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Shivani
Department of Forest Products, Dr. Yashwant Parmar University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh, India

Bhupender Dutt
Department of Forest Products, Dr. Yashwant Parmar University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh, India

Meenu Sood
Department of Forest Products, Dr. Yashwant Parmar University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh, India

Sunny Kumar
Department of History, Himachal Pradesh University, Summerhill, Shimla, Himachal Pradesh, India

Corresponding Author:
Shivani
Department of Forest Products, Dr. Yashwant Parmar University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh, India

Influence of organic manures, inorganic fertilizers and harvesting schedules on growth and yield of *Stevia rebaudiana* Bertoni under mid-hill conditions of Himachal Pradesh

Shivani, Bhupender Dutt, Meenu Sood and Sunny Kumar

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Abstract
Field crop nutrition is poorly managed, which affects both quality and production standards. The experiment was carried out in the experimental field as well as in laboratory of the Department of Forest Products, College of Forestry, Dr Y S Parmar University of Horticulture and Forestry, Nauni, Solan (HP) during 2019-2020. Among different treatments, vermicompost (N content equivalent to RDF) + NPK (60:45:30 kg/ha) resulted significant effect on growth and yield in two harvests. Highest total fresh leaf yield (91.67 q/ha), total dry leaf yield (31.77 q/ha), total fresh foliage yield (169.49 q/ha) and total dry foliage yield (63.55 q/ha) with B:C ratio (1.09) were observed in treatment combinations vermicompost (N content equivalent to RDF(Recommended Dose of Fertilizers)) + NPK (60:45:30 kg/ha) but the highest B:C ratio (1.11) was observed in integrated nutrient management of FYM (N content equivalent to RDF) + NPK (60:45:30 kg/ha) with economic dry leaf yield (29.65 q/ha).

Keywords: Organic manure, *Stevia rebaudiana* yield, harvesting schedules, economic analysis

Introduction
Sugar plays a significant role on human eating patterns. For a long time, cane sugar with a small proportion of beet sugar has been the main source of sugar ((Kienle, 2016) [9]. *Stevia* may replace regularly used sucrose, which is wise in the fight against obesity, type 2 diabetes, caries and other illnesses of civilization (Kumar, 2002) [11]. *Stevia rebaudiana* Bertoni, belonging to the family Asteraceae (Lester, 1999) [15] and is native to Paraguay (South America). It is a perennial herb having an extensive root system and brittle stems producing small, elliptic leaves (Shock, 1982) [25]. It is commonly known as “Sweet weed”, “Sweet herb”, “Sweet leaf” and “Honey leaf” (Ranjan *et al*., 2011) [23]. The vernacular names of the species are “Madhupatra”, “Meethipatti” and “Meethitulsi” (Singh *et al*., 2015) [26].
Its leaves are the economic part of the plant containing high concentration of steviol glycoside (Ramesh *et al*., 2006) [24]. The characteristic sweetness of Stevia is due to the presence of stevioside (4%-13%), rebaudioside A (2%-4%), rebaudioside C (1%-2%), rebaudioside B, D and E and dulcoside A (0.4%-0.7%) as well as other less common glycosides, such as stevioside, rubusoside, steviolbioside and rebaudiana F (Tanaka, 1982; Alaam, 2007, Lemus-Moncada *et al*., 2012) [28, 2, 16]. The sweetness percentage of Rebaudioside-A ranged from 30%-40% which is 180-400 times sweeter than table sugar (Kaplan and Turgut, 2019) [8]. Stevioside is one of the active constituents that have the largest share in *Stevia* leaves (5-10% of dry weight basis) (Das *et al*., 2008) [5]. *Stevia rebaudiana* is characterized as a cross-pollinated, photoperiod-sensitive crop that produces self-incompatible flowers (Yadav *et al*., 2014) [30]. It grow well in semi-humid subtropical, with temperatures ranging from -6 to 43 °C, with an average is 23 °C and rainfall ranging between 1500-1800 mm per annum. It has been used to sweeten tea since dating back to the Guarani Indians of South America (Ramesh *et al*., 2006) [24]. China is the largest producer of *Stevia* in the world. Japan and Korea are the main consumers (Pal *et al*., 2015) [21].

Stevia has been successfully cultivated in many Indian states like Rajasthan, Maharashtra, Punjab, Kerala and Orissa. *Stevia rebaudiana* leaves can be used as an alternative for sugar and artificial sweeteners in association with other sweeteners, used as flavor enhancers for food and beverage, herbal tea and pharmaceutical preparations (Midmore and Rank, 2002) [18]. *Stevia* production demand from the past decade is rising due to the fast-growing trend in dietary foods and beverages. The plant thus possesses considerable economic value and is in high demand because of its specific pharmacological and pharmaceutical properties.

