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Full Length Research Paper

Influence of city finished compost and nitrogen, phosphorus and potassium (NPK) fertilizer on yield, nutrient uptake and nutrient use efficiency of radish (*Raphanus sativus* L.) in an acid soil

Ashoka Sarker, Abul Kashem* and Khan Towhid Osman

Department of Soil Science, University of Chittagong, Chittagong 4331, Bangladesh.

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A pot experiment was carried out to investigate the influence of city finished compost (CFC) and nitrogen, phosphorus and potassium (NPK) fertilizer on the yield, nutrient uptake and nutrient use efficiency of radish (*Raphanus sativus* L.). Air dried sandy loam soil was mixed with five rates of CFC equivalent to 0, 5, 10, 20, 40 ton ha^{-1} and three rates of NPK fertilizer equivalent to 50, 100 and 150% (N-P-K = 137-32-70 kg ha^{-1}). Five plants were grown in each pot. Only, four plants were harvested after 45 days of growth and the remaining plant was harvested at 90 days of growth. The harvested plants were separated into leaves and bulbs and dried. The dry matter yield of leaves and bulbs, N and K concentrations, their uptake by radish increased with the rates of CFC and NPK fertilizer amendments. Among the treatments, growth performance of radish was better with the highest rate of 40 t ha^{-1} CFC treatments. Uptake of N and K by plant showed very strong and positive correlation ($P<0.001$) with total dry matter yield. Agronomic and physiological use efficiency of N and K of radish decreased with increasing the rates of CFC and NPK fertilizer treatments. The performance of agronomic efficiency of added nutrients by radish was better with the application of CFC at 5 and 10 ton ha^{-1} and of NPK fertilizer at 50 and 100% rates. Results of the present study indicated that 10 ton ha^{-1} CFC could be used instead of 100% NPK fertilizer to obtain similar yield and nutrient use efficiency.

Key words: Compost, soil, yield, nutrient use efficiency, nitrogen, potassium, crop.

INTRODUCTION

Farmers use inorganic fertilizers to improve soil fertility and to increase the yield of their crops. However, extensive applications of inorganic fertilizers have some disadvantages on environment. Ayoola and Adeniyan (2006) reported that the use of inorganic fertilizers has not been helpful under intensive agriculture because it is often associated with reduced yield, nutrient imbalance, leaching and pollution of groundwater (Sridhar and Adeoye, 2003). Furthermore, fertilizer cost and concern for sustainable soil productivity and ecological stability in relation to chemical fertilizer use has emerged as an important issue (Aulakh and Singh, 1997). There is renewed interest in the use of organic manures, such as farmyard manure, compost and green manure as sources of plant nutrients (Aulakh, 1994). The inorganic manures are a primary substrate for replenishment of soil organic matter which upon mineralization, supply essential plant nutrients (Walters et al., 1992).

Disposal of organic waste on agricultural land is increasing throughout the world. Organic waste may contain useful agronomical amounts of macro and micro nutrients (Campbell and Beckett, 1988). The availability of organic waste derived metals in most soil acidification processes by nitrification and leaching (Roca and Pomares, 1991). City finished compost may be more superior to un-composted materials in terms of nutrients content and less probability of other potential contaminants that cause pollution (Zia et al., 2003).

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*Corresponding author. E-mail: kashem00@yahoo.com.

Additionally, composting is one of the best solutions to reduce the huge piles of organic wastes and convert it into a valuable product (Inckel et al., 1996).

