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TSS, Yield and Energetics of Stevia as Influenced by Nitrogen Levels and Spacing under Eastern U.P. Conditions

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ABSTRACT

Background: Stevia is a natural sweetener plant with zero calorie content which is used as an alternative source of sugar. Stevioside extract from stevia is considered to be 300-350 times sweeter than sugar. It is safe for use by both diabetics and hypo glycaemics due to its low glycaemic index. Stevia has some bitter aftertaste along with sweetness due to the presence of some essential oils, tannins and flavonoids.

Methods: Field experiment was conducted at Eastern Block of Crop Research Farm, Department of Agronomy, Naini Agricultural Institute, Prayagraj during *Zaid* 2018. The experiment was carried out in randomized complete block design comprising of three N levels *i.e*. 50, 75 and 100 kg N/ha and inter row spacing of 30, 40 and 50 cm with 20 cm of plant to plant spacing. The study was carried out to find out response of nitrogen levels and spacing on stevia.

Result: Maximum plant height (51.24 cm), leaf area (4596.99 cm^2) was observed with treatment 100 kg N ha^{-1} at 50 cm x 20 cm spacing and leaf area index (7.30), total soluble solids (TSS) (18.73 ^oBrix) was noticed with treatment 100 kg N ha^{-1} at 30 cm x 20 cm spacing, whereas the maximum Leaf number (342.52) was recorded with treatment 100 kg N ha^{-1} at 40 cm x 20 cm spacing. The results of this experiment revealed that increased dose of nitrogen with narrow spacing gave maximum quality.

Key words: Energetics, Nitrogen levels, Spacing, Stevia, Stevioside, TSS.

INTRODUCTION

Increasing health-consciousness among consumers is the major cause of increasing demand of natural sweeteners as a substitute for sucrose and other artificial sweeteners which acts as nutritional terrorist such as saccharine, aspartame *etc*. Stevia is a medicinal herb commonly known as sugar leaf, honey leaf; belongs to Asteraceae family. It is a low calorie natural sweetener; native of northeastern Paraguay, cultivated as a cash crop in China, Brazil, Mexico, Russia, India, Canada and Argentina (Ramesh *et al.,* 2006). Presently total annual production of stevia in India is about 600 tonnes with an average yield of 2500 to 2700 kgs of dried leaves per acre. Research on stevia is still in nascent stage in India so, there is unavailability of data regarding its area, production and productivity.

Stevia is a small perennial, cross pollinated crop of 70-90 cm height with sessile, oppositely arranged leaves. Leaves of stevia have commercial importance due to the presence of non-calorie diterpenes and sweet glycosides, especially stevioside and rebaudioside-A which are 300 times sweeter than sugar (Lokesh *et al.* 2018). The sweet steviol glycosides, present in the leaves and are not absorbed by human body during digestion process. Further, the human body does not metabolise the sweet glycosides from the stevia leaf or any of its processed forms. The cultivation of stevia has an immense scope for intensive agriculture and fits well for high return (Barathi, 2003).

MATERIALS AND METHODS

The present investigation was carried out during *Zaid* season of 2018 at CRF situated at 25° 39′ 42″N latitude, 81° 67′ 56″ E longitude and 98 meters altitude above the mean sea level (MSL). It has subtropical and humid monsoon climate. The soil of experimental site was well drained and clayey loam in texture with pH 7.8, low in organic carbon content 0.3%, available N 183.50 kg ha^{-1}, available P_2O_5 15.63 kg ha^{-1} and available K_2O 197.63 kg ha^{-1}. The experiment consisted of nine treatments with three replications.

