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Growth, leaf biomass yield of stevia and post-harvest soil fertility as influenced by different levels of poultry manure

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Abstract

Stevia represents an interesting species for the development of new ingredients characterized by a low caloric contribution having high antioxidant and phytochemical properties. As a valuable organic fertilizer, poultry manure (PM) serves as a suitable alternate to chemical fertilizer due to having higher total solid content than most other manures. The present study was conducted in the net house of the Department of Agricultural Chemistry, Bangladesh Agricultural University, Mymensingh to evaluate the effects of poultry manure on growth and leaf yield of stevia and post-harvest soil fertility. The experiment was laid out in a Complete Randomized Design (CRD) with three replications. PM was applied at rates of 0, 5, 7.5 and 10 t ha^{-1}. Data of the plant height, number of branches and number of leaves per plant were collected at 0, 15, 30, 45 and 60 days after planting (DAP). At harvest, leaf area, fresh weight, dry weight of leaves of stevia and post-harvest soil were evaluated. Plant that received 5 t ha^{-1} of PM was the best with respect to all the parameters assessed except post-harvest soil fertility. The contents of total N, available P, exchangeable K, Ca, Mg, available S, Zn and B were significantly increased with the increased levels of PM up to 10 t ha^{-1} in both soils. pH and soil organic matter content were also increased several folds and favored higher growth and yield of stevia. It can be recommended from the findings of the study that farmers should apply PM @ 5 t ha^{-1} to obtain maximum growth and leaf yield of stevia where as PM @ 10 t ha^{-1} can be applied for maintaining soil fertility in the agro-climatic condition of Bangladesh.

Introduction

In recent years, it becomes the major concern to long-run agricultural sustainability and ensure global food needs with the global population projected to exceed 7.5 billion by the year 2020 and 9.2 billion by 2050 (Gruhn *et al.*, 2000). The long-term and intensive use of synthetic chemical fertilizers is hazardous to human health, soil productivity, water quality, aquatic life and environmental safety. Organic agriculture is a low-input sustainable agricultural production management system that promotes the environmentally, socially and economically sound production of food, fiber, timber etc (IFOAM, 2008). A traditional source of soil organic matter and primary nutrients for agricultural crops is the wide use of poultry manure in Bangladesh.

Poultry manure (PM) is a valuable organic fertilizer and can serve as a suitable alternate to chemical fertilizer. In agriculture, the main reasons for applying PM include the organic amendment of soil and the provision of nutrients to crops (Warren *et al.*, 2006). PM application registered over 53% increases of N level in the soil, from 0.09 to 0.14 % and exchangeable cations increase with manure application (Boateng *et al.*, 2006). Stefan (2003) indicated that fresh poultry dropping contained 70% water, 1.4% N, 1.1% P_2O_5 and 0.5% K_2O while dried PM contained 13% water, 3.6% N, 3.5% P_2O_5 and 1.6% K_2O. Manure not only provides high nutrient contents (N, P, and K) in comparison with chemical fertilizer, but also adds organic matters to the soil for the improvement of soil structure, aeration, soil moisture-holding capacity, and water infiltration. Many studies indicated that using PM over a long period of time would change the biological and chemical properties of the soil with the increase of soil organic matter (Whalen *et al.*, 2000; Yang *et al.*, 2004; Moore and Edwards, 2005; Tejada *et al.*, 2006; Varvel, 2006). Soil organic content supplied from PM affects greatly the physical condition of the soil such as runoff, infiltration, water retention capacity, soil pH and so on (Hillel, 1998). The application rates of PM and types of PM (broiler or litter) play the main role on soil properties (Gilley *et al.*, 2000).