Appropriate fertilizer use leads to increased crop yields and high crop recovery of applied nutrients. Some elements may be hazardous to the environment if unused in various forms such as nitrates. Efficient fertilization is therefore important in ensuring crops attain maturity within specific growing seasons (Okalebo, 1997). Recovery of applied inorganic fertilizers by plants is low in many soils. Estimates of overall efficiency of these applied fertilizers have been about 50% or lower for N and close to 40% for K (Baligar and Bennett, 1986a, 1996b). These lower efficiencies are due to significant losses of nutrients by leaching, run-off, gaseous emission and fixation by soil. It is also reported that between 1 to 60% N of nutrient based fertilizers such as urea is lost through ammonia volatilization (Prasertsak et al., 2001). These losses can potentially contribute to degradation of soil and eventually lead to overall environmental degradation. These are compelling reasons of the need to increase nutrient use efficiency (NUE). Blair (1993) defined nutrient efficiency as the ability of a genotype/cultivar to acquire nutrients from growth medium and/or to incorporate or utilize them in the production of shoot and root biomass or utilizable plant material (seed, grain, leaves, bulbs). Higher NUE by plants could reduce fertilizer input costs, decrease the rate of nutrient losses, and enhance crop yields. Therefore, it is necessary to determine the nutrient content, more importantly the nitrogen and potassium contents of the plants and to identify their use efficiencies of the added nutrients in relation to bulb yields considering that chemical fertilizers are very expensive commodity for smallholder farmer. It is also necessary to develop appropriate recommendations that can be used by smallholder resource poor farmers and extension agents. Therefore, the objective of this study was to determine suitable NPK fertilizers and CFC application rates and their comparative effect on radish yield and N and K use efficiency in an acidic soil.

MATERIALS AND METHODS

Plant growth experiment

A pot experiment was carried out in the crop field of the University of Chittagong, Bangladesh using a sandy loam surface soil (0 to 15 cm). About 100 kg of moist soil was air dried and passed through 4 mm sieve for using plant growth pot experiment. For laboratory analysis, a sub sample (500 g) was air dried and passed through a 2 mm sieve and stored. Soil pH was of 5.07 (1:2.5 soil to water ratio), organic carbon (Walkley and Black, 1934) was 0.93% and CEC (extraction with 1 M NH_4OAc) (Soil Survey Laboratory Staff, 1992) was 4.01 cmol kg^{-1}. The texture of the soil used in this study was 73% sand, 13% silt and 14% clay measured by hydrometer method (Bouyoucos, 1962). CFC was obtained from the composting plant of Chittagong City Corporation, Halishahar, Chittagong and ground, sieved and analyzed for chemical properties. The pH of CFC was 7.13. Five rates of CFC equivalent to 0 (control), 5, 10, 20, 40 t ha^{-1} and three NPK fertilizer rates equivalent to 50% (N-P-K = 69-16-35 kg ha^{-1}), 100% (N-P-K = 137-32 -70 kg ha^{-1}) and 150% (N-P-K = 206 -48 - 105 kg ha^{-1}) were applied separately in each pot containing four (4) kg soil. The pots were arranged in a completely randomized design (CRD) with three replications. Eight seeds of radish were sown in each pot and water was applied to field capacity. After 15 days of emergence, 5 healthy seedlings were kept in each pot. The plants were harvested two times from the same pot. The first set comprising four plants were harvested at 45 days of growth. The last plant was harvested at 90 days of growth. At each harvest, the plants were separated into leaves and bulbs. The leaves and bulbs were dried at room temperature to remove excess water prior to oven dry at 65°C for 72 h and dry mass was recorded. Total nitrogen (N) and potassium (K) in the soil, CFC and in the plant tissues were determined by Kjeldahl and flame photometric methods, respectively after digestion with H_2O_2-H_2SO_4. Total N and K concentration in the experimental soil were 0.1 and 0.39% and in the CFC were 1.3 and 0.66%, respectively. The nutrient uptake of the plants was calculated by multiplying the nutrient concentration in the tissue and the dry matter (DM) yield. The nutrient use efficiencies such as, agronomic efficiency (response ratio) and physiological nutrient efficiency (uptake efficiency) were calculated as follows:

$$\text{Agronomic use efficiency (g/g)} = \frac{\text{Yield (T)} - \text{Yield (C)}}{\text{Quantity of applied nutrient}}$$

$$\text{Physiological use efficiency (g/g)} = \frac{\text{Yield (T)} - \text{Yield (C)}}{\text{Total nutrient uptake (T)} - \text{Total nutrient uptake (C)}}$$

Where, T and C denote treatment and control pots respectively.

