organic acids released by the decomposition of organic matter, thereby reducing P adsorption (Dalton *et al.* 1952, Moreno *et al.* 1960, Barrow 1989). Another suggestion is that P adsorption sites become preoccupied by organic P, especially phytic acid (Anderson *et al.* 1974, Evans 1985, Chen 1996). It has also been suggested that adsorption sites may be preoccupied by inorganic P ions dissolved from organic fertilizer or released by the mineralization of organic P fractions (Chen 1996). A fourth explanation is that the surface charge on soil colloids is variable after compost has been applied, because of changes in the soil pH.

Table 1. Estimated mineralization potential* of N after application of compost into strongly acidic soils

Soil group	Treatments	Mineralization potential of N (mg/kg)
Da-Du Shan (clay loam)	Control	19.1 ± 0.4
	Composted mushroom wastes (3%)	43.3 ± 0.6
	Composted swine manure (3%)	89.0 ± 0.2
Kuan-Chi (clay)	Control	25.8 ± 0.7
	Composted mushroom wastes (6%)	56.4 ± 0.2
	Composted swine wastes (6%)	89.4 ±0.2

* Mineralization potential based on compound 1st order equation

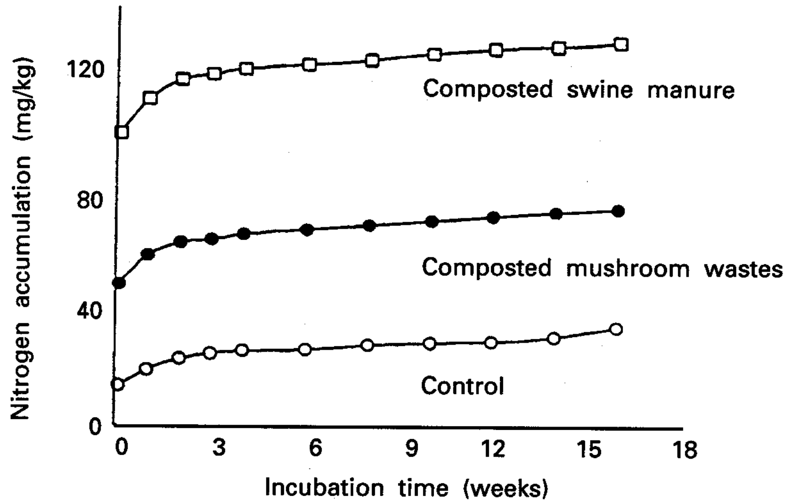

Fig. 1. Total accumulated N in the leached solution of Da-Du Shan clay loam soil amended with composted swine manure or mushroom waste after different incubation periods

Fig. 4 and Fig. 5 show that all three types of compost could increase the anion resin exchangeable P and solution P concentration in the soil. However, the effects varied according to the type of soil and the type of compost (Chen 1995). In general, straw compost was found to be the most effective in increasing the concentration of P in the soil solution, the resin exchangeable P, the organic P, and the rate of mineralization. This was followed by composted cattle manure, and composted swine manure, in that order.

With regard to the soil, the increase in P availability after compost application was higher in the slightly acid soil, and lower in the strongly acidic soil. This suggests that the P sorption capacity of the soil was the main factor in the differences in P availability after compost application.

Some researchers have suggested that the concentration of P in the soil solution should be above 0.2 mg/L to meet the needs of the crop (Buckwith 1965, Ozanne and Shaw 1968). This value could be used to evaluate the P status of the soil, to diagnose whether the P supply is enough for the crop. In this experiment (Chen 1995), compost at a rate of 50 mt/ha was applied to strongly acidic soil. However, the concentration of P in the soil solution was only 0.02 - 0.1 mg/L, far below the 0.2 mg/L recommended, so that the possibility of P deficiency should be considered. When compost is applied to strongly acidic soil, the P content of the

