Original Research Article

Growth rate and nutrient uptake of *Stevia Rebaudiana* Bertonias influenced by organic manures in laterite soils of Kerala, India

Abstract:A field experiment was conducted to understandthe effect of organic manureson the crop growth rate (CGR), relative growth rates(RGR), and nutrient uptake of stevia (S*tevia rebaudiana* Bertoni)from April to August of 2022 and 2023at the Agronomy farm, Department of Agronomy, College of Agriculture, Vellanikkara, Thrissur.The experiment was laid out in randomized block design (RBD) with 7 treatments replicated thrice which consisted of different levels of organic manures *viz.*, three levels of farmyard manure (FYM@5, 10, 15 t ha^{-1}), three levels of vermicompost (VC@2.5, 5, 7.5 kg ha^{-1}) and a control.The organic manure treatments significantly affected crop growth rate (CGR) and relative growth rate (RGR) in all the growth periods.The two-year pooled mean of CGR of steviawas significantly superior in FYM@15 t ha^{-1}over control in all the three growth periods *i.e.*, at 0-30 DAP, 30-45 DAP and 45DAP to harvest. Whereas, the two-year mean of RGR ofstevia was found statistically higher in FYM@15 t ha^{-1} over control in the first two growth periodsonly. The organic manure treatments had a significant influence on the plant nutrient (NPK) uptake as well in both the years. The two-year pooled mean data regarding plant uptake of nitrogen and phosphorous was found significantly higher in FYM@15 t ha^{-1} over control whereas statistically higher pooled mean potassium uptake by stevia was found in VC@7.5 kg ha^{-1} over control.Overall, the higher levels of organic manure, especially FYM, significantly improve growth and nutrient uptake in stevia.

Keywords: Stevia, farmyard manure, vermicompost, growth rate, nutrient uptake

1. Introduction:

Stevia rebaudiana Bertoni has emerged as a leading natural sweetener, renowned for its exceptional ability to deliver high sweetness without the calories associated with traditional sugars. This perennial herb, native to South America, has been utilized for centuries by indigenous communities for its sweet leaves (Brandle & Rosa, 1992). The main sweetening compounds in *Stevia rebaudiana* Bertoni are stevioside, rebaudioside-A, rebaudioside-C, and dulcoside-A, with their relative sweetness compared to sucrose being 210, 242, 30, and 30 times sweeter, respectively (Kinghorn, 1987).Its global appeal has grown significantly following the approval of stevioside and other steviol glycosides in key markets, including the United States and the European Union (Risso *et al.*, 2014). As consumers increasingly seek healthier alternatives to sugar and artificial sweeteners, Stevia offers a compelling option, being not only low in calories but also rich in antioxidants and beneficial phytochemicals.Research has consistently demonstrated that stevia leaf products are safe for individuals with diabetes, high blood pressure, and obesity, potentially aiding in the management or prevention of complications linked to these conditions (Carrera-Lanestosa*et al.*, 2017). Furthermore, studies have confirmed that stevia is safe for children as well (Aguero *et al.*, 2014).The popularity of stevia, driven by its pleasant taste and zero-calorie natural sweetener status, has encouraged Indian farmers to commercially cultivate it. As a result, stevia is now successfully grown in several Indian states, including Rajasthan, Maharashtra, Punjab, and Orissa (Goyal *et al.*, 2010).

The cultivation of *Stevia rebaudiana*Bertoni is influenced by environmental conditions and agricultural practices, especially nutrient management, which enhances growth and yield. As the crop is highly adaptable to the poor-qualityParaguayan soils,which is its natural habitat, stevia requires a low to moderate level of nutrition (Goenadi, 1987).However, commercial cultivation of Stevia needs exogenous fertilization to achieve sustainable yield (Rashid *et al*., 2013). With the global population projected to reach 9.2 billion by 2050 (Gruhn *et al*., 2000), a shift to sustainable agricultural practices is essential. Moreover, indiscriminate use ofinorganic fertilizers in modern farming, especially in medicinal crops, can leave residues in the medicinal preparations that can harm human health and the environment hence an urgent transition towards safe and sustainable organic farming practices is necessary (Umesha *et. al.*, 2011).Organic manures like farmyard manure and vermicompost provide viable, low-input alternatives, supplying essential nutrients and improving soil structure and microbial activity for healthier crop growth. Although the specific nutrient requirements of Stevia, particularly in the context of South Indian soils are still not well understood, the RDF is estimated at 60:30:45 kg NPK ha^{-1} for Bengaluru conditions (Farooqi and Sreeramu, 2004).There has been limited research on supplementing inorganic nutrientsources with organics without compromising the productivity and quality of Stevia, prompting this study on organic nutrition.