Treatments were as follows:

T_1 50 kg ha^{-1} N at 30 cm × 20 cm spacing
T_2 50 kg ha^{-1} N at 40 cm × 20 cm spacing
T_3 50 kg ha^{-1} N at 50 cm × 20 cm spacing
T_4 75 kg ha^{-1} N at 30 cm × 20 cm spacing
T_5 75 kg ha^{-1} N at 40 cm × 20 cm spacing
T_6 75 kg ha^{-1} N at 50 cm × 20 cm spacing
T_7 100 kg ha^{-1} N at 30 cm × 20 cm spacing
T_8 100 kg ha^{-1} N at 40 cm × 20 cm spacing
T_9 100 kg ha^{-1} N at 50 cm × 20 cm spacing

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The experimental area was thoroughly ploughed and harrowed in order to obtain good tilth. The crop was sown in the middle of February and harvested in May. Recommended quantities of P and K fertilizers were applied according to the soil and crop requirements. Weeding was done manually at 20 and 40 DAT. One spray was neem oil (0.5%) was enough to control the incidence of diseases like leaf blight, leaf spot. The crop was non-destructively harvested at 90 DAT, cleaned, sun dried followed by shade drying for 3-4 days. Observations like plant height (cm), leaf number, leaf area (cm^2), leaf area index, SPAD value, total soluble solids (^oBrix), yield attributes and energetics of stevia were studied. Mean data of each traits were statistically analysed by the technique of analysis of variance given by Panse and Sukhatme (1967).

RESULTS AND DISCUSSION

Effect of nitrogen levels and spacing on plant height (cm)

Height of plant is very essential production component due to the photosynthetic activity. The average plant height of stevia for all the treatments are shown in Table 1. At 80 DAT, the maximum plant height (51.24 cm) was observed in the treatment 100 kg ha^{-1} N at 50 cm × 20 cm spacing (T_9).

Increased plant height in the following treatments might be due to higher availability of nutrients and spaced required by each plant to grow faster. The results are in harmony with those reported by Taleie *et al.* (2012) and Inugraha *et al.* (2014).

Effect of nitrogen levels and spacing on SPAD value

Soil plant analysis development (SPAD) value indicates the amount of chlorophyll present in the plant leaves which is related to the condition of the plant and thus can be used to determine when additional fertilizer is necessary. Observations regarding response of spacing and levels of nitrogen on SPAD value of stevia is presented in Table 1.

The effect of the treatment on SPAD value was found to be non-significant. The results underline that in stevia there is a lack of correlation between Nitrogen level and SPAD value (chlorophyll content). SPAD value is directly proportional to the amount of chlorophyll present in leaf.

Effect of nitrogen levels and spacing on Number of leaves, Leaf area and LAI

Nitrogen levels and spacing had significant influence on the number of leaves, leaf area, leaf area index and it could be clearly noticed from Table 2. Leaf is the economic part hence, production of more leaf is the main aim of stevia performance. At harvest, significantly maximum number of leaves (342.52 $plant^{-1}$) was observed in treatment 100 kg ha^{-1} N at 40 cm × 20 cm spacing (T_8).

Rashid *et al.* (2015) also mentioned that more no. of leaves is the result of more no. of branches per plant. The results are in accordance with the findings of Aladakatti *et al.* (2012) and Maheswar (2005) who reported increased number of leaves per plant with higher N levels.

Leaf area is governed by number of leaves per plant and size of leaves and it plays a vital role for plant growth and crop yield. The leaf area, being the most important yield determinant and is greatly influenced by different row to row spacing. Increase in leaf area with increase in spacing might be due to the fact that with increase in spacing there was more space for growth of the plant as compared to closer spacing. Maximum leaf area is obtained when sufficient amount of sunlight is just able to pass through the canopy.

At harvest, highest leaf area (4596.99 cm^2 $plant^{-1}$) was noticed in treatment 100 kg ha^{-1} N at 50 cm × 20 cm spacing (T_9). The results are in conformity with those of Rashid *et al.* (2015). The higher dose of nutrient levels increased the leaf area compared to lower dose. This could be attributed to the enhanced availability of nutrients at the appropriate time which have increased the number of leaves as well as leaf area. These results are also in consonance with the findings of Chalapathi *et al*. (1999) in *Stevia rebaudiana*.

Significant interaction occurred between the treatments on leaf area index at harvest and the maximum LAI (7.30) was observed in treatment 100 kg ha^{-1} N at 30 cm x 20 cm spacing (T_7), whereas the minimum LAI (3.70) was observed in treatment 50 kg ha^{-1} N at 50 cm × 20 cm spacing (T_3).

