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Efficacy of Vermicompost to Improve Soil Health, Yield and Nutrient Uptake of Cauliflower in Grey Terrace Soil of Bangladesh

Sohela Akhter[1*] • Ranjit Sen[1] • Shahana Akter[2] • Jaime A. Teixeira da Silva[3] • Azizul Haque[1] • Shamsun Noor[1]

[1] Soil Science Division, Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur-1701 Bangladesh
[2] Spice Research Center, Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur-1701 Bangladesh
[3] Faculty of Agriculture and Graduate School, Kagawa University, Miki-cho, Kagawa, 761-0795, Japan

Corresponding author: * **sohela@bangla.net**

ABSTRACT

Vermicompost (VC) is a potential input for sustainable agriculture. This paper reports on the ability of VC to efficiently increase the growth, yield and nutrient uptake of cauliflower (*Brassica oleracea* var. *botrytis*) and to improve soil health. Field trials were conducted with cauliflower 'Snow White' during 2007-2008 in Grey Terrace Soil (Inceptisol) of Bangladesh, Agro Ecological Zone (AEZ)-28. There were 12 treatments replicated three times. The sources of VC were cowdung and kitchen wastes (3: 1) processed by epigeic earthworm *Eisenia fetida*. Leaf number, circumference and curd yield of cauliflower were significantly higher when NPKSZnB fertilizers (100% recommended dose of chemical fertilizer, RDCF) were used together with 1.5 t ha^{-1} VC but were statistically identical to 100% RDCF + 1.5 t ha^{-1} aerobic compost (AC), NPKSZnB (80% RDCF) + 3 t ha^{-1} VC and 80% RDCF + 3 t ha^{-1} AC. VC performed better than AC alone or in combination with chemical fertilizers. In this case, enhanced cauliflower yield was attributed to the elevated levels of NPKSZnB in VC. There was a considerable increase in nutrient uptake by VC-treated cauliflower. The residual effect of VC showed an increase in available nutrients in post-harvest soil. To improve and maintain soil health and crop production, chemical fertilizers need to be reduced. VC (1.5 t ha^{-1}) + 100% RDCF favours higher curd yield of cauliflower but VC (3 t ha^{-1}) + 80% RDCF may be economically and environmentally suitable since it contains 20% less chemical fertilizer and 1.5 t ha^{-1} more organic manure. Hence, 3 t ha^{-1} VC + 80% RDCF is recommended for cauliflower cultivation in Grey Terrace Soils of Bangladesh.

Keywords: Aerobic compost, crop growth, curd yield, NPKSZnB, organic matter, soil fertility
Abbreviations: AC, aerobic compost; **AEZ**, Agro Ecological Zone; **CD**, cowdung; **FYM**, farmyard manure; **IPNS**, integrated plant nutrition system; **MBCR**, marginal benefit cost ratio; **NPKSZnB**, nitrogen, phosphorus, potassium, sulphur, zinc and boron; **OM**, organic matter; **RDCF**, recommended dose of chemical fertilizer; **VC**, vermicompost

INTRODUCTION

Cauliflower (*Brassica oleracea* L. var. *botrytis* sub var *cauliflora*) is a kale belonging to the Cruciferae family. They commonly grow in vegetable-producing countries around the world. It is a popular winter vegetable in Bangladesh. It is low in fat, high in dietary fibre, folate, water and vitamin C, possessing a very high nutritional density which can help to protect from a range of diseases from cancer to cataracts (Kirsh *et al*. 2007). Cauliflower contains 8.0 g carbohydrate, 2.3 g protein, 40 IU carotene, 0.13 mg B_1, 0.11 mg B_2, 50 mg Vit C, 30 mg Ca and 0.8 mg iron 100 g^{-1} of fresh weight, respectively (Rashid 1999). The growth and yield of cauliflower are remarkably influenced by organic and inorganic fertilizer management, for which an integrated approach benefits yield sustainability and maintains soil fertility (Noor *et al*. 2007). The demand and price of cauliflower are higher, both in national and international markets. The rate of change of area, production and yield of cauliflower are increasing nowadays 60, 70 and 7%, respectively in Bangladesh (Mostofa *et al.* 2010). The imbalanced use of chemical fertilizer in vegetable and other crop production is common in Bangladesh.

In Bangladesh, the yield of vegetable crops has declined due to depleted soil fertility. With consistently growing demand on shrinking land resources to feed an escalating population, it is necessary to maintain the biological health of soils at an optimum level for sustaining the productivity of agricultural soils. Environmental degradation is a major threat confronting the world, and the rampant use of chemical fertilizers contributes largely to the environment through depletion of fossil fuels, generation of carbon dioxide (CO_2) and contamination of water resources (Nagavallemma *et al.* 2006). Soil fertility is lost due to imbalanced use of fertilizers that adversely impacts agricultural productivity and causes soil degradation. The continuous use of chemical fertilizers badly affects the texture and structure, reduces organic matter (OM) content and decreases the microbial activity of soil (Alam *et al*. 2007). Now there is a growing realization that the adoption of ecological and sustainable farming practices can only reverse the declining trend in global productivity and environment protection (Aveyard 1988; Wani and Lee 1992; Wani *et al*. 1995). The applica-

