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Influence of NPK levels on growth and yield of *Stevia rebaudiana* Bertoni under hills of Uttarakhand

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A field experiment was carried out at CSIR-Central Institute of Medicinal and Aromatic Plant Research Centre Purara, Bageshwar, Uttarakhand, India during 2014 and 2015 in sandy loam soil on Influence of NPK levels on plant growth and yield of *Stevia rebaudiana* Bertoni under lower hills of Kumaon Uttarakhand were tested in a randomized block design with factorial concept in three replications. Four harvestings were taken in a year. Stevia were treated with three doses of nitrogen (100,200,300 N kg/ha), three doses of phosphorus (60,120,180 P_2O_5 kg/ha) and two levels of potassium (80,160 K_2O kg/ha). Pooled results indicated that significantly higher dry leaf yield was obtained with nitrogen @ 300 Kg/ha (45.68 t/ha) and it was on par with 200 kg/ha (43.76 t/ha). Phosphorus @ 180/ha recorded significantly highest dry leaf yield (40.68 t/ha) and it was on par with 120 kg/ha (43.40 t/ha). Potassium @ 160 kg/ha recorded dry leaf yield of 43.12 t/ha and it was comparable with potassium @80 kg/ha (41.84 t/ha). The growth parameters viz., plant height (cm), number of branches per plant and number of leaves per plant were significantly higher with nitrogen, phosphorus and potassium @ 300 kg/ha, 180 kg/ha and 160 kg/ha, respectively which were on par with 200 kg/ha, 120 kg/ha and 80 kg/ha respectively. In pooled data nitrogen N_3 i.e., 300 kg/ha recorded the highest B:C (4.60) which was on par with nitrogen @ N_2 i.e., 200 kg/ha (4.34), but significantly higher than N_1 i.e., 100 kg/ha (3.38). Phosphorous P_3 i.e., 180 kg/ha resulted in higher B:C (4.61) which was on par with P_2 i.e., 120 kg/ha (4.50). Potassium level influenced the B:C non-significantly. Significantly lowest B:C was recorded with absolute control in pooled data (2.19). Nutrient level of 300:180:160 kg/ha NPK applied in equal splits to four harvestings in a year has been considered as an economically optimum level of nutrients for stevia.

Keywords: Growth performance, Nitrogen, Phosphorus, Potassium, *Stevia rebaudiana* Bertoni.

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Introduction

Stevia (*Stevia rebaudiana* Bertoni) is a herbaceous zero-calorie natural sweetener plant. It's belonging to family Asteraceae. It is known by different names which include sweet herb, sweet leaf, honey leaf, candy leaf and honey herb[1]. Stevia is a perennial nature plant and endemic shrub that grow up to one meter. Small flowers are white in colour with pale purple throat and arranged in the form of small corymbs[2]. The roots lead an extensive system[3]. The stem is woody and the upper surface of leaves slightly glandular-pubescent. Stevia (*S. rebaudiana* Bertoni) is native to North-Eastern Paraguay and grow in sandy soil. It was first established in Japan in 1968. It is cultivated in Japan, China, Korea, Mexico, USA, Thailand, Malaysia, Indonesia, Australia, Canada, Russia and India[4]. In India, it is cultivated in some part of Rajasthan, Punjab, Uttar Pradesh, Bengal, Madhya Pradesh, Karnataka, Chhattisgarh and Uttarakhand.

Dry leaves of stevia are economic part of the stevia plant, with a high concentration of steviol glycosides and possible substitutes of synthetic sweeteners[5-6]. Stevia extract is much sweeter compared to other sugars. The sweet stevio glycosides of stevia extracted from leaves are considered as possible sugar substitutes every species of stevia (*S. rebaudiana* Bertoni) containing sweetening compound but *S. rebaudiana* Bertoni is the sweetest among all[7]. There are eight groups of active compound namely as steviol glycosides that are the source of sweet taste in stevia that can be divided into stevioside,

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steviobioside, dulcoside and rebaudiosides A, B, C, D, and E[8]. An extraction of stevia is known as a stevioside. It is 100 to 300 times sweeter than table sugar and the natural form of stevia is approximately 20 to 30 times sweeter[9]. Hence, stevia is a no calorie sweetener and it is alternative to the synthetic sweetening agents like saccharine and aspartame that are available in the market to the diet-conscious consumers and diabetics.

