Australian Journal of Basic and Applied Sciences, 1(4): 706-716, 2007
ISSN 1991-8178

Effect of Vermicompost and NPKS Fertilizers on Growth, Yield and Yield Components of Red Amaranth

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Abstract: The experiment was conducted to evaluate the effect of vermicompost and NPKS fertilizers on growth and yield of red amaranth in "Level Barind Tract (AEZ-25)" soils of Bangladesh during the period from November 2001 to January 2002. The land was medium fertile and P^H was 5.4. There were 12 treatments viz. control (T_1), vermicompost (VC) 2.5 t/ha (T_2), VC 5.0 t/ha (T_3), VC 10.0 t/ha (T_4), VC 2.5 t/ha+50% NPKS (T_5), VC 5 t/ha+50% NPKS (T_6), VC 10 t/ha+50% NPKS (T_7), VC 2.5 t/ha+100% NPKS (T_8), VC 5 t/ha+100% NPKS (T_9), VC 10 t/ha+100% NPKS (T_{10}), 50% NPKS (T_{11}) and 100% NPKS (T_{12}). The experiment was laid out in RCBD with three replications and 100% doses of N-P-K-S were 25-15-20-9 kg/ha. Application of vermicompost and NPKS significantly influenced the growth and yield of red amaranth. The 10 t/ha vermicompost showed better growth and yield than 100% NPKS (T_{12}) in red amaranth. The highest yield (13.25 t/ha) of red amaranth was found in T_7 followed by T_{10} (13.17 t/ha) but both are statistically similar and lowest in control (T_1). Application of various amounts of vermicompost (2.5, 5, 10 t/ha) with NPKS fertilizers (50% and 100%) increased the vegetative growth and yield of red amaranth. The highest yield increased by T_7 (307.1%) followed by T_{10} (305.7%). The yield of red amaranth was strongly correlated with total dry matter (r = 0.994**), plant height (r = 0.967**), leaf length (r = 0.951**) and also stem length (r = 0.937**). The results showed that effects of vermicompost are more efficient for the vigorous production of red amaranth. It is also suggested that vermicompost (10 t/ha) + NPKS (50%) is more favorable for vigorous production of red amaranth and maintenance of soil environment but vermicompost (5 t/ha) + NPKS (100%) can be economically and environmentally suitable.

Key words: Red amaranth, Vermicompost, Growth, Yield, NPKS fertilizer, Wastes management

INTRODUCTION

Amaranth (*Amaranthus tricolor* L.) plays an important role in nutrition among the leafy vegetables grown in Bangladesh. The leafy amaranth is said to be the native of India (Shanmugavelu, 1989 and Nath, 1976). Among the leafy types, *Amaranthus tricolor* L. is the most commonly cultivated species in Bangladesh. It is cultivated all over the country in any season due to its adaptability to wide range of soil and climate. However, during winter its growth and development is slower than summer and rainy season (Bose *et al*., 1993).

Growth, yield and quality of red amaranth depend on nutrient availability in soil, which is related to the judicious application of manures and fertilizers. Nutrients may be applied through two sources viz. organic and inorganic sources. Increased use of inorganic fertilizers in crop production deteriorates soil health, causes health hazard and cerates imbalance to environment by polluting air, water, soil etc. The continuous use of chemical fertilizers badly affects the texture and structure, reduces organic matter content and decreases microbial activities of soil.

A good soil should have an organic matter content of more than 3% . But in Bangladesh, most soils have less than 1.5%, some soils have less than 1% organic matter (BARC, 1997). In continuous cropping area, organic matter supply to the crop field through different manuring practices is made only to a minimum extent (Islam and Hossain, 1992).

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Now-a-days gradual deficiencies in soil organic matter and reduced yield of crop are alarming problem in Bangladesh. The cost of inorganic fertilizers is very high and sometimes it is not available in the market for which the farmers fail to apply the inorganic fertilizers to the crop field in optimum time. On the other hand, the organic manure is easily available to the farmers and its cost is low compared to that of inorganic fertilizers. The crop production cost is more or less similar with organic and inorganic fertilizer (Haque, 2000), the use of readily available organic sources of nutrients should be used to maximize the economic return. Vermicompost is a good source of different macro and micronutrients particularly NPKS. Use of vermicompost for vegetable production in large scale can solve the problem for disposal of wastes and also solve the lack of organic matter. On the other hand, a judicious combination of organic and inorganic sources of nutrients might be helpful to obtain a good economic return with good soil health for the subsequent crop.

Earthworms are one of the important and dominant soil fauna of class Oligochaeta under Annelida phylum and are well known for their contribution to soil formation and wide spread global distributions (Kale, 1998). Earthworms consume large quantities of organic matter excrete soil as cast and this cast have several enzymes and rich in plant nutrients, beneficial bacteria and mycorrhizae (Reddy and Reddi, 2002). They also noted that vermicompost is an excellent base for the establishment of beneficial non-symbiotic and symbiotic microbes. Application of vermicompost increases the total microbial population of N-fixing bacteria and actinomycetes. The increased microbial activity improves the availability of soil phosphorous and nitrogen. Vermiculture is the science of rearing of earthworms for mass propagation on organic wastes under semi-natural conditions and vermicomposting is the bioconversion of organic waste materials through earthwormic way (Senapati, 1992). Senesi *et al.* (1996) mentioned that vermicomposting is a controlled, aerobic, biological process and able to convert biodegradable humus like organic substances and suitable for the application of soil amendment. On the other hand, vermicompost or vermifertilizer is the composting of organic wastes by the action of earthworm into a semi-natural and controlled condition.

