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ASSESSMENT OF SPACING REGIMES FOR GROWTH AND HERBAGE YIELD IN STEVIA (*STEVIA REBAUDIANA* BERTONI.) UNDER NORTH-EASTERN TRANSITIONAL ZONE OF KARNATAKA INDIA

V. P. Singh^{1*}, Mohammed Farooq², S. V. Patil², A. G. Patil³, Vijaymahantesh²,
Jyoti Uppar¹ and Shanigala Raviteja²

¹Kittur Rani Channamma College of Horticulture, Arabhavi, University of Horticultural Sciences, Bagalkot, Karnataka, India

²College of Horticulture, Bidar, University of Horticultural Sciences, Bagalkot, Karnataka, India

³Directorate of Education, University of Horticultural Sciences, Bagalkot, Karnataka, India

*Corresponding author E-mail: vpsingh.neev@gmail.com

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ABSTRACT

Stevia (Stevia rebaudiana Bertoni.) is an important zero-calorie natural sweetener crop belonging to the family Asteraceae. A field experiment was conducted during 2020-21 and 2021-22 at the College of Horticulture, Bidar, UHS Bagalkot, Karnataka to study the effect of spacing on growth and yield of stevia under the North-Eastern transitional zone of Karnataka. The experiment was laid out in Randomized Block Design (RBD) with three replications and nine spacing treatments such as T₁ with the spacing of 30×10 cm, T₂ - 30×20 cm, T₃ - 30×30 cm, T₄ - 45×10 cm, T₅ - 45×20 cm, T₆ - 45×30 cm, T₇ - 60×10 cm, T₈ - 60×20 cm and T₉ - 60×30 cm. Observations on growth parameters such as number of leaves, branches per plant and yield parameters including fresh and dry herbage yield per plant, plot and hectare were recorded. Results revealed that wider spacing significantly increased growth and yield per plant. Among the treatments, T₉ (60 × 30 cm) recorded maximum number of leaves per plant (324.03), branches per plant (24.32), fresh herb yield per plant (79.67 g) and dry herbage yield per plant (17.70 g). However, closer spacing increased yield per unit area. T₂ (30 × 20 cm) recorded maximum fresh herb yield per plot (0.72 kg), dry herb yield per plot (0.24 kg), fresh herbage yield per hectare (8.69 t) and dry herbage yield per hectare (1.81 t). Hence, spacing of 30 × 20 cm was found suitable for obtaining higher herbage yield and better economic returns in stevia cultivation.

Key words: *Stevia (Stevia rebaudiana* Bertoni.), Spacing Regimes, Growth and Herbage Yield

Introduction

Stevia (Stevia rebaudiana Bertoni.) belongs to the family Asteraceae, is an important zero-calorie natural sweetener plant. It is cultivated as a commercial crop in many countries including Japan, China, India, Korea, USA, Canada, Mexico, Russia, Indonesia, Tanzania, Brazil, Paraguay, Canada and Argentina (Ramesh *et al.*, 2007). It is native plant of Paraguay (Yadav *et al.*, 2010). It has achieved a major economic importance due to the presence different natural sweet compounds called steviol glycosides which are obtained from its leaves. *Stevia* primarily contains four glycosides in its leaves such as: stevioside (5-10%), rebaudioside-A (2-4%), rebaudioside-

C (1-2%) and dulcoside (0.5-1%). *Stevia* is the sweetest gift from mother nature called as sweet leaf of Paraguay, sweet herb, honey leaf, honey yerba, candy leaf *etc* (Peteliuk *et al.*, 2021). *Stevia* is also known as the “sweetest plant of the world” (Joshi *et al.*, 2006). Since longtime, the main source of sugar is sugarcane and sugar beet, which are rich in calories are not to be consumed by diabetic patients. The dried leaves of *stevia* mainly contain stevioside and rebaudioside, which are is 200-450 times sweeter than sucrose (Amala *et al.*, 2026). These compounds are pH stable, heat stable, not fermentable and contains health promoting potential. As a natural and low-calorie sweetener, *stevia* is considered

as safe option for people with diabetes and obesity (Sakthivel and Kumar, 2025). Along with sweetness, stevia has some bitter aftertaste due to the presence of some essential oils, tannins and flavonoids (Schiatti *et al.*, 2023).