Stevia (*S. rebaudiana* Bertoni) is an important crop, therefore, it is essential to promote farming. Western Himalayan region of Uttarakhand has more potential for cultivation of stevia, but there is adequate research work on the nutrient requirement for stevia. The present research work was undertaken to determine the appropriate amount of nitrogen, phosphorus and potash levels for higher vegetative growth and yield of stevia under the lower hills of Kumaon Uttarakhand.

Material and Methods

Experimental site, climate, and soil

A field experiment was conducted during 2014 and 2015 cropping year at the CSIR-Central Institute of Medicinal and Aromatic Plant Research Centre Purara, Bageshwar India, the research centre of CSIR-CIMAP is situated in temperate to humid zone of the Western Himalayan region of Uttarakhand, India. The valleys are usually hot during summer and cold during the winter. The monsoon usually breaks in June and continues to September. The soil of the experimental field was sandy loam with 6.2 pH, organic carbon content of 0.36%, available N 160.3 Kg/ha, available P 7.5 Kg/ha and exchangeable K_2O 130 Kg/ha.

Treatments and crop culture

The experiment was laid out in randomized block design with factorial concept in three replications and one absolute without of nutrients. The treatments were all factors of three levels of nitrogen fertilizers (100, 200, 300 Kg/ha), three levels of phosphorus (60, 120, 180 Kg/ha) and two levels of potassium fertilizers (80, 160 Kg/ha). All nutrients in each treatment were applied in equal splits after each harvesting and crop harvested four times a year. Nitrogen, phosphorus and potash were applied in the form of urea, single super phosphate, and muriate of potash. About 150 quintal farm-yard manure per hectare was applied at the time of field preparation. Similar doses also applied in ratoon crop in the same manner. Forty-five days old seedlings of stevia cv. CIM-Mithi were transplanted on 1st February 2014 with the spacing of 30×30 cm. The crop was irrigated regularly so that moisture always remains; weeding and hoeing were also done at 15 to 20 days interval to control the weeds in the crop for proper growth and development of the plant[10].

Measurements

Observation was recorded at harvest; five plants per plot were selected for recording plant height (cm), number of braches per plant, number of leaves per plants, fresh biomass yield (t/ha), fresh leaf yield (t/ha) and dry leaf yield (t/ha). The crop was harvested at 90 days after transplanting, whereas ratoon crops were harvested at regular interval of 70 days. The plants were uniformly 10 cm meter above the ground level. The green biomass was sun-dried for a day, then shade dried for 7 days. The dry stevia leaves were stripped off from the plant and dried separately under sunlight for a day and stored in gunny bags. Total four harvestings per year were taken and crop was maintained for two years.

Economics analysis

Cost of cultivation of stevia was calculated on the basis of different operations performed and materials used for growing the crop. For stevia, the operations and material used were; field and nursery preparation, cutting preparation, cutting maintenance, transplanting, irrigation, fertilization, weeding, harvesting, drying of leaves and other agricultural operations. Gross returns (GR) were calculated by multiplying leaves yield by leaves price. Net return were calculated as Net return (NR) =Gross returns (GR) - Cost of cultivation (CC).

Statistical analysis

The pooled data of both cropping years was analysis of variance (ANOVA) technique as applicable to randomized block design with factorial concept[11].

Results and Discussion

The main objective was to study the different level of NPK on the yield of stevia crop and also compares the expected returns from different treatments. Results and discussion of all growth and yield attributes are given below.

Plant height (cm)

The mean data on plant height is presented in table 1. The pooled data revealed that the increase in

Table 1 — Growth attributes of Stevia as different levels of nitrogen, phosphorus and potassium during the two seasons of 2014 and 2015

