Influence of compost application on growth and phosphorus exploitation of ryegrass (*Lolium perenne* L.)

H.W. Scherer

Agricultural Faculty of the University of Bonn, Germany

ABSTRACT

Information on the availability of P following compost addition to soil may help to a better management of P fertilization of the crop in respect to plant growth and the environment. Therefore a greenhouse experiment was conducted to investigate the effect of compost within the official classes of stability III and V on growth and P exploitation of ryegrass (*Lolium perenne* L. cv. Turilo). The following result was obtained: As compared to a control without P application, compost application resulted in a significant yield increase. Application of composts of the official class of stability V resulted in higher yields as compared with the application of compost of the official class of stability III. P uptake of ryegrass was higher in the treatments in the class of stability V. Based on CAL-extractable compost P exploitation of P ranged between 8.5 and 104.0% in the first year of compost application and in total (sum of two years) 37.8 and 204.5%. P exploitation on the basis of total compost P ranged between 3.6 and 22.1%.

Keywords: compost application; phosphorus; availability; exploitation; ryegrass; yield formation

In Germany about 4×10^6 t compost per year are produced from different solid organic wastes like household and garden wastes. In agriculture and horticulture, composts are used as C and N amendments to improve soil quality and to support plant growth (Crecchio et al. 2001). Intensive studies are dealing with the forms of the organic matter in the compost and N mineralisation after compost is incorporated into the soil (Gigliotti et al. 1999), because compost contains both inorganic and organic N. The amounts of plant-available N are more or less depending on the degree of compost maturity (Scherer et al. 1996).

Until now, little has been done to unravel the forms and availability of P in compost, although the total P concentration of the composts is ranging between 0.4 and 0.8% in d.m, resulting in a P application rate between 40 and 80 kg P/ha with 10 t compost d.m. According to Frossard et al. (2002) composted organic solid wastes contain from 2 to 16% of their total P as rapidly exchangeable inorganic P, between 40 and 70% as slowly exchangeable or not exchangeable inorganic P and some organic P. Less information exists on the availability of P in composts and in the literature a wide variation in results exists concerning the effectiveness of composts to sustain the P nutrition of crops (Murillo et al. 1997). In the studies of Sinaj et al. (2002) between 6.5 and 11.6% of the total P supplied within four different composts were utilized by red clover. Using a water-soluble mineral P fertilizer as a reference the amount of P taken up from the compost may vary between 10 and about 250% (Sikora et al. 1982, Bezolla et al. 1994). This large variability is assumed to be caused by the composition of the compost P.

Excessive inputs of available P in soils must be avoided in order to prevent a degradation of the quality of surface water (Sharpley and Rekolainen 1997). To use compost in a sustainable way it is a prerequisite to quantify the amount of P, which is plant available and could be taken up by a crop (Traoré et al. 1999). Therefore in the present investigations, a greenhouse pot experiment was conducted to determine the percentage of the apparent bioavailable P of a collection of composts with two different classes of stability (III and V) and the efficiency in supplying P to the soil-plant system.

MATERIAL AND METHODS

Composts. The compost samples used in this study were collected in Northrhine-Westfalia (Germany) from a composting plant using garden and solid kitchen wastes. The composts belong to the official classes of stability III (microbial heat production of the compost material in a Dewar pot = 40–50°C) and V (microbial heat production of the compost material in a Dewar pot = 20–30°C), respectively (Table 1). Some of the compost characteristics are summarized in Table 2. Total P content of composts, measured after digestion in hot concentrated $HClO_4$, ranged between 1.10 and 2.90 g P/kg compost dry matter

Table 1. Official classes of stability of the composts and the composition of the composted raw material

Compost No.	Official class of stability	Household waste (%)	Garden waste (%)
1	III	–	100
2	III	20	80
3	III	50	50
4	III	80	20
5	III	80	20
6	V	–	100
7	V	20	80
8	V	50	50
9	V	80	20
10	V	80	20

(d.m.) and the plant available P, extracted with CAL (Ca acetate + Ca lactate) solution, ranged between 0.24 and 1.21 g P/kg compost d.m. The percentage of CAL-extractable P of the total P ranged from 16.2 and 45.0%. pH (Table 2) was determined in 0.01M $CaCl_2$ solution and total N (Table 2) according to the Kjeldahl method.