The Indian farmers have also started taking up stevia cultivation following the large demand for diabetic market. In India, farmers have started growing stevia in some parts of Rajasthan, Punjab, Uttar Pradesh, West Bengal, Madhya Pradesh, Andhra Pradesh, Karnataka, Chhattisgarh and West Bengal *etc* (Dhange *et al.*, 2023). Since the production potential of stevia in India is 2-3 t ha⁻¹ of dry leaves which is completely depend on agronomic practices followed by the farmers. Yield is the major concern for farmers in terms of benefit: cost ratio (Misra *et al.*, 2011). As stevia is a new and emerging crop, very little information is available on the crop geometry and the quality control in Indian condition. Stevia has achieved economic importance due to different natural steviol glycosides from its leaves which influences sweetening property (Marcinek and Krejpcio, 2015). Therefore, in view of the above, the present investigation was undertaken to find out planting density of stevia is an important tool in order to achieve high crop yield, high quality, suitable adaptation and mitigation strategies able to encourage responsible sustainable development to the farmers under North-Eastern transitional zone of Karnataka.

Material and Methods

Experimental site and weather data

The experiment was carried out during 2020-21 and 2021-22 at College of Horticulture, Bidar, University of Horticultural Sciences, Bagalkot, Karnataka. The experimental site is located at 17.92° N latitude, 77.52° E longitude and 670 m altitude above the mean sea level. Weather conditions of experimental site, where the annual rain fall for the year 2020-21 was 872.4 mm and for 2021-22 was 1120.8 mm. The maximum average temperature was recorded in the month of May (39°C) and April (36.8°C) in the year 2020-21 and 2021-22 respectively. The minimum average temperature was recorded in the month of December in both the years. The highest average relative humidity in the morning was recorded in the month of August (87%) and September (89%) for the year 2020-21 and 2021-22 respectively.

Experimental design and treatment details

The experiment was laid out in Randomized block design (RBD) with three replications and nine treatments. Details of treatments were T₁ with the spacing of 30×10 cm, T₂ - 30[□]×20 cm, T₃ - 30×30 cm, T₄ - 45×10 cm, T₅ -

45×20 cm, T₆ - 45×30 cm, T₇ - 60×10 cm, T₈ - 60×20 cm and T₉ - 60×30 cm.

Planting material and cultural practices

One month old seedlings of the GKVK Stevia⁻¹ variety were used for transplanting in the respective plots with the plot size of 1.80 m × 2.40 m as per design. The inorganic nutrients were applied at the time of transplanting viz; Urea (N 46%), Single Super Phosphate (P₂O₅ 16%) and Muriate of Potash (K₂O 60%). Half dose of nitrogen was applied at the time of transplanting while the remaining half was applied in two equal splits at 30 and 60 days after transplanting (DAT), whereas, the full doses of phosphorus and potassium were applied at the time of transplanting. In order to maintain the plant population, gap filling was done at 20 DAT. Weed control was done by hand weeding whenever necessary and plant protection measures were taken as and when required. Need based irrigation was supplied at an interval of 5-7 days.

Observations

In the experiment observations were recorded at an interval of 30, 60 and 90 DAT. Five plants/plot were randomly selected for recording observations which includes number of leaves per plant and number of branches per plant, while yield parameters includes fresh and dry weight of herb per plant, plot and hectare. The crop was harvested manually at 90 DAT by cutting 5 cm above ground level with the help of sickle and dried under shade for 3-5 days.

Statistical analysis

The experimental data were analyzed statistically by Analysis of Variance (ANOVA) appropriate to Randomized Block Design (RBD) as described by Gomez and Gomez (1984). Significance of treatment difference was tested by F-test and treatment means were compared using Critical Difference (CD) at 5 per cent level of significance.

