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Effects of vermicompost on growth and leaf biomass yield of stevia and post harvest fertility status of soil

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Abstract

In view of the growing awareness about eco-friendly organic farming, vermicompost (VC) could be a very good option for increasing crops yield. The organic carbon in VC releases nutrients slowly and steadily into the system and enables the plant to absorb these nutrients. To assess the effect of VC on soil fertility, growth and yield of stevia in acid and non-calcareous soils, an experiment was undertaken in the net house of the Department of Agricultural Chemistry, Bangladesh Agricultural University, Mymensingh, during February to May, 2012. Four levels of VC viz. 0, 5, 7.5 and 10 t ha^{-1} in two contrasting soils (Acid and Non-calcareous) were examined following CRD with three replications. Growth and yield attributes such as plant height, branch and leaf number, leaf area, fresh and dry weight of leaves were significantly influenced by different levels of VC. All the plant parameters increased with the advancement of growth period as well with increased rate of VC up to 7.5t ha^{-1} and then declined with further additions. The leaf biomass yield was 335% and 338% higher in acid soil and in non-calcareous soil, respectively over control. The overall performance of non-calcareous soil was superior to acid soil in terms of both plant and soil parameters studied. The acidity of both soils significantly decreased with the increased application of VC ranging from 4.9 to 5.7 in acid soil and 6.5 to 7.2 in non-calcareous soil. Total N, available P, exchangeable K, Ca, Mg, available S, Zn, B were also significantly increased with the increased levels of VC up to its highest level (VC @ 10t ha^{-1}) in both soils. Thus the results suggest that VC @ 7.5t ha^{-1} should be applied for getting maximum leaf biomass yield of stevia and 10t ha^{-1} for increasing the fertility of both soils under the agro-climatic conditions of the studied area.

Keywords: Stevia, Vermicompost, Leaf biomass yield, Soil fertility

Introduction

Stevia, approximately 100 to 300 times sweeter than table sugar, has numerous health benefits (Barathi, 2003). It gives a feeling of even energy, rather than the ups and downs created with white sugar (Sunrider, 2007). Stevia leaf is calorie-free and non-disruptive to blood sugar levels. So far, there have been no recorded side effects from stevia consumption (Wort, 2013). In Bangladesh, about 8 millions of people between 20 to 69 years have been suffering from this serious disease which is about 5.9% of the total population and increasing at an alarming pace. Most dangerous message is huge numbers of children aged from 8 to 20 years old have also been suffering from this serious disease (Genus,, 2004). It is a new avenue to do research for the researcher and is a good opportunity for the farmers to earn cash money through cultivation of stevia. Though it is a perennial crop, leaves can be harvested 3 to 4 times in a year. The stevia cultivation has an immense scope for intensive agriculture and fits well for high return agriculture (Barathi, 2003). In view of the above fact, cultivation of stevia is gradually coming into focus in Bangladesh agriculture due to having no optimum agronomic management practices (Khanom, 2007, Nasrin, 2008 and Hasan, 2008). Few experiments were conducted on different agronomic aspects like date of planting, pruning, stem cutting etc on the growth and yield of stevia (Khan, 2014). It is expected that a higher and balanced nutrient supply will result in higher foliage yield. One of the best organic materials for increasing crop yield is vermicompost. In view of the growing awareness about eco-friendly organic farming, it showed growth promoting effect on the crops. Vermicomposting involves the bio-oxidation and stabilization of organic material by the joint action of earthworms and microorganisms. Earthworms act as mechanical blenders and by comminuting the organic matter they modify its physical and chemical status by gradually reducing the C: N ratio and increasing the surface area exposed to microorganisms thus making it much more favourable for microbial activity and further decomposition (Domínguez *et al*., 1997).