Pot experiment. In a completely randomised pot experiment with a 1:1 mixture of a top- and a subsoil of a Luvisol derived from loess (9 kg/pot; pH_{CaCl_2} 6.0; 8.2 mg CAL-extractable P/kg soil) 393 mg P/pot were supplied as compost, whereby the amount of CAL-extractable P ranged between 87 and 177 mg P/pot (Table 3). In the first year compost (except in the control treatment without P application) was incorporated thoroughly into the soil together with the basal dressing, providing all nutrients save P before sowing ryegrass (*Lolium perenne* cv. Turilo), which was cut six times. Soil humidity was kept at 75% of the maximum water holding capacity during the growing season by daily controlling the pot weight. In the spring of the following year roots and stubbles were incorporated into the soil together with the basal dressing (without P) before sowing ryegrass again, which was harvested another six times. After drying the plant samples, P was analysed after dry ashing in a muffle furnace (8 h at 550°C) and subsequent solubilisation of the ash in 2 ml 1N HCl. Net P uptake was calculated as follows: P uptake (P concentration in the tissue times dry matter yield) of the plants supplied with compost minus P uptake of a control treatment without P fertilizer application.

Statistical analysis. Statistical evaluation was done by the *LSD* test using SPSS. The statistical significance indicates a 0.05 probability level.

RESULTS AND DISCUSSION

World phosphate fertilizer consumption has increased almost six-fold from approximately 5 million tons in 1950 to 30 million tons in 1995, which gives an annual growth rate of some 4%. In different regions of Europe and locally in the USA and Central and Eastern Europe, there is an oversupply of phosphorus in agriculture due to the large combined input of phosphate in the form of mineral P fertilizer and organic manures derived from feed. On the other hand, there is an insufficient supply of phosphate in large parts of the developing countries. Using the assumption

Table 2. Compost characteristics

Compost No.	pH	Total P	CAL-extractable P	% CAL extractable P of total P	Total N (g/kg d.m.)
		(mg/kg d.m.)			
1	6.8	1110	245	22.1	7.47
2	6.6	1201	288	24.0	8.63
3	6.2	2100	341	16.2	10.29
4	7.1	1598	590	36.9	8.05
5	6.3	1201	297	24.7	12.49
6	7.7	1799	747	41.5	10.06
7	7.5	1502	533	35.4	8.10
8	7.6	2598	1030	39.7	10.53
9	7.4	2899	1050	36.2	13.70
10	7.3	2699	1213	45.0	12.79

Table 3. Amounts of CAL-extractable P (mg/pot) applied with 393 mg total P

Compost No.	CAL-extractable P
1	87
2	94
3	64
4	97
5	97
6	140
7	140
8	156
9	142
10	177

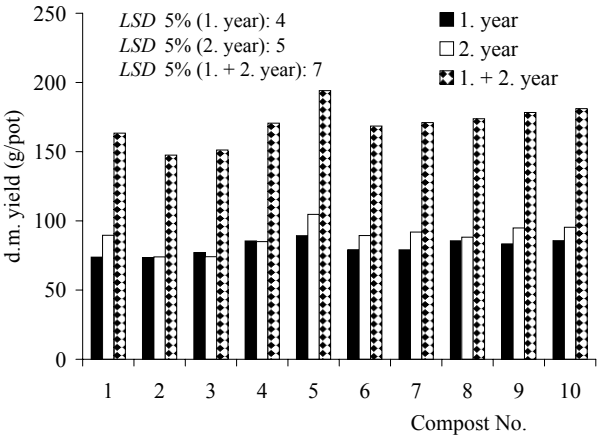

Figure 1. Influence of compost application on dry matter yield of ryegrass

that the P fertilizer consumption in developed agriculture could stabilize at its present level of around 8.7 to 10.9 kg P_2O_5 per hectare as an average and about 90% of the phosphate mined is used for fertilizer production, the global known deposits of rock phosphate will only last about 400 years. Therefore to spare non-renewable resources like phosphate, recycling of nutrients from organic wastes therefore should be increased wherever environmentally compatible. Due to their relatively high P content, urban sewage sludges are used since it included many years as sources for P for agricultural crops (Kirkham 1982). The application of sludges to the soil has shown to increase soil available P and plant uptake (McCoy et al. 1986, McLaughlin and Champion 1987).