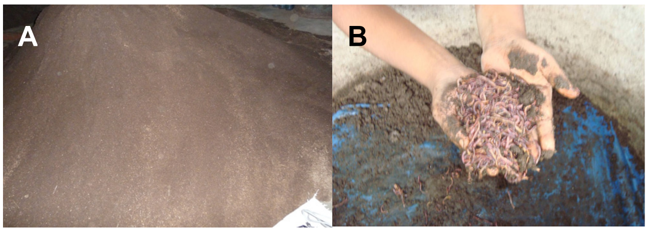

Fig. 1 (**A**) Vermicompost used in the study and (**B**) earthworm species, *Eisenia fetida*.

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Table 1 Initial soil characteristics of the experimental field.

Soil properties	pH	OM %	Ca	Mg	K	Total N %	P	S	B	Cu	Fe	Zn
			meq 100 g^{-1}				mg kg^{-1}					
2007	6.2	0.85	7.1	2.1	0.15	0.05	16	11	0.15	9.3	100	1.8
2008	6.4	0.94	8.1	2.7	0.15	0.06	14	20	0.25	8.2	109	1.2
Critical level	-	-	2.0	0.8	0.2	-	14	14	0.20	1.0	10	2.0

tion of organic resources to soil is essential to maintain soil fertility and crop productivity in agricultural systems (Karmegam and Daniel 2009). The disposal of organic wastes from domestic, agricultural and industrial sources causes environmental and economic problems throughout the world. Tropical soils are deficient in all necessary plant nutrients and on the other hand, large quantities of such nutrients contained in wastes are not effectively used (Nagavallemma *et al*. 2006). About 4,000 Mt of municipal wastes originate from Dhaka City Corporation while about 17,000 Mt of municipal wastes per day originate from all municipalities of Bangladesh. Similarly, 25 million rural households generate 2.5 million M ton of kitchen wastes which is either burned or land filled (Dainik Sangbad 2009).

The long known beneficial roles of flora and fauna in maintaining soil health and also in composting different waste materials are now receiving renewed attention. Utilization of earthworms to decompose and stabilize organic wastes has received increasing interest and popularity in recent years (Kale 1998; Nagavallemma *et al*. 2006; Ansary 2007; Akhter *et al.* 2009). Several methods have been developed to convert bio-wastes into organic manure as an alternate source of farmyard manure and a substitute for chemical fertilizers. Among the various methods of waste management, vermicomposting is an important aspect as it converts non-toxic organic wastes into potential organic manure within a short period by using epigeic earthworms as the biological agent. Vermicomposting differs from composting in several ways (Gandhi *et al*. 1997). Vermicomposting converts household wastes into compost within 30 days, reduces the C: N ratio and retains more N than traditional methods of preparing composts. The composting process is faster than composting. The compost prepared by the action of earthworms on non-toxic biodegradable waste is called VC and is considered to be a very important aspect in organic farming. Earthworms, through a type of biological alchemy, are capable of transforming garbage into 'gold' (Vermi 2001; Tara 2003). In Bangladesh, the epigeic earthworm *Eisenia fetida* is widely used for vermicomposting as it is readily available. This organic manure is a good source of different macro- and micronutrients, particularly NPKS. Use of VC for vegetable production at a large scale can solve the problem of disposal of wastes and also solve the lack of OM in soil (Alam *et al.* 2007). 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 a subsequent crop (Kannan *et al.* 2005; Behera *et al*. 2007). Vermicomposting is a viable, cost effective and rapid technique for the efficient management of solid wastes (Ushakumari *et al*. 2006). It is a suitable technology for decomposition of different types of organic waste (domestic and industrial) into value-added material. It plays a significant role in building up soil fertility and improving soil health for sustainable agriculture.

The prospect of VC in Bangladesh is bright. A huge amount of cowdung (CD) and other animal dung, water hyacinth, kitchen waste, municipal waste and other decomposable substances are available in Bangladesh. About 25 million cows, 1 million buffalo and 220 million poultry exist in Bangladesh (Dainik Sangbad 2009). From these sources 2.7 million M t of dung are formed every day. Approximately 60% or more of household waste is of organic type that could be recycled using vermiculture (Tripathi *et al*. 2005a). Beside these, compost worms are sold to households for recycling organic waste and have the potential to be used in vermitechnology waste conversion systems for industrial or municipal applications.

Several groups stated that the application of N, P, K or organic manure increased the yield of vegetables: Sohrab and Sarwar (2001) in brinjal, tomato and okra; Kannan *et al.* (2005), Behera *et al*. (2007) and Khanam *et al*. (2009) in okra, Uddin *et al*. (2009) in kohlrabi, etc. But there is no available research information about the effect of VC and NPKS fertilizers on the yield of cauliflower. The preset investigation was undertaken to study the efficacy of VC to improve soil health, yield and nutrient uptake of cauliflower in Grey Terrace Soil (AEZ-28) of Bangladesh.