Increasing demand for dietetic products and natural food ingredients draw attention towards dietary natural antioxidants (Lobo *et. al.*, 2010), capable to inhibit reactive oxygen species (ROS), responsible for the determination of several human pathologies, such as cancer, diabetes, cardiovascular diseases etc. At the same time, the increasing health concern over the consumption of sugar and the problems related to the safety of some artificial non nutritive sweeteners (NNS) have stimulated the interest toward natural sweeteners (Pawar *et al.*, 2013). Stevioside and other steviol glycosides extracted from the leaves of the plant *Stevia rebaudiana* Bertoni were the first natural high potency sweeteners to be approved for consumption in the United States, the European Union (Risso *et al*., 2014), as well as in Australia and New Zealand. Nowadays it becomes an interesting species due to containing low calorie having high antioxidant and phytochemical properties. It is well known how the biosynthesis of secondary metabolites in medicinal plants is strongly influenced by several pre-harvest factors, such as environmental conditions, agricultural management, harvest time, water and nutrient requirements.

To best of our knowledge, till now no detailed study has yet been investigated about the agronomic management practices, ecological and nutrient requirements of stevia cultivation in Bangladesh. Some preliminary experiments on morphological and physiological parameter have been conducted by BSRI and *brac*. In Bangladesh Agricultural University recently some study has been conducted and reported on suitable soils (Zaman *et al.,* 2015a), N and S requirement, critical N and S content (Zaman *et al*., 2016a and 2016b), vermicompost as organic manure (Zaman *et al.*, 2015b) and P use efficiency and critical P content; K requirement and K nutrition (Zaman *et al*., 2017a and 2017b) in stevia grown in both acid and non-calcareous soil. Moreover, information on the effects of PM as a source of plant nutrients is scanty. Thus, according to the importance of phytochemicals and antioxidant power for functional aspect of stevia, the present study was conducted to evaluate the effects of PM on growth and yield of leaf biomass as well as the post-harvest status of stevia cultivated soil.

Materials and Methods

A pot experiment was conducted during February to May, 2012 under net house condition at the Department of Agricultural Chemistry, Bangladesh Agricultural University, Mymensingh. Stevia was grown in 24 pots containing two contrasting soil (acid and non-calcareous soils) treated with different rates of poultry manure (PM) *viz.*, PM_0 (without PM); PM_5 (5 kg PM ha^{-1}); $PM_{7.5}$ (7.5 kg PM ha^{-1}) and PM_{10} (10 kg PM ha^{-1}). PM contained 17.86, 2.50, 1.62, 0.72, 0.25, 0.20 and 0.019% organic C, total N, P, K, S, Ca and Mg, respectively. Each earthen pot was filled with 8.0 kg of processed soil. Soils used in this study were collected from Madhupur (Tangail) and BAU campus (Mymensingh). The experimental set up was done in Complete Randomized Design (CRD) with three replications. Stevia (*Stevia rebaudiana* Bertoni) seedlings of 45 day old, belonging to *brac* Biotechnology Laboratory, Joydebpur, Gazipur, were used. Physicochemical properties of both soils were measured (Zaman *et al*., 2015a). Initially small amount of urea was added to each pot including control. Time to time necessary intercultural operations were done *viz.*, irrigation, soil loosening, weeding, plant protection and deflowering etc. as per requirement. Harvesting, cleaning, drying and weighing were done properly. Growth and leaf yield parameters i.e. plant height, branches $plant^{-1}$, leaves $plant^{-1}$, leaf area $plant^{-1}$, fresh leaf weight and dry leaf weight were studied at 15, 30, 45 and 60 days after planting (DAP). 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 using Latin Square Design (Gomez and Gomez, 1984).

Results and Discussion

Effect of poultry manure (PM) on plant height

Plant height of stevia was significantly affected by different levels of PM from 15 to 60 DAP irrespective of soils used (Fig. 1). PM application increased plant height by 51cm and 45 cm in acid and non-calcareous soils, respectively at harvest. Plant height was significantly increased with the advancement of the growth period. Increase of plant height was slow between 0 and 15 DAP and rapid between 15 and 60 DAP. The highest plant height was measured from the plant receiving 5 t PM ha^{-1} which was identical with 7.5 t PM ha^{-1} in acid soil but significantly different from those plants fertilized with 10 t PM ha^{-1} and PM_0 and the lowest plant height was observed from the plant receiving no PM.