The crop growth rate (CGR)and relative growth rates (RGR)of a crop are vital indicators for assessing the viability and productivity of its cultivation. These metrics provide valuable insights into how well the plant adapts to varying agricultural practices and environmental conditions, essential for maximizing yield. Moreover, analysing growth rates at various developmental stages provides deeper insights into the plant's nutritional requirements and its ability to withstand abiotic stress, which is essential for effective crop management. A comprehensive understanding of nutrient uptake is essential for developing effective fertilization strategies that align nutrient availability with the specific needs of Stevia rebaudiana (Angelini &Tavarini, 2014). Key nutrients such as nitrogen (N), phosphorus (P), and potassium (K) are crucial for physiological processes, including photosynthesis, energy transfer, and overall plant growth. Additionally, a thorough understanding of NPK dynamics in plants can help identify specific nutrient deficiencies or imbalances, facilitating the optimization of fertilization practices for enhanced plant health and productivity.

Against this backdrop, this research was carried out to explore the growth rates and nutrient uptake of Stevia rebaudiana as influenced by organic manures, providing insights to optimize sustainable nutrient management, especially in laterite soils of Kerala.

2. Materials and methods:

The field experiment entitled ‘Effect of organic manures on growth, yield and quality of Stevia rebaudiana B.’was conducted at the Agronomy farm, Department of Agronomy, College of Agriculture, Vellanikkara, Thrissur, KeralafromApril to August of 2022 and 2023. The site is located at 13° 32’N latitude and 76° 26’E longitude, at an altitude of 40 m above mean sea level and the annual rainfall in 2022 was 3128.3 mm and 2697.3 mm in 2023. The texture of the experimental fieldwas sandy clay loam and was acidic in reaction with pH 4.68, EC (0.07 ds m^{-1}, 1.33 % OC, available N (146 kg ha^{-1}), P (33 kg ha^{-1}) and K (188 kg ha^{-1}). The experiment was laid out in randomized block design (RBD) with 7 treatments replicated thrice which consisted of different levels of organic manures *viz.*,three levels of farmyard manure, three levels of vermicompostand a control.The treatmentsinclude~~T_1~~-nomanure; ~~T_2~~- FYM@ 5t ha^{-1}; ~~T_3~~- FYM@ 10 t ha^{-1};T_4- FYM@ 15 t ha^{-1}; ~~T_5-VC@2.5 t ha^{-1}; T_5~~- VC @ 2.5 t ha^{-1}; ~~T_6~~- VC @ 5 t ha^{-1};and T_7- VC @ 7.5 t ha^{-1}.After thorough field preparationbyploughing

and discing, beds of size 3m x 3m were prepared and mulched with 30 µ plastic mulch. A green colour shade net with 25 per cent sunlight permeability was used to provide artificial shading over the whole experimental area. The individual beds were fertilized according to the treatments using well-decomposed farmyard manure and vermicompost during preparation, before mulching as a basal application two weeks before transplantation. One-month-old rooted stem cuttings with 4-5 nodes raised in the nursery were transplanted uniformly in all the beds at a spacing of 30cm x 30cm in both years.Regularintercultural operations such as irrigation, weeding etc. were carried out during the experimental period and a single harvest was done in both years110 days after planting (DAP) by uprooting the plants. The data were analysed statistically using analysis of variance (ANOVA) with the statistical package 'grapes Agri 1' (Gopinath et al., 2020) which is an R-based online software developed by Kerala Agricultural University. LSD test was employed for multiple comparison of means.