MATERIALS AND METHODS

Field experiments on cauliflower 'Snow White' was carried out in the *rabi* season of 2007 and 2008 at the Bangladesh Agricultural Research Institute (BARI), Joydebpur (24° 00′ N, 90° 25′ E and 8.4 m asl). Joydebpur soil belongs to the Chhiata series of Grey Terrace Soil (Inceptisol; AEZ-28) (BARC 2005). There were 12 treatments: T_1 = NPKSZnB (100% RDCF), T_2 = NPKSZnB (80% RDCF), T_3 = NPKSZnB (60% RDCF), T_4 = VC (1.5 t ha^{-1}) + NPKSZnB (100% RDCF), T_5 = VC (3.0 t ha^{-1}) + NPKSZnB (80% RDCF), T_6 = VC (6.0 t ha^{-1}) + NPKSZnB (60% RDCF), T_7 = VC (6.0 t ha^{-1}), T_8 = aerobic compost (AC) (1.5 t ha^{-1}) + NPKSZnB (100% RDCF), T_9 = AC (3.0 t ha^{-1}) + NPKSZnB (80% RDCF), T_{10} = AC (6.0 t ha^{-1}) + NPKSZnB (60% RDCF), T_{11} = AC (6.0 t ha^{-1}) and T_{12} = control. Two experiments were laid out in 2007 and 2008 in 8.1 m^2 plots in a randomized complete block design replicated three times.

The initial soil was collected from a depth of 0-15 cm from experimental fields and analyzed following standard methods. Soil pH was measured with a glass calomel electrode (Jackson 1958). Organic carbon was determination by the Walkley and Black (wet digestion) method. Total N was determined by a modified Kjeldahl method. Ca and Mg were determined by a KCl extractable method. K, Cu, Fe, Zn were determined by $NaHCO_3$ extraction followed by an AAS (atomic absorption spectrophotometer) reading (ASI 1980). Boron was determined by a $CaCl_2$ extraction method. P was determined by the Bray and Kurtz method, S by the turbidity method with $BaCl_2$. **Table 1** shows that the soil of Joydebpur is poor, with pH 6.4 and 8.1, 2.7 and 0.15 meq/100 g for exchangeable Ca, Mg and K, respectively. Total N content was very low (0.06%), the available Zn content was below the critical level while the available P was at the critical level, all of which indicated the poor fertility of the study soil. The sources of VC (**Fig. 1A**) were CD and kitchen wastes (3: 1) processed by the earthworm *E. fetida* (**Fig. 1B**). The VC and AC were also subjected to NPK analysis following standard procedures. In the present study, kitchen wastes, especially vegetable wastes and CD, were used as vermibed substrates due to their availability in large quantities.

The 100% recommended dose of N-P-K-S-Zn-B was 250-35-65-40-5-2 kg ha^{-1}, respectively and these were used in the form of urea, TSP (triple super phosphate), MP (muriate of potash), gypsum, zinc sulphate and boric acid, respectively. The entire amount of P, K, S, Zn, B, VC and AC and $^1/_3$ N were broadcasted and incorporated in the soil at the time of final land preparation and the remaining $^2/_3$ N was applied in two equal installments at 25 and 45 days after transplanting. Seedlings 25-days-old were transplanted in the third week of November, 2007 and 2008 with a row-to-row spacing of 50 cm and plant-to-plant spacing of 45 cm. Weeding, irrigation, drainage and other intercultural operations were done as and when necessary. The cauliflower curd was harvested at full maturity. Data on growth, yield and yield contributing parameters were recorded from 10 randomly selected cauliflower plants and statistically analyzed with the help of a statistical package MSTAT-C and mean separation was tested at 1% for significance

Table 2 Nutrient content of applied vermicompost and aerobic compost (air dry basis).

Organic manure	Year	N	P	K	Ca	Mg	S	B	Zn	C : N
		%								ratio
Vermicompost	2007	2.9	1.8	1.2	7.4	1.5	0.9	0.01	0.50	14.09
	2008	2.5	1.6	1.1	6.2	1.3	0.8	0.01	0.41	14.01
Aerobic compost	2007	1.3	1.3	1.1	5.4	1.1	0.5	0.01	0.30	15.81
	2008	1.3	1.1	0.9	4.6	0.9	0.4	0.01	0.25	15.67

Table 3 Effect of organic manure and chemical fertilizer on the soil fertility status after cauliflower harvest (2008).