Materials and methods

The experiment was conducted on the research farm of Department of Forest Products, Dr Y S Parmar University of Horticulture and Forestry, Nauni, Solan ($30^0$52'N, $77^0$11'E, 1270 m above MSL) for the two consecutive harvesting seasons (during 2019-2020) at the same site. The study area comes under sub-tropical, sub humid agro-climatic zone of Himachal Pradesh, India. During the experimental period, the temperature at the location ranged from 12.7 ºC to 33.7ºC in summer (fig.1) (April-June/July), from 6.6 ºC to 25.6 ºC in winter (fig.2) (March/September-October) and 18.6 ºC to 28.8 ºC in rainy season (July/August-September). Maximum relative humidity (79%) was in July and August 2019 (fig.3) followed by September 2019 (78%). Minimum relative humidity (44%) was recorded in May 2019 followed by June 2019 (48%). The area received maximum rainfall in August 2019 (225.8 mm) followed by July 2019 (218.1 mm) (fig.4). The data pertaining to the relevant meteorological parameters recorded at meteorological observatory of Department of Environmental Science, College of Forestry was procured for the periods of experimentation.

Field techniques

The experiment was laid out in Randomized Block Design (factorial) with three replications and eight treatments. The seedlings were raised by root cuttings in the month of March-April. Seedlings (height up to 20-25 cm) were transplanted after (one month after sowing) to the main field. A crop treatment in a replication occupied 2.4 m ×1.8 m area. Full quantity of FYM (N content equivalent to RDF) was applied at the time of field preparation, Basal dose of 30 kg N, 45 kg P_2O_5 and 30 kg K_2O was applied. Second spilt dose of 30 kg N/kg was applied after one month of transplanting. The crops were irrigated as and when required. In all, four irrigations were given to the crop. Three manual weeding followed by earthing up were carried out.

Parameter of multi harvested crop

The measurements made on individual harvests were plant height, number of leaves/plant, number of shoots/plant, leaf and total foliage yield in fresh and dry basis of multi-harvested crop.

Treatments

The experiment was consisting of eight treatments and two harvesting schedules. The seedlings were transplanted on 6th April, 2019. The treatments were T_1: control, T_2: RDF(recommended dose of fertilizers)(60:45:30 kg/ha), T_3: FYM (N content equivalent to RDF), T_4: vermicompost (N content equivalent to RDF), T_5: jeevamrit (N content equivalent to RDF two applications), T_6: panchgavya (N content equivalent to RDF two applications), T_7: FYM+RDF(N content equivalent to RDF+ 60:45:30 kg/ha) and T_8: Vermicompost + RDF(N content equivalent to RDF+60:45:30 kg/ha). FYM in full quantity and half dose of nitrogen + full dose of single super phosphate and muriate of potash were applied before transplanting of seedlings. Jeevamrit and panchgavya were applied after one month of transplanting and second application after first harvest.

Jeevamrit and Panchgavya preparation

Jeevamrit was prepared by mixing cow dung and cow urine in water. Then add jaggery, gram flour and handful of field soil in a mixture. Now stir the mixture in clockwise direction two times in a day. Keep the solution for 5-7 days for fermentation. For panchgavya, add fresh cow dung and cow ghee in a container. Mix it twice a day for 3 days. On the fourth day add cow urine, cow curd, cow milk, jaggery and water. On the nineteenth day, panchgavya mixture is ready for use.

Harvesting of the crop

First harvesting was 50-60 days after transplanting and second harvesting was 70-80 days after first harvesting.

Economic analysis

Economic analysis was done by calculating the cost of cultivation, gross and net returns per hectare and benefit cost ratio (B:C). Cost of cultivation (the variables as well as fixed inputs and corresponding rates, the cost incurred on each treatment was worked out so as to find the most economic treatment for profitable cultivation of *Stevia rebaudiana*). Gross return (the prevailing local market prices were used to convert the yield of the crop), net returns (gross returns-total cost) and B:C ratio (gross returns/cost of cultivation) (Desai *et al.*, 2018) [7].

Statistical analysis

The data recorded were subjected to statistical analysis under Randomized Block Design (factorial). Analysis of variance was worked out and critical difference at 5 percent level of significance was calculated with the help of latest computer software's by using MS-Excel.

