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Research Paper

Effect of fertigation on stevia (*Stevia rebaudiana*) under drip irrigation

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ABSTRACT

A field experiment was conducted at the Directorate of Water Management, Bhubaneswar (Odisha) during *rabi* seasons of 2005-06 and 2006-07 to study the effect of drip irrigation regimes and fertigation levels on stevia (*Stevia rebaudiana*, Bertoni), grown in rice fallow. The treatments included three irrigation regimes (I_1- drip irrigation at 100% PE, I_2 at 80% PE and I_3 at 60% PE) and three fertility levels (F_1 -100%, F_2 – 75% and F_3 - 50% recommended dose of 110-45-45 kg N-P_2O_5-K_2O/ha) with an extra treatment as control having surface irrigation with soil application of fertilizers were tested in a factorial randomized block design with three replications. Pooled data of two years showed that drip fertigation improved fresh leaf by 4.9 %, dry leaf by 4.0 % and total biomass yield by 2.04 % over conventional surface irrigation with soil application of fertilizer. Irrigation through drip at 100% PE produced maximum fresh leaf (8.95 t/ha), dry leaf (2.74 t/ha) and total biomass yield (34.44 t/ha). Application of 100% RD (F_1) gave highest quantity of fresh leaf (8.21 t/ha), dry leaf (2.53 t/ha) and biomass (33.50 t/ha) compared to 75% RD and 50% RD. Application of irrigation at 100% PE with 100% recommended dose of fertilizer produced 9.13 t of fresh leaf 2.90 t dry leaf and 35.0 t biomass yield per hectare and; improved glycoside contents. However, the magnitude of N, P and K contents in both soils and plants have also been enhanced with 100% fertilizer application of N, P_2O_5 and K_2O (110-45-45 kg/ha) compared to lower levels.

Key words: Biomass yield, Drip fertigation, Dry leaf yield, Fresh leaf yield, Stevia, Surface irrigation

Stevia is an important zero calorie natural endemic sweet herb from Paraguay. The Asian markets consume over 85% of the global supply of the fluffy white crystalline stevia extracts. The current extract market demand is 1.5 million kg, processed from 12 million kg of stevia leaf (Das *et al*., 2010). Stevia leaves contain sweetening compounds viz., Stevioside, Rebaudieside-A, Rebaudieside-B and C and six other compounds which plays major role to balance insulin concentration in human beings (Farooqi and Sreeramu, 2001). Stevioside is one of the major active constituent in the leaves of stevia (5-10% on dry weight basis) and is 300- 350 times more sweeter than sucrose (Zhang *et al*., 1999). Due to the non-calorie nature of this crop, stevia leaves and their compounds are used in many therapeutic applications such as diabetes, obesity, plague retardant, hypoglycemia, indigestion, dental health, yeast infection, oral health, skin toning and healing burns and wounds (Maiti and Purohit, 2008). It naturally grows in low lying areas on poor sandy acidic soils adjacent to swamps and requires constantly wet or shallow water tables (Columbus, 1997). Stevia plant has a high requirement of nutrients especially N, P and K and their deficiency is probably the major limitation for the quality biomass production (Das *et. al*., 2006). Hence, there is a need to develop a suitable agricultural system which requires lower fertilizer input with higher fertilizer use efficiency. Stevia can be cultivated profitably wherever irrigation facilities are available. Earlier studies revealed that frequent irrigation is required for stevia to maintain soil moisture above wilting point up to 80 per cent of field capacity and moisture stress reduces leaf production (Lavini *et. al*. 2008). Some research work on nutrient and water requirement for stevia was carried out in loamy soils at University of Agricultural Sciences, Bengaluru in Karnataka (Chalapathi *et. al*., 1999) and at the Institute of Himalayan Bioresource Technology (IHBT), Palampur, Himachal Pradesh during 1996 and 2003, respectively (Megeji *et. al*., 2005 and Ramesh *et. al*., 2006). Considering the medicinal value of the crop, its increasing industrial demand and meager scientific information available on the cultivation of stevia under drip irrigation system, the present

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study was undertaken to optimize the irrigation regimes and fertilizer levels for higher economic yield and nutrient uptake by stevia in the rice fallow under Odisha region.