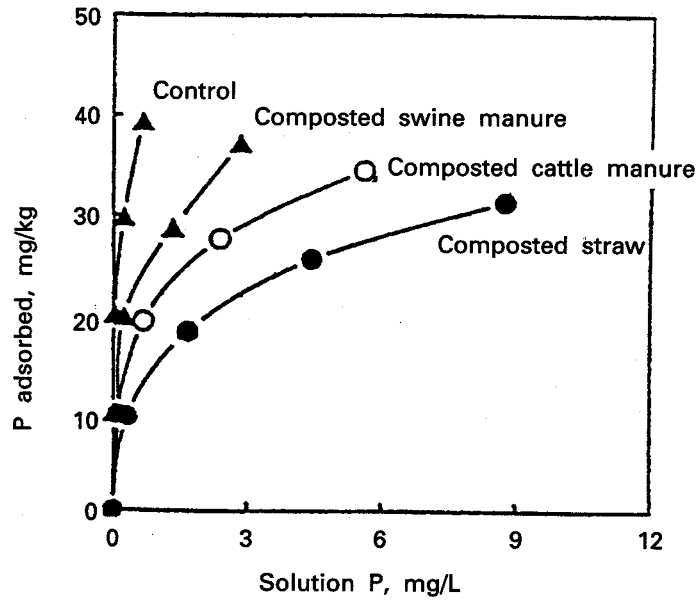

Fig. 2. The inorganic P adsorption isotherms of strongly acidic soil after the addition of composted rice straw, cattle manure and swine manure.

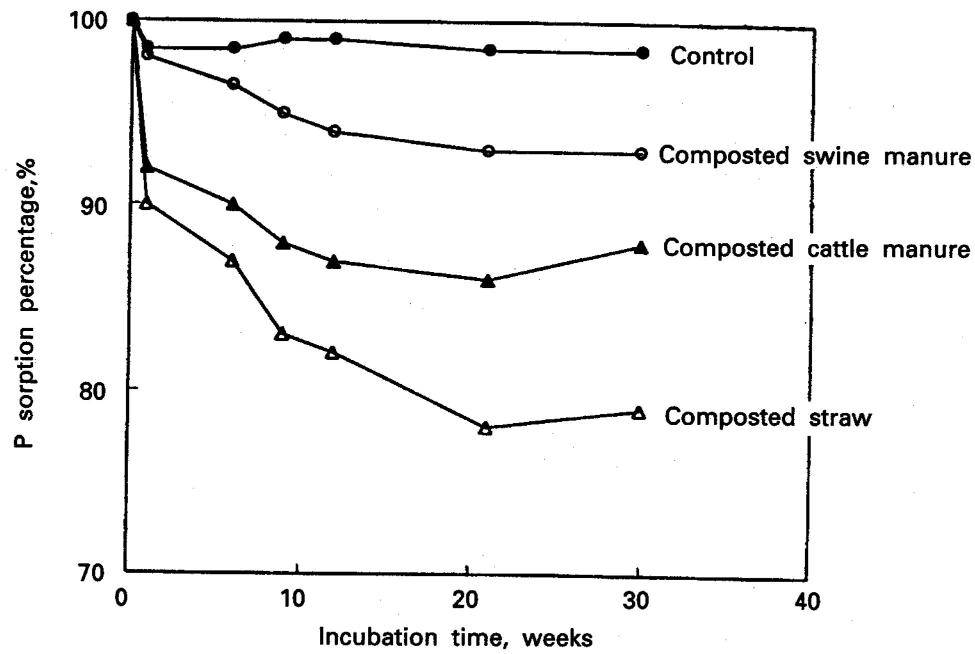

Fig. 3. Changes over time in the percentage of absorped P in strongly acid soil to which has been applied compost made from straw, cattle manure and swine manure, respectively

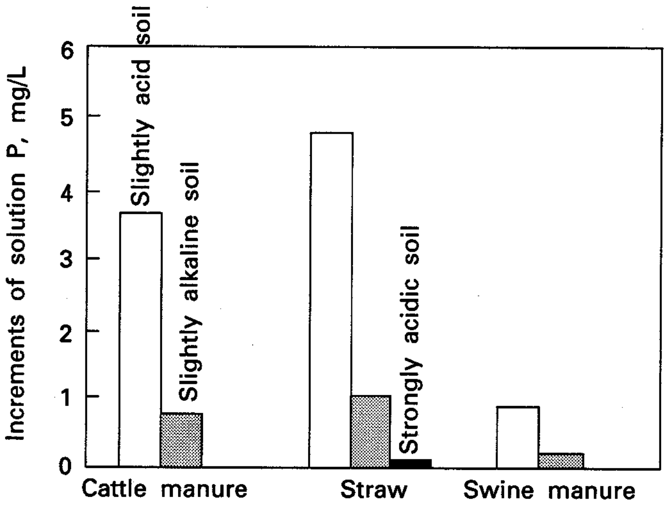

Fig. 4. Increased concentration of P in the soil solution 30 weeks after the application of composted rice straw, cattle manure or swine manure.

compost should be considered, so that P deficiency does not become a limiting factor for normal crop growth.