Results

Growth parameters

The results presented in Table 1 revealed that the maximum plant height (60.67 cm), number of branches (9.89) and number of leaves (309.78) per plant were observed in treatment T_8 (Vermicompost (N content equivalent to RDF) + NPK (60:45:30 kg/ha)). Fresh leaf weight per plant ranged from 99.00 to 46.89 g (Table 2). The maximum fresh and dry leaf (99.00 g and 34.31 g) as well as foliage (183.06 g and 68.64 g) weight per plant were recorded in treatment T_8.

Yield parameters

Yield attributes of *Stevia rebaudiana* from sub-tropical region of western Himalaya are presented in Table 3. In the present study, the Maximum fresh and dry leaf yield (45.83 q/ha and 15.88 q/ha respectively) were observed in T_8 which was significantly different from others treatments. Estimated fresh and dry foliage yield (Table 3) (fig.5 and fig.6) was recorded in the combination of T_8 (Vermicompost (N content equivalent to RDF) + NPK (60:45:30 kg/ha)) followed by T_7 (FYM (N content equivalent to RDF) + NPK (60:45:30kg/ha)).

Economic analysis of Stevia rebaudiana

The maximum cost of cultivation and gross return during both harvesting schedules was recorded in T_8 (2, 92,514.21 Rs/ha) (Table 5). The positive net return was recorded in T_7 (Rs

29,735.79) followed by T_8 (Rs 25,185.79), T_2 (Rs 14,635.79) and negative net return was recorded in other treatments. The cost of *Stevia* planting was highest in the first year as land preparation and planting were only required during the first year. The cost of cultivation was decreased in second, third and fourth year with the increase in net returns up to a third year.

Discussion

The increase in the dry leaf weight/plant was recorded in (Vermicompost (N content equivalent to RDF) + NPK (60:45:30 kg/ha)) which was 101.15% and 82.61% higher than control in first and second harvesting.

FYM helps to increase crop yield by its favorable effect on physical, chemical and biological factors that determine productivity and fertility status of soil and supply nutrients in their available form. The present studies are also in line with Kumar (2019) [14] on *Ocimum* species who reported that the combination of vermicompost (3 t/ha) + NPK (120:60:60 kg/ha) and FYM (15t/ha) + NPK (120:60:60 kg/ha) gave significant increase in the plant height, number of branches and which might be due to the activity of the basic plant nutrients which are in readily available form for the plant as nitrate, phosphate and potash in both organic and inorganic fertilizers to the plant during the whole growing period. Similar results are reported by Bhutia (2019) [3] in *Acorus calamus*.

Vermicompost is known to increase the population of microbes also provides sufficient energy for them to remain active. It also provides the vital macro-nutrients such as N, P, K, Ca, Mg and micronutrients such as Fe, Zn, Cu, Mn and Mo. The present findings are in agreement with the results of Umesha *et al.* (2011) [29] in *Stevia rebaudiana* who reported maximum dry leaf yield during first and second year of cropping with the treatment combination of FYM (25 t ha^{-1}) + vermicompost (2 t ha^{-1}) + neem cake (1 t ha^{-1}) + bio-fertilizers (10 kg ha^{-1}). Kumar *et al.* (2017) [13] observed the higher values for most of the growth and yield parameters *viz*., plant height (20.97 cm), number of leaves plant (70.37), LAI (2.24), total fresh weight (61.57 q /a) of *Stevia rebaudiana* under plum + *Stevia rebaudiana* + 75% recommended dose of NPK and 25% vermicompost.

Kumar (2009) [12] also reported that the application of 50% of recommended dose of nitrogen through vermicompost (basal) + 50% of nitrogen through neem cake (top dressing) + bio-fertilizers resulted in significantly higher plant height, maximum number of branches per plant, maximum fresh weight of leaves and dry weight of leaves in *Stevia rebaudiana*. Zaman (2015) [31] reported that the application of vermicompost increased the plant height, number of branches and dry weight of leaves in *Stevia* with the advancement of growth period (60 DAP). Aderourmu and Gunwande (2019) [1] also reported similar results in black afara (*Terminalia ivorensis).* Oyedegi *et al.* (2014) [20] observed that, with the NPK treatment having the significantly highest number of branches, fresh and dry weight than organic manures in *Amaranthus deflexus* and three species.

