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Kumari Shivani
Department of Agronomy, Naini Agricultural Institute, SHUATS, Prayagraj, Uttar Pradesh, India

Ghosh Gautam
Department of Agronomy, Naini Agricultural Institute, SHUATS, Prayagraj, Uttar Pradesh, India

Correspondence
Kumari Shivani
Department of Agronomy, Naini Agricultural Institute, SHUATS, Prayagraj Uttar Pradesh, India

Influence of different levels of nitrogen on yield and economics of stevia (*Stevia rebaudiana* Bertoni) under different planting geometry

Kumari Shivani and Ghosh Gautam

Abstract
Stevia (*Stevia rebaudiana* Bertoni) is a crop of economic importance due to its utilization as the alternative source of sugar. The productivity of stevia depends on many agronomical factors such as planting density, nutrient levels, field preparation, spacing etc. A field experiment was conducted during *Zaid* season 2018 in a clayey soil under irrigated conditions to study the "Influence of different levels of nitrogen on yield and economics of stevia (*Stevia rebaudiana* Bertoni) under different planting geometry. The experiment was laid out in randomized block design which comprised of 2 factors *viz.,* Nitrogen levels (50, 75 and 100 kg ha^{-1}) and Plant spacing S1 (30 cm x 20 cm), S2 (40 cm x 20 cm), and S3 (50 cm x 20 cm). The combination of 100 kg ha^{-1} N at (30 cm x 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}). However, maximum leaf to stem ratio on fresh weight basis (0.78) and harvest index (0.44) was obtained in treatment T_4 *i.e.,* 75 kg ha^{-1} N at (30 cm x 20 cm) spacing.

Keywords: Stevia, spacing, fresh leaf to stem ratio, nutrient

Introduction

Stevia rebaudiana Bertoni was officially discovered by Dr M.S. Bertoni in 1905, belonging to the family Asterceae is a recent high demanding medicinal crop in herbal world. Stevia is a natural sweetener plant with zero calorie content, becomes an inevitable alternative to cane sugar especially with over 346 million diabetic population across the world and this figure might increase to 592 million by 2035 (Kumari, 2014) [4]. Stevia rebaudiana gives the sweetest essence due to the fact that these leaves accumulate sweet diterpene glycoside having a sweetness of 250-350 times that of sucrose. This plant has an extraordinary sweetness in its natural form of dried leaves; it is about 10 to 15 times sweeter than white sugar. Stevia has some bitter aftertaste due to the presence of some essential oils, tannins and flavonoids (Phillips, 1987) [11]. Stevia is grown as a crop in many countries including Japan, China, India, Korea, USA, Canada, Mexico, Russia, Indonesia, Tanzania, Brazil, Paraguay, Canada and Argentina. Global stevia market is rapidly increasing, in 2014, the global consumption of stevia as food ingredient was estimated at 5,100 tonnes and it is projected to reach 8,507 tonnes by 2020. Stevia can play an important role in India which tops the diabetic population in the world with 30 million patients, and this is expected to increase to 80 million by 2025 as per the reports of world health organization. The Indian farmers have also started taking up stevia cultivation following the large demand for diabetic market here. 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. Since the production potential of stevia in India is 2-3 t ha^{-1} of dry leaves as against 1-2 t ha^{-1} in China, it has definite advantage over China. The climatic conditions in most parts of India are quite favorable for stevia cultivation. Studies showed that the stevia leaf contains proteins, fiber, carbohydrates, iron, phosphorus, calcium, sodium, magnesium, zinc, vitamin A, vitamin C and oil. Stevia has no toxicity. It is safe for use by both diabetics and hypoglycemic due to its low glycaemic index (Singh and Rao, 2005) [14]. Since, it is a newly adopted crop there is almost no information available on its proper production techniques, which may be one of cause for the non-availability of its quality raw materials (Singh, 2012) [15]. The biomass yield of stevia can be increased with the balanced application of N, P and K fertilizers, but the role of micronutrients cannot be ignored, which might have favourable effect on the biomass production as well as quality of stevia (Das *et al*., 2005) [3]. Optimum spacing and nutrient provided to each plant helps to utilize resources (sunlight, water, space, nutrient) optimally resulting in better yields. Hence, keeping in view the above facts the present research was carried out.