The information of the availability of P supplied with compost is still scarce. To integrate compost in the crop rotation from an ecological as well as from an economical point of view, the short-term and the long-term availability of P supplied with compost should be known. Ideally, one would like to be able to identify certain P compounds in the compost, which are responsible for the P delivery

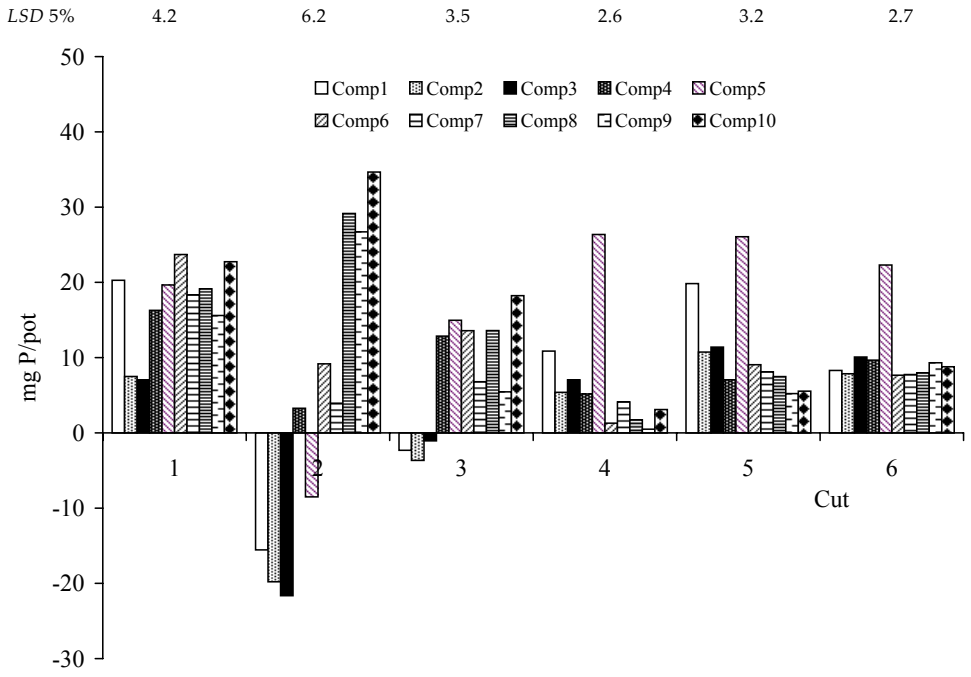

Figure 2. Influence of compost application on P uptake of ryegrass (1. growing season) in individual cuts

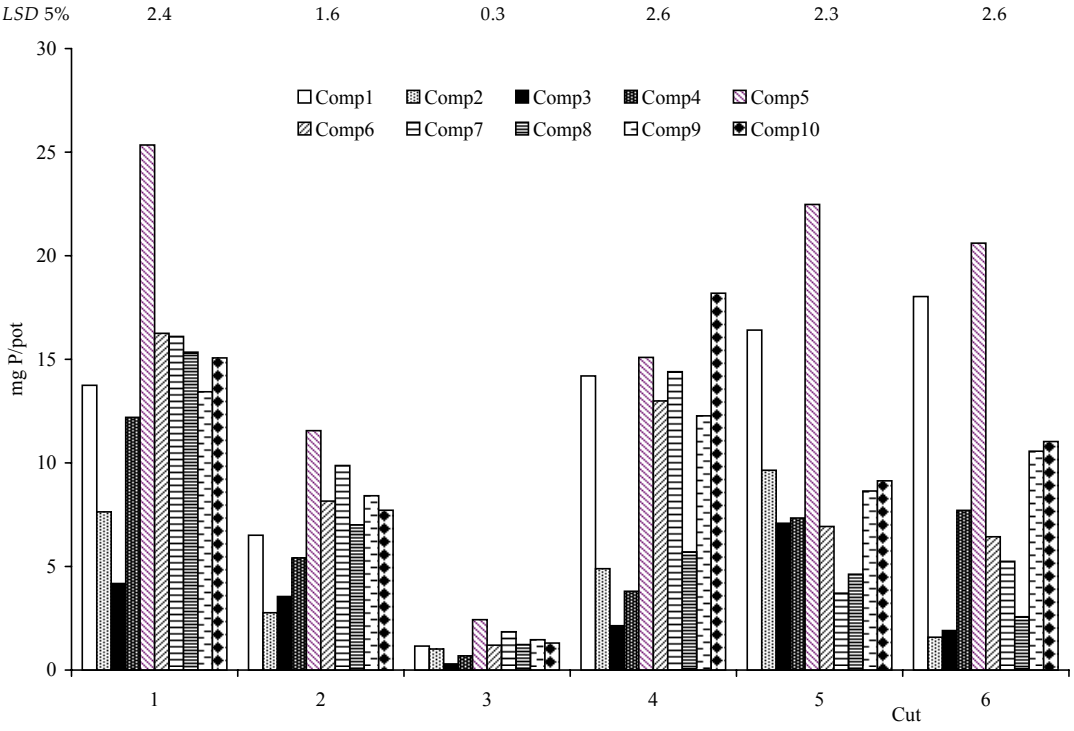

Figure 3. Influence of compost application on P uptake of ryegrass (2. growing season) in individual cuts