This result was in agreement with previous reports (Agboola and Obigbesan, 1975; Agboola and Omueti, 1982; Agboola and Fagbenro, 1985; Okwuagwu *et al.*, 2003). Tiamiyu *et al*. (2012) reported that plant height of okra was greater in poultry manure treated soil. Ajari *et al.* (2003) asserted that poultry manure @ 5 t ha^{-1} treated soil could increase plant height when compared with other sources of manure. Comparatively high N content of poultry manure increased the vegetative growth of stevia. The increase in plant height with poultry manure was mainly due to more availability of nutrients throughout the growing season. These results were in accordance with the findings of Mitchell and Tu (2005) and Warren *et al*. (2006). Height increase was 82% higher in acid soil and 64% higher in non-calcareous soil over control.

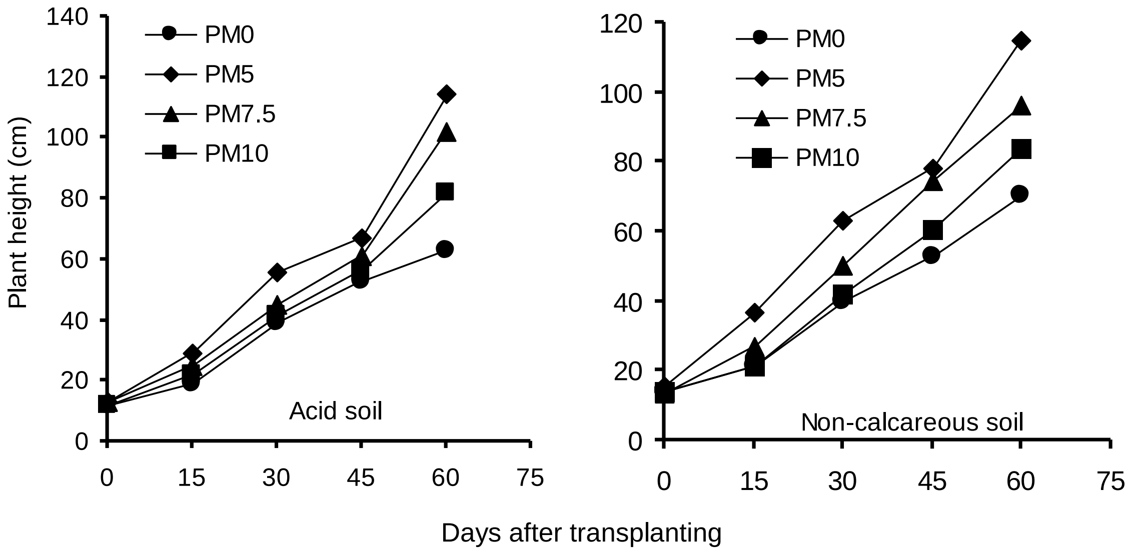

Fig. 1. Effects of different levels of poultry manure (PM) on the plant height of stevia at various DAP

Effect of poultry manure (PM) on branch number

In the present study, the addition of PM significantly influenced the number of branches of stevia plant (Fig. 2). Branch numbers variably and significantly increased from 15 to 60 DAP. The increase was very rapid from 0 to 45 DAP and then either remained constant or little increased or decreased. The highest number of branches (5.7 in both acid and non-calcareous soil) was counted from the plants receiving PM @ 5 t ha^{-1} which was statistically identical with all other PM levels in non-calcareous soil except control. The lowest number of branches was counted from control. This finding was in line with Garg and Bahla (2008). They reported that poultry manure @ 5 t ha^{-1} more readily supplied P to plants than other organic manure sources which improved the plant cell structure and increased number of branches plant^{-1}. PM application at all levels increased branch number by 73 to 147% in acid soil and 115 to 185% in non-calcareous soil at harvest. This finding was in agreement with that of Ojeniyi *et al.* (2007) who observed that application of N, P, K and animal manure increased the number of branch of tomato as compared to control.