THE USE OF PHOSPHOCOMPOST IN STRONGLY ACIDIC SOILS

The heavy application of manure or compost in excess of crop needs can cause a significant buildup of nitrogen, phosphorus and salt in soil. Applying enough manure or compost to meet the nitrogen requirements of corn may greatly increase the levels of P and other ions in the soil (Eghball and Power 1997).

The reason for this is probably because the N/P ratio in most livestock manure, even after composting, was lower than the N/P uptake ratio of most crops. Eghball and Power (1995) found that the phosphorus content (measured by Bray-1) increased by 81 mg/kg after a single application of manure based on nitrogen requirements, and by 114 mg/kg after a similar application of compost. A high level of phosphorus in the soil is an environmental concern. It may be washed into streams and lakes by runoff or soil erosion, and cause eutrophication (Sharpley *et al.* 1996).

Phosphorus deficiency of crops may sometimes be found where compost is applied to strongly acidic soils with a high P-fixing capacity. In such cases, chemical P fertilizers must be added to meet the P requirement of the crop (Chen 1995). Several studies have demonstrated that rock phosphate in composted livestock manure increases both the uptake of P by crops and the yield. This increase is probably because of the increase in the available P in the rock phosphate (Singh and Yaday 1986, Singh and Amberger 1991). Mahimairaja *et al.* (1995) evaluated the results from field experiments, and suggested that composting poultry manure with sulfur and rock phosphate not only reduces the environmental pollution from manure application, but also increases the agronomic effectiveness of the compost.

A fortified compost known as "phosphocompost" has recently been developed in Taiwan. Rock phosphate (16.5 g/kg) or bone meal (15.9 g/kg) are passed through 100 mesh and added to dried chicken manure and rice hull. The ratio of manure to rice hull is 1:2 (V/V). The phosphate (P_2O_5) content of the rock phosphate and bone meal was 34.5 and 35.8%, respective.

The mixture was composted in 200 L plastic barrels. Passive aeration was used, and the compost was mixed six times by up-ending the barrel. On the first day, the temperature of the compost rose rapidly to 75°C and remained above 50°C. The final temperature after six weeks was around 30 - 40°C. The total C content fell continuously during composting, to reach a constant value after 35 days. The nitrogen content also fell over time (Fig. 7), probably because the ammonium volatilized at high temperatures. However, the phosphate content