after compost application. However, until now only rough information about the share of moderately plant available P chemical extractions is available. Alt et al. (1994) and Kuhn et al. (1996) used chemical extraction methods to assess phosphate availability in composts and divided the total compost P in plant available and plant unavailable forms of P. In the present investigations the composts of the classes of stability III and V, respectively, were used (Table 1). The content of CAL-extractable P is influenced by the composting time (Table 2). It was higher in the composts of the class of stability V as compared with the class of stability III. Further the share of CAL-extractable P of total P increased with the time of the composting process. Therefore it may be assumed that the short-term P supplying capacity is higher in composts of the class of stability V.

However, when discussing the P availability of composts the influence of the plant roots on the uptake of the phosphate supplied with compost must be taken into consideration, because it is well established that the presence of low molecular weight organic acids in the rhizosphere soil enhances the solubility of P (Bar-Yosef 1996). Therefore in the present investigation ryegrass was cropped over a period of two years to get information about the short-term P delivery of compost as well as the mobilization of P from more stable P compounds.

As shown in Figure 1 ryegrass yields differed between the different compost treatments. However, the yield differences were not the result of a differential N supply, as N was applied additionally in the basal fertilization and after the third harvest in both years. Further N d.m. concentration did not differ significantly (data not shown). Differences in dry matter yield were consequently caused by differences in P availability of the composts. However, it should be pointed out that the applications of compost No. 5 (class of stability III), which was characterized by a very low content of 297 mg CAL-extractable P/kg compost d.m. resulted in the highest total dry matter yield. This higher total yield of treatment 5 is mainly caused by the higher yield in the second experimental year. Higher yields in the second year as compared to the first year were also observed in all of the compost treatments of the class of stability V and one other compost of the class of stability III.

Because yield formation is not alone a suitable parameter to gain information about the P availability of compost, P uptake of ryegrass was taken into consideration. To distinguish between P taken up from the soil and P derived from the compost, P uptake of a treatment grown without P fertilization was subtracted from the P uptake of ryegrass supplied with compost. In the first year the low content of the CAL-extractable phosphate in the compost of the class of stability III became obvi-

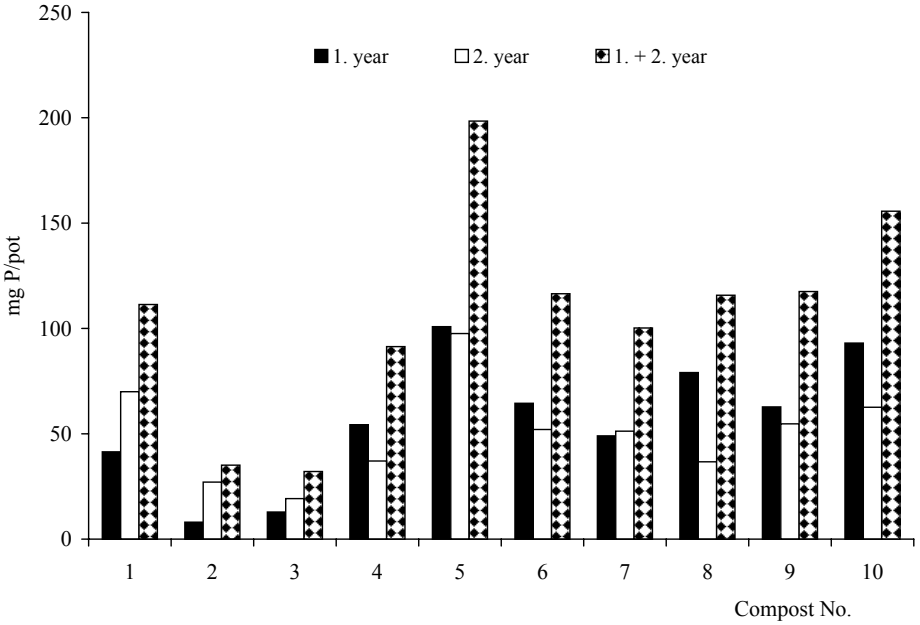

Figure 4. Influence of compost application on total P uptake of ryegrass in the 1. and 2. growing season and the sum of two years

ous. In some composts the apparent plant available compost P was fixed by the soil resulting in a lower P uptake of ryegrass of the second and third cut (Figure 2) as compared to the control without P application. After the third harvest the highest P uptake rates were achieved in those treatments where P was formerly fixed. However in total, P uptake was mostly significantly higher in the treatments supplied with compost of the class of stability V compared to the treatments supplied with compost of the class of stability III, which is the result of a higher yield as well as a higher P concentrations in the dry matter. Except at the second harvest, where apparent plant available compost P was fixed, P uptake of treatment 5 was highest from the fourth to the sixth harvest suggesting a high P mobilization later in the growing season.