MATERIALS AND METHODS

The experiment was conducted at the Directorate of Water Management, Bhubaneswar, Odisha during *rabi* seasons of 2005-06 and 2006-07 to assess the performance of stevia crop under different irrigation and fertility levels through drip system**,** which was grown in the rice fallow cropping system. The experiment was laid out in Factorial Randomized Block Design with three replications. The treatments comprised of three irrigation regimes (I_1- drip irrigation at 100% PE, I_2 at 80% PE and I_3 at 60% PE) and three fertility levels (F_1 -100%, F_2 – 75% and F_3 - 50% recommended dose of NPK) with an extra (control) treatment having surface irrigation and soil application of fertilizer. The soil was sandy clay in texture with pH 5.7, low in organic carbon (0.46%) and nitrogen (159 kg/ha); medium in available phosphorus (21 kg/ha) and potassium (183 kg/ha) in plough layer (0-15 cm soil depth). The climate is warm, moist with hot and humid summer and mild winter. The total amount of rainfall received during the cropping season of stevia was 464 mm in 2005-06 and 351 mm in 2006-07 in 41 and 22 rainy days, respectively. Out of the total rainfall 157 mm in 2005-06 and 135 mm in 2006-07 became effective for different irrigation levels, which were taken into account for calculating the consumptive use. The total evaporation from open pan evaporimeter during the cropping period was 959 mm and 844 mm, maximum temperature ranged from 25.5^{0}C to 37.5^{0}C and 28.1^{0}C to 39.6^{0}C, whereas minimum temperature ranged from 12.0^{0}C to 26.1^{0}C and 11.5^{0}C to 25.9^{0}C in 2005-06 and 2006-07, respectively. The relative humidity (RH) varied from 93.3 to 98.1 %; 94.0 to 98.9% in the morning (RH maximum) and 37.2 to 66.0% and 44.4 to 71.3% in the afternoon hours (RH minimum) in respective years.

Stevia was propagated vegetatively consisting of 3-4 nodes with the terminal bud and 3-4 crown top leaves were planted in polythene bags containing a mixture of soil and sand (1:1) in October during both the seasons. Forty five days old seedlings of stevia variety “SRB-126” was planted in crop geometry of 60 cm x 30 cm during the evening hours to avoid transplanting shock from higher temperature. The recommended fertilizer dose for stevia was 110-45-45 kg N-P_2O_5-K_2O/ha. Full dose of phosphorus was applied as basal. Required amount of urea and potash was dissolved in water and fed to the drip system using ventury. Fertigation was given in 10 equal splits at fortnightly interval starting from 15 days after planting (DAP) up to 30 days before final harvest. Fertigation was made by regulating the taps of the laterals by allowing the solution to the specified plots as per the treatments. Different irrigation levels were imposed on the basis of pan evaporation through meteorological approach (Jenson *et al.*, 1961). Cumulative pan evaporation for different treatments was taken and computed using data from a standard US Weather Bureau Class A open pan evaporimeter, which was installed near experimental field. The depth of irrigation water was 60 mm in case of surface irrigation. The water was drawn from the secondary reservoir. First irrigation was given one day prior to planting. Subsequent irrigations were given at two days interval in drip irrigation. If rainfall event occurred between irrigation cycles, then the rainfall amount was deducted and irrigation water was applied accordingly. Computation of irrigation water required for the crop through drip system was made according to the following equation.

$$\text{Amount of irrigation water in litre} = \frac{\begin{array}{c}\text{(Lateral spacing in m} \times \text{dripper spacing in m)} \\ \times \text{ Wetted area (60\%)} \times \text{crop coeficient at diferent} \\ \text{crop growth period } \times \text{two days pan} \\ \text{evaporation (mm)}\end{array}}{\text{Uniformity coefficient (\%)}}$$

The crop coefficient values of 0.70, 1.10 and 0.70 were taken as standard during vegetative, full growth and later part of the growth stages, respectively. Water was pumped from a well through a 3 Hp diesel pump and conveyed to the field using PVC pipes of 63 mm diameter after filtering through a screen filter (Fig. 1). Ventury was installed for fertigation ahead of the screen filter in the main line. Water was taken to the field through sub mains PVC pipes (50 mm diameter). In each plot four laterals were placed at a spacing of 0.90 m (Fig. 1). Drippers were fixed at 0.60 m. In each plot (Gross plot size-5.0 m x 3.60 m and net plot size-4.20 m x 2.70 m) there were 32 drippers (4 laterals x 8 drippers/lateral). A tap was fixed at the head of each lateral in order to regulate the water supply. Sub mains were closed with end caps and laterals were closed with end plugs. After the installation, trial run was con-