Effect of poultry manure (PM) on leaf number

Poultry manure at different levels has significant effect on the number of leaves plant^{-1} both in acid and non-calcareous soils at various DAP (Fig. 3). Different levels of PM significantly influenced the number of leaves of stevia plants at all growth stages except 0 DAP irrespective of soils used. Leaf number was increased with the increasing levels of PM up to 5 t ha^{-1} and then declined with further addition. This result was contradictory with the findings reported by Akdeniz *et al*. (2006) and Garg and Bahla (2008) that sorghum and vegetable crops produced maximum number of leaves when PM and sewage sludge was applied in the field @ 10 t ha^{-1}, respectively. At initial growth stage (0–30 DAP) leaf number increase rate was very slow while later it became rapid (30 to 60 DAP) irrespective of PM levels except control. Initially complete decomposition of organic manure has not been occurred which results nutrient deficiency in the soil. In the early growth stage, the number of leaves plant^{-1}, leaf length, leaf breadth and dry weight were lower in organic manure cultivation than chemical fertilizer cultivation. But in the later growth stage the situation become quite different, there was higher number of leaves plant^{-1}, rapid growth and other physiological indexes. PM application at all levels increased the number of leaves by 134 to 273 in non-calcareous soil and 114 to 244 in acid soil. Maximum number of leaves was recorded with PM_5 which was significantly higher than all other levels of PM in non-calcareous soil. Plants fertilized with $PM_{7.5}$ and PM_{10} produced identical number of leaves in acid soil. The minimum number of leaves plant^{-1} was counted from the control irrespective of soils and growth period. In ginger, Khandkar and Nigam (1996) observed the highest plant height (39.3 cm), number of leaves (20.30), tillers per plant (3.7) and yield (3300 kg ha^{-1}) due to application of FYM (6 t ha^{-1}) compared to control.

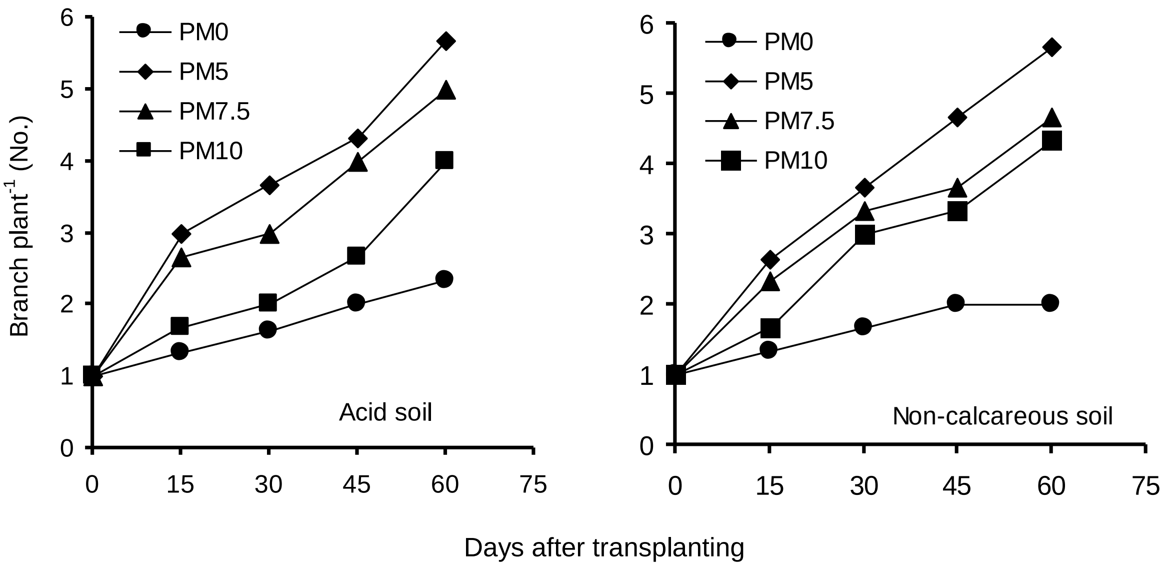

Fig. 2. Effects of different levels of poultry manure (PM) on the branch number of stevia at various DAP