Soil properties	pH	OM %	Ca	Mg	K	Total N %	P	S	Zn
			meq 100 g^{-1}				mg kg^{-1}		
T_1	6.5	0.93	8.3	2.9	0.16	0.08	16	14	1.9
T_2	6.5	0.91	8.1	2.8	0.15	0.07	14	13	1.8
T_3	6.4	0.90	7.6	2.2	0.12	0.05	13	11	1.7
T_4	6.7	0.98	8.9	4.3	0.20	0.15	17	17	2.1
T_5	6.8	0.99	9.0	4.1	0.20	0.17	19	20	2.3
T_6	6.8	1.04	8.9	4.0	0.19	0.16	18	19	2.0
T_7	6.5	1.00	8.3	3.8	0.16	0.11	15	14	1.5
T_8	6.6	0.96	8.5	3.4	0.17	0.12	16	17	2.0
T_9	6.7	0.98	8.7	4.0	0.18	0.13	17	19	2.2
T_{10}	6.6	0.99	8.3	3.3	0.16	0.13	14	15	1.8
T_{11}	6.5	0.99	8.1	3.2	0.13	0.11	14	10	1.4
T_{12}	6.3	0.84	7.4	2.5	0.12	0.04	11	10	1.2

by DMRT (Duncan's multiple range test) according to Steel and Torrie (1960).

The plant samples from each plot were dried at 65°C in an electric oven for 72 h then ground to pass through a 20 mesh sieve and analyzed following standard procedures. Plant samples were digested with H_2SO_4 for N and HNO_3-$HClO_4$ (3: 1) for P, K and S determination. Nutrient uptake was calculated by multiplying the concentration of the nutrients in the plant samples with the corresponding plant dry weights. Nutrient balance was calculated by subtracting outputs (nutrient removed or taken up by cauliflower) from the inputs (nutrient added as fertilizer) (Panaullah *et al*. 2000). The postharvest soil of each treatment plot was also collected and analyzed.

Production of vermicompost and aerobic compost

Earthworms are chosen for their resistance to extreme conditions as well as feeding and reproductive rate. *E. fetida* is the most efficient waste processor in Bangladesh. VC was produced by the vermicomposting chari method. In this method, an earthen round container (71 cm in diameter and 33 cm in height), termed a "chari", with a broad base and drainage holes at the bottom was used. The bedding material comprised miscellaneous kitchen wastes and was well moistened with water, which was sprinkled over the vermibed on alternate days to hold moisture content at about 50-60%. The wet mixture was stored for about 7-8 days, covered with a damp sack to minimize evaporation and dim the light, and was mixed thoroughly several times. CD was also decomposed under aerobic conditions for 10-15 days. When fermentation and decomposition were complete, CD and kitchen wastes were mixed in a 3: 1 ratio and maintained in the chari. The mixture was sufficiently loose for the worms to burrow and it was able to retain moisture because during vermicomposting, the container was covered with a piece of gunny bag to prevent water evaporation. About 200 worms were added to the mixture in the chari, which was left for a week without disturbing. Adequate moisture level (50-60%) was maintained by sprinkling water whenever necessary. When the VC was ready, the compost was removed from the top, sun-dried and sieved to produce material with more plant nutrition than AC. AC was produced by decomposing waste materials composed of dead leaves, straw, weeds, water hyacinth, household wastes like non-edible food, fruit and vegetable parts, after-meal waste, municipal garbage, rice husk, crop residues and CD without earthworms under aerobic conditions. This AC is a miscellaneous mixture of the above materials and which was obtained from the BARI farm. The materials were kept in layers, one above the other. In order to promote microbial activities, thin layers of soil or fresh CD were placed in between the layers in the heap. The top of the heap was covered with soil and kept moist by spraying water at regular intervals (FRG 2005). In summary, the traditional method of composting consisted of an accelerated bio-oxidation of organic matter, which took 4-5 months to decompose fully, as it passed through a thermophilic stage (45-65°C) in which microorganisms liberated heat, CO_2 and water (Domínguez *et al*. 1997).

Cost and return analysis

The price of the organic and inorganic components used per treatment was calculated by the sum of the price of individual fertilizers (**Table 5**). Gross return was calculated by multiplying the average of two years' yield of cauliflower (kg ha^{-1}) with its market price. The market price of cauliflower was obtained from the local market. Gross margin per treatment was calculated by subtracting the variable cost from gross return of the respective treatment output (yield). Finally, the marginal benefit cost ratio (MBCR) of the respective treatment or package was calculated by subtracting the gross return of the control treatment from each treatment and by dividing the result by the respective variable cost (Elias and Karim 1984).

RESULTS

NPK contents in vermicompost and aerobic compost

In the present study, the VC was produced from CD and kitchen waste. The NPK content in VC was higher than in AC used in the study (**Table 2**). The C: N ratio was lower in VC than in AC.

Postharvest soil fertility status

Significant variation was observed in the chemical properties of soil after harvest where the VC was incorporated into the soil (**Table 3**). Among the different doses of VC, T_6 (VC 1.5 t ha^{-1}) showed the highest OM content (1.04%) after crop harvest. On the other hand, the lowest OM content (0.84%) was observed in the control treatment where no VC was applied. Soil pH increased with the increasing rate of VC and AC application. The macro- and micronutrients of postharvest soil of the cauliflower field increased with different doses of VC and AC application.

Number of leaves per plant

The application of different doses of VC along with RDF significantly increased leaf number in cauliflower in both

Table 4A Yield components of cauliflower as influenced by chemical fertilizers and organic manure.