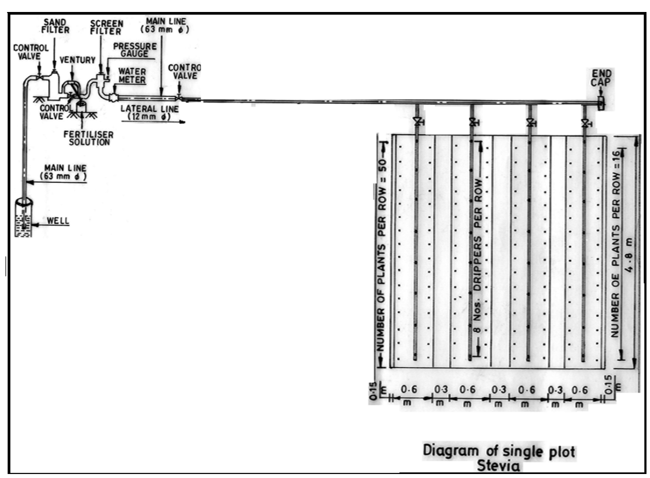

Fig. 1. Layout and design of drip irrigation system

ducted to assess the mean emitter discharge and uniformity coefficient. To estimate approximate time required to operate the system for irrigating each treatment i.e., 100%, 80% and 60% PE, the discharge rate of emitor was measured and then emission uniformity of the system was computed with the following formula:-

$$EU\ (\%) = \frac{q-25\%}{q-} \times 100$$

where,

EU = Emission uniformity (%), $q^{-25\%}$ = is mean of lowest 25% emitter discharge, q^{-} = mean discharge rate (lph)

The rating of drip design system was done on the basis of EU value and various statistical parameters like CD and CV%. To irrigate each treatment, time required to apply a fixed quantity of water was computed based on discharge rate and emission uniformity as per above formulae. In drip irrigation system, discharge rate of drippers was monitored frequently and uniformity coefficients were estimated for operating the system to meet the actual irrigation requirement of a crop. The results revealed that the mean discharge rate was 3.0 lph with standard deviation of 0.19 lph and coefficient of variation of 6.34%, respectively. Based on the above discharge rates, emission uniformity was found to be 96.3% for stevia. The above values were quite satisfactory as per the standard design system of drip irrigation. The rating of standard design of drip irrigation system described by Ortega *et. al*. (2002) was followed. Extremely high and low discharging emitters were replaced so as to ensure a uniformity coefficient of not less than 90%. The coefficient of variation obtained in the experiment was quite satisfactory as it was within the desirable limit and the design system was rated as medium in category.

From randomly selected five plants of stevia in the net plot, plant height was recorded from the ground surface up to the top most growing point and mean plant height was computed. The number of physiologically active leaves from 5 randomly selected plants were counted and the mean value was computed. Dry matter was determined by taking 5 sampled plants without root from each treatment leaving the border row. The plants were sun-dried and thereafter oven dried at 80^0C for 24 hours till constant weight was achieved. The dry weight so obtained from five plants was averaged out to get dry matter per plant in gram. It was multiplied by the number of plants/m^2 to get the dry matter in g/m^2. The leaves of plants from net plot were stripped out from the stem, weighed and expressed in dry leaf as kg/ha. The leaves were separated from the plant by beating with wooden stick. These were sun dried and the weight was expressed on oven dry basis as dry leaf yield in kg/ha. The plants in the net plot were cut from the base and fresh total biomass yield was expressed in kg/ha. The oven-dried samples were grounded using Willey Mill and analysed for nitrogen, phosphorus and potassium content. Plant samples were wet digested in di-acid mixture ($3HNO_3$:1HCl) for determination of P and K. Phosphorus was determined by the Vanadomolybdo-phosphoric acid yellow colour method and neutral normal NH_4OAc extractable K by flame photometer. N was determined by modified micro Kjeldahl method (Jackson, 1973). Nutrient uuptake in sampled plants was determined by multiplying the N, P and K concentration with corresponding dry matter and expressed in kg/ha. Available N (kg/ha), P (kg/ha) and K (kg/ha) was determined from soil samples before starting of experiment and after post harvest using alkaline potassium permanganate method (Subbiah and Asija, 1956), $NaHCO_3$ extractable P (Jackson, 1973) and Ammonium acetate extraction (Jackson, 1973).