During the process, important nutrients are released by earthworms (Edwards, 1995). Vermicompost contains plant growth hormones (Arancon and Edwards, 2006), growth regulating substances and humic acids (Atiyeh *et al*., 2002) which enhance plant growth and productivity (Sahni *et al*., 2008). Vermicompost being a stable fine granular organic matter, when added loosens the soil and improves the passage for the entry of air. The mucus associated with the cast being hydroscopic absorbs water and prevents water logging and improves water-holding capacity. The organic carbon in vermicompost releases the nutrients slowly and steadily into the system and enables the plant to absorb these nutrients. The soil enriched with vermicompost provides additional substances that are not found in chemical fertilizers (Kale, 1998). Along with the chemical fertilizers organic manures can be mixed to the soil to control nutrient deficiency, increase organic matter content, water holding capacity of the soil to stimulate the activity of beneficial microorganisms that makes the plant food elements in the soil readily available to the plants. The existing situation demands the need for research to study the fertilizer recommendation for cultivation of stevia plant in Bangladesh maintaining soil health using eco-friendly organic material like vermicompost. The current aim of the study was to examine the influence of vermicompost application on the growth, leaf yield of stevia and to investigate the fertility status of post harvest soil.

Materials and Methods

The experiment was carried out with stevia plant in the Department of Agricultural Chemistry, BAU, Mymensingh during February to May, 2012. The research works were accomplished in 24 earthen pots in a completely randomized design with three replications. The soil was mixed thoroughly with vermicompost (VC) as per treatments {VC_0 (control), VC_5 (5 t ha^{-1}), $VC_{7.5}$ (7.5 t ha^{-1}) and VC_{10} (10 t ha^{-1})}. The VC contained 8.93, 1.35, 0.81, 0.62, 0.28, 0.15 and 0.016% organic C, total N, P, K, S, Ca and Mg, respectively. Eight kg of processed soil was taken in each earthen pot.

Forty five day old *in vitro* produced stevia seedlings were collected from *brac* Biotechnology Laboratory, Joydebpur, Gazipur to use in the experiment. Two soils (Acid and non-calcareous) of contrasting physico-chemical properties (Zaman *et al,* 2015) collected from Madhupur (Tangail) and BAU campus (Mymensingh), respectively were used. For the initial growth and development of the seedling, small amounts of urea (appx.1g) were applied to each pot including control. Intercultural operations like irrigation, soil loosening, weeding, plant protection and deflowering were done as and when necessary. Harvesting, cleaning, drying and weighing were done properly.

Plant height, branches $plant^{-1}$, leaves $plant^{-1}$, leaf area $plant^{-1}$, fresh leaf weight, dry leaf weight were studied at 15, 30,45 and 60 days after planting (DAP). Initial and post-harvest soil properties were determined following standard methods (Page *et al*., 1982) in the Laboratories of the Departments of Agricultural Chemistry, Biochemistry, Professor Muhammed Hussain Central Laboratory (PMHCL), BAU, Mymensingh and SRDI Regional Laboratory, Dhaka. Analysis of variance (ANOVA) was done following the principle of F-statistics and the mean values were separated by Duncan's Multiple Range Test (Gomez and Gomez, 1984).

Results and Discussion

Plant height

The mean data on plant height as influenced by different levels of VC have been presented in Table 1. The data revealed that VC application significantly affected the height of stevia plant irrespective of growth period and soils used.

VC @ 7.5 t ha^{-1} recorded the highest plant height of 105 cm in acid soil and 98 cm in the non-calcareous soil at 60 DAP which was identical with VC_{10} and the lowest plant height was observed from control. VC application at all levels increased plant height by 20 to 41 cm in acid soil and 23 to 36 cm in non-calcareous soil, respectively at harvest. Plant height was also significantly increased with the advancement of the growth period irrespective of VC levels. Plant height was 65% higher in acid soil and 58% in non-calcareous soil over control. The result was identical with Kumar *et al.* (2011) and Shadanpour *et. al*. (2011) who found that application of vermicompost increased the plant height in stevia and marigold, respectively.