Results and discussion

Effect of spacing on growth parameters

Number of leaves per plant:

The green leaves are important plant growth indices that determine the capacity of plant to trap solar energy for photosynthesis. Data was recorded at an interval of 30, 60 and 90 DAT is presented (Table 1). Among all the treatments, the number of leaves per plant was increased with increasing of spacing (Fig. 3). Pooled data of T₉(60×30 cm) showed the maximum number of leaves per plant (119.27) and T₁(30×10 cm) revealed the minimum number of leaves per plant (43.52) whereas,

Table 1: Effect of spacing on number of leaves per plant at different growth stages in stevia.

Treatment	Number of leaves per plant								
	30 DAT			60 DAT			90 DAT (At harvest)		
	2020-21	2021-22	Pooled	2020-21	2021-22	Pooled	2020-21	2021-22	Pooled
T ₁ (30×10 cm)	45.09	41.94	43.52	120.37	111.94	116.15	225.70	209.90	217.80
T ₂ (30×20 cm)	60.35	56.13	58.24	131.07	121.89	126.48	234.50	218.09	226.29
T ₃ (30×30 cm)	87.44	81.32	84.38	195.07	181.41	188.24	282.33	262.57	272.45
T ₄ (45×10 cm)	98.60	91.70	95.15	164.36	152.85	158.61	275.40	256.12	265.76
T ₅ (45×20 cm)	75.78	70.48	73.13	142.56	132.58	137.57	260.28	242.06	251.17
T ₆ (45×30 cm)	110.20	102.49	106.34	220.70	205.25	212.98	293.94	273.36	283.65
T ₇ (60×10 cm)	115.50	107.42	111.46	234.58	218.16	226.37	315.49	293.40	304.44
T ₈ (60×20 cm)	120.18	111.77	115.98	240.68	223.83	232.26	324.50	301.79	313.14
T ₉ (60×30 cm)	123.60	114.95	119.27	191.69	178.41	185.05	335.78	312.28	324.03
S Em. ±	5.54	4.94	5.05	15.35	12.63	13.98	16.39	16.06	16.20
C.D. at 5%	16.61	14.82	15.15	46.02	37.87	41.92	49.15	48.16	48.58

*DAT: Days After Transplanting

T₈(60×20 cm) was on par to T₉. At 60 DAT, significantly maximum number of leaves per plant (232.26) was observed in T₈ (60×20 cm), whereas the minimum number of leaves per plant (116.15) was recorded from T₁(30×10 cm). However, treatment T₇(60×10 cm), was found to be statistically on par to treatment T₈ (60×20 cm). The pooled data of number of leaves per plant at 90 DAT was recorded maximum (324.03) from T₉(60×30 cm) and minimum (217.80) was recorded from T₁(30×10 cm) whereas, T₈(60×20 cm) was on par to T₉(60×30 cm). The reason for increase in number of leaves per plant may be that the wider spacing result in less inter-plant competition for space, nutrient, light and moisture which in turn might have increased the photosynthetic and metabolic activity of the plant confirmed by the findings of Singh *et al.*, (2012), Kumar *et al.*, (2021), Shivani *et al.*, (2019), Rashid *et al.*, (2015) and Tadesse *et al.*, (2016).

Number of branches per plant:

Number of branches per plant determines the crop growth and development. Data was recorded at an interval of 30, 60 and 90 DAT is presented in Table 3. The number of branches per plant was increased with increasing of spacing. At 30 DAT, T₉(60×30 cm) showed the maximum number of branches per plant (11.79), T₁(30×10 cm) showed the minimum number of branches per plant (5.37) whereas, T₈(60×20 cm) with (11.58) was on par to T₉(60×30 cm) among all treatments. At 60 and 90 DAT, significantly maximum number of branches per plant *i.e* 18.70, 24.32 respectively, was observed in T₉, whereas the minimum number was recorded from T₁. However, the T₈ was on par to T₉(60×30 cm). The results are in conformity with the findings of Maheshwar (2005), Aladakatti *et al.*, (2012), Rashid *et al.*, (2015), Tadesse *et al.*, (2017) and Shivani *et al.*, (2019) who reported higher branches number per plant at the wider spacing

Table 2: Effect of spacing on number of branches per plant at different growth stages in stevia.