RESULTS AND DISCUSSION

Growth attributes

Drip irrigation significantly increased the growth attributes such as plant height (29.2%), number of leaves (12.3%) and dry matter accumulation (2.05%) of stevia crop at harvest as compared to surface irrigation method (Table 1). Increasing the level of irrigation from 60% PE to 100% PE significantly enhanced the growth attributes such as plant height, number of leaves and dry matter accumulation at harvest. Irrigation at 100% PE produced taller plants with maximum number of leaves, which decreased with 80% and 60% PE. Maximum amount of dry matter was produced by application of irrigation water at 100% PE (1389 g/m^2) and minimum with 60% PE (1231 g/m^2). Megeji *et al*. (2005) reported the taller plants and more dry matter accumulation under irrigated conditions than rainfed conditions in an experiment conducted in India at an altitude of 1300 m above msl. Frequent irrigation enhanced growth parameters due to quick development of extensive root system, which created a conducive environment to absorb more water and nutrient (Taylor and Klepper, 1978). It is well known that proper supply of moisture and nutrients helps in maintaining high photosynthetic rate, which increases the cell elongation and its multiplication at a much faster rate, which resulted in taller plants and more accumulation of dry matter. Higher leaf temperature under low frequency irrigation might have increased photorespiration and decreased net assimilation rate resulting in low accumulation of dry matter. These results are in close conformity with the findings of Aladakatti *et al.,* (2012b).

At harvest, plant height, number of leaves and dry matter accumulation were significantly influenced by application of 100% RD of fertilizer. The dry matter was increased due to application of 100% RD by 2.3% and 5.6%, respectively in comparison with 75% and 50% RD at harvest. This may be attributed to more proliferation of root system resulting in more absorption of nutrients and water from the soil leading to production of higher vegetative biomass (Taylor and Klepper, 1978; Hamblin, 1985). At harvest, maximum number of leaves per plant were produced by application of fertilizer at 100% RD (310) and minimum with 50% RD (284). Adequate nutrition plays an important role in plant vegetative growth and development through cell enlargement, multiplication and increase in the rate of photosynthesis. Similar findings were reported by Aladakatti *et. al*., 2012 a.

Yield

Adoption of drip irrigation system improved fresh, dry leaf and biomass yield over surface irrigation method, the magnitude of yield improvement was 4.9%, 4.0% and 2.04% over surface irrigation method (Table 1). Similar results were reported by Aladakatti *et al*. (2012 a, b) at Dharwar, Karnataka where they conducted field experiment during 2004-05 to 2005-06 on stevia crop with three levels of irrigation and three levels of N, P and two levels of K fertilizer. Among the three irrigation regimes applied to this crop, on an average of two years, the maximum fresh leaf, dry leaf and biomass yield of 8.95, 2.74 and 34.45 t/ha, respectively were recorded at 100% PE irrigation schedule. With increasing quantum of irrigation water to the extent of 100% PE, the magnitude of increase in fresh leaf yield was 17.1% and 27.5%, respectively compared to 80% and 60% PE. Similarly, with irrigation at 100% PE, the increase in dry leaf (15.6% and 24.8%) and biomass yield (4.3% and 12.8%) was observed over 80% and 60% PE treatments. Irrigation at 80% PE gave 3.6% more dry leaf yield than 60% PE. Similar findings were reported by Aladakatti *et al*., (2012b) at Dharwar, Karnataka where irrigation were given based on IW: CPE ratio of 1.0. As, this crop is very much sensitive to moisture stress, reduction in yield was observed under reduced amount of water application by Oddone (1999).

Application of full dose of fertilizer (100% RD) produced significantly maximum fresh leaf yield of 8.21 t/ha, which was 4.6% and 8.7% higher than 75% RD (7.84 t/ha) and 50% RD (7.57 t/ha), respectively. Also the highest dry leaf yield of 2.53 t/ha was recorded with application of 100% RD followed by 75% RD (2.43 t/ha) and 50% RD (2.35 t/ha). Reduction of 25% fertilizer dose from the full dose (100% RD) decreased the dry leaf yield by 3.9% and that of 50% by 7.1%. Full dose of fertilizer (100% RD) application also helped to produce maximum biomass yield of 33.50 t/ha as compared to 75% and 50% RD. The magnitude of increase in biomass yield with 100% RD was 2.3% and 5.5% over 75% and 50% RD, respectively. Similarly, Chalapathi *et al*. (1999) from Bengaluru reported significant increase in biomass yield due to increasing fertilizer levels in stevia ratoon crop where as fertilizer dose of 300–150–100 NPK kg/ha has been considered as an optimum level of nutrients for stevia in vertisols of Dharwar, Karnataka (Aladakatti *et al.*, 2012a). Whereas, application of 50-60-50 kg NPK/ha in Western Himalaya