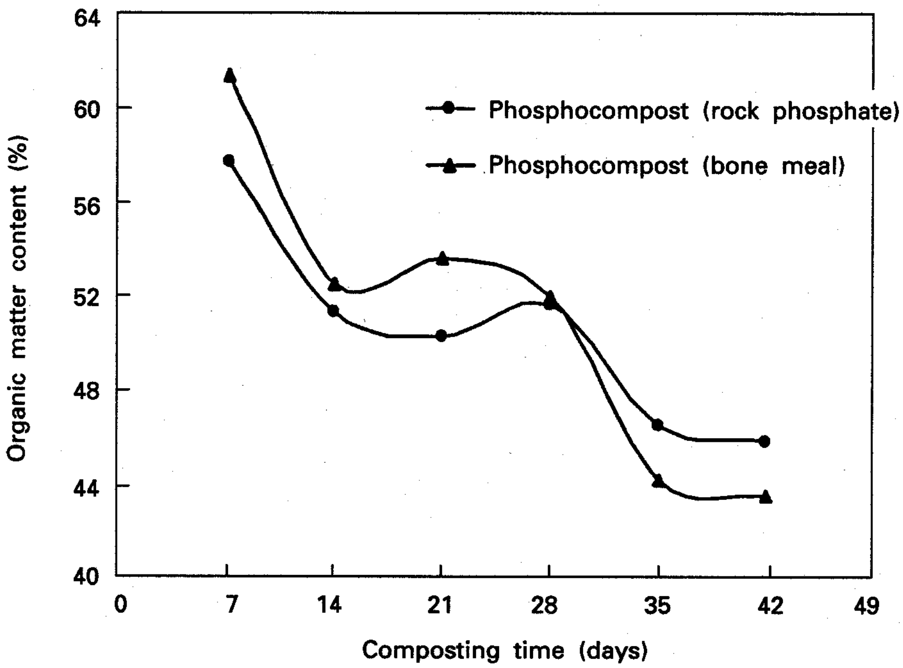

Fig. 5. Changes in nitrogen content during composting

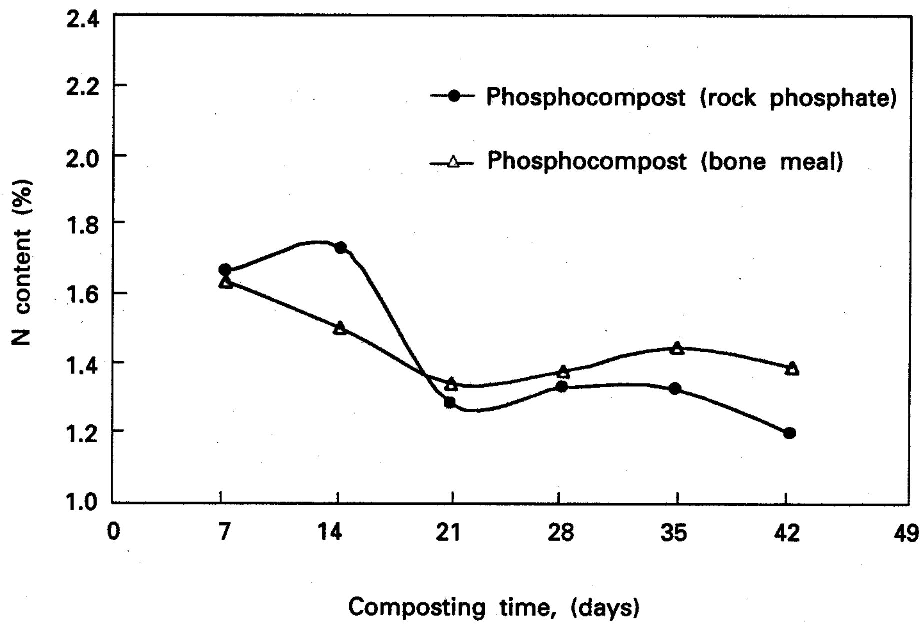

Fig. 6. Changes in organic matter content during composting

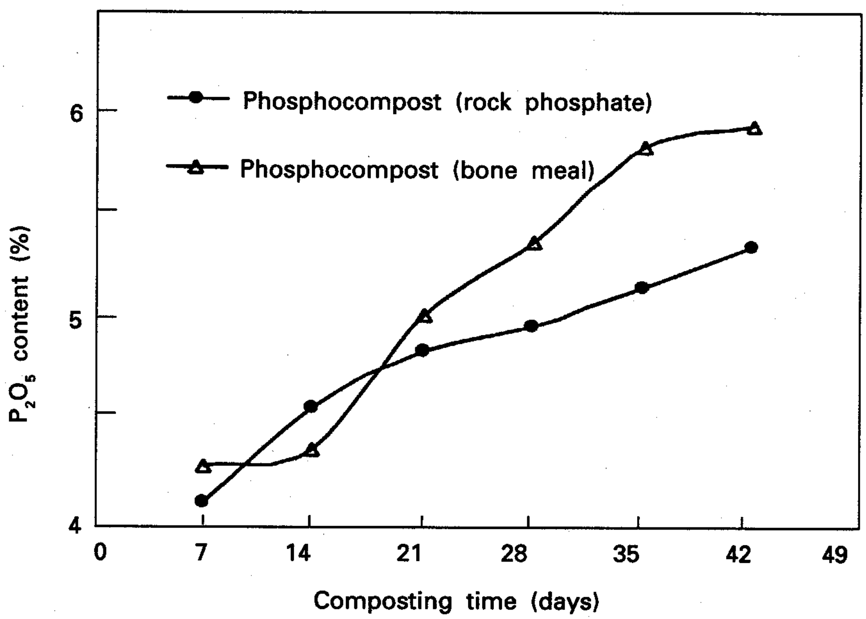

Fig. 7. Changes in phosphate (P_2O_5) content during composting

increased significantly during composting. Besides the concentration effect from the decomposition of organic matter (Inoko 1982, Haga 1990), the release of phosphorus from the rock phosphate or bone meal during composting was also an important factor.

The compost with enhanced phosphate content is called "phosphocompost", and has a phosphate content of 5 - 6%. The nitrogen content is less than 1.5%. A greenhouse experiment was conducted to evaluate the effects of the phosphocompost containing bone meal as a P source on the growth of cabbage in strongly acidic soil, as well as the uptake of N and P.