Materials and Methods

The field experiment was conducted to study the "Influence of different levels of Nitrogen on yield, yield attributes and economics of stevia (*Stevia rebaudiana* Bertoni) under different Planting geometry" during *zaid* season of 2018 at Crop Research Farm, Department of Agronomy, Naini Agricultural Institute, SHUATS, Prayagraj (Uttar Pradesh). The experimental area falls in humid sub-tropical region. It is situated at 25^o 39' 42'' N latitude, 81^o 67' 56" E longitude and 98 m altitude above the mean sea level (MSL). The experiment was laid out in completely randomized block design with three replications. The experiment consisted of nine treatments. Factor one consisted of levels of Nitrogen and factor two *i.e.*, Planting geometry. The details of treatments were, T_1 = 50 kg ha^{-1} nitrogen at (30 cm x 20 cm) spacing, T_2 = 50 kg ha^{-1} nitrogen at (40 cm x 20 cm) spacing, T_3 = 50 kg ha^{-1} nitrogen at (50 cm x 20 cm) spacing, T_4 = 75 kg ha^{-1} nitrogen at (30 cm x 20 cm) spacing, T_5 = 75 kg ha^{-1} nitrogen at (40 cm x 20 cm) spacing, T_6 = 75 kg ha^{-1} nitrogen at (50 cm x 20 cm) spacing, T_7 = 100 kg ha^{-1} nitrogen at (30 cm x 20 cm) spacing, T_8 = 100 kg ha^{-1} nitrogen at (40 cm x 20 cm) spacing and T_9 =100 kg ha^{-1} nitrogen at (50 cm x 20 cm) spacing. One month old seedlings were transplanted in field in the evening. Inorganic nutrients were applied at the time of transplanting *viz*; urea (N 46%), single super phosphate (P_2O_5 16%), and muriate of potash (K_2O 60%). Half dose of Nitrogen at the time of transplanting and the remaining half was applied in two equal splits; 1st half 30 days after transplanting and 2nd half 60 days after transplanting, whereas, the full doses of phosphorus and potassium at the rate of 40 kg ha^{-1} were applied at the time of transplanting. Need based irrigation was supplied at an interval of 5-7 days. Leaves of stevia become ready for first harvesting after three-four months of planting. The crop was harvested in the early morning at 90 DAT from the bottom leaving 5 cm up to the ground level and dried under shade for 4-5 days. Data regarding yield and yield attributes *viz.*, Fresh biomass yield (t/ha), fresh leaf yield (t/ha), dry leaf yield (t/ha), fresh stem yield (t/ha), leaf: stem ratio on fresh weight basis and harvest index (%) were taken at harvest. The data were statistically analyzed as procedures given by Panse and Sukhatme (1978) [10].

Results and Discussion

Yield and yield attributing parameters

Leaf is the economic part of stevia hence production of more leaf is the main aim of crop performance. Data presented in Table 1 depicts that the yield and yield attributing parameters varied significantly with application of different levels of nitrogen under different planting geometry.

Fresh biomass yield (t ha^{-1})

Fresh biomass yield was significantly affected by levels of nitrogen under different planting geometry. Significantly highest biomass yield (24.35 t ha^{-1}) was recorded in treatment T_7 *i.e.*, 100 kg ha^{-1} nitrogen at (30 cm x 20 cm) spacing over all other treatments except treatment T_4 *i.e.*, 75 kg ha^{-1} nitrogen at (30 cm x 20 cm) spacing which was found at par with treatment T_7 whereas the lowest (12.17 t ha^{-1}) was observed under treatment T_3 *i.e.*, 50 kg ha^{-1} nitrogen at (50 cm x 20 cm) spacing. It can be due to the effect of growth and yield-attributing characters owing to nitrogen nutrition. Greater availability of metabolites (photosynthates) and nutrients to developing tissue seems to have resulted in increase in the yield-attributing characters which ultimately improved the yield of the crop.

The results are in line with the findings of Chalapathi *et al.* (1999) [2] who reported that yield of stevia crop increased with levels of NPK up to 60:30:45 kg/ha under Indian conditions.

This finding is in agreement with the result of Kumar *et al.* (2014) [5] who reported maximum fresh above ground biomass yield per hectare at closer spacing than the wider spacing on Stevia.

Fresh leaf yield (t ha^{-1})

Fresh leaf yield was influenced significantly under various treatments at harvest. The data presented in Table 1 showed that among the different treatments, T_7 *i.e.*, 100 kg ha^{-1} nitrogen at (30 cm x 20 cm) spacing gave highest fresh leaf yield (10.54 t ha^{-1}) and the lowest fresh leaf yield (5.15 t ha^{-1}) was observed under treatment T_3 *i.e.*, 50 kg ha^{-1} nitrogen at (50 cm x 20 cm) spacing. However, treatment T_4 *i.e.*, 75 kg ha^{-1} nitrogen at (30 cm x 20 cm) spacing was found at par with treatment T_7.