Asiegbu and Oikeh (1995) found that NPK fertilizers were more efficient than the organic manures in supplying N, P and K at least in the short run, while the organic manure had an advantage in supply of other macro and micro nutrient elements not contained in NPK fertilizer. Noor *et al.* (2002) suggested that addition of 10t/ha cowdung instead of 50% recommended dose of chemical fertilizer can able to produce satisfactory higher yield of cauliflower.

Several workers stated that application of N, P, K or organic manure increased yield of vegetables. But there is no available research information about the effect of vermicompost and NPKS fertilizers on yield of red amaranth. Recently, few researches worked on vermicompost (Tomar *et al.*, 1998 in carrot; Saikia *et. al.*, 1998 in potato; Upadhayay *et al.*, 2003 in potato; Bongkyoon, 2004 in potato, Alam, 2005 in carrot etc.). Conditions are looking however, information regarding the use of NPKS and vermicompost alone or in combination on the yield of red amaranth. So, the present investigation was undertaken to study the effect of vermicompost and NPKS fertilizers on growth, yield and yield components of red amaranth in Barind soils of Bangladesh.

MATERIALS AND METHODS

The experiment was carried out in the "Level Barind Soil" (FAO, 1988) during rabi season from November 2001 to January 2002 to study the effect of vermicompost and NPKS fertilizers on growth, yield and yield components of red amaranth (cv. Altapati). There were 12 treatments viz. T_1= Control, T_2=Vermicompost (2.5 t/ha), T_3= Vermicompost (5.0 t/ha), T_4=Vermicompost (10.0 t/ha)+ NPKS (50%), T_7= Vermicompost (10.0 t/ha)+ NPKS (50%), T_8= vermicompost (2.5 t/ha)+NPKS (100%), T_9=Vermicompost (5.0 t/ha) +NPKS (100%), T_{10}= Vermicompost (10.0 t/ha) +NPKS (100%), T_{11}= NPKS (50%) and T_{12}= NPKS (100%). Three crop experiments were laid out in RCBD with 3-replications. Soil analysis was done for particle size distribution by Hydrometer method and other parameters by ASI method (Hunter, 1984). Table 1 showed that the soil was medium fertile with very low content of N, P and pH was 5.4. The doses of N-P-K-S were 25-15-20-9 kg/ha. The whole amount of vermicompost, TSP, MP, gypsum and 50% of urea were applied at final land preparation. The rest of urea was applied at 20 days after sowing seeds. The unit plot size was 1.6 m ´1.25 m. The red amaranth seeds were sown on 20 November 2001. Weeding, irrigation, drainage and other intercultural operation were done when necessary. Data on growth, yield and yield contributing parameters were recorded and statistically analyzed with the help of computer package MSTAT-C and also tested DMRT (Ressel, 1996). The correlation matrix was analyzed by SPSS program.

Production of Vermicompost:

Vermicompost was produced by using following vermicomposting pit method:

Table 1: Initial soil characteristics of experimental field soil (0-15cm)

Texture	P^H	OM%	Total N%	meq/100g			mg/kg						
				Ca	Mg	K	P	S	Fe	Cu	Mn	Zn	B
Loam	5.4	1.03	0.07	3.73	1.30	0.11	11.6	15.4	12.6	0.70	3.90	1.20	0.40
			(VL)	(OP)	(M)	(L)	(VL)	(L)	(H)	(M)	(H)	(OP)	(M)
Critical level*	-	-	0.12	2.0	0.80	0.20	14	14	4.0	0.20	1.0	0.60	0.20

* According to BARC (1997). VL= Very low, L= Low, M= Medium, OP= Optimum, H= High, VH= Very high.

Nutrient Content of Applied Vermicompost (Air Dry Basis):

The following parameters were analyzed by ASI method (Hunter, 1984)

Parameters	Value
P^H	7.20
Organic carbon (%)	43.6
Total N (%)	2.30
Total P (%)	1.10
Total K(%)	1.40
Total S(%)	0.44
Ca (%)	1.30
Mg (%)	0.60
Na (%)	0.20
Fe (%)	0.30
Mn (ppm)	117
Cu (ppm)	105
Zn (ppm)	56
B (ppm)	22

RESULTS AND DISCUSSIONS

Plant Height:

The plant height is the major important yield contributing parameter of red amaranth. The plant height was recorded at different growth periods i.e. at 17, 24, 31, 38 and 45 days after sowing (Table 2). The plant height was increased significantly due to the application of different doses of vermicompost and inorganic fertilizers alone or their combinations. The plant height was increased gradually with increase of growth periods.

Table 2: Effect of vermicompost and NPKS fertilizers on plant height of red amaranth at different days after sowing