Statistical analysis

Microsoft Excel and MINITAB program (Minitab, 1996) were used for statistical analysis.

RESULTS

Dry matter yield

City finished compost (CFC) and NPK fertilizer application substantially influenced the dry matter (DM) yield of radish. The DM yield of radish leaves and bulbs

Table 1. Effect of CFC and NPK fertilizer on dry matter yield (DM) of radish.

Treatment	Dry matter yield (g pot^{-1}) 45 days			Dry matter yield (g pot^{-1}) 90 days		
	Leaves	Bulbs	Total	Leaves	Bulbs	Total
Control	0.52^{c} ± 0.32	0.05^{c} ± 0.01	0.57^{d} ± 0.34	2.21^{d} ± 0.05	0.19^{d} ± 0.07	2.40^{e} ± 0.03
CFC						
5 t ha^{-1}	$1.65b^{c}$ ± 0.17	0.11^{c} ± 0.01	1.76^{cd} ± 0.16	7.60^{cd} ± 0.16	6.26^{c} ± 0.27	13.86^{d} ± 0.18
10 t ha^{-1}	2.83^{b} ± 0.21	0.23^{b} ± 0.02	3.06^{bc} ± 0.19	10.29^{c} ± 0.52	15.34^{b} ± 1.31	25.63^{c} ± 0.42
20 t ha^{-1}	3.75^{ab} ± 0.59	0.27^{ab} ± 0.01	4.02^{b} ± 0.60	25.17^{ab} ± 1.59	21.02^{a} ± 3.48	46.19^{a} ± 3.94
40 t ha^{-1}	4.77^{a} ± 0.27	0.37^{a} ± 0.06	5.14^{a} ± 0.24	28.46^{a} ± 5.12	23.92^{a} ± 0.73	52.38^{a} ± 5.10
NPK fertilizer						
50%	1.25^{c} ± 0.25	0.09^{c} ± 0.01	1.34^{c} ± 0.24	7.13^{c} ± 0.03	6.23^{c} ± 0.69	13.36^{d} ± 0.67
100%	2.64^{b} ± 0.56	0.18^{bc} ± 0.00	2.82^{c} ± 0.56	10.14^{c} ± 0.73	14.27^{b} ± 0.70	24.41^{c} ± 0.73
150%	3.92^{ab} ± 0.06	0.38^{a} ± 0.02	4.30^{b} ± 0.67	23.21^{bc} ± 4.11	15.82^{b} ± 1.77	39.03^{b} ± 4.20
Mean	2.67	0.21	2.87	14.28	12.88	27.16

Means followed by the same letter (s) in column (s) are not significantly different at $P<0.05$. '±' means standard deviation.

at 45 and 90 days of growth increased significantly ($P<0.001$) with the rates of CFC and NPK fertilizer. With the duration of growth, DM yield of radish increased but the treatment effects were found similar at both 45 and 90 days of growth (Table 1). Total DM yield of radish (leaves plus bulb) increased more than 5 folds at 45 days of growth and 20 folds at 90 days of growth by the application of 40 t ha^{-1} CFC and 150% NPK treatments, respectively over the control (Table 1).

N and K concentration in plant parts and their uptake

Both nitrogen and potassium concentration in leaves and bulbs and their uptake by radish at two stages of growth varied and increased significantly ($P<0.001$) with CFC and NPK fertilizer amendments and their application rates.

Nitrogen concentration and uptake

At 45 days of growth, N concentration in leaves of radish increased from 1.66% in control to 3.46% in 150% NPK fertilizer treated pots with a mean value of 2.57%. In bulbs, it increased from 0.48% in control to 2.76 and 150% in NPK fertilizer treated plants with a mean value of 1.66%.