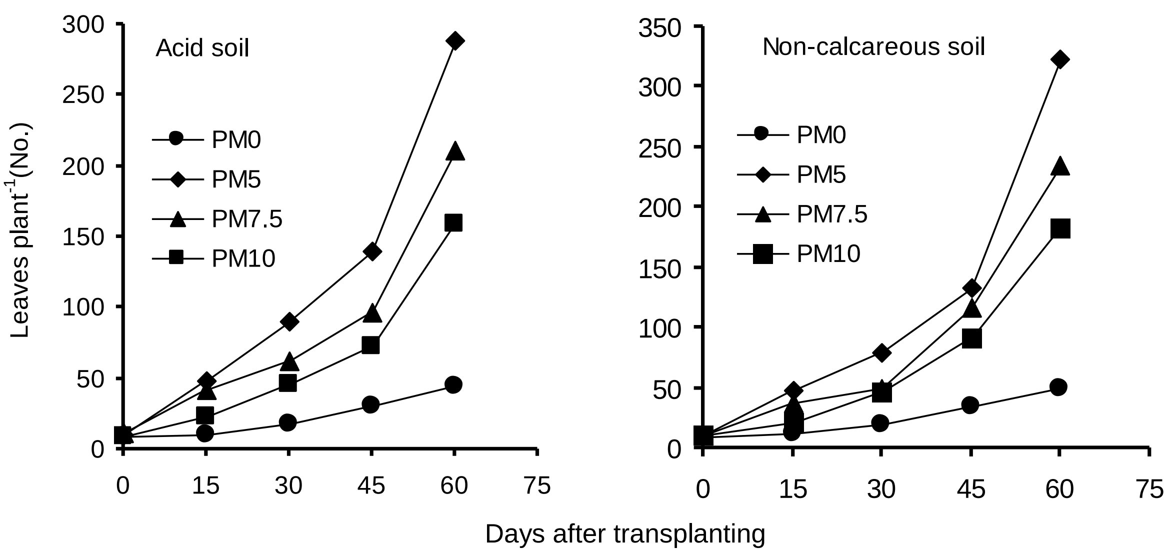

Fig. 3. Effects of different levels of poultry manure (PM) on the leaf number of stevia at various DAP

Effect of poultry manure (PM) on leaf area

The data on total leaf area plant^{-1} at different stages as influenced by different doses of PM have been presented in Table 1. Leaf area plant^{-1} responded significantly due to the application of different levels of PM. The highest total leaf area plant^{-1} (2303cm^2 in acid soil and 2700cm^2 in non-calcareous soil) at harvest was measured from the plant receiving 5 t PM ha^{-1} which was significantly higher than other levels of PM. Treatment $PM_{7.5}$ was responsible for second highest values (1507cm^2 in acid soil and 1591cm^2 in non-calcareous soil). At harvesting stage, PM application at all levels increased leaf area by 291 to 933% and 344 to 881% in acid and non-calcareous soils, respectively.

Similar findings were previously reported by Ofusu-Anim and Leitech (2009) that the highest leaf area was counted from the plants treated with PM @ 5 t ha^{-1} and the lowest from the zero treatment of potato cultivation. Katung *et al.* (1996) mentioned that PM @ 5 t ha^{-1} application easily decomposed in soil and produced the highest leaf area index of onion. PM is generally rich in manorial ingredients, early decomposer and quick supplier of nutrients. PM application in soil increased nutrient availability in the correct proportion leading to increased photosynthetic activity, thus an increase in light interception, dry matter production, accumulation and partitioning (Robert and Walker, 1989; Smith *et al.*, 1992; Hartz *et al.*, 1996).