*Treatment	Plant height (cm)			Number of branches/ plant			Number of leaves/ plant		
	2014	2015	Mean	2014	2015	Mean	2014	2015	Mean
Nitrogen levels									
N_1 (100 kg/ha)	40.48	38.80	39.64	31.92	38.16	35.04	583.04	617.60	600.32
N_2 (200 kg/ha)	44.16	42.88	43.52	37.20	43.76	40.48	644.00	675.36	659.68
N_3 (300 kg/ha)	46.32	44.80	45.56	38.80	45.20	42	660.16	696.08	678.12
Phosphorus levels									
P_1 (60 kg/ha)	41.52	40.32	40.92	33.52	40.16	36.84	592.56	626.80	609.68
P_2 (120 kg/ha)	43.84	42.08	42.96	36.16	42.64	39.40	635.76	671.40	326.79
P_3 (180 kg/ha)	45.60	44.08	44.84	38.24	44.24	41.24	658.72	690.72	674.72
Potassium levels									
K_1 (80 kg/ha)	43.12	41.68	42.40	35.44	41.84	38.64	621.36	656.72	639.04
K_2 (160 kg/ha)	44.24	42.72	43.48	36.56	42.88	39.72	636.72	669.20	692.96
Control	32.40	29.28	30.84	19.44	19.52	19.48	255.84	246.32	251.80
S.E.M.	0.384	0.607	0.509	0.384	0.333	0.608	0.384	0.192	0.577
CD at 0.05%	1.153	1.820	1.526	1.153	0.999	1.824	1.153	0.576	1.730

2014: Average of first four harvestings, 2015: Average of first four next continuously five harvestings, * N, P and K doses applied for three harvestings in equal spilt doses., Pooled: Average of all cuttings

nitrogen levels from 100 kg/ha (N_1) to 300 kg/ha (N_3) increased plant height progressively. N_3 i.e. 300 kg/ha recorded significantly higher plant height 45.56 cm in pooled data closely followed by N_2 i.e. 200 kg/ha 43.52 cm. The nitrogen level 100 kg/ha (N_1) recorded lower plant height (39.64 cm) at harvest in pooled data. Increase in phosphorus levels also increased the plant height in pooled data, but phosphorus level P_2 (120 kg/ha) recorded the plant height 42.96 cm, which were on par plant height with P_3 i.e. 180 (44.84 cm) in pooled data. Levels of potassium did not influence the plant height at harvest significantly. However, pooled data revealed that potassium level of K_2 (160 kg/ha) recorded the plant height (43.48 cm) closely followed by K_1 i.e. 80 kg/ha (42.40 cm). Absolute control without any nutrients recorded significantly lowest plant height in pooled data (Table 1). Plant height at harvest was significantly influenced by the higher level of nitrogen, phosphorus and potassium, which in turn were responsible for higher number of branches per plant and number of number of leaves per plant resulting to higher leaves yield. Aladakatti *et al.* found that increased plant height with increased level of NPK fertilizer[12].

Number of branches per plant

The mean data about the number of branches per plant is presented in table 1. The pooled data revealed that the increase in nitrogen levels from 100 kg/ha (N_1) to 300 kg/ha (N_3) increased the number of branches per plant progressively. N_3 i.e. 300 kg/ha recorded significantly maximum number of branches per plant (42) in pooled data closely followed by N_2 i.e. 200 kg/ha (40.48). The nitrogen level 100 kg/ha (N_1) recorded the minimum number of branches per plant (35.04) at harvest in pooled data. Increase in phosphorus levels also increased the number of branches per plant in pooled data, but phosphorus level P_2 (120 kg/ha) recorded the number of branches per plant 39.40, which were on par number of branches per plant with P_3 i.e. 180 (41.24) in pooled data. Levels of potassium did not influence the number of branches per plant at harvest significantly. However, pooled data revealed that potassium level of K_2 (160 kg ha) recorded the number of branches per plant (39.42) closely followed by K_1 i.e. 80 kg/ha (38.64). Absolute control without any nutrients recorded a significantly minimum number of branches/plant in pooled data (Table 1). K. Puttanna *et al and* Rashid *et al.* had also reported an increased number of branches with the higher application of NPK[13,14].

Number of leaves per plant

The mean data on the number of leaves per plant is presented in table 1. The pooled data revealed that the increase in nitrogen levels from 100 kg/ha (N_1) to 300 kg/ha (N_3) increased the number of leaves per plant progressively. N_3 i.e. 300 kg/ha recorded significantly maximum number of leaves per plant (678.12) in pooled data closely followed by N_2 i.e. 200 kg/ha (659.68). The nitrogen level 100 kg/ha (N_1) recorded a minimum number of leaves/plant (600.32) at harvest in pooled data. Increase in phosphorus levels also increased the number of leaves per plant in pooled data, but phosphorus level P_2 (120 kg/ha) recorded the lowest number of leaves per plant (326.79), In P_3 i.e. 180 kg/ha 674.72 leaves per plant was recorded in pooled data. Levels of potassium did not influence the number of leaves per plant at harvest significantly. However, pooled data revealed that potassium level of K_2 (160 kg/ha) recorded the number of leaves per plant (692.96) closely followed by K_1 i.e. 80 kg/ha (639.04). Absolute control without any nutrients recorded a significantly minimum number of leaves per plant in pooled data (Table 1). Maheshwar also found that the increased number of leaves per plant with increased levels of NPK fertilizers in stevia crop[15].