At 90 days of growth, N concentration in leaves ranged from 1.58% in control to 2.68% in 40 t ha^{-1} CFC treated pots with a mean value of 2.26%. Nitrogen concentration in bulbs ranged from 0.57 to 2.76% with a mean value of 1.73% (Figure 1).

Similarly, N uptake (concentration × DM of plant) by the plant (plant parts) increased linearly with the rates of CFC and NPK fertilizer. Total N uptake (leaves plus bulbs) ranged from 0.01 to 0.15 g pot^{-1} at 45 days of growth and 0.04 to 1.43 g pot^{-1} at 90 days of growth. Plant N uptake was 8 times higher at 90 days of growth than at 45 days of growth, however, the trend of treatment effect was found similar at both stages of growth. Nitrogen uptake was 1.5 folds higher with the highest rate of CFC (40 t ha^{-1}) than the highest rate of NPK (150%) treatment at 90 days of growth. The results of 10 t ha^{-1} of CFC were comparable with the results of 100% NPK fertilizer treatment (Figure 1).

Potassium concentration and uptake

At 45 days of growth, K concentration in leaves ranged from 2.24% in control to 6.22% in 40 t ha^{-1} CFC treated pots with a mean value of 4.40%. Potassium concentration in bulbs ranged from 0.24 to 2.60% with a mean value of 1.44%. The highest K concentration of 2.60% in bulbs was obtained by the application of 40 t ha^{-1} CFC which showed significant difference with NPK fertilizer at 150%. At 90 days of growth, K concentration in leaves ranged from 2.42% in control to 5.40% in 40 t ha^{-1} CFC treated pots with a mean value of 3.95%. Potassium concentration in bulbs ranged from 1.47 to 6.79% with a mean value of 4.10% (Figure 2).

Total K uptake by plant (leaves plus bulbs) ranged from 0.01 to 0.31 g pot^{-1} at 45 days of growth and 0.06 to 3.16 g pot^{-1} at 90 days of growth. Plant K uptake was 10 times higher at 90 days of growth than at 45 days of growth, however, the trend of treatment effect was found similar at both stages of growth. Like N, potassium uptake was 1.5 folds higher with the highest rate of CFC (40 t ha^{-1}) than the highest rate of NPK (150%) treatment. The