Treatments	Plant height (cm) at				
	17 DAS	24 DAS	31 DAS	38 DAS	45 DAS
T_1 = Control	5.26 h	6.10 g	7.33 i	9.06 i	10.80 f
T_2 = VC(2.5 t/ha)	5.63 g	7.33 f	9.53 h	12.33 i	16.30 e
T_3 = VC(5 t/ha)	6.30 f	9.10 de	11.60 f	14.43 g	19.68 d
T_4 = VC(10 t/ha)	6.60 e	11.60 c	17.76 d	19.86 e	26.56 b
T_5 = VC(2.5 t/ha) + NPKS (50%)	6.16 f	8.80 e	12.63 e	14.30 g	19.96 d
T_6 = VC(5 t/ha) + NPKS (50%)	7.10 d	12.90 b	17.46 d	19.63 e	26.20 b
T_7 = VC(10 t/ha) +NPKS (50%)	8.76 a	14.03 a	21.53 b	25.60 b	31.83 a
T_8 = VC(2.5 t/ha) + NPKS (100%)	7.43 c	13.33 b	19.90 c	22.20 d	24.13 c
T_9 = VC(5 t/ha) + NPKS (100%)	7.83 b	13.76 b	20.86 b	23.60 c	27.47 b
T_{10} = VC(10 t/ha) + NPKS (100%)	8.93 a	14.36 a	22.70 a	26.50 a	31.23 a
T_{11} = NPKS (50%)	6.40 ef	8.73 e	10.50 g	13.50 h	15.67 e
T_{12} = NPKS (100%)	7.30 cd	9.43 d	12.80 e	15.13 f	18.53 d
LSD	0.2813	0.5022	0.7172	0.633	1.591
CV (%)	6.82	7.10	4.13	6.58	5.20

In a column, figures having same letter(s) do not differ significantly by DMRT at the 5 % level.

At 17 DAS, the plant height was significantly influenced by treatments. The plant height ranged from 5.26cm to 8.93cm. The highest plant height was recorded in T_{10} treatment having 8.93cm followed by T_7 (8.76cm) but they are statistically similar. The shortest plant height (5.26cm) was grown by the control.

Application of vermicompost 2.5, 5.0 and 10.0 t/ha gave the plant height of 5.63, 6.30 and 6.60cm. The increasing rates of vermicompost (2.5, 5.0 and 10.0 t/ha) plus 50% recommended doses of NPKS fertilizers (RDF) produced plant height of 6.16cm (T_5), 7.10cm (T_6) and 8.76cm (T_7). On the other hand, 100% NPKS with increasing rates of vermicompost obtained 7.43 (T_8), 7.83 (T_9) and 8.93cm (T_{10}) respectively. It was concluded that chemical fertilizers are more favorable in earlier stages of crop growth.

At 24 DAS, the highest plant height was found (14.36 cm) by T_{10} and T_{10} is statistically similar with T_7 treatment. The shortest plant height (6.10cm) was recorded in control.

After passing one month or at 31 DAS, the plant height ranged from 7.33 to 22.70cm. The highest plant height (22.70cm) was found in T_{10} and the second highest plant height (22.53cm) in T_7 treatment and lowest (7.33cm) in control. The statistically similar plant height was recorded of 17.76cm and 17.46cm respectively by 10 t/ha of vermicompost (T_4) and by 5.0 t/ha vermicompost + 50% NPKS respectively. Similarly, application of 2.5 t/ha vermicompost + NPKS (50% or 100%) produced the statistically similar plant height of 12.63cm and 12.80cm, respectively.

At 38 DAS, there was significant variation of plant height in different treatments. The highest plant height was observed in T_{10} (26.50cm) followed by T_7 (25.60cm). The shortest plant height (9.06cm) was produced by the control treatment.

The highest plant height (31.83cm) at 45 DAS (or harvest) was found in T_7 (vermicompost 10 t/ha + NPKS of 50%), which was statistically similar with T_{10} (vermicompost 10 t/ha + NPKS of 100%). This finding strongly agreed with Alam (2005), who stated that vermicompost (10 t/ha) with NPKS 50% or 100% produced the statistically similar and highest plant height in carrot. The shortest plant height (10.80cm) was recorded in control (T_1). However, there are no significant difference among treatments T_3, T_5 and T_{12}; T_4, T_6 and T_9; T_2 and T_{11} at 45 DAS. Ali and Jahan (2001) found that application of vermicompost with NPK significantly increased the plant growth of sesame and lady's finger.

It is noted that chemical fertilizers are more efficient than vermicompost within one month and after one month the effects of vermicompost are more favorable than chemical fertilizers. Asiegbu and Oikeh (1995) reported that chemical fertilizers (NPK) were efficient than the organic manures in the short run.

The results are in agreement with the findings of Alam (2006) and Azad (2000), who stated that combined application of manures and chemical fertilizers performed the highest plant height of cabbage. Bonkyoon (2004) reported that the plant height of potato was higher in the plots where earthworm casts (vermicompost) and NPK fertilizers were applied than in the control plot. Application of N, P, K and S significantly increased plant height of broccoli also reported by Anwar *et al*. (2001) and Kadir (2002).

Number of Leaves per Plant:

The number of leaves/plant is an important yield contributing parameter of red amaranth. The number of leaves/plant showed significant variations by the applications of treatments at different DAS (Tables 3). The number of leaves was increased gradually with time and reached its peak at harvest (45DAS) in respect of all treatments.

Table 3: Effect of vermicompost and NPKS fertilizers on leaves per plant of red amaranth at different days after sowing