2.1 Measurement ofCropgrowthrate(CGR)

Crop growth rate illustrates the dry matter accumulation by the crop per unit land area perunit time and it was estimated at 0-30DAP, 30-45 DAP and at 45 DAP to harvest in both the years. CGR was determined using the formulaprovided by Watson(1952)andexpressedasgramsofdrymatterproducedperday.

$$CGR(gm^{-2}day^{-1}) = \frac{W_2-W_1}{A(t_2-t_1)}$$

Where W_1 and W_2 are dry weights of plants at time t_1 and t_2, respectively, A is the land area.

2.2 Measurement ofRelativegrowthrate(RGR)

Relative growth rate explains the rate of growth of the crop per unit of dry matter per unit of timeand it was calculated at 0-30 DAP, 30-45 DAP and 45 DAP to harvestin both years. RGR was determined using theformula proposed by Blackman(1919)andexpressedasgramsofdrymatterproducedby agram ofexisting dry matter in aday.

$$RGR(gg^{-1}day^{-1}) = \frac{\log_e W_2-\log_e W_1}{t_2-t_1}$$

WhereW_1andW_2aredryweightsofplantsattime$t_1$andt_2,respectively.

2.3 Plant uptake of N, P and K at harvest

The replication-wise collected plant samples were cleaned, shade-dried and dried further in a hot air oven at 65±5°C to achieve a constant weight and ground to fine powder. These powdered samples were used to analyse plant NPK content by following the standard procedures(Di and tri acid mixture sample digestionfollowed by subsequent analytical procedures). The nutrient uptake was then determined by multiplying dry matter production and nutrient content in per cent and expressed as kg ha^{-1}.

3. Results and discussion:

3.1 Crop growth rate (g m^{-2} day^{-1})

Crop growth rates(CGR) of stevia at three different growth stages in two years and the pooled mean are presented in Table1. In the first two growth periods of both the years (2022 and 2023), *i.e.*, from 0-30 DAP and 30-45 DAP, the organic manures had a significant effect on the crop growth rateof stevia whereas,in the pooled mean, the CGR was significantly affected by the organic manures in all the three growth periods.Despite the treatments, a steepincrease in the CGR was observed from the first to the second growth period, whereas a steady increase was observed from the second to third growth period in both years.At 0-30 DAP, the two-year pooled mean of CGR was found significantly higher in FYM@15 t ha^{-1}over control and was on par with FYM@10 t ha^{-1} followed by VC@7.5 t ha^{-1}Whereas, at 30-45 DAP, significantly highest pooled mean of CGR was found inFYM@15 t ha^{-1}over control followed by FYM@10 t $ha^{-1}$and VC@7.5 t ha^{-1}. However, at 45 DAP to harvest, the two-year mean data of CGR was found significantly higher in FYM@15 t ha^{-1}over control and was on par with VC@7.5 t ha^{-1},VC@5 t $ha^{-1}$and FYM@10 t ha^{-1}treatments.The crop growth rate of stevia was found to be increasing with increasing quantity of manure (both farmyard manure and vermicompost) applied. This can be attributed to the improved soil physical chemical and biological properties by the application of well-decomposed organic manures. Better soil aeration, microbial growth and enhanced nutrient availability might have caused better root proliferation and establishment and nutrient absorption thereby increasingthe growth parametersand leading to better herbage production and growth rate(Kumar *et. al*., 2023).