Table 1: Plant height and SPAD value of stevia influenced by nitrogen levels and spacing.

Treatment no.	Treatment combinations	Plant height (cm)	SPAD value
		80 DAT	80 DAT
T_1	50 kg ha^{-1} N at 30 cm × 20 cm spacing	39.11	47.64
T_2	50 kg ha^{-1} N at 40 cm × 20 cm spacing	41.42	50.07
T_3	50 kg ha^{-1} N at 50 cm × 20 cm spacing	43.97	51.50
T_4	75 kg ha^{-1} N at 30 cm × 20 cm spacing	43.73	50.30
T_5	75 kg ha^{-1} N at 40 cm × 20 cm spacing	48.00	51.53
T_6	75 kg ha^{-1} N at 50 cm × 20 cm spacing	48.13	50.83
T_7	100 kg ha^{-1} N at 30 cm × 20 cm spacing	47.71	54.39
T_8	100 kg ha^{-1} N at 40 cm × 20 cm spacing	48.31	51.73
T_9	100 kg ha^{-1} N at 50 cm × 20 cm spacing	51.24	49.67
	F-test	S	NS
	SEm ±	1.15	2.48
	CD (P = 0.05)	3.44	7.43

Table 2: Leaf number, leaf area and leaf area index (LAI) of stevia influenced by nitrogen levels and spacing.

Treatment no.	Treatment combinations	Leaf number	Leaf area (cm^2)	Leaf area index
T_1	50 kg ha^{-1} N at 30 cm × 20 cm spacing	299.28	3110.54	5.18
T_2	50 kg ha^{-1} N at 40 cm × 20 cm spacing	301.63	3234.97	4.04
T_3	50 kg ha^{-1} N at 50 cm × 20 cm spacing	309.60	3700.81	3.70
T_4	75 kg ha^{-1} N at 30 cm × 20 cm spacing	317.03	3911.62	6.82
T_5	75 kg ha^{-1} N at 40 cm × 20 cm spacing	323.30	3936.81	5.02
T_6	75 kg ha^{-1} N at 50 cm × 20 cm spacing	325.06	4082.99	4.08
T_7	100 kg ha^{-1} N at 30 cm × 20 cm spacing	330.98	4377.31	7.30
T_8	100 kg ha^{-1} N at 40 cm × 20 cm spacing	342.52	4283.75	6.88
T_9	100 kg ha^{-1} N at 50 cm × 20 cm spacing	337.33	4596.99	4.79
	F-test	S	S	S
	SEm±	5.05	117.16	0.18
	CD (P = 0.05)	15.15	351.26	0.54

Table 3: Yield and yield attributes of stevia influenced by nitrogen levels and spacing.

Treatment no.	Treatment combinations	Fresh biomass yield (t ha^{-1})	Fresh leaf yield (t ha^{-1})	Fresh leaf to stem ratio	Harvest index (%)
T_1	50 kg ha^{-1} N at 30 cm × 20 cm spacing	17.91	7.04	0.65	39.33
T_2	50 kg ha^{-1} N at 40 cm × 20 cm spacing	15.01	6.10	0.69	40.67
T_3	50 kg ha^{-1} N at 50 cm × 20 cm spacing	12.17	5.15	0.73	42.33
T_4	75 kg ha^{-1} N at 30 cm × 20 cm spacing	22.85	9.98	0.78	43.67
T_5	75 kg ha^{-1} N at 40 cm × 20 cm spacing	15.71	6.55	0.72	41.67
T_6	75 kg ha^{-1} N at 50 cm × 20 cm spacing	13.32	5.37	0.68	40.33
T_7	100 kg ha^{-1} N at 30 cm × 20 cm spacing	24.35	10.54	0.77	43.34
T_8	100 kg ha^{-1} N at 40 cm × 20 cm spacing	17.96	7.18	0.67	40.00
T_9	100 kg ha^{-1} N at 50 cm × 20 cm spacing	15.56	6.28	0.68	40.33
	F-test	S	S	S	S
	SEm±	0.51	0.25	0.03	0.94
	CD (P = 0.05)	1.55	0.75	0.08	2.84

Increasing nitrogen level increases LAI and LAI was significantly higher when stevia was planted at (30 cm × 20 cm). The present findings lend to support from the results of Kumar *et al.* (2014).

