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Influence of organic and inorganic fertilizers on mineral nutrition of Stevia in different types of soil

S. Khanom, M.A.H. Chowdhury, M.T. Islam and B.K. Saha
Department of Agricultural Chemistry, Bangladesh Agricultural University, Mymensingh-2202, Bangladesh

Abstract

A pot culture experiment was conducted in a net-house of Bangladesh Agricultural University (BAU), Mymensingh from January to June 2007 to study the effect of organic and inorganic fertilizers on the nutrient contents and their uptake by *Stevia rebaudiana* (Bert.) grown in four types of soil. The soils were saline, acid, calcareous and non-calcareous in nature and they were collected from Khulna, Tangail, Natore and Mymensingh districts, respectively. There were four fertilizer treatments viz., 2 organic fertilizers (poultry manure and cowdung) and 1 inorganic fertilizer and a control were used. The rate of poultry manure and cowdung was 5 t ha^{-1} and the fertilizer nutrients *viz.*, N, P, K and S were applied at the rate of 120, 24, 80 and 20 kg ha^{-1}, respectively. The experiment was laid out following completely randomized design with 16 treatments and three replications. The concentration and uptake of various nutrients (N, P, K, S, Ca & Mg) in stevia leaves varied with different types of soil. Generally the highest values were recorded with the plants grown in non-calcareous soil and lowest in saline soil. Concerning fertilizer treatments, the chemical fertilizer produced the highest contents of nutrients, however an identical result was obtained in cowdung treatment in most of the nutrients whereas the nutrients uptake were highest in plants treated with cowdung. Overall results suggest that stevia can be successfully grown in non-calcareous soil treated with chemical fertilizers or cowdung at the recommended rate.

Keywords: Stevia, Cowdung, Poultry manure, Fertilizer, Nutrients

Introduction

Stevia rebaudiana (Bert.) is a semitropical perennial herb of the daisy family, native to the mountains of Brazil and Paraguay. Stevia is a major source of high-potency bio-sweetener for replacing chemical sweeteners and even table sugar (Geuns, 2004). In Bangladesh the number of diabetic people in the age group of 25-45 is increasing at an alarming pace. Stevia is a new crop and is gaining very high popularity amongst all type of sweetener users as most ideal substitute for sugar. Stevia leaves are 20-30 times sweeter than sugar. Stevia leaves are nutritious, containing substantial amounts of protein, calcium and phosphorus. Stevia can be safely used in regulating blood sugar, preventing hypertension, treatment of skin disorders and prevention of tooth decay. Stevia plant has a high requirement of major nutrients especially N, P and K and their deficiencies are the major limitations for the quality biomass production of stevia (Chalapathi, *et al.,* 1999). Since the feeder roots of stevia plants tend to be very near to the surface, it could be a good idea to add compost for extra nutrients. A crop production system, providing information on optimized crop inputs, weed and disease control, harvesting and handling methods would have to be detailed out. Bangladesh being an agro-based country could easily cultivate the plant in its relatively high land such as 'char' lands as it grows well in open space having regular sunlight. Some laboratory trials on vegetative propagation of stevia have been conducted by Bangladesh Rural Advancement Committee (BRAC) and Bangladesh Sugarcane Research Institute (BSRI). But no detailed reports on the nutritional aspects of this crop were found in Bangladesh. Hence, the present investigation was undertaken with an objective of increasing mineral nutritional status of stevia through fertilizer treatments.