Table 1. Effect of organic manures on the crop growth rate of *stevia rebaudiana*Bertoni at (0-30 DAP), (30-45 DAP) and (45 DAP – Harvest)

CGR(g m^{-2} day^{-1})	2022			2023			Pooled mean		
Treatments	**0-30 DAP**	**30-45 DAP**	**45DAP-Harvest**	**0-30 DAP**	**30-45 DAP**	**45DAP-Harvest**	**0-30 DAP**	**30-45 DAP**	**45DAP-Harvest**
No manure	0.231	1.188	1.989	0.271	1.389	2.066	0.260	1.316	2.121
FYM@ 5 t ha^{-1}	0.286	1.573	2.334	0.364	1.735	2.458	0.325	1.654	2.396
FYM@ 10 t ha^{-1}	0.357	2.705	2.585	0.415	2.767	2.866	0.386	2.736	2.725
FYM@15 t ha^{-1}	0.381	2.883	2.582	0.460	3.030	3.006	0.421	2.957	2.794
VC@ 2.5 t ha^{-1}	0.282	1.653	2.359	0.331	1.616	2.615	0.307	1.635	2.487
VC@ 5 t ha^{-1}	0.304	1.630	2.705	0.390	1.852	2.823	0.347	1.741	2.764
VC@ 7.5 t ha^{-1}	0.339	2.068	2.708	0.408	2.260	2.823	0.374	2.164	2.766
CD (0.05)	0.058	0.449	NS	0.087	0.606	NS	0.038	0.152	0.291
Sem (±)	0.019	0.146	0.175	0.028	0.197	0.204	-	-	-

***DAP- days after planting**

3.2Relative growth rate (g g^{-1} day^{-1})

Relative growth rates (RGR) of stevia at three different growth stages in two years and the pooled mean are presented in Table 2. In the first and third growth periods of2022 *i.e.*, at 0-30 DAP and 45 DAP to harvest, the organic manures had a significant effect on the relative growth rate of stevia whereas, in2023, the RGR was not significantly affected by the treatments in all the growth periods except 0-30 DAP. However, the pooled mean of the RGR was significantly affected by the organic manures in all three growth periods.The two-year mean RGR was found significantly higher in FYM@15 t ha^{-1} over control and was on par with FYM@10 t ha^{-1}followed by VC@7.5 t ha^{-1}at 0-30 Dap and 30-45 DAP growth periods.However, the pooled mean of RGR was found significantly higher incontrol and stood on par with FYM@5 t ha^{-1},VC@2.5 t ha^{-1}, and VC@5 t ha^{-1}.Irrespective of the treatments, a slight increase of RGR was observed in all the treatments from the first to the second growth period and a steep decrease was found from the second to the third growth

stage in both years. The trend in relative growth rate can be viewed as normal, as biomass production efficiency may decline over time due to plant senescence and an increase in the growth of non-photosynthetic woody tissues (Jarma-Orozco*et al.*, 2020).

3.3 Plant nutrient uptake (NPK in kg ha^{-1})

Majornutrient uptake (NPK) by stevia was significantly influenced by the organic manure treatments in both the years, 2022 and 2023 and the data is presented in Table 3. Two-year pooled mean data regarding uptake of nitrogen was found significantly higher in FYM@15 t ha^{-1} over control but was on par with FYM@10 t ha^{-1},VC@7.5 t ha^{-1}, and VC@5 t ha^{-1} treatments. Plots treated with either farmyard manure or vermicompost, alone or in combination with apple pomace, showed a greater accumulation of nitrogen in the soil increasing N availabilityand thereby higher N uptake by plants, likely due to the slow mineralization of N from the manures, as noted by Anwar *et al.* (2005). The two-year pooled mean uptake of phosphorous by stevia was found significantly greater in FYM@15 t ha^{-1} over control and was on par with FYM@10 t ha^{-1}treatment. The increased concentration of phosphorus in stevia from organic manures attributing to higher P uptake may result from enhanced solubilization of P, either through the activation of microorganisms that excrete organic acids (Suba Rao, 1982) or due to increased phosphatase activity (Sainz*et al.*, 1998). When it comes to the pooled mean of potassium uptake by stevia,a significantly higher quantity was found in VC@7.5 t ha^{-1} over control and was on par with FYM@15 t ha^{-1} treatment. The increase in potassium uptake by stevia from vermicompost treatments may be attributed to improved K availability, which shifts the equilibrium in the soil from relatively exchangeable K to more soluble forms (Basker*et al.*, 1992).It was noted that the uptake of nitrogen and potassium exceeded that of phosphorus and these findings were in line with those of Kumar *et al.* (2013). The higher uptake of NPK across various treatment combinations can be attributed to the combined effects of increased nutrient concentrations and dry matter yield associated with these treatments. Similar patterns have been documented in previous studies involving basil (Anwar *et al.*, 2005), mint (Patra*et.al.*, 2000), and wheat (Dudhat*et al.*, 1997).