Dried manure mixtures were prepared by blending the same quantities of dried chicken manure, rice hull, and bone meal as in the phosphocompost. The application rates of phosphocompost, dried manure mixture, and urea were calculated based on the N rate recommended for cabbage (= 300 kg/N). However, the mineralization rates of phosphocompost and chicken manure were assumed to be 50%. The same amount of P and K fertilizer was added to each treatment

The application of phosphocompost, dry manure mixture and urea had a significant effect on the weight of cabbage (dry matter basis) (Fig. 8). Although the highest weight was obtained with the application of phosphocompost, it was not significantly different from the yield from the dried manure mixture. However, both were significantly higher than the yield obtained from the urea treatment.

Phosphocompost and a dried manure mixture could both greatly increase the pH, the organic matter content and the availability of P in soils, and the N and P uptake of crops compared to those obtained from urea. The effect of the dried manure mixture seemed to be significantly greater than that obtained from the phosphocompost. This finding was in agreement with Castellanos and Pratt (1981), who reported higher efficiency of fresh manure compared to compost, because of its higher organic matter and N content, and the higher rate of mineralization compared to composted manure.

With regard to the concentration of Bray-1 phosphate, soil treated with chemical fertilizer had a value of only 3 mg/kg, rated as 'very low". However, soil treated with phosphocompost contained 47 mg/kg P, rated as "high" in terms of P availability. Hence, it seems that phosphocompost was effective in raising the availability of P in strongly acidic soil. The use of phosphocompost at a rate based on the N requirement of the crop not only improves soil productivity, but also efficiently overcomes the problem of insufficient P in strongly acidic soil with a high P fixing capacity.

CONCLUSION

A high proportion of arable soils in Taiwan are strongly acidic. The use of composted livestock

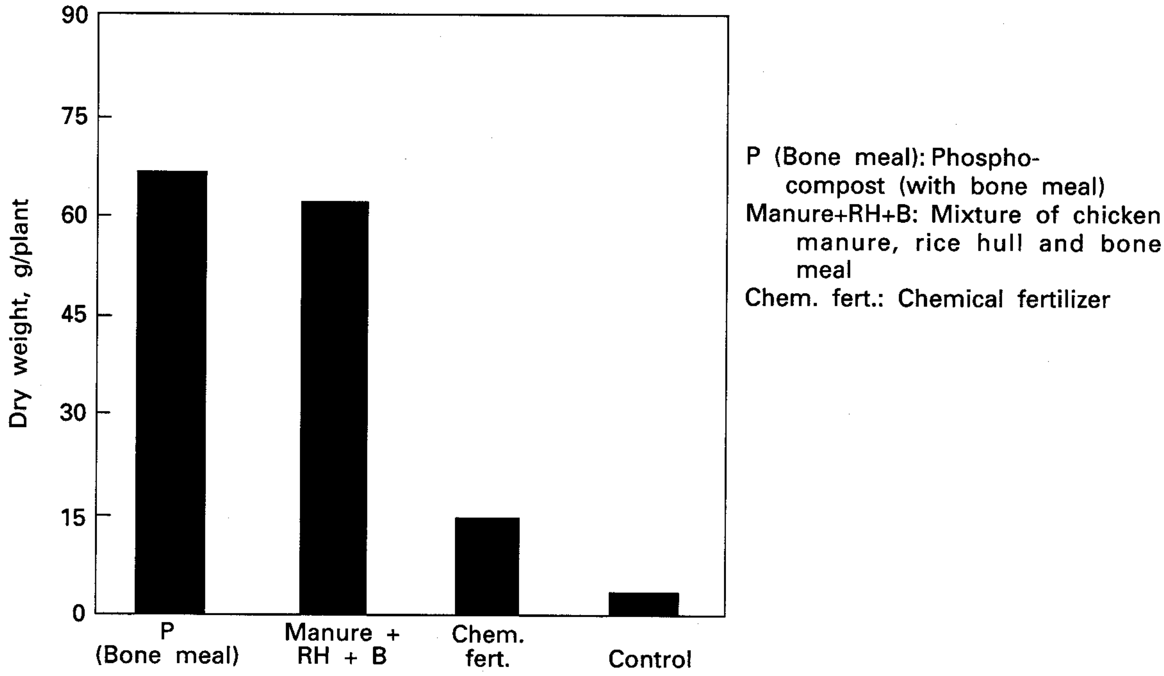

Fig. 8. Dry weight of cabbage treated with different nutrient sources in pot experiments

manure on strongly acidic soils not only improves soil productivity, but is also a way of recycling waste materials and protecting the environment from pollution. Supplementing composted livestock manure with added phosphorus to make "Phosphocompost" makes the compost into a more complete nutrient source for strongly acidic soils. This also improves the management of livestock manure, contributing towards a more rational fertilization strategy.

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