Treatments	Number of Leaves plant^{-1} at				
	17 DAS	24 DAS	31 DAS	38 DAS	45 DAS
T_1 = Control	5.13 i	6.20 f	6.80 f	7.36 h	7.76 h
T_2 = VC(2.5 t/ha)	5.43 h	6.60 e	7.20 f	7.80 g	8.36 g
T_3 = VC(5 t/ha)	6.33 f	7.73 d	8.06 e	8.73 e	9.93 d
T_4 = VC(10 t/ha)	6.86 d	8.00 c	8.60 cd	9.33 c	10.16 cd
T_5 = VC(2.5 t/ha) +NPKS (50%)	6.60 e	7.90 cd	8.23 de	8.40 f	8.93 f
T_6 = VC(5 t/ha) + NPKS (50%)	7.00 cd	8.36 b	8.80 bc	9.10 d	9.46 e
T_7 = VC(10 t/ha) + NPKS (50%)	7.36 ab	8.43 b	9.13 ab	9.66 b	10.90 b
T_8 = VC(2.5 t/ha) +NPKS (100%)	7.20 bc	8.26 b	8.56 cd	8.80 e	10.33 c
T_9 = VC(5 t/ha) + NPKS (100%)	7.23 bc	8.40 b	8.66 bcd	9.73 ab	10.63 b
T_{10} = VC(10 t/ha) + NPKS (100%)	7.50 a	8.66 a	9.40 a	9.93 a	11.43 a
T_{11} = NPKS (50%)	5.76 g	6.66 e	6.86 f	7.60 g	8.20 g
T_{12} = NPKS (100%)	6.76 de	7.76 d	8.40 e	8.63 e	8.93 f
LSD	0.2333	0.1989	0.4503	0.2224	0.2984
CV (%)	2.58	3.17	2.46	3.15	4.42

In a column, figures having same letter(s) do not differ significantly by DMRT at the 5% level.

At 17 DAS, the number of leaves per plant ranged from 5.13 to 7.50. The maximum number of leaves /plant (7.50) was observed in T_{10} followed by T_7. The minimum number of leaves per plant was found in the control (T_1). At 24 DAS, number of leaves per plant ranged from 6.20 to 8.66. The maximum number of leaves (8.66) per plant was recorded in T_{10} treatment. The second highest and statistically similar number of leaves was observed from T_6 to T_9 treatments. The lowest (6.20) number of leaves per plant was in control.

At 31 DAS, the number of leaves per plant in different treatments ranged from 6.80 to 9.40. The lowest and statistically similar number of leaves per plant was observed in T_1, T_2 and T_{11} treatments. The maximum number of leaves (9.40) was produced by T_{10} treatment. The treatments T_6, T_7 and T_9 did not differ significantly with regard to number of leaves per plant. Similarly, T_4 was similar to T_8 and T_9. The application of 5 t/ha of vermicompost (T_3) produced the number of leaves per plant (8.06), which was statistically similar (8.40) with 100% NPKS (T_{12}).

At 38 DAS, the highest number of leaves (9.93) was also observed in T_{10} treatment, which was similar to T_9. The similar leaves per plant were found between T_3, T_8 & T_{12}, and T_2 with T_{11}.

The maximum number of leaves (11.43) was obtained by adding 10 t/ha vermicompost + NPKS (100%) (T_{10}) and followed by 10 t/ha of vermicompost + 50% NPKS (Table-5). But treatment T_7 and T_9 did not differ significantly. Application of increasing rates of vermicompost (0, 2.5, 5, 10 t/ha) produced the number of leaves per plant of 7.76, 8.36, 9.93 and 10.16, respectively (T_1 to T_4). However, treatment T_3 and T_4 are similar with regard to leaves per plant.

At harvest (45 DAS), the number of leaves per plant was more than previous growth period. Application of vermicompost and NPKS at different doses along or their combinations markedly influenced the number of leaves per plant. The number of leaves per plant in different treatments ranged from 7.76 to 11.43.

The treatment T_4 was similar to T_8 that produced 10.16 and 10.33 of leaves per plant respectively. Application of 2.5 t/ha of vermicompost (T_2) and NPKS of 50% (T_{11}) produced the statistically similar number of leaves per plant. On the other hand, application of 2.5 t/ha vermicompost + NPKS 50% and NPKS (100%) performed similar number of leaves per plant.

The results were in agreement with the findings of Asiegbu and Oikeh (1995). Application of 8-10 t/ha vermicompost tended to increased tuber diameter, number of stems/plant and chlorophyll level of potato plant (Bongkyoon, 2004).

Kabir (1998) and Azad (2000) mentioned that the maximum number of loose leaves in cabbage plant was obtained when organic manures and inorganic fertilizers were used in combination. Anwar *et al*. (2001) noted that application of N, P, K and S significantly increased the number of leaves/ plant of broccoli.

Largest Leaf Length:

Largest leaf length is the indicator of plant size as well as yield of red amaranth. Significant effect of different treatments was observed on the leaf length at growth period (Table 4). It was found that leaf length was increased gradually with the increase of growth period.

At 17 DAS, the leaf length varied significantly by the application of different doses of vermicompost and NPKS of 50% or 100% alone or in combination. The application of vermicompost (10 t/ha) + NPKS (100%) produced maximum length of leaf (4.26cm) and followed by vermicompost (5 t/ha) + NPKS (100%) of 4.03cm. The treatment T_3 (vermicompost 5 t/ha) is similar to T_{12} (100% NPKS) and T_4 with T_8. The smallest leaf length (2.50cm) was found in control (T_1).

At 24 DAS, the leaf length was increased rapidly than 17 DAS in respect of all treatments. The highest leaf length was found in T_{10} followed by T_7 and the lowest was in control. The treatment T_7 is similar to T_9. In growth period within 24 days, the response of chemical fertilizer is more efficient than vermicompost.

At 31 DAS, the largest leaf length ranged from 4.16cm to 8.36cm. The highest leaf length 8.36cm was obtained with T_{10}. The T_{10} is statistically similar to T_7. The second highest leaf length (7.50cm) was recorded by the application of vermicompost (5 t/ha) + NPKS (100%). The treatment T_2 (vermicompost 2.5 t/ha) is similar to T_1 and T_{11}.