Table 2. Effect of organic manures on the relative growth rate of *stevia rebaudiana*

RGR(g g^{-1} day^{-1})	2022			2023			Pooled mean		
Treatments	**0-30 DAP**	**30-45 DAP**	**45DAP - Harvest**	**0-30 DAP**	**30-45 DAP**	**45DAP-Harvest**	**0-30 DAP**	**30-45 DAP**	**45DAP-Harvest**
No manure	0.029	0.034	0.013	0.031	0.034	0.012	0.030	0.033	0.012
FYM@ 5 t ha^{-1}	0.031	0.036	0.012	0.034	0.033	0.011	0.033	0.034	0.012
FYM@ 10 t ha^{-1}	0.034	0.043	0.010	0.036	0.041	0.010	0.035	0.042	0.010
FYM@15 t ha^{-1}	0.035	0.043	0.010	0.038	0.041	0.010	0.036	0.042	0.010
VC@ 2.5 t ha^{-1}	0.031	0.037	0.012	0.033	0.034	0.012	0.032	0.035	0.012
VC@ 5 t ha^{-1}	0.032	0.035	0.013	0.035	0.033	0.012	0.034	0.034	0.012
VC@ 7.5 t ha^{-1}	0.034	0.038	0.011	0.036	0.037	0.011	0.035	0.037	0.011
CD (0.05)	0.002	NS	0.002	0.003	NS	NS	0.001	0.002	0.001
Sem (±)	0.001	0.002	0.001	0.001	0.003	0.001	-	-	-

Bertoni at (0-30 DAP), (30-45 DAP) and (45 DAP – Harvest)

Table 3. Effect of organic manures on the plant nutrient uptake of *stevia rebaudiana*Bertoni in 2022, 2023 and pooled mean in kg ha^{-1}

Uptake (kg ha^{-1})	N	P	K

Treatments	2022	2023	Pooled	2022	2023	Pooled	2022	2023	Pooled
No manure	15.39	16.64	18.41	3.19	3.54	3.57	24.82	29.12	29.07
FYM@ 5 t ha^{-1}	28.08	30.48	29.28	4.16	5.01	4.59	35.36	39.71	37.53
FYM@ 10 t ha^{-1}	34.65	38.14	36.39	5.19	6.58	5.89	44.60	55.39	50.00
FYM@15 t ha^{-1}	35.82	41.16	38.49	5.90	7.46	6.68	52.05	62.35	57.20
VC@ 2.5 t ha^{-1}	27.79	30.37	29.081	3.87	4.61	4.24	43.10	49.01	46.06
VC@ 5 t ha^{-1}	32.71	35.28	33.99	4.73	5.67	5.20	51.42	55.64	53.53
VC@ 7.5 t ha^{-1}	34.20	36.61	35.41	5.12	5.85	5.49	57.55	64.78	61.16
CD (0.05)	4.777	5.652	4.735	0.742	0.959	0.906	7.227	8.962	6.455
Sem (±)	1.55	1.834	-	0.241	0.44	-	2.345	2.909	-

Conclusion:

Based on thefindings of the current study application of the organic manure can be recommended for the sustainable cultivation of stevia in the laterite soils of Kerala. As per the results, the organic nutrition of stevia especially in the form of farmyard manure at the rate of 15 t ha^{-1} results in better overall growth of stevia as evidenced by the crop and relative growth rates. Along with the improved plant growth, the crop's nutrient uptakealso showed significant improvement with the application of organic manures in higher quantities.Additional research is needed to examine the effects of organic manure application on soil health and nutritional profile of stevia, and overall sustainability in the long run.

Disclaimer (Artificial intelligence)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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