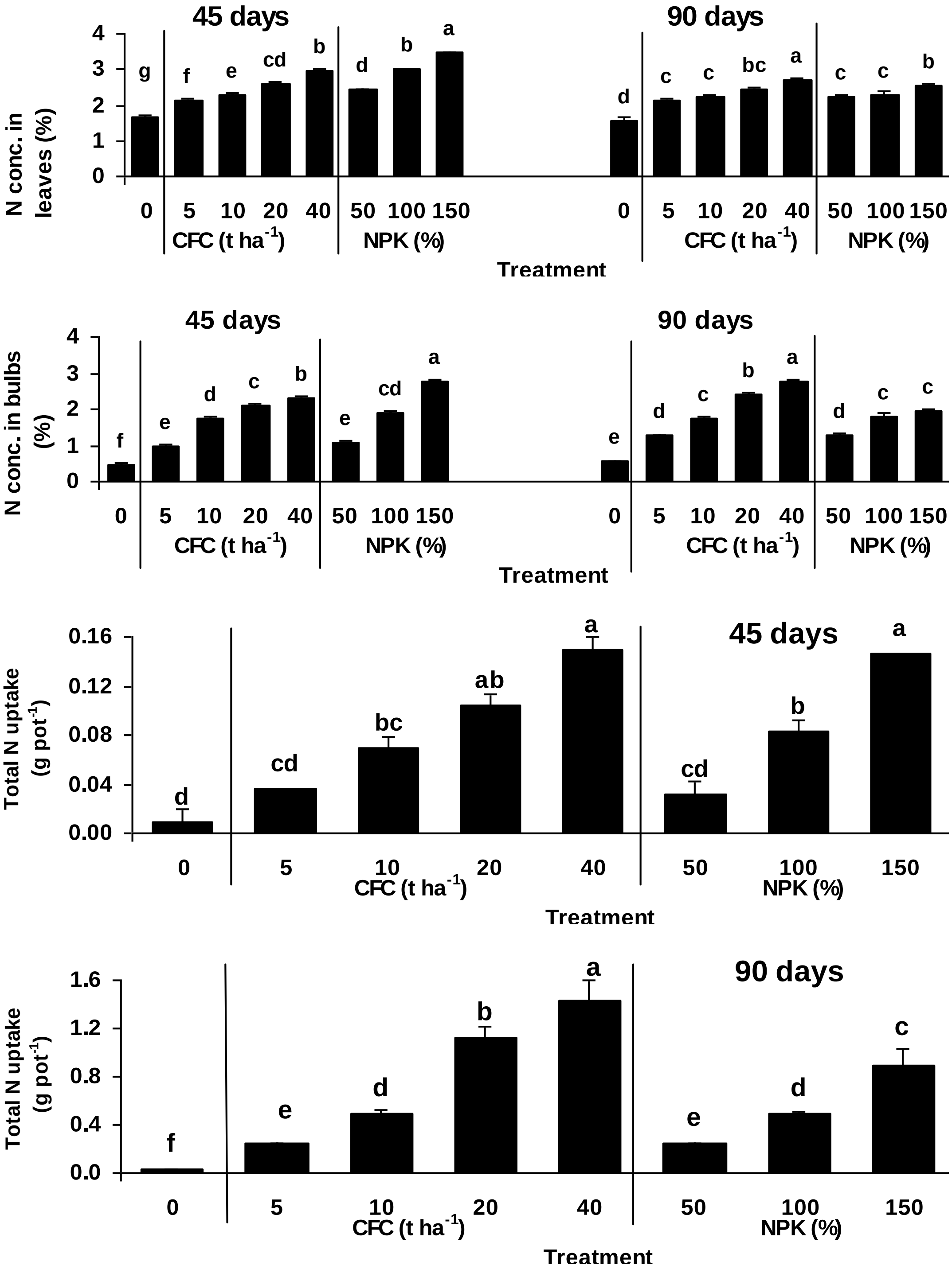

Figure 1. Effect of CFC and NPK fertilizer on nitrogen concentration in plant parts and their total uptake at 45 and 90 days of growth.

results of 10 t ha^{-1} CFC were comparable with the results of 100% NPK fertilizer treatment (Figure 2).

Nitrogen uptake was highly correlated (r = 0.99 and 0.98) with total dry matter yield and leaves yield while potassium uptake correlated strongly (r = 0.98) with total dry matter yields at later growth period.

N and K Use efficiency

City finished compost and NPK fertilizer application had significant ($p< 0.001$) effect on both nitrogen and potassium use efficiency at later stage of growth. Control treatment had no applied nutrient and thus no data to