Treatment	No. of leaves plant^{-1}		Circumference of curd (cm)	
	2007	2008	2007	2008
T_1	17.7 ab	13.0 bc	50.5 abc	40.5 abc
T_2	15.4 bcd	12.8 bc	44.0 d	40.0 bc
T_3	14.5 dc	12.7 bc	38.5 e	36.9 bc
T_4	17.9 a	16.3 a	55.7 a	46.5 a
T_5	17.5 a	13.7 b	52.3 abc	42.7 ab
T_6	16.9 ab	12.9 bc	50.2 bc	38.9 bc
T_7	14.9cd	12.4 bc	38.3 e	35.7 c
T_8	17.6 a	16.1 a	54.8 ab	43.2 ab
T_9	16.9ab	13.6 b	51.6 abc	42.2 ab
T_{10}	16.7 abc	12.8 bc	48.0 cd	37.9 bc
T_{11}	14.2 de	12.1 bc	36.5 e	22.7 d
T_{12}	12.9 e	11.9 c	25.5 f	21.1 d
CV %	6.8	6.5	6.3	8.8

Figures in column having same letter(s) do not differ significantly at 1% level of significance

years (**Table 4A**). Maximum number of leaves formed with 100% RDF along with 1.5 t ha^{-1} VC (17.9 and 16.3). Statistically similar results were observed in T_5, T_6, T_8, T_9 and T_{10}. Fewest leaves formed in the control treatment (12.9 and 11.9 during 2007 and 2008, respectively). Moreover, VC produced more leaves than AC-treated cauliflower. To improve a soil's health, the use of chemical fertilizer should be reduced and replaced with organic manure. T_5 appeared to perform better than other treatments as in this treatment chemical fertilizer was reduced by 20%.

Curd circumference

The addition of 1.5 t ha^{-1} VC along with 100% RDF produced the highest circumference (46.47 cm) of cauliflower (**Table 4A**). The VC applied produced a significantly higher circumference than AC-treated cauliflower. The lowest circumference (21.13 cm) was found in the control treatment. VC and AC at 3 t ha^{-1} along with 80% RDF gave statistically similar results.

Curd yield

The marketable yield and curd yield of cauliflower were significantly affected by different combinations of treatments (**Table 4B**). The marketable yield of cauliflower varied from 0.35 to 1.6 kg plant^{-1} in 2007 and 0.28 to 1.26 kg plant^{-1} in 2008 with different levels of VC and AC application with different RDF. The highest marketable yield was attributed to 1.5 t VC ha^{-1} along with 100% RDF (T_4). A statistically similar curd yield was produced with T_5, T_8 and T_9. For these reasons, cauliflower yield also increased with VC and AC application and ranged between 11.2 and 50.4 t ha^{-1} during 2007 and 12.6 and 56.0 t ha^{-1} during 2008.

The highest curd yield (50.4 and 56.0 t ha^{-1} during 2007 and 2008, respectively) was obtained from 1.5 t VC ha^{-1} along with 100% RDF which is significantly higher than the yield of all other treatments. A statistically similar curd yield (49.17 and 51.57 t ha^{-1}) was obtained from 1.5 t ha^{-1} AC along with 100% RDF (T_8). Statistically similar results were also obtained when 3 t ha^{-1} VC or AC was applied together with 80% RDF. VC (1.5 t ha^{-1}) + NPKS (100%) is more favorable for higher curd yield of cauliflower but 20% reduced chemical fertilizer (80% RDF) along with 3 t VC ha^{-1} (T_5) was more favorable for the soil environment. The effect of VC was also evident from treatments T_1 and T_4 where 100% RDF and 100% RDF + 1.5 t ha^{-1} VC, respectively were applied. Among the organic manures, VC yielded higher curd yield (T_7 and T_{11}, respectively) but they were statistically lower than 100% chemical fertilizer (T_1). From **Table 4B**, it is clearly observed that chemical fertilizer or organic manure alone could not produce attainable yield of cauliflower.

From **Table 4B**, it is observed that the highest increase in yield over the control was obtained with 1.5 t ha^{-1} VC along with 100% RDF (T_4). The second highest increase in yield was obtained from T_8 where 1.5 t ha^{-1} AC was applied along with 100% RDF. It is evident from these results that organic manures are needed with chemical fertilizers for potential sustainable cauliflower yield. However, VC was clearly superior to AC as organic manure.

Nutrient uptake and nutrient balance

Nutrient uptake by cauliflower, as affected by different combinations of VC and AC with RDF, is presented in **Fig. 2**. The amount of N, P, K, S uptake by cauliflower plants varied widely with the treatments and yield levels (**Fig. 2, Table 4B**). Nutrient uptake was higher as the yield and biomass production was higher in T_4. The highest N uptake was attributed to integrated use of 1.5 t VC ha^{-1} with 100% RDF (T_4). Integrated use of 1.5 t AC ha^{-1} also contributed to higher N uptake by cauliflower (T_8). Uptake of N by cauliflower was higher with applied VC alone at 6 t ha^{-1} than with 6 t ha^{-1} AC (**Fig. 2**). Like N, PKS uptake also followed the same trend. The lowest uptake of NPKS was observed in the control treatment (T_{12}).