Materials and Methods

A pot culture experiment was conducted at the net-house of the Department of Agricultural Chemistry of Bangladesh Agricultural University (BAU), Mymensingh from January to June 2007. Four different soil types namely saline, acidic, calcareous and non-calcareous were collected from four districts of Bangladesh *viz.*, Khulna (Koira), Tangail (Madhupur), Natore (Kachi Kata) and Mymensingh (BAU Campus), respectively. The soils at 0-15 cm depth were collected, air dried, ground and sieved through a 5 mm sieve. The soil samples were analyzed following the standard methods of analysis (Page *et al.,* 1982) for their physical and chemical properties. Four fertilizer treatments, 2 organic (poultry manure and cowdung), 1 inorganic fertilizer and 1 control were used. Nitrogen, P, K and S were applied at the rate of 120, 24, 80 and 20 kg ha^{-1} and cowdung and poultry manure at the rate of 5 t ha^{-1}, respectively (BARC, 2005). One-third amount of urea and full dose of other fertilizers were applied one day before transplanting. Well decomposed cowdung and poultry manure were mixed thoroughly with the soil of respective pots 15 days before transplanting. Stem cuttings were collected from the BRAC Plant Biotechnology Lab. Joydebpur, Gazipur. One seedling was transplanted in each pot containing 8.5 kg soil. The experiment was conducted in a completely randomized design with three replications. The crop was harvested at 60 days after transplanting and the leaves were taken for chemical analysis. Nitrogen content was determined following micro- Kjeldahl method as described by Jackson (1973) and other nutrients were analyzed following the standard methods (Page *et al.,* 1982). Analysis of variance was done with the help of computer package MSTAT developed by Russel (1986) and the mean differences of the treatments were adjudged by LSD test. The physical and chemical properties of soils have been presented in Table 1.

Table 1. Physical and chemical properties of the experimental soils

Soil properties	Different soil types			
	Saline	Acid	Calcareous	Non-calcareous
Textural class	Silt loam	Clay loam	Clay loam	Silt loam
pH	7. 8	4.7	6.9	6.5
Total N (%)	0.17	0.12	0.22	0.15
Available P ($\mu g\ g^{-1}$ soil)	5.12	5.41	17.94	14.31
Exchangeable K (cmol kg^{-1}soil)	0.14	0.18	0.40	0.16
Available S ($\mu g\ g^{-1}$ soil)	30.4	4.15	15.94	10.66

Results and Discussion

Nitrogen: Significant variation was found in leaf N content of stevia grown in different types of soil. The highest value (1.01%) was measured from the plants grown in non- calcareous soil and it was lowest (0.83%) in saline soil (Table 2). Application of different fertilizers significantly influenced N content of stevia. The highest N content (1.24%) was obtained from chemical fertilizer treated plant and the lowest (0.66%) in control plants (Table 3). Interaction effect of different soils and fertilizers was not significant. The highest content (1.49%) was obtained from the plants grown in non calcareous soil treated with chemical fertilizer and the lowest content (0.62%) was determined from the unfertilized plant grown in calcareous soil (Table 3). The N concentration of stevia leaf was positively and significantly correlated with P, K and S concentration, indicating that plant maintain a definite ratio of N-P-K-S. Significant relationship was not found with N and Ca or Mg concentrations (Table 5)

Table 2. Effects of different types of soil on N, P, K, S, Ca and Mg concentrations and their uptake by stevia

Soil Types	Nitrogen		Phosphorus		Potassium		Sulphur		Calcium		Magnesium	
	Content (%)	Uptake (mg pot^{-1})	Content (%)	Uptake (mg pot^{-1})	Content (%)	Uptake (mg pot^{-1})	Content (%)	Uptake (mg pot^{-1})	Content (%)	Uptake (mg pot^{-1})	Content (%)	Uptake (mg pot^{-1})
S_1	0.83	57.5	0.43	27.0	0.58	42.0	0.38	29.4	0.38	23.91	0.14	9.14
S_2	0.85	77.5	0.54	48.8	0.61	59.5	0.47	47.3	0.39	34.56	0.15	12.19
S_3	0.86	45.0	0.49	26.0	0.49	30.0	0.43	27.9	0.36	19.99	0.15	7.96
S_4	1.01	109.2	0.69	70.6	0.60	71.0	0.55	60.3	0.40	40.26	0.16	15.72
LSD (0.05)	0.13	19.83	0.04	9.8	0.03	10.8	0.03	6.2	0.03	6.83	0.03	2.57

Legend: S_1: Saline soil, S_2: Acid soil, S_3: Calcareous soil, S_4: Non-calcareous soil

Types of soil significantly influenced the N uptake by stevia. The highest uptake (109.2 mg pot^{-1}) was calculated from the plant grown in non calcareous soil and the lowest uptake (45.0 mg pot^{-1}) was recorded in calcareous soil (Table 2). Nitrogen uptake was significantly affected by different fertilizer application. The highest value (140.8 mg pot^{-1}) was obtained from cow dung treated pot and it was lowest (29.2 mg pot^{-1}) in unfertilized pot (Table 3). Interaction effect of different types of soil and fertilizers showed significant variation with respect to N uptake by stevia. The highest uptake (146.0 mg pot^{-1}) was obtained from the plants grown in non calcareous soil fertilized with cow dung and the lowest uptake (20.0 mg pot^{-1}) was calculated from unfertilized plant grown in calcareous soil (Table 4).