Table 1. Effects of different levels of vermicompost on the plant height of stevia at various DAP*

VC level	Plant height (cm)									
	Acid soil					Non-calcareous soil				
	0	15	30	45	60	0	15	30	45	60
VC_0	11.0	18.3c	44.0b	50.0c	64.0d	13.0	20.0b	40.0b	43.0d	61.7c
VC_5	12.0	20.0c	47.0b	59.7b	84.0c	13.3	21.7b	51.3a	60.3c	85.0b
$VC_{7.5}$	13.3	26.0a	58.3a	82.0a	105.3a	15.0	25.3a	56.3a	73.3a	97.7a
VC_{10}	11.3	22.7b	53.0a	77.0a	93.7b	14.0	24.3a	52.3a	66.7b	89.0b
CV(%)	1.4	1.6	1.4	2.1	1.9	1.3	1.3	1.5	2.0	1.8
$LSD_{0.05}$	1.9	2.6	5.3	7.0	9.1	2.1	2.8	5.2	6.2	8.0

*DAP = Days after planting, CV = Coefficient of variance, LSD = Least significant difference

Branch number

Branch number plant^{-1} was significantly affected by the addition of VC in both soils (Table 2). The result revealed that branches plant^{-1} progressively increased with increasing levels of VC up to 7.5 t ha^{-1} in both soils and then declined with further addition.

Table 2. Effects of different levels of vermicompost on the branch number of stevia at various DAP*

VC level	Branches Plant^{-1} (No.)									
	Acid soil					Non-calcareous soil				
	0	15	30	45	60	0	15	30	45	60
VC_0	1.0	1.3b	1.7b	1.7b	2.0c	1.0	1.3b	1.3b	1.7b	2.0c
VC_5	1.0	1.7a	2.0b	2.3b	3.3b	1.0	1.7a	2.0a	2.3b	3.3ab
$VC_{7.5}$	1.0	2.3a	3.3a	3.7a	4.7a	1.0	2.3a	2.7a	3.3a	4.7a
VC_{10}	1.0	2.0a	2.3b	3.3a	4.3a	1.0	2.0a	2.3a	3.0a	3.7a
CV(%)	0.0	3.8	3.7	3.7	3.5	0.0	3.8	3.7	3.4	3.7
$LSD_{0.05}$	0.0	0.8	0.8	0.8	0.9	0.0	0.8	0.8	0.8	1.1

*DAP = Days after planting, CV = Coefficient of variance, LSD = Least significant difference

VC application influenced branch numbers variably from 15 to 60 DAP irrespective of soils. The highest number of branches plant^{-1} was obtained from the plant receiving 7.5 t VC ha^{-1} at harvest which was significantly different from other treatments in non-calcareous soil whereas identical results on branch number were observed with all the VC levels except control in acid soil. The lowest branch number was counted from the plant grown in control pot. VC application at all levels increased branch number by 65-135% in both acid and non-calcareous soil at harvest. Kumar *et al.* (2011) studied with stevia showed that application of organic manures instead of chemical fertilizers using vermicompost resulted in significantly maximum number of branches plant^{-1}.

Leaf number

The data revealed that the number of leaves plant^{-1} was significantly influenced by different levels of VC in both acid and non-calcareous soils at all growth stages except 0 DAP (Table 3). Leaf number was increased with the increased levels of VC up to 7.5 t ha^{-1} and then declined with further addition (VC_{10}) by 43% and 35% in acid soil and non-calcareous soil, respectively.

Table 3. Effects of different levels of vermicompost on the leaf number of stevia at various DAP*

VC level	Leaves Plant^{-1} (No.)									
	Acid soil					Non calcareous soil				
	0	15	30	45	60	0	15	30	45	60
VC_0	6.0	9.0c	18.0d	27.3d	42.3c	6.0	14.0d	21.3d	29.7d	44.7d
VC_5	6.0	12.0c	25.0c	49.0c	92.0b	6.0	23.0c	35.7c	55.3c	97.0c
$VC_{7.5}$	7.3	47.3a	67.3a	95.0a	181.0a	6.3	34.0a	56.0a	114.0a	196.7a
VC_{10}	8.0	36.7b	43.7b	82.0b	103.0b	6.0	28.3b	47.3b	80.7b	128.0b
CV(%)	3.5	6.3	5.1	4.3	4.9	2.9	3.1	3.4	4.6	4.8
$LSD_{0.05}$	2.3	3.1	4.3	7.5	12.1	2.3	2.5	4.4	8.1	13.4

*DAP = Days after planting, CV = Coefficient of variance, LSD = Least significant difference

The increasing trend of number of leaf was slower at the early growth stages (0-30 DAP) while it was rapid between 30 and 60 DAP irrespective of VC levels except control. VC application at all levels increased the number of leaves by 50 to 139 in acid soil and 53 to 152 in non-calcareous soil, respectively. Maximum number of leaves was recorded with $VC_{7.5}$ which was significantly higher than all other levels of VC in both soils. Plants fertilized with VC_5 and VC_{10} produced identical number of leaves in acid soil. The minimum number of leaves plant^{-1} was harvested from the plants fertilized with no VC irrespective of soils and growth period. The application of organic manures like vermicompost instead of chemical fertilizers resulted in significantly maximum number of leaves of stevia plant (Kumar *et. al.*, 2011).