Maintaining soil fertility and use of plant nutrients in sufficient and balanced amounts is one of the key factors in increasing crop yield. Nitrogen plays a vital role in growth processes as it is an integral part of chlorophyll, protein and nucleic acid (Dharaiya *et al.*, 2018) [6]. Phosphorus also increases the initiation of both first and second order rootlets and their development. The extensive root system helps in exploiting the maximum nutrients and water from soils. Potassium (K+) is of unusual significance because of its live role in biochemical functions of the plant like activating various enzymes, improvement of protein, carbohydrates and fat concentration, developing tolerance against drought and resistance to frost, lodging, pests and disease attack. Potassium is one of the major essential plant nutrient required for normal growth and development of plants. The improvement in nutritional status of plant might have resulted in greater synthesis of amino acids and protein and other growth promoting substances which seems to have enhanced the meristematic activity and increased cell division and enlargement and their elongation resulting in higher plant height (Chopra *et al.*, 2016) [4]. They reported that 5 t ha^{-1} poultry manure + 75% NPK + dual inoculation of Azotobacter + PSB were gave significant yield in wheat (*Triticum aestivum)*. Kreethi *et al.* (2013) [10] reported that the application of 180:75:60 kg NPK+ vermiwash at 20, 35 and 50 days after sowing (DAS) or vermicompost at the same level of NPK gave highest green cob yield of sweet corn in North Coastal zone of Andhra Pradesh.

Table 1: Effect of different organic manures, fertilizers and harvesting schedules on plant height (cm), number of shoot per plant and number of leaves per plant

Parameters / Treatments	Plant height (cm)			Number of shoots per plant			Number of leaves per plant		
	H_1	H_2	Pooled data	H_1	H_2	Pooled data	H_1	H_2	Pooled data
T_1 Control	23.54	73.45	48.49	3.67	8.56	6.11	262.11	266.00	264.06
T_2 NPK	27.11	80.67	53.89	5.11	10.56	7.84	278.55	304.08	291.32
T_3 FYM	25.33	76.78	51.06	4.56	9.66	7.11	275.89	281.55	278.72
T_4Vermicompost	27.64	83.45	55.55	4.89	13.67	9.28	285.33	315.45	300.39
T_5 Jeevamrit	24.84	75.78	50.31	4.78	8.33	6.56	264.00	275.55	269.78
T_6 Panchgavya	25.28	76.22	50.75	4.44	10.67	7.56	273.11	301.78	287.44
T_7 NPK + FYM	29.78	85.11	57.44	5.33	12.11	8.72	291.88	318.45	305.17
T_8 NPK + Vermicompost	33.22	88.11	60.67	6.22	13.56	9.89	293.77	325.78	309.78
Mean	27.09	79.95		4.88	10.89		278.08	298.58	
Factors	$CD_{0.05}$			$CD_{0.05}$			$CD_{0.05}$		
Treatments	1.04			1.14			5.74		
Harvesting Schedules	2.07			2.28			11.49		
Treatments × Harvesting Schedules	2.93			NS			NS		

Table 2: Effect of different organic manures, fertilizers and harvesting schedules on leaf and foliage weight per plant (g)

Parameters / Treatments	Fresh leaf weight per plant (g)			Dry leaf weight per plant (g)			Fresh foliage weight per plant (g)			Dry foliage weight per plant (g)		
	H_1	H_2	Pooled data	H_1	H_2	Pooled data	H_1	H_2	Pooled data	H_1	H_2	Pooled data
T_1 Control	20.34	73.44	46.89	8.67	28.02	18.34	28.56	170.89	99.72	12.44	58.98	35.71
T_2 NPK	34.22	112.33	73.28	13.11	42.46	27.78	57.67	250.89	154.28	17.00	85.17	51.09
T_3 FYM	27.56	105.45	66.50	12.00	40.56	26.28	49.78	238.11	143.95	14.78	82.01	48.39
T_4 Vermicompost	41.22	117.78	79.50	13.89	44.96	29.42	62.78	270.22	166.50	18.67	90.55	54.61
T_5 Jeevamrit	30.44	93.22	61.83	10.22	35.79	23.01	45.00	221.78	133.39	14.00	76.41	45.20
T_6 Panchgavya	32.00	95.22	63.61	10.22	35.73	22.98	43.11	225.67	134.39	13.44	78.91	46.18
T_7 NPK + FYM	48.11	131.44	89.78	15.67	48.38	32.02	74.89	274.44	174.67	21.00	100.90	60.95
T_8 NPK + Vermicompost	55.45	142.56	99.00	17.44	51.17	34.31	85.00	281.11	183.06	23.89	113.39	68.64
Mean	36.17	108.93		12.65	40.88		55.85	241.64		16.90	85.79	
Factors	$CD_{0.05}$			$CD_{0.05}$			$CD_{0.05}$			$CD_{0.05}$		
Treatments	5.23			1.10			5.57			5.59		
Harvesting Schedules	10.46			2.20			11.15			11.19		
Treatments × Harvesting Schedules	14.80			3.11			NS			15.82		