At 38 DAS, the leaf length increased significantly by treatments. The application of different treatments produced the leaf length from 4.63cm to 9.06cm. The highest leaf length of 9.06cm was found by adding vermicompost (10 t/ha) + 50% NPKS, which is statistically similar by vermicompost (10 t/ha) + 100% NPKS (T_{10}). The lowest leaf length was found in control. The treatments T_1, T_2 and T_{11} are also statistically similar. Similarly, T_5 is similar with T_{12} and T_8 is similar with T_4 & T_6.

At 45 DAS, the largest leaf length of red amaranth remarkable influenced due to the application of treatments. The leaf length ranged from 5.05cm to 10.10cm. The treatment T_7 caused the maximum leaf

Table 4: Effect of vermicompost and NPKS fertilizers on largest leaf length of red amaranth at different days after sowing

Treatments	Largest leaf length (cm) at				
	17 DAS	24 DAS	31 DAS	38 DAS	45 DAS
T_1 = Control	2.50 h	3.30 g	4.16 g	4.63 f	5.04 f
T_2 = VC(2.5 t/ha)	2.70 gh	3.60 h	4.43 g	4.86 f	5.40 f
T_3 = VC(5 t/ha)	3.10 f	4.23 e	5.36 ef	5.50 g	7.33 d
T_4 = VC(10 t/ha)	3.50 de	5.43 c	7.06 c	7.83 c	8.63 c
T_5 = VC(2.5 t/ha) +NPKS (50%)	3.33 ef	4.10 e	5.10 f	6.20 d	7.10 d
T_6 = VC(5 t/ha) + NPKS (50%)	3.70 cd	5.10 d	6.53 d	7.46 c	8.23 c
T_7 = VC(10 t/ha) +NPKS (50%)	3.93 bc	6.20 b	8.20 a	9.06 a	10.10 a
T_8 = VC(2.5 t/ha) + NPKS (100%)	3.50 de	5.26 cd	6.80 cd	7.90 c	8.50 c
T_9 = VC(5 t/ha) + NPKS (100%)	4.03 ab	6.00 b	7.50 b	8.40 b	9.16 b
T_{10} = VC(10 t/ha) + NPKS (100%)	4.26 a	6.63 a	8.36 a	8.83 ab	9.80 a
T_{11} = NPKS (50%)	2.80 g	3.46 fg	4.36 g	4.66 f	5.20 f
T_{12} = NPKS (100%)	3.20 f	4.26 e	5.50 e	6.30 d	6.50 e
LSD	0.2631	0.2631	0.3145	0.4821	0.5263
CV (%)	5.47	4.45	6.33	5.18	8.12

In a column, figures having same letter(s) do not differ significantly by DMRT at the 5% level

Table 5: Effect of vermicompost and NPKS fertilizers on largest leaf breadth of red amaranth at different days after sowing

Treatments	Largest leaf breadth (cm) at				
	17 DAS	24 DAS	31 DAS	38 DAS	45 DAS
T_1 = Control	1.86 g	2.44 h	3.10 g	3.56 g	4.03 i
T_2 = VC(2.5 t/ha)	2.23 f	2.90 fg	3.73 ef	4.03 ef	4.56 gh
T_3 = VC(5 t/ha)	2.43 e	3.16 e	4.10 de	4.30 e	5.13 f
T_4 = VC(10 t/ha)	2.73 c	3.60 c	4.26 cde	5.50 c	6.40 d
T_5 = VC(2.5 t/ha) + NPKS (50%)	2.46 e	3.03 e	4.10 de	4.73 d	5.00 f
T_6 = VC(5 t/ha) + NPKS (50%)	2.76 c	3.40 d	4.56 bcd	5.00 d	5.80 e
T_7 = VC(10 t/ha) + NPKS (50%)	3.13 b	4.16 b	4.73 bc	6.70 a	8.63 a
T_8 = VC(2.5 t/ha) + NPKS (100%)	2.66 cd	3.73 c	4.53 bcd	5.70 c	7.23 c
T_9 = VC(5 t/ha) + NPKS (100%)	3.16 b	4.00 b	4.90 b	6.03 b	7.46 bc
T_{10} = VC(10 t/ha) + NPKS (100%)	3.40 a	4.40 a	5.43 a	6.46 a	7.73 b
T_{11} = NPKS (50%)	2.10 f	2.73 g	3.40 fg	3.83 fg	4.30 hi
T_{12} = NPKS (100%)	2.53 de	3.40 d	3.80 ef	4.23 e	4.76 fg
LSD	0.1861	0.1723	0.5216	0.3066	0.4040
CV (%)	3.09	4.35	5.56	4.91	7.07

In a column, figures having same letter(s) do not differ significantly by DMRT at the 5% level

length (10.10cm) which was statistically identical with the treatment T_{10} but significantly different from the rest treatments. The results reveal that vermicompost (10 t/ha) with 50% or 100% recommended dose of NPKS fertilizers influenced markedly on the leaf length. Application of 50% and 100% doses of NPKS fertilizers produced leaf length of 5.20cm and 6.50cm, respectively. The treatments T_1, T_2 and T_{11} are statistically similar leaf length and treatment T_4 is similar with T_6 and T_8.

The results are in agreement partially with Asieghu and Oikeh (1995), Kabir (1998), Azad (2000) and Upadhayay *et al.* (2003). Anwar *et al.* (2001) mentioned that application of NPKS to soils significantly increased leaf length of broccoli.

Largest Leaf Breadth:

Largest leaf breadth per plant of red amaranth was significantly influenced by treatments at different growth period (Table 5). The leaf breadth was gradually increased up to harvest of the crop.