Leaf area

Total leaf area plant^{-1} at harvest as influenced by different levels of VC has been presented in Table 4. Leaf area plant^{-1} responded significantly due to the application of different levels of VC. The result revealed that leaf area progressively increased with increasing levels of VC application up to 7.5 t ha^{-1} in both soils and then declined with further addition (VC_{10}). The highest total leaf area plant^{-1} (1126 cm^2 in acid soil and 1480cm^2 in non-calcareous soil) at harvest was measured from the plant receiving 7.5t VC ha^{-1} which was significantly higher than other levels. The lowest leaf area was found from the control treatment irrespective of soils used. At harvest, VC application at all levels increased leaf area by 142-402% in acid soil and 175 to 464% in non-calcareous soil, respectively. Kumar *et. al.* (2011) found that the application of organic manures like vermicompost instead of chemical fertilizers resulted in significantly maximum leaf area of stevia plant.

Dry weight

The dry weight of stevia leaves plant^{-1} at harvest varied significantly due to the application of different levels of VC (Table 4).

Table 4. Effects of different levels of vermicompost on leaf area, dry weight and yield increase of stevia leaves over control at harvest

VC level	Leaf area plant^{-1} (cm^2)		Leaf dry weight (g plant^{-1})		Yield increase over control (%)	Yield increase over control (%)
	Acid soil	Non-calcareous soil	Acid soil	Non-calcareous soil	Acid soil	Non-calcareous soil
VC_0	224d	262c	1.35d	1.45d	-	-
VC_5	544c	721bc	2.98c	3.11c	119	114
$VC_{7.5}$	1126a	1480a	5.95a	6.35a	335	338
VC_{10}	797b	1032b	3.42b	4.20b	151	190
CV(%)	4	5	4.91	4.82	-	-
$LSD_{0.05}$	157	413	0.41	0.45	-	-

CV = Coefficient of variance, LSD = Least significant difference

Dry weight gradually increased with increasing levels of VC application up to 7.5 t ha^{-1} in both soils and then declined with further addition (VC_{10}). The highest dry weight plant^{-1} (5.95 g in acid soil and 6.35 g in non-calcareous soil) at harvest was obtained from the plant fertilized with 7.5t VC ha^{-1} which was significantly higher than other levels. The lowest values were obtained from the control treatment (1.35g in acid soil and 1.45g in non-calcareous soil). VC application at all levels increased leaf dry yield at harvest by 119 to 335% in acid soil and 114 to 338% in non-calcareous soil, respectively over control. Azarpour *et al*., (2013) showed that vermicompost had a significant positive effect on dry weight of stevia as compared with the plant grown in soil without vermicompost. They obtained highest fresh leaf biomass yield of stevia from the treatment where10t ha^{-1} vermicompost were applied.

Post-harvest fertility status of soil

Results on the chemical properties of post harvest soils as influenced by different levels of VC are presented in Table (5a and 5b). The data revealed that all the parameters were significantly influenced by the addition of VC irrespective of soils used.

Table 5a. Effects of different levels of vermicompost on the fertility of post harvest soils

Levels of VC	pH		Organic matter (%)		Total N ($\mu g\ g^{-1}$)		Available P ($\mu g\ g^{-1}$)		Exch. K ($cmol\ kg^{-1}$)	
	AS	NS	AS	NS	AS	NS	AS	NS	AS	NS
VC_0	4.9	6.5	1.70d	1.28d	0.10b	0.12b	2.83d	10.00d	0.18ab	0.15b
VC_5	5.2	6.7	1.89c	1.71c	0.15ab	0.18ab	4.47c	14.08c	0.23a	0.19ab
$VC_{7.5}$	5.4	7.0	2.13b	2.19b	0.21a	0.22a	7.30b	17.10b	0.27a	0.24a
VC_{10}	5.7	7.2	2.39a	2.61a	0.25a	0.25a	8.64a	20.26a	0.29a	0.31a
CV(%)	4.2	4.1	3.10	5.40	8.12	7.30	9.40	4.85	5.30	5.31
$LSD_{0.05}$	0.08	0.09	0.09	1.00	0.07	0.09	0.72	2.96	0.09	0.08