Table 3: Effect of different organic manures, fertilizers and harvesting schedules on estimated leaf and foliage yield (q/ha)

Parameters / Treatments	Estimated Fresh leaf yield (q/ha)			Estimated dry leaf yield (q/ha)			Estimated fresh foliage yield (q/ha)			Estimated dry foliage yield (q/ha)		
	H_1	H_2	Pooled data	H_1	H_2	Pooled data	H_1	H_2	Pooled data	H_1	H_2	Pooled data
T_1 Control	9.42	34.00	21.71	4.01	12.97	8.49	13.22	79.12	46.17	5.76	27.30	16.53
T_2 NPK	15.84	52.00	33.92	6.07	19.66	12.86	26.70	116.15	71.43	7.87	39.43	23.65
T_3 FYM	12.76	48.82	30.79	5.56	18.78	12.17	23.05	110.24	66.64	6.84	37.97	22.40
T_4 Vermicompost	19.08	54.53	36.81	6.43	20.81	13.62	29.06	125.10	77.08	8.64	41.92	25.28
T_5 Jeevamrit (Desi Cow)	14.09	43.16	28.63	4.74	16.57	10.65	20.83	102.67	61.75	6.48	35.37	20.93
T_6 Panchgavya (Desi Cow)	14.81	44.08	29.45	4.73	16.54	10.64	19.96	104.48	62.22	6.22	36.54	21.38
T_7 NPK + FYM	22.27	60.85	41.56	7.25	22.40	14.83	34.67	127.06	80.87	9.72	46.71	28.22
T_8 NPK + Vermicompost	25.67	66.00	45.83	8.08	23.69	15.88	39.35	130.14	84.75	11.06	52.49	31.78
Mean	16.74	50.43		5.86	18.93		25.86	111.87		7.83	39.72	
Factors	$CD_{0.05}$			$CD_{0.05}$			$CD_{0.05}$			$CD_{0.05}$		
Treatments	2.42			0.51			2.48			1.10		
Harvesting schedules	4.84			1.02			4.97			2.20		
Treatments × Harvesting schedules	6.85			1.44			7.02			3.12		

Table 4: Effect of different organic manures, fertilizers and harvesting schedules on total leaf and foliage yield (q/ha)

Parameters / Treatments	Total leaf yield (q/ha)		Total foliage yield (q/ha)	
	Fresh yield	Dry yield	Fresh yield	Dry yield
T_1 Control	43.42	16.99	92.34	33.06
T_2 NPK	67.85	25.73	142.85	47.30
T_3 FYM	61.57	24.33	133.29	44.81
T_4 Vermicompost	73.61	27.24	154.16	50.56
T_5 Jeevamrit	57.25	21.31	123.50	41.85
T_6 Panchgavya	58.90	21.28	124.44	42.76
T_7 NPK + FYM	83.13	29.65	161.73	56.43
T_8 NPK + Vermicompost	91.67	31.77	169.49	63.55

Table 5: Economics of cost of cultivation, gross return, net return and B:C ratio of *Stevia rebaudiana*

Treatments	Total cost of cultivation (Rs/ha)	Total dry leaf yield (kg/ha)	Average price Rs/kg	Gross return (Rs)	Net return (Rs)	B:C ratio
T_1 Control	**2,41,019.00**	**1,699.00**	**100**	**1,69,900.00**	**-71,119.00**	**0.70**
T_2 RDF (60:45:30) kg/ha	2,42,564.21	2,573.00	100	2,57,300.00	14,735.79	1.06
T_3 FYM (N content equivalent to RDF)	2,65,219.00	2,433.00	100	2,43,300.00	-21,919.00	0.92
T_4 Vermicompost (N content equivalent to RDF)	2,90,969.00	2,724.00	100	2,72,400.00	-18,569.00	0.94
T_5 Jeevamrit (N content equivalent to RDF)	2,51,190.20	2,131.00	100	2,13,100.00	-38,090.20	0.85
T_6 Panchgavya (N content equivalent to RDF)	2,66,330.00	2,128.00	100	2,12,800.00	-53,530.00	0.80
T_7 FYM (N content equivalent to RDF)+ RDF(60:45:30) kg/ha)	2,66,764.21	2,965.00	100	2,96,500.00	29,735.79	1.11
T_8 Vermicompost (N content equivalent to RDF)+RDF (60:45:30 kg/ha)	2,92,514.21	3,177.00	100	3,17,700.00	25,185.79	1.09