At 17 DAS, the leaf breadth ranged from 1.86cm to 3.40cm. The maximum leaf breadth (3.40cm) was recorded in T_{10} (vermicompost 10 t/ha + NPKS 100%) followed by T_7 and T_9. The treatment T_7 and T_9 are similar in statistically. Similarly, the treatment T_2 is similar with T_{11}; T_3 is similar with T_5 & T_{12}; T_4 is similar with T_6 & T_8. The lowest leaf breadth was also found in control.

At 24 DAS, the maximum leaf breadth was observed in T_{10} followed by T_7 and T_9. The treatments did not differ significantly in T_4 with T_8, T_3 with T_5, T_2 with T_{11}, T_6 with T_{12}.

At 31 DAS, the leaf breadth ranged from 3.10cm to 5.42cm as influenced by treatments. The maximum leaf breadth (5.43cm) was recorded in T_{10}. The treatments T_9, T_8, T_7 and T_6 did not differ statistically. The minimum leaf breadth was also found in control (T_1).

In growth period up to 31 DAS, the maximum leaf breadth was observed in T_{10} treatment, but after one month i.e. 38 and 45 DAS the highest leaf breadth was produced by T_7 followed by T_{10}.

The results showed that applied vermicompost are more effective after one month of growth period. Application of 50% recommended doses of NPKS with vermicompost (10 t/ha) is more favorable than 100% NPKS + vermicompost (10 t/ha) in respect of leaf breadth. Alam (2006) showed that the largest leaf breadth of cabbage was found by 5 t/ha vermicompost + 100% recommended doses of chemical fertilizers.

Stem Length:

The stem length is an important yield contributing parameter of red amaranth. The stem length was measured after harvest of the crop. Application of different treatments performed significantly and varied widely over the control. Application of vermicompost at 2.5, 5.0 and 10.0 t/ha increased stem length of 10.40, 15.20 and 18.93cm respectively. The increasing rates of vermicompost with 50% or 100% NPKS showed stem length in the following orders: $T_8 > T_5$, $T_9 > T_6$ but $T_7 > T_{10}$. The treatment T_4 is similar with T_9. The treatments T_{11} and T_{12} produced stem length of 11.3cm and 14.46cm, respectively. Application of vermicompost (10 t/ha) + NPKS (50%) obtained higher stem length (21.60cm) than vermicompost (10 t/ha) with NPKS (100%). This may be due to the over nutrition to the crop, because red amaranth is a short durable vegetable.

Stem Breadth:

The stem breadth was significantly influenced by different treatments. The stem breadth ranged from 11.16mm to 21.53mm in different treated plot. The maximum stem breadth (21.53mm) was found by the application of vermicompost (10 t/ha) + NPKS (50%) (T_7) followed by T_{10} (20.96mm) and T_4,but they are statistically similar.

The treatment T_8 is similar with T_9; T_1 is similar with T_2 & T_{11}; T_6 is similar with T_{12} and T_3 is similar with T_5. The above results showed that the response of vermicompost is more efficient than chemical fertilizers when N-P-K-S were used at 25-15-20-9 Kg/ha (100%) in Barind soils.

Weight of Plan:

The weight of plant responded significantly by the application of different treatments (Table 6). The treatment T_7 with 11.80g per plant gave the highest plant weight but T_7 is similar with T_{10} (11.50g), and followed by T_4, T_9 and T_6. The treatment T_4 and T_9 did not differ significantly. Similarly, T_2 is similar with T_{11}; T_5 with T_8 & T_{12}. The lowest plant weight (2.80g) was found in control.

Table 6a: Effect of vermicompost and NPKS fertilizers on yield and yield components of red amaranth

Treatments	Stem length (cm)	Stem breadth (mm)	Wt. of plant (g)	% DM of plant	Total DW (kg/ha)	Yield (t/ha)
T_1 = Control	8.03 j	11.16 f	2.80 g	10.36 e	337.38 h	3.25 i
T_2 = VC(2.5 t/ha)	10.40 i	12.13 f	3.30 f	10.80de	608.51 g	5.63 g
T_3 = VC(5 t/ha)	15.20 ef	14.56 e	4.50 e	11.06 cde	811.70 ef	7.33 e
T_4 = VC(10 t/ha)	18.93 c	20.46 a	9.80 b	11.80 ab	1025.56 d	8.68 d
T_5 = VC(2.5 t/ha) + NPKS (50%)	14.56 fg	15.06 de	6.30 d	10.56 de	766.31 f	7.25 ef
T_6 = VC(5 t/ha) + NPKS (50%)	17.13 d	16.96 c	8.10 c	10.90de	1083.66 d	9.95 c
T_7 = VC(10 t/ha)+ NPKS (50%)	21.60 a	21.53 a	11.80 a	11.26 bcd	1491.33 b	13.25 a
T_8 = VC(2.5 t/ha)+ NPKS (100%)	15.46 e	17.26 ab	6.80 d	10.86 de	887.66 e	8.17 d
T_9 = VC(5 t/ha) + NPKS (100%)	18.43 c	18.73 b	9.40 b	11.1 bcde	1402.56 c	12.47 b
T_{10} = VC(10 t/ha)+ NPKS (100%)	19.90 b	20.96 a	11.50 a	12.23 a	1609.70 a	13.17 a
T_{11} = NPKS (50%)	11.53 h	11.93 f	3.20 f	10.96 cde	539.01 g	4.83 h
T_{12} = NPKS (100%)	14.46 g	16.16 cd	5.20 de	11.66 abc	790.13 f	6.78 f
LSD	0.6672	1.5120	2.1640	0.6597	80.21	0.5216
CV (%)	3.94	4.18	3.17	5.66	9.95	6.79

In a column, figures having same letter(s) do not differ significantly by DMRT at the 5% level.