AS = Acid soil, NS = Non-calcareous soil, CV = Coefficient of variance, LSD = Least significant difference, Exch.= Exchangeable

The values of the soil parameters were increased with the increased levels of VC. The acidity of both soils decreased with the application of VC (pH ranged from 4.9 to 5.7 in acid soil and 6.5 to 7.2 in non-calcareous soil). Organic matter content of both soils increased significantly over control and ranged from 1.7 to 2.39% in acid soil but 1.28 to 2.61% in non-calcareous soil. The contents of total N, available P, exchangeable K, Ca, Mg, available S, Zn, B were also significantly increased with the increased levels of VC up to its highest level (VC_{10}) in both soils. Except available P, all the nutrient contents were much higher in non-calcareous soil compared to acid soil.

Table 5b. Effects of different levels of vermicompost on the fertility of post harvest soils

Levels of VC	Available S ($\mu g\ g^{-1}$)		Exch. Ca ($cmol\ kg^{-1}$)		Exch. Mg ($cmol\ kg^{-1}$)		Available Zn ($\mu g\ g^{-1}$)		Available B ($\mu g\ g^{-1}$)	
	AS	NS	AS	NS	AS	NS	AS	NS	AS	NS
VC_0	13.06d	13.00d	0.15b	2.10d	0.60b	1.20c	1.30b	0.80c	0.33c	0.23c
VC_5	16.35c	17.62c	1.80a	5.36c	0.85a	3.73b	1.75ab	0.92c	0.49b	0.30bc
$VC_{7.5}$	20.25b	24.76b	2.18a	7.55b	0.99a	5.90a	1.93a	1.10b	0.80a	0.47b
VC_{10}	22.16a	29.79a	2.50a	10.67a	1.15a	6.25a	2.07a	1.29a	0.90a	0.58a
CV(%)	4.53	10.38	10.61	4.12	5.20	9.30	9.30	3.40	9.40	7.40
$LSD_{0.05}$	1.95	3.13	0.90	0.81	0.85	0.51	0.24	0.12	0.11	0.08

AS = Acid soil, NS = Non-calcareous soil, CV = Coefficient of variance, LSD = Least significant difference, Exch.= Exchangeable

The highest values of the parameters were obtained when vermicompost was applied @ 10 t ha^{-1} and the lowest from the initial soil (VC_0). Orozco *et al*. (1996) described that vermicompost contains nutrients such as phosphorus, potassium, and magnesium as available to plants. Manivannan *et al*. (2009) has reported that an earthworm-processed waste material contains a higher concentration of exchangeable K due to enhanced microbial activity during the vermicomposting process, which consequently enhances the rate of mineralization.

Conclusion

The results revealed that growth and yield attributes such as plant height, branch and leaf number, leaf area and dry weight of leaves were significantly influenced by different levels of VC. All plant parameters were increased with the advancement of growth period (60 DAP) and increased rate of VC up to 7.5t ha^{-1} and then declined with further additions. The leaf biomass yield increased by 335% and 338% in acid and in non-calcareous soil, respectively over control. The overall performance of non-calcareous soil was superior to acid soil in terms of both plant and soil parameters studied. The acidity of both soils significantly decreased with the increased application of VC ranging from 4.9 to 5.7 in acid soil and 6.5 to 7.2 in non-calcareous soil. Total N, available P, exchangeable K, Ca, Mg, available S, Zn, B were also significantly increased with the increased levels of VC up to its highest level (VC @ 10t ha^{-1}) in both soils. Thus the results suggest that VC @ 7.5t ha^{-1} might be applied for getting maximum leaf biomass yield of stevia and 10t ha^{-1} for increasing the fertility of both soils.

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