Effect of nitrogen levels and spacing on yield attributing parameters

The data on yield attributing parameters are presented in the Table 3.

Fresh biomass yield

Levels of nitrogen significantly affected fresh biomass yield under different planting geometry. Highest fresh biomass yield (24.35 t ha^{-1}) was obtained in treatment 100 kg ha^{-1} N at 30 cm × 20 cm spacing (T_7).

The results of present study is in accordance with the findings of Btru *et al.* (2017) and Kumar *et al.* (2014) who concluded that maximum fresh above ground biomass yield per hectare at closer spacing than the wider spacing in Stevia.

Fresh leaf yield

The results showed that fresh leaf yield was much influenced under various treatments at harvest. Treatment 100 kg ha^{-1} N at 30 cm × 20 cm spacing (T_7) gave higher fresh leaf yield (10.54 t ha^{-1}) and the lowest fresh leaf yield (5.15 t ha^{-1}) was observed under treatment 50 kg ha^{-1} N at 50 cm × 20 cm spacing (T_3) among various treatments. The results are in line with findings of Lokesh *et al.* (2018).

Fresh leaf to stem ratio

A perusal of data revealed that highest leaf to stem ratio (0.78) was recorded in treatment 75 kg ha^{-1} N at 30 cm × 20 cm spacing (T_4). The results corroborate findings of Aladakatti *et al.* (2012). Kumar *et al*. (2012) reported leaf to stem ratio of (0.73) with application of 100:60:50 kg/ha of NPK.

Harvest index

Treatment (T_4), 75 kg ha^{-1} N at 30 cm × 20 cm spacing showed highest harvest index (43.67%) and lowest harvest index (39.33%) was recorded under treatment (T_1), 50 kg ha^{-1} N at 30 cm × 20 cm spacing.

The possible reason for lowering harvest index may be due to the less amount nutrient supplied which results in lower leaf yield which is the economic part of stevia because of lower translocation of photosynthates. The results are in conformity with the findings of Aladakatti *et al.* (2012).

Total soluble solids of stevia

At 40, 60, 80 DAT and at harvest treatment 100 kg ha^{-1} N at 30 cm × 20 cm spacing (T_7) demonstrated significantly

Table 4: Total soluble solids (TSS) of stevia influenced by nitrogen levels and spacing.

Treatment No.	Treatment Combinations	Total Soluble Solids (°Brix)				
		20 DAT	40 DAT	60 DAT	80 DAT	At harvest
T_1	50 kg ha^{-1} N at 30 cm × 20 cm spacing	6.23	7.23	12.70	16.23	16.80
T_2	50 kg ha^{-1} N at 40 cm × 20 cm spacing	6.17	6.70	10.03	16.10	16.30
T_3	50 kg ha^{-1} N at 50 cm × 20 cm spacing	5.73	6.60	10.23	15.93	16.06
T_4	75 kg ha^{-1} N at 30 cm × 20 cm spacing	6.60	8.00	13.30	17.43	17.90
T_5	75 kg ha^{-1} N at 40 cm × 20 cm spacing	6.40	7.56	12.66	17.20	17.46
T_6	75 kg ha^{-1} N at 50 cm × 20 cm spacing	6.33	7.50	12.40	17.10	17.40
T_7	100 kg ha^{-1} N at 30 cm × 20 cm spacing	6.80	8.80	14.83	18.33	18.73
T_8	100 kg ha^{-1} N at 40 cm × 20 cm spacing	6.50	8.50	14.30	18.03	18.56
T_9	100 kg ha^{-1} N at 50 cm × 20 cm spacing	6.27	8.30	14.20	17.93	18.33
	F-test	NS	S	S	S	S
	SEm±	0.20	0.08	0.35	0.27	0.19
	CD (P = 0.05)	0.60	0.25	1.05	0.82	0.58

Table 5: Energy input, energy output, net energy, energy use efficiency and specific energy as influenced by spacing and levels of nitrogen.