Table 6b: Correlation matrix among different parameters of Red Amaranth as influenced by treatments

Parameters	1	2	3	4	5	6	7	8	9	10
1. Plant height	1.000									
2. Leaves/plant	0.935**	1.000								
3. Largest leaf length	0.976**	0.964**	1.000							
4. Largest leaf breadth	0.934**	0.931**	0.953**	1.000						
5. Stem length	0.973**	0.921**	0.962**	0.885**	1.000					
6. Stem breadth	0.957**	0.915**	0.958**	0.906**	0.967**	1.000				
7. Wt. of plant	0.970**	0.892**	0.959**	0.916**	0.953**	0.974**	1.000			
8. % DM of plant	0.619*	0.648*	0.560*	0.493NS	0.657*	0.710**	0.629*	1.000		
9. Total DW	0.964**	0.928**	0.944**	0.913**	0.936**	0.918**	0.948**	0.650*	1.000	
10. Yield	0.967**	0.920**	0.951**	0.922**	0.937**	0.906**	0.942**	0.573NS	0.994**	1.000

NS = Not significant, * = 5% level of significance, ** = 1% level of significance

The results showed that vermicompost performed the best response on growth of red amaranth plant. The results are in conformity with the findings of many workers in different crops (Tomar, *et al*. 1998 in brinjal and carrot; Saikia *et. al*.1998 in potato; Azad 2000 in cabbage and Bongkyoon 2004 in potato).

Percentage of Dry Matter of Plant:

Significant variation in respect of percent dry matter of red amaranth plant was observed in different treatments. The maximum dry matter (11.50%) was found from the plants that were treated with T_{10} (10 t/ha vermicompost + 100% NPKS), whereas the lowest (10.36%) was found in control. There were no significant difference in treatments T_9 with T_7; T_2 with T_5, T_6, T_8 and T_{11}.

The effect of inorganic + organic fertilizer in this regard may be attributed to the provision of favorable soil condition and supply of proper nutrients for better growth and yield of plant which produced higher amount of dry matter of red amaranth plant.

The results are in partial agreement with the findings of different crops (Kabir, 1998 in cabbage; Azad, 2000 in cabbage; Kadir, 2002 in broccoli; Anand and Krishnappa, 1988 in potato).

Yield (t ha^{-1}):

Application of different doses of vermicompost and NPKS fertilizers alone and their combinations significantly influenced the fresh yield of red amaranth (Table 6). The increasing rates of vermicompost (2.5, 5, 10 t/ha) gave the yield of 5.63, 7.33 and 8.68 t/ha respectively. Application of 2.5, 5 & 10 t/ha produced the yield increase by 73.2, 125.5 & 167.0% over control, respectively.

Application of 50% and 100% recommended doses of NPKS produced the yield of 4.83 and 6.78 t/ha respectively. The highest yield (13.25 t/ha) was observed in vermicompost (10 t/ha) + 50% NPKS (T_7) which was statistically similar yield (13.17 t/ha) found by vermicompost (10 t/ha) + 100% NPKS (T_{10}). It is indicated that 50% NPKS with 10 t/ha of vermicompost produced best economic yield and also helps to minimizing soil pollution and health hazard. Similar results was also reported by Noor *et al*. (2002).

The statistically second highest yield (12.47 t/ha) was found by the application of vermicompost (5 t/ha) + 100% NPKS (T_9) followed by 9.95 t/ha (T_6), 8.68 t/ha (T_4), 8.17 t/ha (T_8), 7.33 t/ha (T_3) and 7.25 t/ha (T_5). The treatment T_4 is similar with T_8 and T_3 with T_5. The lowest yield 3.25 t/ha was found in control.

The yield response over control presented in Figure 1. The minimum yield increase over control was 48.6% by the application of NPKS (50%), while application of NPKS (100%) increased yield by 108.6%

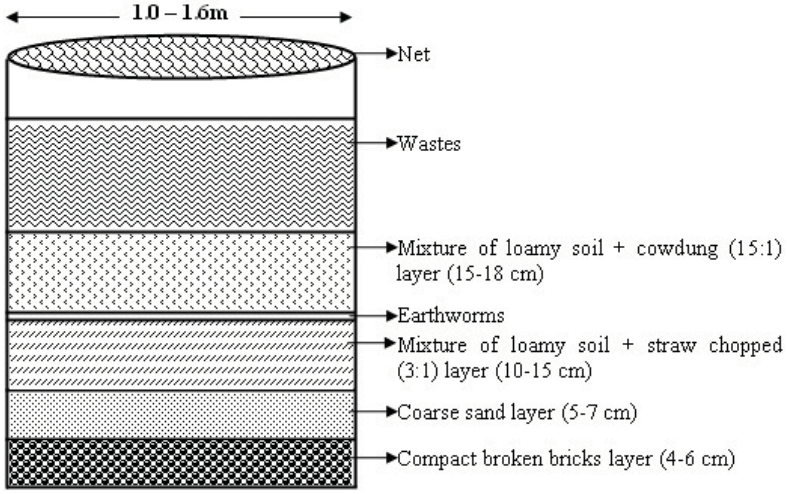

Fig. 1: Layout of a vermicomposting pit

Application of 2.5 t/ha of vermicompost increased the yield by 73.2%, while addition of 50% NPKS and 100% NPKS increased the yield by 123.0% and 151.3% respectively. Similarly, 5.0 and 10.0 t/ha vermicompost increased by 125.5% and 167.0%, while 50% and 100% NPKS increased by 206.1% and 283.7% respectively. The highest yield increased by T_7 (307.1%) followed by T_{10} (305.7%). Noor *et al*. (2002) suggested that addition of 10t/ha cowdung instead of 50% recommended dose of chemical fertilizer can able to produce satisfactory higher yield of cauliflower. The results suggested that the effects of vermicompost are

more efficient than chemical fertilizers for the production of red amaranth. Bongkyoon (2004) reported that the effect of vermicompost (EWC) application were favourable than the effects of the application of a chemical fertilizers.