Treatment	Number of Branches per plant								
	30 DAT			60 DAT			90 DAT (At harvest)		
	2020-21	2021-22	Pooled	2020-21	2021-22	Pooled	2020-21	2021-22	Pooled
T ₁ (30×10 cm)	5.56	5.17	5.37	9.40	8.74	9.07	12.80	11.90	12.35
T ₂ (30×20 cm)	6.20	5.77	5.98	12.78	11.89	12.33	13.64	12.69	13.16
T ₃ (30×30 cm)	9.40	8.74	9.07	16.74	15.57	16.15	19.45	18.09	18.77
T ₄ (45×10 cm)	8.95	8.32	8.64	15.86	14.75	15.30	18.62	17.32	17.97
T ₅ (45×20 cm)	6.88	6.40	6.64	15.25	14.18	14.72	16.22	15.08	15.65
T ₆ (45×30 cm)	10.32	9.60	9.96	17.28	16.07	16.68	22.40	20.83	21.62
T ₇ (60×10 cm)	11.15	10.37	10.76	18.58	17.28	17.93	23.60	21.95	22.77
T ₈ (60×20 cm)	12.00	11.16	11.58	18.90	17.58	18.24	24.08	22.39	23.24
T ₉ (60×30 cm)	12.22	11.36	11.79	19.38	18.02	18.70	25.20	23.43	24.32
S Em. ±	0.73	0.70	0.71	1.18	1.12	1.15	1.39	1.30	1.34
C.D. at 5%	2.19	2.11	2.13	3.56	3.37	3.45	4.17	3.91	4.03

*DAT: Days After Transplanting

Table 3: Effect of spacing on fresh and dry herb yield per plant (g).

Treatment	Fresh weight per plant (g)			Dry weight per plant (g)		
	2020-2021	2021-2022	Pooled	2020-2021	2021-2022	Pooled
T ₁ (30×10 cm)	5.56	5.17	5.37	9.40	8.74	9.07
T ₂ (30×20 cm)	6.20	5.77	5.98	12.78	11.89	12.33
T ₃ (30×30 cm)	9.40	8.74	9.07	16.74	15.57	16.15
T ₄ (45×10 cm)	8.95	8.32	8.64	15.86	14.75	15.30
T ₅ (45×20 cm)	6.88	6.40	6.64	15.25	14.18	14.72
T ₆ (45×30 cm)	10.32	9.60	9.96	17.28	16.07	16.68
T ₇ (60×10 cm)	11.15	10.37	10.76	18.58	17.28	17.93
T ₈ (60×20 cm)	12.00	11.16	11.58	18.90	17.58	18.24
T ₉ (60×30 cm)	12.22	11.36	11.79	19.38	18.02	18.70
S.E.m. ±	0.73	0.70	0.71	1.18	1.12	1.15
C.D. at 5%	2.19	2.11	2.13	3.56	3.37	3.45

than the closest in stevia.

Effect of spacing on yield parameter

Fresh and dry herb yield per plant (g):

The crop is harvested at 90 DAT, where the fresh and dry weight per plant is increased with increasing of spacing (Table 3). The pooled data from 2020-2022 of T₉(60×30 cm) showed the maximum fresh (79.67 g) and dry (17.70 g) herb yield per plant with a 22.22 % recovery and T₁(30×10 cm) showed the minimum fresh (42.70 g) and dry (9.49 g) herb yield per plant with a 22.22 % recovery from fresh to dry weight and whereas, T₈(60×20 cm) with fresh (75.52 g) and dry (16.78 g) herb yield per plant was on par with T₉ (60×30 cm) among all treatments. The herb yield (fresh and dry) per plant is increased with the increasing of spacing due to the adequate availability of nutrients, water, aeration and

Table 4: Effect of spacing on fresh and dry herb yield per plot (kg).