Fresh biomass yield (t/ha)

The mean data on fresh biomass yield (t/ha) is presented in table 2 and fig 1. Fresh biomass yield (t/ha) was significantly influenced by varied levels of nitrogen and phosphorus levels but the result of potassium was not significant in pooled data. Highest fresh biomass yield (367.62 t/ha) was possible with nitrogen level of N_3 i.e., 300 kg/ha which was on par with N_2 i.e., 200 kg/ha (351.36 t/ha) and both were superior over N_1 (303.46 t/ha). Phosphorus levels P_3 (180 kg/ha) recorded the highest fresh biomass (358.83 t/ha) which was on par P_2 i.e., 120 kg/ha (346.42 t/ha), but superior to P_1 (316.52 t/ha). Different potassium levels did not influence the fresh biomass of stevia significantly. Significantly lower fresh biomass (346.24 t/ha) was obtained with the absolute control as against all other treatments. Davies *et al*., in Egypt reported higher fresh biomass yield with increased levels of NPK fertilizers in *Artemisia annua* L. plant[16]. In addition, Esar Ucar *et al*., indicate that the highest fresh biomass yields (26.75 t/ha) were obtained from 150 kg/ha N dose and followed by 100 kg/ha N dose (26.29 t/ha) in stevia crop[17].

Fresh leaf yield (t/ha)

The mean data on fresh leaf yield (t/ha) is presented in table 2 and fig 1. Fresh leaf yield (t/ha) was significantly influenced by the varied levels of nitrogen and phosphorus levels but the result of potassium was not significant in pooled data. Highest fresh leaf yield (189 t/ha) was possible with nitrogen level of N_3 i.e., 300 kg/ha which was on par with N_2 i.e., 200 kg/ha (187.44 t/ha) and both were superior over N_1 (156.76 t/ha). Phosphorus levels P_3 (180 kg/ha) recorded the highest fresh leaf yield (163.80 t/ha) which was on par P_2 i.e., 120 kg/ha (179.70), but superior to P_1 (163.80 t/ha). Different potassium levels did not influence fresh leaf yield of stevia significantly. Significantly lower fresh leaf yield

Table 2 — Yield attributes of stevia at harvest as different levels of nitrogen, phosphorus and potassium during the two seasons of 2014 and 2015

*Treatment	Fresh biomass yield (t/ ha)			Fresh leaf yield (t/ ha)			Dry leaf yield (t/ ha)		
	2014	2015	Mean	2014	2015	Mean	2014	2015	Mean
Nitrogen levels									
N_1 (100 kg/ha)	290.36	316.56	303.46	153.16	160.36	156.76	36.96	39.04	38
N_2 (200 kg/ha)	336.28	366.44	351.36	175.84	187.44	181.64	42.64	44.88	43.76
N_3 (300 kg/ha)	349	386.24	367.62	182.88	195.12	189	44.48	46.88	45.68
Phosphorus levels									
P_1 (60 kg/ha)	305.88	327.16	316.52	160.72	166.88	163.80	38.72	42.64	40.68
P_2 (120 kg/ha)	328.16	364.68	346.42	172.72	186.68	179.70	42.08	44.72	43.40
P_3 (180 kg/ha)	340.16	377.50	358.83	178.40	190.92	184.66	43.32	45.84	44.58
Potassium levels									
K_1 (80 kg/ha)	320.88	349.92	357.90	168.32	178.80	173.56	40.76	42.92	41.84
K_2 (160 kg/ha)	329.56	362.92	346.24	172.92	184.20	178.56	41.96	44.28	43.12
Control	146.44	133.92	140.18	68.70	59.44	64.07	18.80	15.04	16.92
S.E.M.	0.608	0.335	0.585	0.384	0.383	0.608	0.508	0.508	0.384
CD at 0.05%	1.823	1.005	1.754	1.152	1.151	1.824	1.524	1.524	1.153

2014: Average of first four harvestings, 2015: Average of first four next continuously five harvestings, * N, P and K doses applied for three harvestings in equal spilt doses., Pooled: Average of all cuttings

(64.07 t/ha) was obtained with the absolute control as against all other treatments. Singh *et al.*, also reported a significantly increased leaf yield of stevia with a high dose of NPK fertilizers compared to a lower dose of fertilizers[18]. Abderrahmane Benhmimou *et al.*, also found that the significantly higher fresh yield (69.87 gm/plant) was obtained with treatment (300 N, 100 P, 240 K) in stevia crop[19].