Apparent nutrient balance (**Fig. 2**) was calculated by subtracting nutrient removal by plants from nutrients added through fertilizers and manures. The apparent nutrient balance indicated that there was a negative N balance in all treatments. P and S showed a positive balance in all treatments except for the control treatment (T_{12}). The negative balance for P and S in the control treatment was essentially due to no fertilizers or manures being added. K also showed a negative balance in all treatments.

Table 4B Yield of cauliflower as influenced by chemical fertilizers and organic manure.

Treatment	Marketable curd yield (kg plant^{-1})		Yield (t ha^{-1})		Percent yield increase over control	
	2007	2008	2007	2008	2007	2008
T_1	1.41 bcd	1.10 bc	45.77 bc	49.03 b	309	289
T_2	1.22 e	0.95 d	40.03 d	42.07 c	257	234
T_3	1.03 f	0.91 de	32.43 e	40.60 cd	190	222
T_4	1.60 a	1.26 a	50.40 a	56.00 a	350	344
T_5	1.52 ab	1.14 ab	48.20 ab	50.53 ab	330	301
T_6	1.33 cde	1.04 bcd	43.23 cd	46.20 c	286	267
T_7	0.69 g	0.80 e	22.97 f	35.43 d	105	181
T_8	1.57 ab	1.16 ab	49.17 ab	51.57 ab	339	309
T_9	1.43 bc	1.12 ab	47.67 ab	49.77 ab	326	295
T_{10}	1.27 dc	0.97 cd	41.60 cd	42.97 c	271	241
T_{11}	0.59 g	0.60 f	21.60 f	26.53 e	93	111
T_{12}	0.35 h	0.28 g	11.20 g	12.60 f	-	-
CV %	7.33	8.10	6.48	8.10		

Figures in column having same letter(s) do not differ significantly at 1% level of significance