In the second growing season P uptake of all treatments with a compost of class of stability V was similar until the third harvest, while later P uptake was the highest in the treatments with the highest total P content of this compost group, although the same amount of P was applied with compost (Figure 3). In contradiction to the first year P uptake of the treatments supplied with compost of the class of stability III sometimes reached or exceeded the treatments with compost of class of stability V. It is believed that root-borne acid phosphatase enzymes together with fungal acid phosphatase and bacterial alkaline phosphatase (Chen et al. 2002) are responsible for hydrolysis of organic P and therefore for the higher P delivery of the less mature composts in the second year. Moreover, it has been shown that P-deficiency in plants increases phosphatase activity (Dalal 1977).

Despite the increased P delivery of the composts of class of stability III in the second year after compost application, the total P uptake of ryegrass (sum of two years) was higher in the treatments with compost of the class of stability V (Figure 4). To avoid a continued addition of P in excess of crop requirements, which leads to a P accumulation in the soil surface horizon and therefore to environmental problems (Sui et al. 1999) composts of the class of stability class V should be recommended for agricultural use.

To integrate compost in a crop rotation from an economical as well as from an ecological point of view the exploitation of the applied nutrient should be known. In the present investigation P efficiency on the basis of the plant available (CAL-extractable) P ranged between 8.5 and 104.0% in the first year (Table 4). In total the exploitation of the plant available P ranged between 37.8 and 204.5%. These results provide evidence that mineralization of organic P was likely to occur after incorporation of compost No. 1 and No. 5 into the soil. Further it should be pointed out that the P exploitation on the basis of the total applied P ranged between 4.0 and 22.1%. As with the exploitation of CAL-extractable P the range of the exploitation of total P was larger with the composts of the class of stability V. This is a further reason, why compost of the class of stabilization V should be used for a specific P fertilization.

Table 4. Exploitation of CAL-extractable P and total P, respectively, applied with compost in %

Compost No.	CAL-extractable P			Total P Σ of two years
	1. year	2. year	Σ of two years	
1	47.5	80.5	128.0	13.4
2	8.5	29.3	37.8	4.0
3	20.2	30.1	50.3	3.6
4	37.4	25.6	63.0	10.1
5	104.0	100.5	204.5	22.1
6	39.6	31.9	71.5	12.9
7	35.0	36.6	71.6	11.1
8	50.7	23.4	47.1	12.8
9	44.2	38.6	82.8	12.9
10	52.6	35.3	87.9	17.2

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ABSTRAKT

Vliv aplikace kompostu na růst jílku vytrvalého (*Lolium perenne* L.) a využití dodaného fosforu rostlinami

Znalost přístupnosti fosforu z půdy po aplikaci kompostu může pomoci zlepšit postup hnojení P v souladu s požadavky rostliny a ochrany životního prostředí. Skleníkový pokus byl proto zaměřen na sledování vlivu aplikace kompostu (zařazeného do třídy stability III a V) na růst a využití P jílkem (*Lolium perenne* L., odrůda Turilo). Ve srovnání s kontrolní variantou bez aplikace P vedla aplikace kompostu k významnému zvýšení výnosu. Aplikace kompostu třídy stability V zvýšila výnos jílku výrazněji v porovnání s kompostem třídy stability III. Také příjem P jílkem byl vyšší z varianty s kompostem třídy stability V. V prvním roce byl P z aplikovaného kompostu extrahovaný metodou CAL využit v rozsahu 8,5–104,0 % , celkové využití za oba pokusné roky se pohybuje v rozmezí 37,8–204,5 %. Využití celkového množství P z dodaného kompostu bylo v intervalu 3,6–22,1%.

Klíčová slova: aplikace kompostu; fosfor; přístupnost; využití; jílek; tvorba výnosu

Corresponding author:

Prof. Dr. Heinrich W. Scherer, Institut für Pflanzenernährung der Rheinischen Friedrich-Wilhelms-Universität Bonn, Karlrobert-Kreiten-Strasse 13, D-53115 Bonn, Germany
phone: + 49 228 732 853, fax: + 49 228 732 489, e-mail: h.scherer@uni-bonn.de