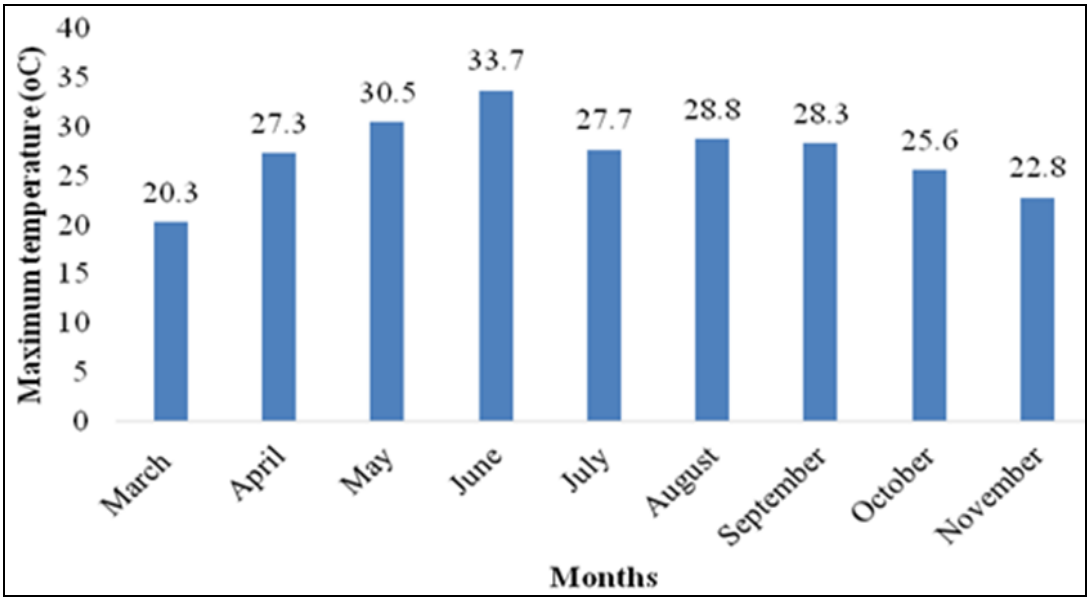

Fig 1: Maximum tempereature of study area during february (2019) Noumber (2019)

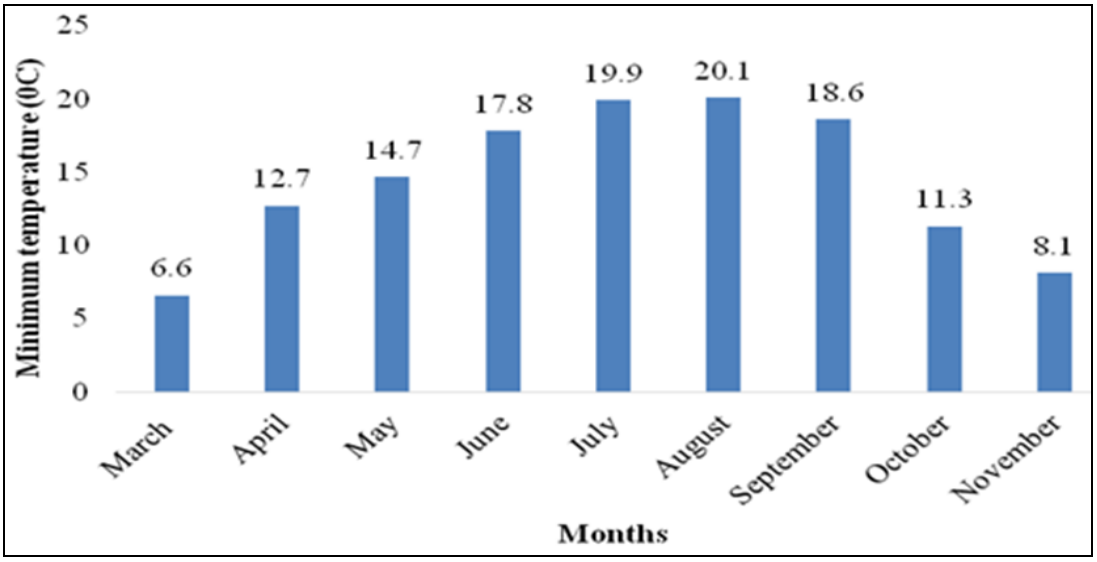

Fig 2: Minimum tempereature of study area during february (2019) Noumber (2019)