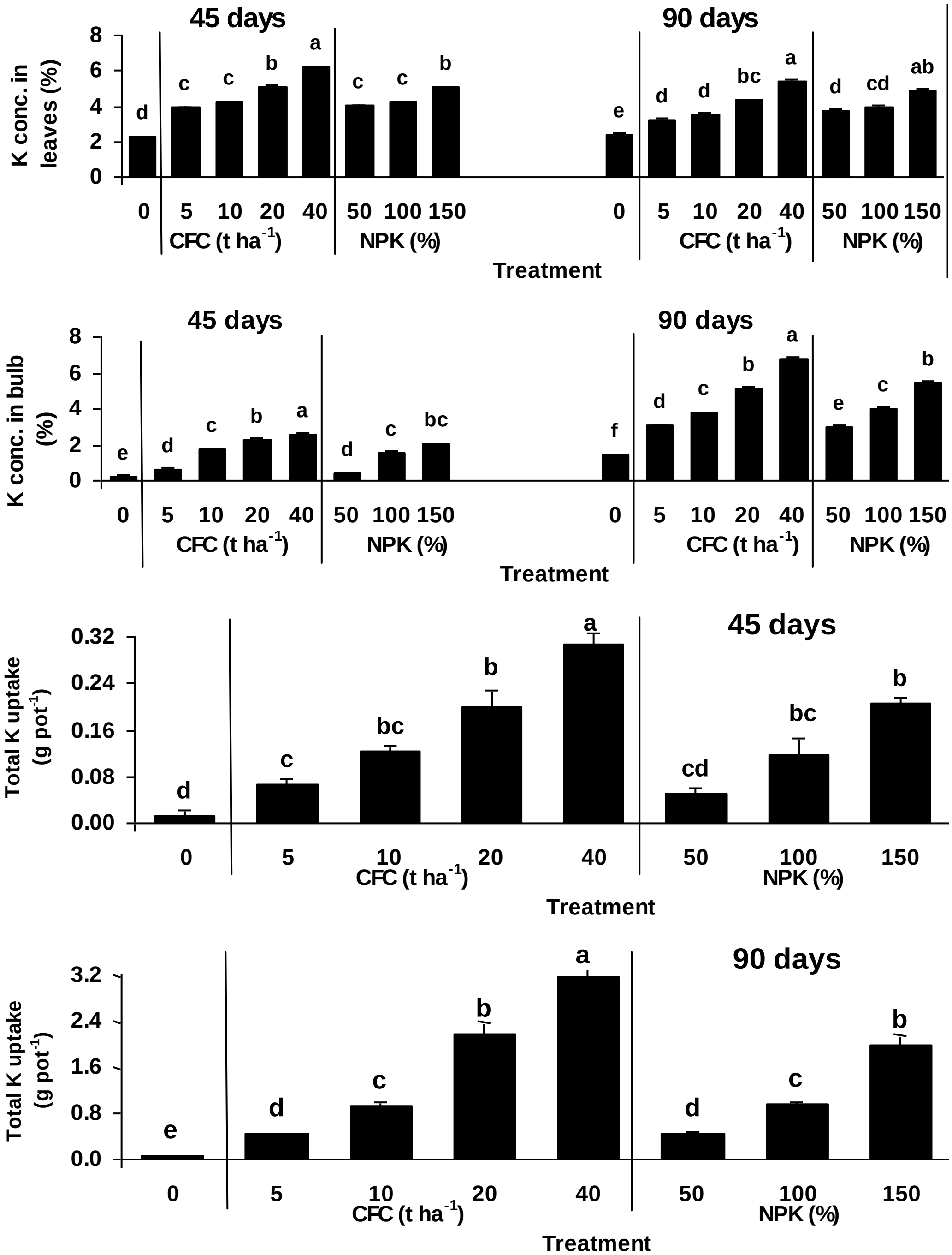

Figure 2. Effect of CFC and NPK fertilizer on potassium concentration in plant parts and their total uptake at 45 and 90 days of growth.

report (Tables 2 and 3).

Nitrogen use efficiency

At 45 days of growth, N agronomic use efficiency (NAUE) was the lowest of 0.24 g bulb per g N from 50% NPK and the highest of 0.80 g bulb per g N from 150% NPK treatment with a mean of 0.48 g bulb per g N treatment (Table 2). The NAUE was similar among the CFC treatments except 10 t ha^{-1}. The NAUE of radish bulb increased about 90 times at 90 days of growth compared with 45 days regardless of amendment and rates of application. At 90 days of growth, NAUE was the lowest of 22.81 g bulb per g N applied as 40 t ha^{-1} and highest of 58.26 g bulb per g N applied as the 10 t ha^{-1} CFC

Table 2. Effect of CFC and NPK fertilizer on nitrogen use efficiency of radish bulb.