Dry leaf yield (t/ha)

The mean data on dry leaf yield (t/ha) is presented in table 2 and fig 1. Dry leaf yield (t/ha) was significantly influenced by varied levels of nitrogen and phosphorus levels but the result of potassium was non-significant in pooled data. Highest dry leaf yield (45.68 t/ha) was possible with nitrogen level of N_3 i.e., 300 kg/ha which was on par with N_2 i.e., 200 kg/ha (43.76) and both were superior over N_1 (38 t/ha). Phosphorus levels P_3 (180 kg/ha) recorded the highest dry leaf yield (44.58 t/ha) which was on par P_2 i.e., 130 kg/ha (43.40 t/ha), but superior to P_1 (40.68 t/ha). Different potassium levels did not influence dry leaf yield of stevia significantly. Significantly lower dry leaf yield (16.92 t/ha) was obtained with the absolute control as against all other treatments. Kumar R *et al.*, found that higher dry leaf yield with increased levels of NPK in stevia (100, 60, 50 kg/ha)[20]. A similar increase in dry leaf yield of stevia with NPK combination was also reported by Pal *et al*[21].

Economics of stevia cultivation

Economics of stevia cultivation was influenced by varied levels of nutrients in pooled data (Table 3 and fig. 2). The pooled data revealed that the increase levels from 100 kg/ha (N_1) to 300 kg/ha (N_3) increased the net return and B:C progressively. N_3 i.e. 300 kg/ha

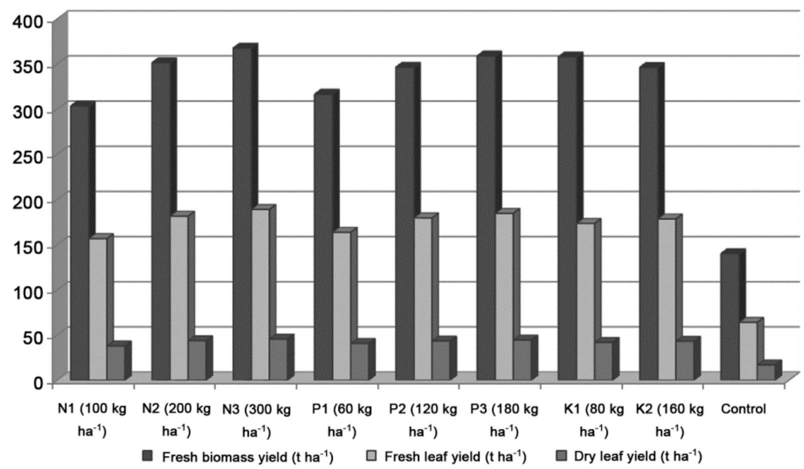

Fig. 1 — Influence of NPK levels on herb yield under lower hills of Kumaon Uttarakhand during the two seasons of 2014 and 2015.

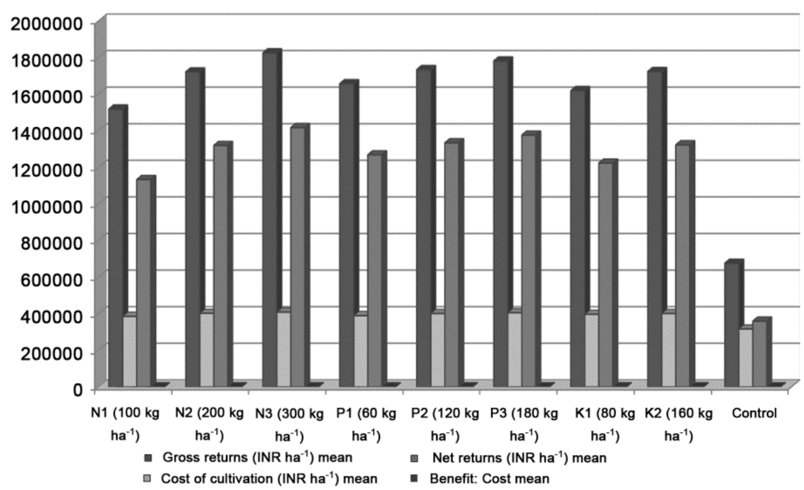

Fig. 2 — Influence of NPK levels on economics of stevia cultivation under lower hills of Kumaon Uttarakhand during the two seasons of 2014 and 2015.