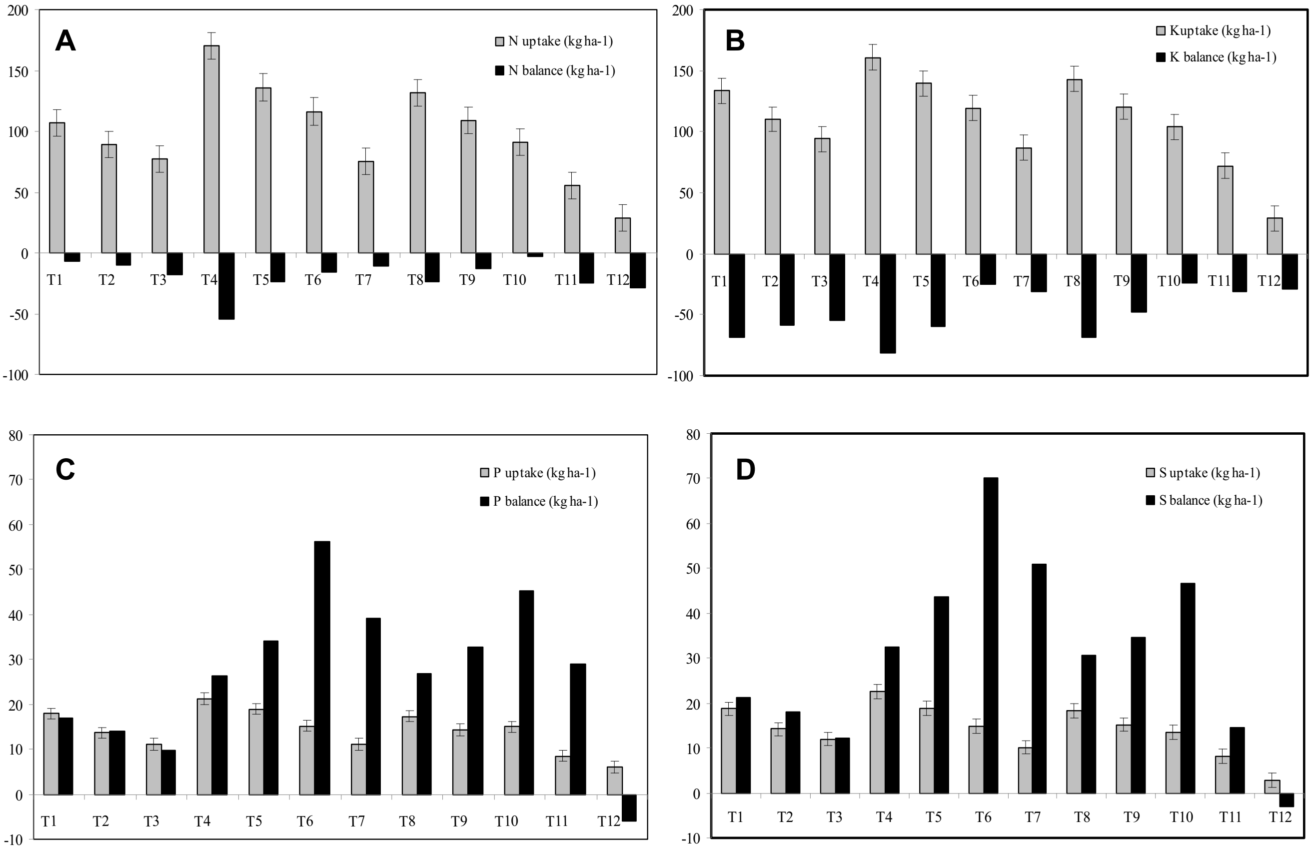

Fig. 2 Nutrient uptake and balance as affected by different treatment packages in cauliflower. (**A**) Nitrogen, (**B**) potassium, (**C**) phosphorus, (**D**) sulphur.

Table 5 Cost and return analysis (July, 2011 prices) of cauliflower as influenced by chemical fertilizers and organic manure, at Joydebpur (average of two years).

Code	Treatment	Vermicompost ($t\ ha^{-1}$)	Aerobic compost ($t\ ha^{-1}$)	Curd yield ($t\ ha^{-1}$)	Gross return ($Tk\ ha^{-1}\ yr^{-1}$)	Variable cost ($Tk\ ha^{-1}\ yr^{-1}$)	Gross margin ($Tk\ ha^{-1}\ yr^{-1}$)	MBCR
T_1	100%RDF	0	0	47.40	474000	14410	459590	24
T_2	80% RDF	0	0	41.05	410500	11528	398972	24
T_3	60% RDF	0	0	36.51	365113	8646	356467	27
T_4	100% RDF	1.5	0	53.20	532000	24910	507090	16
T_5	80% RDF	3.0	0	49.37	493650	32528	461122	11
T_6	60% RDF	6.0	0	44.72	447261	50646	396615	5
T_7	0	6.0	0	29.20	292000	42000	250000	3
T_8	100% RDF	0	1.5	50.37	503700	23410	480290	15
T_9	80% RDF	0	3.0	48.72	487200	29528	457672	11
T_{10}	60% RDF	0	6.0	42.29	422815	44646	378169	6
T_{11}	0	0	6.0	24.07	240650	36000	204650	2
T_{12}	0	0	0	11.90	119000	0	119000	-

* MBCR = marginal benefit cost ratio; 1 US$= 75.00 Tk

Input price:
N = Tk. 26.08 kg^{-1}
P = Tk. 110.00 kg^{-1}
K = Tk. 30.00 kg^{-1}
S = Tk. 22.22 kg^{-1}
Zn = Tk. 140.00 kg^{-1}
B = Tk. 250.59 kg^{-1}
Vermicompost = Tk. 7.00 kg^{-1}
Aerobic compost = Tk. 6.00 kg^{-1}

Output price:
Cauliflower curd = Tk. 10.00 kg^{-1}

Cost and return

The cost and return analysis (**Table 5**) showed that the highest gross margin (Tk. 507,090 $ha^{-1}\ yr^{-1}$) was obtained from treatment T_4 but its variable cost (Tk. 24,910 $ha^{-1}\ yr^{-1}$) was less. The second highest gross margin (Tk. 480,290 $ha^{-1}\ yr^{-1}$) was recorded in T_8 which was closely followed by T_5 and T_9. However, the highest MBCR (27.0) was recorded in T_3 where only 60% chemical fertilizers were used. With organic manure, highest MBCR (16.0) was obtained from T_4 treatment and incase of 20% reduced chemical fertilizer with organic manure, both T_5 and T_9 treatment resulted the next highest MBCR (11.0).

DISCUSSION

In nature, the earthworm cast consists of excreted masses of soil, mixed with residues of comminuted and digested plant residues. VC can be produced from all kinds of organic wastes with suitable preprocessing and controlled conditions (Nagavallemma *et al*. 2006). The final physical structure of this manure produced from organic wastes depends very much on the compostable part of wastes from which they were produced. The nutrient content of VC differs greatly depending on the parent material. VC is a product rich in organic bioremediated matter that differs from AC in its level of humification and the greater presence of microbial metabolites (Tripathi *et al*. 2005b). These metabolites, i.e., growth regulators and polysaccharides, are strongly responsible for the fertilizing value of casts. Composting of organic waste materials on farms, in households and in rural and urban human habitats turns them into valuable agriculture inputs and minimizes environmental pollution. In this context, VC organic manure, produced due to the activity of earthworms is rich in essential plant nutrients than AC. The nutrient content of VC is higher than AC used in the present study (**Table 2**). When earthworms feed on organic wastes, they undergo physical and chemical breakdown during the processes of ingestion and digestion (Kale 1998). About 5-10% of the ingested material is absorbed in the tissue for growth and metabolic activity and the rest is excreted as a cast. The cast is mixed with mucus secretion of the gut wall and of microbes (bacteria, actinomycetes, fungi, yeast, protozoa and nematodes), which add to structural stability of the cast which is used as VC. The gluing effect of gums produced by bacteria or the presence of specific classes of chemical compounds or the distribution of fungal hypae would help to understand their structural stability (Talashilkar and Dosani 2005). VC is a pellet-like excretion of earthworms known to contain elevated levels of nutrients and higher microorganisms than the surrounding soil or worm-un-worked organic material (Kang and Ojo 1996; Karmegam and Daniel 1999, 2000). In the present study, the nutrient level of VC was two-fold greater than that of AC. Similar findings were reported by Harris (1990). Lourduraj and Yadav (2005) reported 10 times high manurial value in VC than farm yard manure (FYM). Analysis of earthworm casting reveals that they are richer in plant nutrients than the soil, having about three times more Ca and several times more N, P and K (Lourduraj and Yadav 2005).