Table 3. Effects of different types of fertilizer on N, P, K, S, Ca and Mg concentrations and their uptake by stevia

Fertilizers	Nitrogen		Phosphorus		Potassium		Sulphur		Calcium		Magnesium	
	Content (%)	Uptake (mg pot^{-1})	Content (%)	Uptake (mg pot^{-1})	Content (%)	Uptake (mg pot^{-1})	Content (%)	Uptake (mg pot^{-1})	Content (%)	Uptake (mg pot^{-1})	Content (%)	Uptake (mg pot^{-1})
T_1	0.66	29.2	0.40	18.0	0.45	27.6	0.32	19.7	0.34	14.93	0.14	6.30
T_2	1.24	65.0	0.63	44.3	0.66	49.9	0.54	43.3	0.42	28.49	0.16	11.84
T_3	0.80	54.2	0.57	36.8	0.57	46.1	0.49	36.2	0.38	26.48	0.16	10.28
T_4	0.84	140.8	0.54	73.3	0.61	78.9	0.48	65.7	0.39	48.82	0.15	16.60
LSD (0.05)	0.13	19.83	0.04	9.8	0.03	10.8	0.03	6.2	0.03	6.83	0.03	2.57

Legend: T_1: Control, T_2: Chemical fertilizer, T_3: Poultry manure, T_4: Cowdung.

Phosphorus: The P content of stevia differed with soil types. The highest (0.69%) and the lowest (0.43%) P contents were obtained from the plants grown in non calcareous and saline soil, respectively (Table 2). Phosphorus contents also varied significantly with different fertilizers. The highest value (0.63%) was noted with chemically fertilized plant which was significantly different from all others including control (Table 3). Chalapathi *et al.,* (1999) reported that application of chemical fertilizers significantly increased P content of stevia. Different types of soil and fertilizer interacted insignificantly on P content of stevia (Table 4).

The results revealed that types of soil significantly influenced the P uptake by stevia. The highest (70.6 mg pot^{-1}) and lowest (26.0 mg pot^{-1}) uptake was done by the plant grown in non calcareous and calcareous soil, respectively (Table 2). Phosphorus uptake varied significantly due to different fertilizer application. The highest value (73.3 mg pot^{-1}) was measured from the plant fertilized with cow dung and the lowest value (18.0 mg pot^{-1}) was calculated from the control treated plant (Table 3). Different types of soil and fertilizer interacted significantly on P uptake by stevia. The highest uptake (136.1 mg pot^{-1}) was observed in the cow dung treated plant grown in non calcareous soil and the lowest (13.6 mg pot^{-1}) uptake was measured from the unfertilized plant grown in calcareous soil (Table 4).

Table 4. Interaction effects of different types of soil and fertilizer on N, P, K, S, Ca and Mg concentrations and their uptake by stevia