Treatment	Fresh weight per plot (kg)			Dry weight per plot (kg)		
	2020-2021	2021-2022	Pooled	2020-2021	2021-2022	Pooled
T ₁ (30×10 cm)	0.49	0.46	0.47	0.16	0.15	0.16
T ₂ (30×20 cm)	0.75	0.70	0.72	0.25	0.23	0.24
T ₃ (30×30 cm)	0.63	0.59	0.61	0.21	0.20	0.20
T ₄ (45×10 cm)	0.57	0.53	0.55	0.19	0.18	0.18
T ₅ (45×20 cm)	0.56	0.52	0.54	0.19	0.17	0.18
T ₆ (45×30 cm)	0.48	0.44	0.46	0.16	0.15	0.15
T ₇ (60×10 cm)	0.30	0.28	0.29	0.10	0.09	0.10
T ₈ (60×20 cm)	0.28	0.26	0.27	0.09	0.09	0.09
T ₉ (60×30 cm)	0.25	0.23	0.24	0.08	0.08	0.08
S.E.m. ±	0.04	0.24	0.04	0.01	0.01	0.01
C.D. at 5%	0.13	0.12	0.13	0.04	0.04	0.04

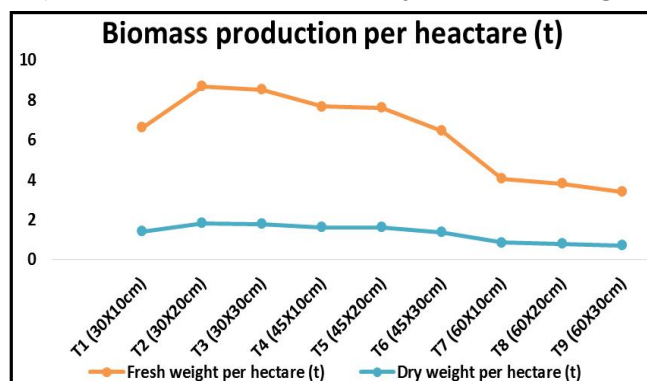
Table 5: Effect of spacing on fresh and dry herb yield per hectare (t).

Treatment	Fresh weight per hectare (t)			Dry weight per hectare (t)		
	2020-2021	2021-2022	Pooled	2020-2021	2021-2022	Pooled
T ₁ (30×10 cm)	6.86	6.38	6.62	1.43	1.33	1.38
T ₂ (30×20 cm)	9.00	8.37	8.69	1.88	1.74	1.81
T ₃ (30×30 cm)	8.82	8.20	8.51	1.84	1.71	1.77
T ₄ (45×10 cm)	7.93	7.38	7.66	1.65	1.54	1.59
T ₅ (45×20 cm)	7.89	7.33	7.61	1.64	1.53	1.59
T ₆ (45×30 cm)	6.67	6.21	6.44	1.39	1.29	1.34
T ₇ (60×10 cm)	4.20	3.91	4.05	0.88	0.81	0.84
T ₈ (60×20 cm)	3.92	3.65	3.78	0.82	0.76	0.79
T ₉ (60×30 cm)	3.50	3.26	3.38	0.73	0.68	0.70
S.E.m. ±	0.62	0.57	0.59	0.12	0.12	0.12
C.D. at 5%	1.86	1.73	1.79	0.38	0.36	0.37

sunlight where, these factors promoted the individual plant growth and development compared with the plants grown under reduced spacing. The results are in conformity with the findings of Aladakatti *et al.*, (2012), Rashid *et al.*, (2015), Tadesse *et al.*, (2017) and Shivani *et al.*, (2019).