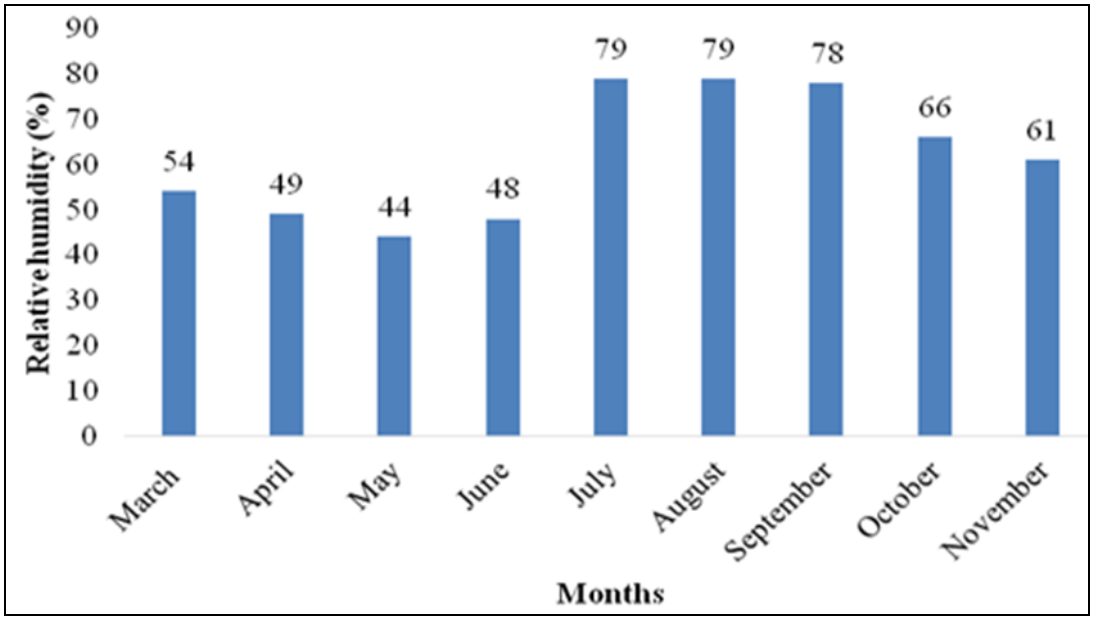

Fig 3: Relative humidity of study area during february (2019) Novemer (2019)

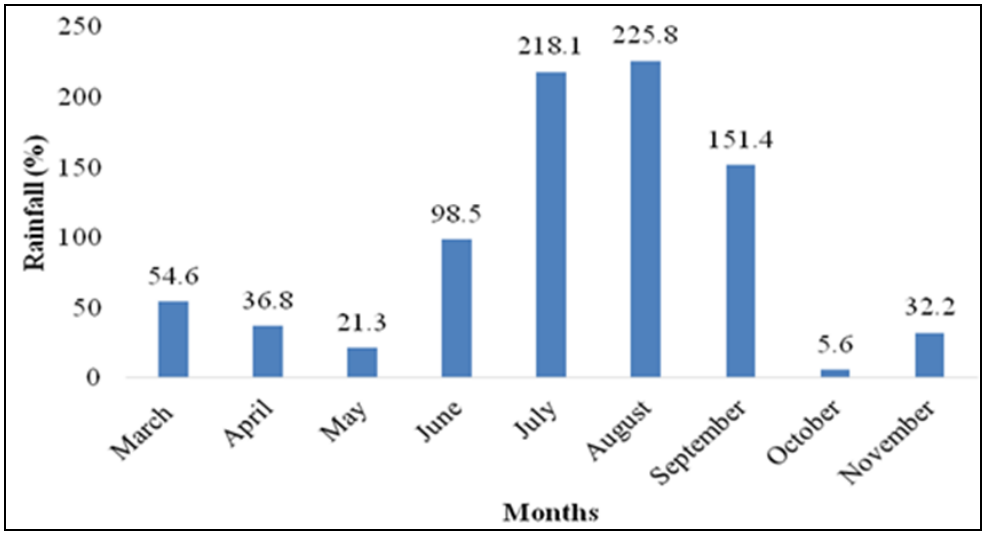

Fig 4: Rainfall of study area during February (2019) November (2019)