The green leaves are important plant growth indices, determining the capacity of plant to trap solar energy for photosynthesis. The increase in yield may be attributed to the fact that due to optimum levels of nitrogen, there would be improved growth of the plant, which leads to production of more number of leaves, branches and ultimately resulting in highest fresh leaf yield. The results are in conformity with the findings of Lokesh *et al.* (2018) [8] and Murayama *et al.* (1980) [9].

The decrease in fresh leaf yield per hectare with increasing plant spacing could be due to lesser plant population. The outcomes are in agreement with the findings of Taleie *et al.* (2012) [16].

Dry leaf yield (t ha^{-1})

A perusal of data shows that there was significant difference between the treatments and has been presented in Table 1. Treatment T_7 *i.e.*, 100 kg ha^{-1} nitrogen at (30 cm x 20 cm) spacing recorded significantly highest (2.63 t ha^{-1}) dry leaf yield which was at par with treatment T_4 *i.e.*, 75 kg ha^{-1} nitrogen at (30 cm x 20 cm) spacing and lowest dry leaf yield (1.29 t ha^{-1}) was recorded under treatment T_3 *i.e.*, 50 kg ha^{-1} nitrogen at (50 cm x 20 cm) spacing.

The role of nitrogen on the dry leaf yield of stevia is, increasing the levels of nitrogen increases yield because of production of higher number of branches and leaves per plant. The results are in agreement with the results of Aladakatti *et al.* (2012) [1] and Murayama *et al.* (1980) [9] in stevia who reported that the application of optimum doses (100 Kg N/ha) of nitrogen produced better growth rate and dry leaf yield than the application of lower dose.

The lower yield at increased planting geometry was due to the fact that increasing plant density decreases dry leaf yield in stevia. The results are in conformity with the findings of Rashid *et al.* (2015) [12] and Lee *et al.* (1980) [7].

Fresh stem yield

Fresh stem yield varied significantly with nitrogen levels under different planting geometry. The data presented in the Table 1 justifies that treatment T_7 *i.e.*, 100 kg ha^{-1} nitrogen at

(30 cm x 20 cm) spacing demonstrated significantly highest fresh stem yield (13.81 t ha^{-1}) which was at par with treatment T_4 *i.e.*, 75 kg ha^{-1} nitrogen at (30 cm x 20 cm) spacing. The lowest fresh stem yield (7.02 t ha^{-1}) was recorded under treatment T_3 *i.e.*, 50 kg ha^{-1} nitrogen at (30 cm x 20 cm) spacing. It might be due to the increased uptake and availability of nitrogen which resulted in improvement of plant metabolic process and finally resulted in higher stem yield.

The results are in line with the findings of Aladakatti *et al.* (2012) [1] who found the similar findings with planting geometry of (30 cm x 20 cm).

Leaf stem ratio

The perusal of the data in Table 1 further reflected that there was significant difference between the treatments. Significant and highest leaf to stem ratio (0.78) was recorded in treatment T_4 *i.e.*, 75 kg ha^{-1} nitrogen at (30 cm x 20 cm) spacing and lower leaf to stem ratio (0.65) was recorded under treatment T_1 *i.e.*, 50 kg ha^{-1} nitrogen at (30 cm x 20 cm) spacing. Further treatments, T_3 *i.e.*, 50 kg ha^{-1} nitrogen at (50 cm x 20 cm) spacing, T_5 *i.e.*, 75 kg ha^{-1} nitrogen at (40 cm x 20 cm) spacing and T_7 *i.e.*, 100 kg ha^{-1} nitrogen at (30 cm x 20 cm) spacing were at par with treatment T_4.

The results are similar with the findings of Aladakatti *et al.* (2012) [1] who recorded higher leaf to stem ratio with planting geometry of 45 cm x 30 cm.

Kumar *et al*. (2012) [6] found leaf stem ratio (0.73) with application of NPK 100:60:50 kg/h.

Harvest index (%)

The data presented in Table 1 showed that the harvest index also followed almost same trend as that of leaf stem ratio and the maximum harvest index (43.67%) was recorded in treatment T_4 *i.e.*, 75 kg ha^{-1} nitrogen at (30 cm x 20 cm) spacing. This was significantly superior to all other treatments except T_3 *i.e.*, 50 kg ha^{-1} nitrogen at (50 cm x 20 cm) spacing, T_5 *i.e.*, 75 kg ha^{-1} nitrogen at (40 cm x 20 cm) spacing and T_7 *i.e.*, 100 kg ha^{-1} nitrogen at (30 cm x 20 cm) spacing which were at par with treatment T_4. The lowest harvest index (39.33%) was recorded under treatment T_1 *i.e.*, 50 kg ha^{-1} nitrogen at (30 cm x 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 present findings lend to support from the results of Aladakatti *et al.* (2012) [1].