Fresh and dry herb yield per plot (kg):

The individual plot weight (fresh and dry herb yield) was measured and the crop was harvested and weighed accordingly to the individual plots (Table 4). The pooled data has recorded that T₂(30×20 cm) with maximum fresh (0.72 kg) and dry (0.24 kg) herb yield per plot, T₉(60×30 cm) with minimum fresh (0.24 kg) and dry (0.08 kg) herb yield per plot, Whereas, T₃(30×30 cm) was on par with the T₂(30×20 cm) with fresh (0.61 kg) and dry (0.20 kg) herb yield per plot. As the spacing increases the plant population or plant density reduces, which leads to the reduction in yield per unit area. From this experiment we can observe that the treatment T₉(60×30 cm) recorded the minimum herb yield (fresh and dry) because of less plant population as compared with the treatment T₂(30×20 cm). The results are in conformity with the findings of

**Fig. 1:** Effect of spacing on fresh and dry herb yield per hectare (t).

Chandana *et al.*, (2020), Bhakar *et al.*, (2025), Rashid *et al.*, (2015), Tadesse *et al.*, (2017) and Shivani *et al.*, (2019).

Fresh and dry herb yield per hectare (t):

Fresh and dry herb yield was measured in kilograms (Table 5). The pooled data from 2020-2022 has recorded that $T_2(30 \times 20 \text{ cm})$ with maximum fresh (8.69 t) and dry (1.81 tons) herb yield per hectare, $T_9(60 \times 30 \text{ cm})$ with minimum fresh (3.39 t) and dry (0.70 tons) herb yield per hectare and whereas, $T_3(30 \times 30 \text{ cm})$ was on par with $T_2(30 \times 20 \text{ cm})$ with fresh (8.51 t) and dry (1.77 t) herb yield per hectare (Fig. 1). As the spacing increases the plant population or plant density reduces, which leads to the reduction in yield per unit area. From this experiment we can observe that minimum herb yield (fresh and dry) is due less plant population. The results are in conformity with the findings of Aladakatti *et al.*, (2012) reported that closer spacing of $30 \times 20 \text{ cm}$ recorded the highest fresh biomass yield (149.27 t ha^{-1}), fresh leaf yield (57.14 t ha^{-1}) and dry leaf yield (11.12 t ha^{-1}). Shivani *et al.*, (2019) observed that closer spacing of $30 \times 20 \text{ cm}$ recorded the highest fresh leaf yield (10.54 t ha^{-1}), fresh stem yield (13.81 t ha^{-1}) and harvest index (43.67%) due to higher plant population per unit area, whereas wider spacing ($50 \times 20 \text{ cm}$) reduced fresh leaf yield ($5.15\text{--}6.28 \text{ t ha}^{-1}$) and fresh stem yield ($7.02\text{--}9.28 \text{ t ha}^{-1}$). Tadesse *et al.*, (2017) reported that spacing levels significantly influenced biomass yield of stevia under South Ethiopian conditions. Closer spacing of $20 \times 40 \text{ cm}$ recorded the highest fresh leaf yield ($19,467 \text{ kg ha}^{-1}$), fresh aboveground biomass yield ($25,002 \text{ kg ha}^{-1}$) and dry leaf yield ($7,834 \text{ kg ha}^{-1}$), whereas wider spacing of $60 \times 40 \text{ cm}$ markedly reduced fresh leaf yield ($10,269 \text{ kg ha}^{-1}$), fresh biomass yield ($16,686 \text{ kg ha}^{-1}$) and dry leaf yield ($3,922 \text{ kg ha}^{-1}$) and results also confirmed Rashid *et al.*, (2015), Sniegowska, and Biesiada (2024).

Conclusion

As per findings from experiment, it is concluded that for better plant growth and herbage yield per plant (fresh and dry), $T_9(60 \times 30 \text{ cm})$ gave maximum herbage yield per plant. However, when it is evaluated to herbage yield per plot and hectare, the same treatment showed the minimum response. Whereas, $T_2(30 \times 20 \text{ cm})$ recorded the maximum fresh (0.72 kg) and dry (0.24 kg) herbage yield per plot, as well as fresh (8.69 t) and dry (1.81 t) herbage yield per hectare. Hence, it is concluded that $T_2(30 \times 20 \text{ cm})$ is the optimum spacing can be adapted by the farmers to cultivate stevia crop for maximum herbage yield and returns.

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