Treatment	Agronomic use efficiency (g dry bulb/ g N applied)		Physiological use efficiency (g dry bulb/ g N taken up)	
	45 days	**90 days**	**45 days**	**90 days**
Control	-	-	-	-
CFC				
5 t ha^{-1}	0.46^{b} ± 0.09	46.64^{b} ± 2.07	2.25^{b} ± 0.67	29.77^{a} ± 1.55
10 t ha^{-1}	0.67a^{b} ± 0.09	58.26^{a} ± 5.05	2.91^{a} ± 0.60	32.75^{a} ± 1.18
20 t ha^{-1}	0.42^{b} ± 0.02	40.05^{bc} ± 6.70	2.35^{b} ± 0.24	19.05^{b} ± 2.03
40 t ha^{-1}	0.30bc ± 0.06	22.81d ± 0.70	2.24^{b} ± 0.50	17.23^{b} ± 2.09
NPK fertilizer				
50 %	0.24^{c} ± 0.08	43.10^{b} ± 4.93	1.66^{b} ± 1.13	29.68a ± 1.42
100%	0.47^{b} ± 0.00	52.14^{ab} ± 2.59	1.78^{b} ± 0.36	31.47^{a} ± 2.84
150%	0.80^{a} ± 0.05	38.12^{c} ± 4.31	2.38^{ab} ± 0.16	18.40^{b} ± 2.79
Mean	0.48	43.02	2.22	25.48

Means followed by the same letter (s) in column (s) are not significantly different at $P<0.05$; '±' means standard deviation.

Table 3. Effect of CFC and NPK fertilizer on potassium use efficiency of radish.

Treatment	Agronomic use efficiency (g dry bulb/ g K applied)		Physiological use efficiency (g dry bulb/ g K taken up)	
	45 days	**90 days**	**45 days**	**90 days**
Control	-	-	-	-
CFC				
5 t ha^{-1}	0.91^{b} ± 0.18	91.87^{bc} ± 4.07	1.14^{b} ± 0.31	15.65^{ab} ± 0.64
10 t ha^{-1}	1.33^{a} ± 0.19	116.51^{a} ± 10.10	1.56^{a} ± 2.26	17.15^{a} ± 0.72
20 t ha^{-1}	0.85b^{c} ± 0.04	80.10^{bc} ± 13.40	1.20^{b} ± 0.19	9.77^{bc} ± 0.90
40 t ha^{-1}	0.59^{c} ± 0.12	44.76d ± 1.37	1.07^{b} ± 0.25	7.69^{c} ± 0.65
NPK fertilizer				
50 %	0.48^{c} ± 0.17	86.19^{bc} ± 9.85	0.95^{b} ± 0.64	15.04^{b} ± 0.83
100%	0.90^{b} ± 0.00	91.02^{ab} ± 5.0	1.26^{b} ± 0.28	15.38^{ab} ± 0.53
150%	1.56^{a} ± 0.10	74.43^{c} ± 8.41	1.67^{a} ± 0.06	8.08^{c} ± 0.99
Mean	0.95	84.92	1.26	12.68

Means followed by the same letter (s) in column (s) are not significantly different at $P<0.05$; '±' means standard deviation.

treatments with a mean of 43.02 g bulb per g N applied (Table 2).

Nitrogen physiological use efficiency (NPUE) in radish bulb decreased with the rates of CFC and NPK fertilizer application rates at 90 days of growth. The NPUE values varied from 1.66 g bulb per g N taken up from 50% NPK to 2.91 g bulb per g N taken up from 10 t ha^{-1} treatments (Table 2) at 45 days and no variation occurred among the treatment levels except 10 t ha^{-1} CFC and 150% NPK treatments. At 90 days of growth, NPUE values were at lease 10 times higher than the values obtained from 45 days of growth and gradually decreased with application rates. The results of 10 t ha^{-1} of CFC were comparable with the results of 100% NPK fertilizer treatment at 90 days of growth (Table 2).