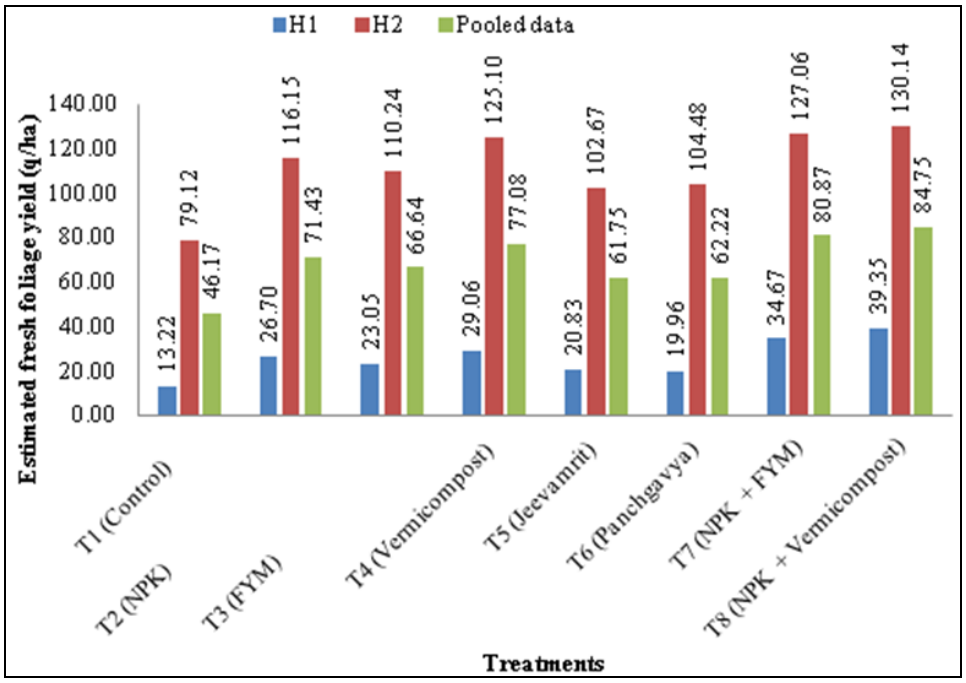

Fig 5: Effect of organic manures, fertilizers and harvesting schedules on estimated fresh foliage yield (q/ha) of *Stevia rebaudiana*

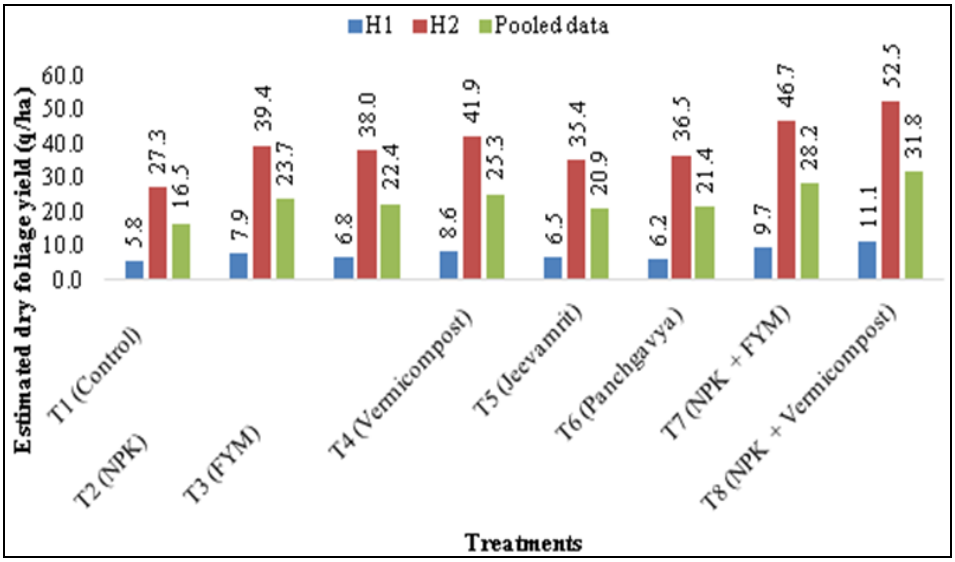

Fig 6: Effect of organic manures, fertilizers and harvesting schedules on estimated dry foliage yield (q/ha) of *Stevia rebaudiana*

Conclusion

Treatment combination of Vermicompost (N content equivalent to RDF) + NPK (60:45:30 kg/ha) resulted highest value for total fresh leaf yield (91.67 q/ha), total dry leaf yield (31.77 q/ha), total fresh foliage yield (169.49 q/ha) and total dry foliage yield (63.55 q/ha) with B:C ratio 1.09. Results indicated that all the growth and yield parameters performed better in combined treatments of Vermicompost (N content equivalent to RDF) + NPK (60:45:30 kg/ha)) in two harvests but the B:C ratio (1.11) was highest in T_7 (FYM (N content equivalent to RDF) + NPK (60:45:30 kg/ha)) due to less cost of cultivation. Individual or different combinations of organic manures and fertilizers resulted better yield in two harvests as compared to control.

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