Table 1. Effects of different levels of poultry manure (PM) on leaf area, dry weight and yield increase of stevia leaves at harvest

PM 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
PM_0	223d	275c	1.50d	1.55d	-	-
PM_5	2303a	2700a	8.96a	9.63a	497	521
$PM_{7.5}$	1507b	1591b	6.16b	7.12b	302	365
PM_{10}	874c	1221bc	4.57c	5.41c	204	249
CV(%)	5	6	5.19	5.07	-	-
$LSD_{0.05}$	223	593	0.61	0.71	-	-
SE±	194	240	0.82	0.90	-	-

CV = Coefficient of variance, LSD = Least significant difference, SE± = Standard error of means

Effect of poultry manure (PM) on dry weight

The data pertaining to dry weight of stevia leaves plant^{-1} at harvest as influenced by different levels of PM have been presented in Table 1. Leaf dry weight variably increased with increased PM levels up to 5 t ha^{-1} in both soils. The highest (8.96g in acid soil and 9.63g in non-calcareous soil) and second highest (6.16g in acid soil and 7.12g in non-calcareous soil) dry weight plant^{-1} at harvest were measured from the plant receiving 5 t and 7.5 t PM ha^{-1} , respectively which were significantly higher than other levels of PM. The result had not agreed with the findings reported by Detpiratmongkol *et al.* (2014). Detpiratmongkol *et al.* (2014) opined that application of 12.5 t ha^{-1} of chicken manure resulted in a significantly higher performance of growth parameters, total dry matter yield when compared to 2.5, 5, 7.5 and 10 t ha^{-1}, respectively. The lowest values were obtained from the control treatment. PM application at all levels increased leaf dry yield at harvest by 204 to 497% in acid soil and 249 to 521% in non-calcareous soil over control. El-Dewiny *et al.* (2006) showed that dry weight of radish and spinach plants increased with application of sewage sludge.

Effect of poultry manure (PM) on fresh weight

Fresh leaf weight was significantly affected by the application of PM treatments (Table 2). Leaf fresh weight was significantly increased with PM application of 5 t ha^{-1} in both soils and then declined with further addition ($PM_{7.5}$ and PM_{10}). The highest fresh weight of leaves plant^{-1} (33.25 g in acid soil and 36.18 g in non-calcareous soil) was found at 5 t PM ha^{-1} and the lowest (5.05 g in acid soil and 5.50 g in non-calcareous soil) at control treatment. PM application at all levels increased fresh weight at harvest by 13.06 to 28.20 g plant^{-1} in acid soil and 14.73 to 30.68 g plant^{-1} in non-calcareous soil. Similar type of result was reported by Uka *et al*. (2013) in the fresh weight of okra. El-Dewiny *et al.* (2006) also depicted that fresh weight of radish and spinach plants increased with increased application of sewage sludge.

Table 2. Effects of different levels of poultry manure (PM) on the fresh weight of stevia leaves at harvest

PM level	Acid soil	Non-calcareous soil
PM_0	5.05d	5.50d
PM_5	33.25a	36.18a
$PM_{7.5}$	25.12b	27.49b
PM_{10}	18.11c	20.23c
CV(%)	5.18	5.13
$LSD_{0.05}$	2.36	2.57
SE±	3.17	3.44

CV = Coefficient of variance, LSD = Least significant difference, SE± = Standard error of means

Effect of poultry manure (PM) on post-harvest fertility of soil

Application of PM significantly influenced the post-harvest properties of both soils (Table 3a and 3b). There was significant increase in all the parameters with the increased levels of PM irrespective of soils used. The pH of both soils ranged from 4.9 to 5.8 in acid soil and 6.5 to 7.1 in non-calcareous soil. Wang *et al.* (2013) gave the same opinion that any organic material if added to the soil that will reduce soil acidity. This may be due to the fact that when organic residues (plant or animal) are added to the soil, they release organic anions which neutralize the hydrogen ion of the acid soil. The organic matter (OM) content of the post-harvest soils significantly increased due to the application of manures or composts in both soils. Organic matter content ranged from 1.7 to 2.5% in acid soil and 1.28 to 2.72% in non-calcareous soil. The contents of total N, available P, exchangeable K, Ca, Mg, available S, Zn, B were significantly increased with the increased levels of PM up to 10 t ha^{-1} in both soils. All the nutrient contents were much higher in non-calcareous soil compared to acid soil. The available P content in acid soil was significantly lower than non-calcareous soil. The higher nutrient content of PM amended soil might be due to higher nutrient contents of PM compared to other amendments. However, the highest values of all the parameters were obtained from PM_{10} and the lowest from the initial soil.