Potassium use efficiency

Similar to nitrogen, K agronomic use efficiency (KAUE) at 45 days of growth was very small (0.48 to 1.56 g bulb per g K application) and was not consistent with rates of amendments. At 90 days of growth, the KAUE values (44.8 to 117 g bulb per g K application) increased > 80 times compared with 45 days of growth and decreased with rates of NPK and CFC application (Table 3). The potassium physiological use efficiency (KPUE) was smaller (0.95 to 1.67 g bulb per g K taken up) and also simillar to N physiological use efficiency in respect to treatment effect at 45 days but at 90 days of growth, the KPUE values (7.69 to 17.15 g bulb per g N uptake) increased at >10 times compared to 45 days of growth and decreased with rates of amendments (Table 3).

DISCUSSION

Comparatively compost showed better plant growth and higher nutrient uptake by radish than NPK fertilizer treatments with increasing the growing period. This is understandable as organic matter improves soil physical, chemical and biological properties as well as supplying additional plant nutrients (Wang et al., 1984). Maynard (1994) also reported that well composted organic amendments with a narrow C: N ratio might release nutrients in better synchrony with plant growth demand and give higher yields. Irrespective of treatment levels, both CFC and NPK fertilizer applications influence the total dry matter accumulation thereby affecting the nutrient demand (uptake/utilization) in comparison with control treatment.

Fertilizer nutrients applied, but not taken up by the crop, are vulnerable to losses through leaching, erosion, and denitrification or volatilization in the case of N, or they could be temporarily immobilized in soil organic matter in case of K to be released at a later time, all of which impact nutrient use efficiency (Roberts, 2008). The increase in agronomic efficiencies with time recorded in this study resulted in greater utilization of applied nutrients in organic systems. Nutrients in compost were probably taken up by the radish more efficiently than NPK fertilizer due to slower release from mineralization and lower gaseous N losses. This also could be due to the release of fixed mineral which is made available because of favourable microbial activity leading to the enhancement of the soil nutrient use efficiency (Son et al., 2000).

Compare to NAUE, the KAUE is greater at both stages of growth. Such low nutrient efficiency may be related to N losses from soil via denitrification and ammonia volatilization (Craswell and Vlek, 1979). There is little information available about potassium (K) use efficiency. However, it is generally considered to have higher agronomic use efficiency than N because it is immobile in most soils and is not subject to the gaseous losses like N (Roberts, 2008). On the other hand, the NPUE is greater than KPUE as the uptake of K is more than the uptake of N. This premise is supported by the fact of N contents in leaves and bulbs and total N up-take by radish plant. This may be as the slow and steady release of nutrients from compost matched the crop uptake sparing not as much nutrients for fixation by soil clays or for losses as from NPK sources resulting in enhanced K uptake from the compost by radish (Jagadeeswaran et al., 2005).

Among different treatments, increasing the levels up to 10 t ha^{-1} CFC and 100% NPK, the nutrient use efficiency was increased. Further, increasing the nutrient levels, both agronomic and physiological nutrient use efficiencies were decreased. This suggests that higher nutrient addition was excessive and results luxury nutrient uptake. It may be due to the application of excess nutrients, which was not effectively utilized by the crop and the rate of production was lesser per unit of nutrients application (Senthil et al., 2008). In the case of higher rates of CFC (> 10 t ha^{-1}) and NPK fertilizers (>100%), the volume of the experimental soil, with which these fertilizer materials were in contact on application was large, evidently nutrient reversion reactions have occurred at a faster rate resulting in the fixation of applied nutrients in amounts of higher magnitude (Jagadeeswaran et al., 2005) as compared to the lower rates of CFC and NPK fertilizers.

Conclusion

Dry matter yield, nutrients concentration, nutrients uptake by plant increased with increasing rates of CFC and NPK fertilizers and agronomic and physiological use efficiency increased with decreasing rates of CFC and NPK fertilizers. The yield response and nutrient use efficiency of 10 t ha^{-1} CFC was similar to that of 100% NPK treatment and hence 10 t ha^{-1} CFC would be recommended to produce optimum yield instead of 100% NPK. Results of the present study, also suggest the need to investigate the effect of CFC and NPK in more detail using different soils and crops in field condition.

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