Interaction S x T		Nitrogen		Phosphorus		Potassium		Sulphur		Calcium		Magnesium	
		Content (%)	Uptake (mg pot^{-1})	Content (%)	Uptake (mg pot^{-1})	Content (%)	Uptake (mg pot^{-1})	Content (%)	Uptake (mg pot^{-1})	Content (%)	Uptake (mg pot^{-1})	Content (%)	Uptake (mg pot^{-1})
S_1	T_1	0.64	26.67	0.32	14.0	0.47	25.5	0.25	17.8	0.34	14.54	0.13	6.23
S_1	T_2	0.64	56.70	0.44	25.4	0.59	38.6	0.44	29.8	0.39	22.81	0.15	8.63
S_1	T_3	0.82	50.00	0.42	27.3	0.61	4.60	0.36	28.2	0.38	25.10	0.15	9.94
S_1	T_4	1.24	96.70	0.53	41.3	0.65	57.7	0.48	41.7	0.42	33.17	0.15	11.78
S_2	T_1	0.68	30.00	0.36	15.4	0.45	22.3	0.37	18.7	0.31	13.33	0.13	5.56
S_2	T_2	0.75	73.3	0.59	56.2	0.64	67.2	0.49	54.3	0.38	36.04	0.16	15.33
S_2	T_3	0.79	60.0	0.56	43.2	0.66	57.6	0.44	39.8	0.40	31.69	0.15	11.86
S_2	T_4	1.17	101.70	0.64	80.5	0.70	90.9	0.56	76.6	0.45	57.20	0.15	16.03
S_3	T_1	0.62	20.00	0.37	13.6	0.40	18.0	0.25	14.6	0.33	11.86	0.14	5.18
S_3	T_2	0.88	46.7	0.52	29.4	0.47	32.4	0.44	28.6	0.36	19.45	0.15	8.43
S_3	T_3	0.87	43.3	0.49	25.9	0.53	28.0	0.52	30.9	0.38	19.89	0.16	8.21
S_3	T_4	1.07	70.0	0.56	35.3	0.56	41.5	0.52	37.6	0.36	28.75	0.16	10.01
S_4	T_1	0.71	40.00	0.54	29.2	0.46	44.7	0.42	27.8	0.37	19.97	0.15	8.22
S_4	T_2	1.49	83.3	0.81	66.3	0.73	61.4	0.62	60.4	0.45	35.68	0.17	14.96
S_4	T_3	0.89	63.3	0.70	50.8	0.65	52.7	0.58	45.8	0.40	29.23	0.15	11.10
S_4	T_4	0.94	146.0	0.71	136.1	0.58	125.4	0.58	107.1	0.38	76.17	0.16	28.60
LSD (0.05)		NS	*	*	*	NS	*	*	*	*	*	*	*
CV (%)		18.03	32.99	10.58	27.34	7.75	25.77	10.53	18.35	11.91	27.68	11.04	27.56

Legend: S_1: Saline soil, S_2: Acid soil, S_3: Calcareous soil, S_4: Non-calcareous soil, T_1: Control, T_2: Chemical fertilizer, T_3: Poultry manure, T_4: Cowdung.

Potassium: The K content of stevia also varied with different soils. The maximum value (0.61%) was measured from the plants grown in acid soil and it was minimum (0.49%) in calcareous soil (Table 2). Significant variation was observed in K content of stevia leaves due to different fertilizer application. The maximum value (0.66%) was observed with plants treated with chemical fertilizer and it was significantly different from others. The minimum value (0.45%) was measured from the control treated plant (Table 3). Potassium content was not significantly affected by the interaction effect of different types of soil and fertilizer (Table 4). Chalapathi *et al.,* (1999) reported that application of chemical fertilizers increased K content of stevia compared to control.

Significant variation was found in K uptake by stevia due to different types of soil. The maximum uptake (71.0 mg pot^{-1}) was measured from the plant grown in non calcareous soil and it was minimum (30.0 mg pot^{-1}) in calcareous soil (Table 2). Fertilizer application significantly influenced the K uptake by stevia. The maximum (78.9 mg pot^{-1}) and the minimum (27.6 mg pot^{-1}) values were obtained from the cow dung and control treated plant, respectively (Table 3). Potassium uptake was significantly affected by the interaction effect of different types of soil and fertilizer. The maximum uptake (125.4 mg pot^{-1}) was recorded from the cow dung treated plant grown in non calcareous soil and the minimum value (18.0 mg pot^{-1}) was measured from the plant grown in calcareous soil which was not treated with any fertilizer (Table 4).

Sulphur: Like N, P and K concentrations, both soils and fertilizers had significant effect on S content of stevia. The highest S content (0.55%) was obtained in non calcareous soil and the lowest amount (0.38%) was recorded in saline soil (Table 2). Comparing fertilizer variation, the highest value (0.54%) was demonstrated by the chemically fertilized plants which was significantly different from the plants treated with other fertilizers. The lowest value (0.32%) was recorded from the control treated plant (Table 3). Chalapathi *et al.,* (1999) reported that application of chemical fertilizers increased S content of stevia compared to control. Different types of soil and fertilizer interacted significantly on S content of stevia. The maximum content (0.62%) was measured from the chemically fertilized plant grown in non-calcareous soil and the minimum (0.25%) in unfertilized plant grown in saline or calcareous soil, respectively (Table 4).