Application of VC increased soil fertility after the harvest of cauliflower more than AC (**Table 3**). VC added more OM to the soil and as a consequence the residual amount of OM showed higher values with the addition of a higher amount of VC. Lourduraj and Yadav (2005) presented evidence that, because of its effect on nutrient dynamics and the physical structure of soil, VC may significantly enhance plant growth and conserve soil quality. It not only helps to improve and protect the soil fertility of top soil but also helps to boost productivity by 40% with 20 to 60% lower nutrient inputs (Dusserre 1992). The advantage of using castings is that the manure passes through the worms' digestive system producing rich organic plant food and a slow-releasing fertilizer that allows for better growth. The availability of P was enhanced in casts compared to non-ingested soil (Tiwari 1989) due to increased solubility of P by high phosphate activity (Syers and Springett 1984). Damshetti (1997) found that the availability of macro- and micronutrients increased in soil with the application of VC. Vasanthi and Kumaraswamy (1999) reported that the organic carbon content and fertility status as reflected by the available status of N, P, K, micronutrients and CEC (cation exchange capacity) were higher in the treatment that received both chemical fertilizer and VC than in the treatment with chemical fertilizer alone. Earthworms reject a significant amount of nutrients in the casts (Lee 1985).

There were significant differences in the number of leaves, circumference and curd yield of cauliflower between VC and AC (**Table 4A, 4B**). Similar results were reported by Kabir (1998) and Azad (2000) in cabbage and Anwar *et al*. (2000) in broccoli. The wider circumference and increased number of leaves which ultimately increased curd yield of cauliflower in the present study can be partially attributed to the elevated levels of N, P, K and S in VC. Plant growth and development also depend on the effect of earthworms on soil structure (Logsdon and Linden 1992). VC effectively enhances N metabolism in plants (Tomati *et al*. 1990, 1996). The results are in agreement with those of Das *et al*. (2002), who reported that yield components were significantly increased by integrated application of VC and chemical fertilizers compared to other chemical fertilizer treatments. Karmegam and Daniel (2008) also reported that vermicasts either alone or in combination with chemical fertilizers, enhanced the growth and yield of hyacinth bean, *Lablab purpureus*. The highest number of leaves, circumference and yield of cauliflower was observed from T_4 in which 1.5 t VC ha^{-1} was applied with 100% RDF. All the parameters produced the highest value with this combination of fertilizer input. In the present study, in both years, a significantly similar yield and other yield-contributing results were observed with 3 t ha^{-1} VC along with 80% RDF. Only chemical fertilizer will not sustain soil health in the long run. Among the chemical and organic manure packages, the highest MBCR was obtained from T_4 where 1.5 t ha^{-1} VC were used with 100% chemical fertilizer. Moreover, 80% chemical fertilizer with 3 t ha^{-1} VC or AC resulted in the next highest MBCR. In this case, chemical fertilizer was reduced by 20%.

Again, a considerable increase in the uptake of N, P, K and S by cauliflower was observed under VC treatment more than AC (**Fig. 2**). The results are in agreement with the findings by Jadhav *et al.* (1997). They observed a considerable increase in the uptake of major and secondary nutrients such as N, P, K, Ca and Mg by rice under VC treatment than FYM. As yield and biomass production were higher, uptake was higher in VC-treated cauliflower (**Table 4B**).

CONCLUSION

The performance of cauliflower clearly showed that circumference, number of leaves and curd yield of cauliflower were higher in VC-treated plots. VC alone or in combination with RDF produced higher yield of cauliflower than AC which could be attributed to the higher levels of major nutrients in VC. The slight variations within VC and AC are due to the differences in VC obtained from kitchen waste and CD processed by *E. fetida*. To improve and maintain soil health as well as to sustain crop production, we need to reduce chemical fertilizer use. It is suggested that VC (1.5 t ha^{-1}) + NPKS (100%) is more favorable for higher curd yield of cauliflower and also most suitable for soil environment but VC (3 t ha^{-1}) + NPKS (80%) can be economically and environmentally suitable. Poor farmers can adopt this package of organic and inorganic fertilizers. The economics of production of VC and its use have shown that it is more economic when VC is prepared by the farmers themselves for on-farm use. The quantity of inorganic fertilizers can be reduced by about 20% of the RDF by applying VC as an organic manure instead of FYM.

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