Table 3a. Effects of different levels of poultry manure (PM) on the fertility of post harvest soils

PM levels	pH		Organic matter (%)		Total N (%)		Available P (µg g^{-1})		Exch. K (cmol kg^{-1})	
	AS	NS	AS	NS	AS	NS	AS	NS	AS	NS
PM_0	4.9b	6.5b	1.70b	1.28b	0.10b	0.12b	2.83c	10.00cd	0.18b	0.15b
PM_5	5.3a	6.7a	1.92b	1.96a	0.19ab	0.19b	4.64b	14.10bc	0.22b	0.20ab
$PM_{7.5}$	5.6a	6.8a	2.24a	2.26a	0.23a	0.23a	7.62a	18.20b	0.26ab	0.25a
PM_{10}	5.8a	7.1a	2.50a	2.72a	0.28a	0.26a	9.91a	21.30a	0.30a	0.28a
CV(%)	3.1	3.3	3.86	6.92	9.62	7.62	10.55	5.73	3.90	5.36
$LSD_{0.05}$	0.5	0.9	0.25	0.35	0.59	0.15	0.91	2.03	0.04	0.06
SE±	0.2	0.2	0.07	0.09	0.01	0.01	0.63	0.95	0.02	0.03

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

Table 3b. Effects of different levels of poultry manure (PM) on the fertility of post-harvest soils

PM levels	Available S (µg g^{-1})		Exch. Ca (cmol kg^{-1})		Exch. Mg (cmol kg^{-1})		Available Zn (µg g^{-1})		Available B (µg g^{-1})	
	AS	NS	AS	NS	AS	NS	AS	NS	AS	NS
PM_0	13.06d	13.00d	0.15b	2.10b	0.60b	1.20b	1.30b	0.80b	0.33b	0.23c
PM_5	16.45c	18.23c	2.17a	7.94a	0.88a	3.50a	1.75ab	0.98b	0.65b	0.38b
$PM_{7.5}$	19.35b	26.68b	3.52a	9.18a	1.10a	5.65a	1.93a	1.16b	0.88a	0.56ab
PM_{10}	22.10a	30.27a	4.79a	11.52a	1.31a	7.75a	2.18a	1.38a	0.98a	0.95a
CV(%)	4.32	12.21	7.85	4.26	5.17	9.35	7.30	4.30	4.39	7.81
$LSD_{0.05}$	1.19	2.03	0.37	0.88	0.08	0.41	0.63	0.31	0.12	0.08
SE±	0.51	2.19	0.32	0.46	0.02	0.40	0.09	0.04	0.09	0.04

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

The present findings were in conformity line with Savithri *et al*. (1991) who reported that application of 6.25 t ha^{-1} poultry manure to the first crop of sorghum had significant residual effect on succeeding crop yield and that also increased the nutrient content of the soil. Senthilkumar (2002), Sudhakara (2005) and Ibeawuchi *et al*. (2006) obtained similar results in African marigold, coleus and continuous cropping system, respectively.

Conclusion

From the investigation, it appeared that PM gave significant positive response towards all the parameters studied. The best PM dose was 5 t ha^{-1} for all the parameters assessed except post-harvest soil conditions. In case of post-harvest soil status the highest values of all the parameters were obtained from PM_{10}. Finally, it would be recommended for the farmers that PM @ 5 tha^{-1} can be applied to obtain maximum growth and yield of stevia and PM @ 10 t ha^{-1} for maintaining soil fertility in agro-climatic condition of Bangladesh.

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