Table 1: Influence of different levels of Nitrogen on yield and yield attributes of Stevia

Treatment No.	Treatment Combinations	Fresh biomass yield (t ha^{-1})	Fresh leaf yield (t ha^{-1})	Dry leaf Yield (t ha^{-1})	Fresh stem yield (t ha^{-1})	Fresh Leaf to Stem ratio	Harvest index (%)
T_1	50 kg ha^{-1} nitrogen at 30 cm x 20 cm spacing	17.91	7.04	1.76	10.86	0.65	39.33
T_2	50 kg ha^{-1} nitrogen at 40 cm x 20 cm spacing	15.01	6.10	1.53	8.91	0.69	40.67
T_3	50 kg ha^{-1} nitrogen at 50 cm x 20 cm spacing	12.17	5.15	1.29	7.02	0.73	42.33
T_4	75 kg ha^{-1} nitrogen at 30 cm x 20 cm spacing	22.85	9.98	2.50	12.87	0.78	43.67
T_5	75 kg ha^{-1} nitrogen at 40 cm x 20 cm spacing	15.71	6.55	1.64	9.16	0.72	41.67
T_6	75 kg ha^{-1} nitrogen at 50 cm x 20 cm spacing	13.32	5.37	1.34	7.95	0.68	40.33
T_7	100 kg ha^{-1} nitrogen at 30 cm x 20 cm spacing	24.35	10.54	2.63	13.81	0.77	43.34
T_8	100 kg ha^{-1} nitrogen at 40 cm x 20 cm spacing	17.96	7.18	1.79	10.79	0.67	40.00
T_9	100 kg ha^{-1} nitrogen at 50 cm x 20 cm spacing	15.56	6.28	1.57	9.28	0.68	40.33
	F-test	S	S	S	S	S	S
	SEm±	0.51	0.25	0.06	0.39	0.03	0.94
	CD (P = 0.05)	1.55	0.75	0.19	1.19	0.08	2.84

Economics

Economics is the main parameter which focuses on maximizing the crop yield while maintaining a good soil ecosystem. It finally decides the adoption of any recommended agro-technology by farmers. The economical indicator presented in Table 2 depicts that highest net return (₹ 2, 21, 864 ha^{-1}) and maximum benefit: cost ratio (1.72) was recorded in treatment T_7 *i.e.*, 100 kg ha^{-1} nitrogen at (30 cm x 20 cm) spacing.

However, the lowest net return (₹ 4, 87, 28 ha^{-1}) and the minimum benefit: cost ratio (1.16) was obtained in T_1 *i.e.*, 50 kg ha^{-1} nitrogen at (30 cm x 20 cm) spacing.

Treatment T_7 recorded (78.03%) higher yield compare to treatment T_1 and (11.52%) compare to treatment T_4 while the plant population was same in all three treatments. The difference in net return is due to the higher doses of nutrient in treatment T_7 *i.e.*, 100 kg ha^{-1} nitrogen.

Table 2: Influence of different levels of Nitrogen on Economics of Stevia

Treatment No.	Treatment Combinations	Cost of Cultivation (₹ ha^{-1})	Net Return (₹ ha^{-1})	B:C ratio
T_1	50 kg ha^{-1} nitrogen at 30 cm x 20 cm spacing	3,03,272	4,87,28	1.16
T_2	50 kg ha^{-1} nitrogen at 40 cm x 20 cm spacing	2,27,672	7,83,28	1.34
T_3	50 kg ha^{-1} nitrogen at 50 cm x 20 cm spacing	1,90,172	6,78,28	1.35
T_4	75 kg ha^{-1} nitrogen at 30 cm x 20 cm spacing	3,03,704	1,96,296	1.64
T_5	75 kg ha^{-1} nitrogen at 40 cm x 20 cm spacing	2,28,104	9,98,96	1.43
T_6	75 kg ha^{-1} nitrogen at 50 cm x 20 cm spacing	1,90,604	7,73,96	1.40
T_7	100 kg ha^{-1} nitrogen at 30 cm x 20 cm spacing	3,04,136	2,21,864	1.72
T_8	100 kg ha^{-1} nitrogen at 40 cm x 20 cm spacing	2,28,536	1,29,464	1.56
T_9	100 kg ha^{-1} nitrogen at 50 cm x 20 cm spacing	1,91,036	1,22,964	1.64

Conclusion

From the above discussion it can be concluded that introduction of stevia in Prayagraj conditions has immense potential in augmenting the farmers income It can be grown successfully with balanced use of nutrients and spacing. The farming community may get additional benefit by adapting stevia in intercropping with cereals, pulses and oilseeds. Further being a new crop to India conformity regarding agronomic practices are required to enhance the production under different agro-climatic conditions.

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