The findings are in partial agreement with many workers in different vegetable crops (Ying *et al*. 1997 in broccoli; Tomar *et al*., 1998 in brinjal and carrot; Saikia *et. al*. 1998 in potato; Azad 2000 in cabbage, Ali and Jahan 2001 in lady's finger, Kadir 2002 in broccoli and Alam 2005 in carrot).

Total Dry Weight (kg ha^{-1}):

The total dry weight of red amaranth was calculated from the fresh yield with multiplied by dry matter (%) in respective treatments. The dry weight was significantly increased in different treatments over control (Table 5). The total dry weight of red amaranth ranged from 337.38 to 1609.70 kg/ha. The maximum dry weight (1609.70 kg/ha) was observed in T_{10} treatment and followed by T_7 (1491.33 kg/ha). The fresh yield by T_7 and T_{10} are similar but percent dry matter $T_7 > T_{10}$. So, the total dry weight in T_{10} was found to be higher than T_7. The lowest dry weight was obtained by 337.38 kg/ha in control. The treatment T_4 is statistically similar with T_6; T_3 with T_8 and T_2 with T_{12}.

The relative increased of dry weight over control have been presented in Figure 2. Application of 2.5, 5.0 and 10.0 t/ha of vermicompost (T_2, T_3 and T_4) increased dry weight over control by 80.3, 140.5 and 203.9% respectively. The minimum increase of dry weight over control was 59.1% by the application of 50% NPKS, while addition of more 50% i.e. 100% of NPKS increased the dry weight by 134.2%. The highest increase of dry weight of 377.1% by the application of vermicompost (10 t/ha) + NPKS (100%) but application of vermicompost (10 t/ha) + NPKS (50%) increased by 342%. The findings are partially supported by Krishnappa (1989).

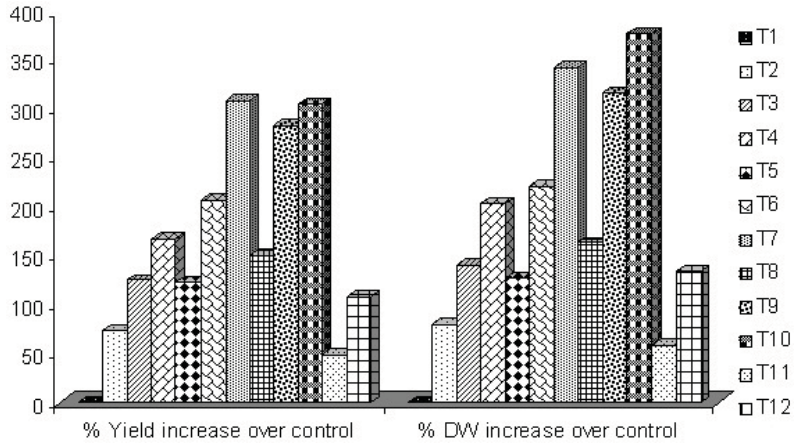

Fig. 2: Effect of vermicompost and NPKS fertilizers on percent increase of yield and dry weight of red amaranth over control.

Correlation Matrix:

Correlation matrix among different plant parameters have been presented in Table 6. The correlation matrix showed that fresh yield of red amaranth had significant and positive correlation with total dry weight (r = 0.994), plant height (r = 0.967**), number of leaves/plant (r = 0.920**), largest leaf length (r = 0.951**), largest leaf breadth (r = 0.922**), stem length (r = 0.937**), stem breadth (r = 0.906**), weight of plant (r = 0.942**) and total dry weight (r = 0.994**). The above results indicated that yield of red amaranth was dependent on plant height, number of leaves/plant, leaf size, stem length, stem breadth and weight of single plant. Total dry weight of red amaranth depends on plant height, number of leaves/plant, leaf size, stem length and breadth, weight of plant and percent dry matter of plant. The strong positive correlation were found among the following parameters i.e. yield with plant height, total dry weight with plant height of dry matter with stem breadth, number of leaves/plant with largest leaf length/plant, plant height with largest leaf length/plant, largest leaf length/plant with stem length and weight of plant with stem breadth.

Conclusions:

The growth performance of plant height showed that chemical fertilizer are more efficient than vermicompost within one month and after one month, the effect of vermicompost are more favorable than chemical fertilizers. Application of 10 t/ha of vermicompost with 50% or 100% NPKS gave the significantly highest plant height, number of leaves, size of largest leaf, weight of single plant, stem length, stem breadth and fresh yield of red amaranth but only 100% NPKS + vermicompost (10 t/ha) gave the maximum dry weight of red amaranth. The yield of red amaranth was strongly correlated with plant height. It is suggested that vermicompost (10 t/ha) + NPKS (50%) is more favourable for vigorous growth of red amaranth and also most suitable for soil environment but vermicompost (5 t/ha) + NPKS (100%) can be economically and environmentally suitable.

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