Table 3 — Economics of stevia cultivation as different levels of nitrogen, phosphorus and potassium during the two seasons of 2014 and 2015

*Treatment	Gross returns (INR/ ha)			Cost of cultivation (INR/ ha)			Net returns (INR/ ha)			Benefit: Cost		
	2014	2015	Mean	2014	2015	Mean	2014	2015	Mean	2014	2015	Mean
Nitrogen levels												
N_1 (100 kg/ha)	1478000	1560000	1519000	566812	204000	385406	911188	1356000	1133594	0.16	6.60	3.38
N_2 (200 kg/ha)	1650000	1794000	1722000	583316	220767	402041.5	1066684	1573233	1319959	1.56	7.12	4.34
N_3 (300 kg/ha)	1778000	1874000	1826000	589394	227308	408351	1188606	1646692	1417649	2.01	7.20	4.60
Phosphorus levels												
P_1 (60 kg/ha)	1548000	1768000	1658000	571525	207254	389389.5	976475	1560746	1268611	1.70	7.53	4.61
P_2 (120 kg/ha)	1682000	1788000	1735000	581775	220367	401071	1100225	1567633	1333929	1.89	7.11	4.50
P_3 (180 kg/ha)	1732000	1832000	1782000	586218	224444	405331	1145782	1607556	1376669	1.95	7.16	4.55
Potassium levels												
K_1 (80 kg/ha)	1630000	1610000	1620000	577805	215107	396456	1052195	1394893	1223544	1.82	6.48	4.15
K_2 (160 kg/ha)	1678000	1770000	1724000	581877	219607	400742	1096123	1550393	1323258	1.88	7.05	4.465
Control	752000	600000	676000	510655	122094	316374.5	241345	477906	359625.5	0.47	3.91	2.19
S.E.M.	153821	56306	401.84	6085.8	6085.8	316373.2	50120.2	56201.7	0.612	0.006	0.006	0.612
CD at 0.05%	461157	168805	1204.74	18245.2	18245.2	948487	150260	168493	1.857	0.018	0.018	1.857

2014: Average of first four harvestings, 2015: Average of first four next continuously five harvestings, * N, P and K doses applied for three harvestings in equal spilt doses., Pooled: Average of all cuttings

recorded significantly highest net returns INR 1417694 and B:C 4.60 in pooled data, closely followed by N_2 i.e. 200 kg/ha (INR 1319959, 4.34 respectively). The nitrogen level of 100 kg/ha (N_1) recorded the lowest net returns INR 1133594 and B:C 3.38 in pooled data. Increase in phosphorus levels was decreased the net returns and B:C in pooled data. Phosphorus level P_3 (180 kg/ha) recorded highest the net returns of INR 1376669 and B:C 4.55, closely followed by P_2 i.e.,120 kg/ha (INR 1333929 and B:C 4.50), the phosphorus level of P_1 (60 kg/ha) i.e. INR 1268611 and B:C 4.61 in pooled data. Increase in potassium levels increased the net returns in pooled data. Potassium level K_2 (160 kg/ha) recorded highest the net returns of INR 1323258 and B:C 4.46, closely followed by K_1 i.e., 80 kg/ha (INR 1223544 and B:C 4.15). Significantly lowest net returns and B:C ratio were recorded with absolute control in pooled data (INR 359625.5 and 2.19 respectably). Kumari S and Ghosh G was reported that the highest net return (INR 221864/ha) and maximum B:C ratio (1.72) in treatment 100 kg/ha nitrogen at (30 cm x 20 cm) spacing. However, the lowest net return (INR 48728/ha) and the minimum B:C ratio (1.16) was obtained in 50 kg/ha nitrogen at (30 cm x 20 cm) spacing[22].

Conclusion

The result indicated that the treatments N_3, P_3 and K_2 have been found superior in growth, yield and economics of stevia crop as compared to other treatment, so it can be calculated that the combination of $N_3P_3K_2$ i.e. 300:180:160 kg/ ha for four harvestings in a year has been considered the level of nutrients for stevia in sandy loamy soil under the lower hills of Kumaon Uttarakhand.

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