Types of soil significantly influenced S uptake by stevia. The highest uptake (60.3 mg pot^{-1}) was done by the plant grown in non calcareous soil and the lowest uptake (27.9 mg pot^{-1}) was found in calcareous soil (Table 2). Sulphur uptake by stevia plant significantly affected due to fertilizers application. The highest amount (65.7 mg pot^{-1}) was uptaken by the plant fertilized with cow dung which was significantly different from those treated with other fertilizers including control. The lowest uptake (19.7 mg pot^{-1}) was recorded in unfertilized plant (Table 3). Different types of soil and fertilizers interacted significantly to bring variation in S uptake by stevia. The maximum uptake (107.1 mg pot^{-1}) was measured from the cow dung treated plant grown in non calcareous soil and it was minimum (14.6 mg pot^{-1}) in unfertilized plant grown in calcareous soil (Table 4).

Calcium: Different types of soil significantly influenced the Ca content of stevia. The highest value (0.40%) being recorded with non-calcareous soil and the lowest value (0.36%) with calcareous soil (Table 2). The Ca concentration of stevia leaves also varied significantly with different fertilizer treatments, the highest value (0.42%) being obtained from chemical fertilizer treated plants and the lowest (0.34%) from unfertilized plant (Table 3). Interaction effects of different types of soil and fertilizer showed significant variation with respect to Ca content. The highest result (0.45%) was found with acid and non-calcareous soils treated with chemical fertilizer and the lowest result (0.31%) was obtained from acid soil untreated with any fertilizer (Table 4).

Significant variation was found in Ca uptake by stevia due to types of soil. The highest (40.26 mg pot^{-1}) Ca uptake was recorded from the plant grown in non calcareous soil and the lowest (19.99 mg pot^{-1}) was found in calcareous soil (Table 2). Calcium uptake affected significantly due to different fertilizers application. The highest value (48.82 mg pot^{-1}) was obtained from cow dung treated pot and the lowest (14.93 mg pot^{-1}) was measured from the unfertilized pot (Table 3). Interaction effects of different types of soil and fertilizer showed significant variation with respect to Ca uptake by stevia. The highest uptake (76.17 mg pot^{-1}) was obtained from the plants grown in non calcareous soil fertilized with cow dung and the lowest uptake (11.86 mg pot^{-1}) was recorded from the plant grown in calcareous soil which was not fertilized by any fertilizer (Table 4).

Magnesium: The Mg concentration of stevia leaf varied with in a narrow range, 0.14-0.16% over the soils (Table 2). Magnesium content in stevia leaves varied significantly due to different fertilization. The highest value (0.16%) was determined from the plant treated with chemical fertilizer and poultry manure and it was lowest (0.14%) in control treated plant (Table 3). There was no significant interaction between soil and fertilizer on the Mg concentrations of stevia leaf (Table 4).

Types of soil significantly influenced the Mg uptake by stevia. Magnesium uptake was highest (15.72 mg pot^{-1}) in plant grown in non calcareous soil and significantly different from the plant grown in other soils. The lowest value (7.96 mg pot^{-1}) was obtained from plant grown in calcareous soil (Table 2). Magnesium uptake varied significantly due to different fertilizer application. The highest uptake (16.60 mg pot^{-1}) was calculated from the plant fertilized with cow dung and the lowest (6.30 mg pot^{-1}) was measured from the control treated plant (Table 3). Different types of soil and fertilizer interacted significantly on Mg uptake by stevia. The highest uptake (28.60 mg pot^{-1}) was observed from the cow dung treated plant grown in non calcareous soil and the lowest (6.23 mg pot^{-1}) from unfertilized plant grown in saline soil (Table 4).

Table 5. Correlation coefficients (r) of relationships among the major nutrient contents of stevia

	Nitrogen	Phosphorous	Potassium	Sulphur	Calcium
Phosphorous	0.72**	-			
Potassium	0.68*	0.71**	-		
Sulphur	0.71**	0.90**	0.71**	-	
Calcium	0.48	0.65*	0.71**	0.67*	-
Magnesium	0.49	0.74**	r = 0.50	0.76**	0.63*

* Significant at P<0.05, ** P<0.01

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