Treatment no.	Treatment details	Energy input (MJ ha^{-1})	Energy output (MJ ha^{-1})	Net energy (MJ ha^{-1})	Energy ratio	Specific energy (MJ Kg^{-1})
T_1	50 kg ha^{-1} N at 30 cm × 20 cm spacing	21905	61100	39195	2.78	3.58
T_2	50 kg ha^{-1} N at 40 cm × 20 cm spacing	21898	50900	29002	2.32	4.30
T_3	50 kg ha^{-1} N at 50 cm × 20 cm spacing	21894	41000	19106	1.87	5.34
T_4	75 kg ha^{-1} N at 30 cm × 20 cm spacing	25145	76500	51355	3.04	3.28
T_5	75 kg ha^{-1}N at 40 cm × 20 cm spacing	25138	53100	27962	2.11	4.73
T_6	75 kg ha^{-1}N at 50 cm × 20 cm spacing	25134	45200	20066	1.79	5.56
T_7	100 kg ha^{-1} N at 30 cm × 20 cm spacing	28385	81500	53115	2.87	3.48
T_8	100 kg ha^{-1}N at 40 cm × 20 cm spacing	28378	61000	32622	2.14	4.65
T_9	100 kg ha^{-1}N at 50 cm × 20 cm spacing	28374	52800	28374	1.86	5.37

highest TSS (8.8 °Bx), (14.83 °Bx), (18.33 °Bx) and (18.73 °Bx) is presented in Table 4. However, the least value of TSS was noted in treatment 50 kg ha^{-1}N at 50 cm × 20 cm spacing (T_3). High amount of TSS was recorded with treatment (T_7), this could be due to production of greater number of photo synthetically active leaves because of adequate supply of nitrogen nutrient. This might have lead to higher metabolic activity, resulting in increased production of carbohydrate and ultimately increased TSS. The results are in conformity with Cheena (2004).Similar reports were reported by Kapuriya *et al.* (2017) who opined that increasing planting geometry reduces TSS content.

Energetic of stevia

Different treatments were assessed under energy parameters and data regarding the same is presented in Table 5, which significantly affected due to different spacing and levels of nitrogen.

Data revealed that the maximum energy input (28.38 × 10^3 MJ ha^{-1}), energy output (81.5 × 10^3 MJ ha^{-1}), net energy (53.14 x 10^3 MJ ha^{-1}) was observed under treatment 100 kg ha^{-1} N at 30 cm × 20 cm spacing (T_7) and the lowest value of energy input (21.89 × 10^3 MJ ha^{-1}), energy output (41 × 10^3 MJ ha^{-1}), net energy (19.10 × 10^3 MJ ha^{-1}) was observed under treatment 50 kg ha^{-1} N at 50 cm × 20 cm spacing (T_3). The highest energy ratio (3.04) was noticed under treatment 75 kg ha^{-1}N at 30 cm × 20 cm (T_4) spacing and lowest ratio (1.79) was noticed under treatment 75 kg ha^{-1}N at 50 cm × 20 cm spacing (T_6).

However, maximum specific energy (5.56 MJ/kg) was observed under treatment 75 kg ha^{-1}N at 50 cm × 20 cm spacing (T_6) and minimum specific energy (3.28 MJ/kg) was noticed under treatment 75 kg ha^{-1}N at 30 cm × 20 cm spacing (T_4). The similar findings have been also reported by Pahalvan *et al.* (2012) and Hedau *et al.* (2014).

CONCLUSION

The objective of this study was to determine the nitrogen and spacing requirement to obtain the enhanced yield of stevia under Eastern U.P. conditions. Results show that the higher rates of 100 kg N ha^{-1} with (50 cm × 20 cm) spacing resulted in higher plant height and leaf area and 100 kg N ha^{-1} at (30 cm × 20 cm) spacing was proved to be best treatment in terms of highest fresh biomass yield (24.35 t ha^{-1}), fresh leaf yield (10.54 t ha^{-1}) and dry leaf yield (2.63 t ha^{-1}). Therefore, there is a need to regulate nitrogen dosage and spacing for enhanced economic yield of stevia in this region and others having similar agro-ecological characteristics.

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