Table 1. Influence of irrigation and fertility levels on growth and yield of stevia (Pooled data of 2 years)

Treatment	Plant height at harvest (cm)	Number of leaves at harvest	Dry matter at harvest (g/m^2)	Fresh leaf yield (t/ha)	Dry leaf yield (t/ha)	Biomass yield (t/ha)
Method of irrigation						
Control	79	265	1291	7.51	2.34	32.01
DF	101	297	1371	7.87	2.43	32.67
SEm±	0.93	2.5	72	0.10	0.02	0.02
CD (P=0.05)	2.7	7.5	21.4	0.04	0.07	0.07
Irrigation (I)						
I_1 = 100% PE	111	339.5	1389	8.95	2.74	34.45
I_2 = 80% PE	102	296.0	1331	7.64	2.37	33.02
I_3 = 60% PE	92	256.0	1231	7.02	2.19	30.53
SEm±	1.6	4.4	12.5	0.02	0.04	0.04
CD (P=0.05)	4.8	13.0	37.1	0.07	0.13	0.12
Fertility (F)						
F_1= 100% RD	105	310	1351	8.21	2.53	33.50
F_2 = 75% RD	106	298	1321	7.84	2.43	32.75
F_3 = 50% RD	99	284	1280	7.57	2.35	31.74
SEm±	1.6	4.4	12.5	0.02	0.04	0.04
CD (P=0.05)	4.8	13.0	37.1	0.07	0.13	0.12

Recommended fertilizer dose: 110-45-45 kg N-P_2O_5-K_2O/ha

Region recorded significantly higher dry leaf yield as compared to other treatments (Kumar *et al*., 2012). With respect to interactive effect, application of irrigation at 100% PE with 100% RD produced maximum fresh leaf (9.13 t/ha), dry leaf (2.90 t/ha) and biomass yield of 35.0 t/ha due to availability of adequate moisture and nutrition (Table 2). Availability of moisture and nutrients during early growth helped to good vegetative growth, which might have enhanced better light utilization resulting in high economic yield (Krishnamurthy, 2001).

Table 2. Interactive effect of irrigation and fertilizer levels on mean fresh, dry leaf and biomass yield (t/ha) of stevia

Mean fresh leaf yield (t/ha)

Irrigation schedules	Fertility levels		
	F_1	F_2	F_3
I_1	9.13	8.98	8.75
I_2	8.16	7.74	7.04
I_3	7.33	6.82	6.91
SEm±		0.13	
CD (P=0.05)		0.38	

Mean dry leaf yield (t/ha)

Irrigation schedules	Fertility levels		
	F_1	F_2	F_3
I_1	2.90	2.70	2.60
I_2	2.47	2.37	2.26
I_3	2.20	2.15	2.17
SEm±		0.07	
CD (P=0.05)		0.22	

Mean biomass yield (t/ha)

Irrigation schedules	Fertility levels		
	F_1	F_2	F_3
I_1	35.0	34.5	33.4
I_2	33.7	32.2	32.6
I_3	31.8	30.5	29.2
SEm±		0.12	
CD (P=0.05)		0.35	

Glycoside content

Stevioside and rebaudioside (steviol glycosides) are the main glycosides which are responsible for the quality of stevia. Their concentration in plant determines the sweetness and bitterness. One sample from control and another from 100% PE with 100% RD (best treatment combination) was used for analysis to know the active chemical constituents of stevia (Table 3). Fertilizer application had a marked effect on the glycoside content. The analysed result showed that the highest stevioside content (7.06%) was observed in case of stevia receiving 100% RD of fertilizer with irrigation at 100% PE (I_1F_1) as compared to control (1.44%). Also, I_1F_1 recorded the highest rebaudioside-A (4.83%) and dulcoside-A (0.10%). It was due to adequate availability of water and nutrients, which increased the stevioside, rebaudioside-A and dulcoside-A content. These results are in close conformity with the findings of Fronza and Folegatti (2003) who recorded a value of 6.5% stevioside content in stevia plants grown in a microlysimeter. Also, Megeji *et al*. (2005) found a stevioside content in the leaves ranging from 3.17 to 9.94% and from 1.54 to 3.85% in stems, while no information was reported on rebaudioside- A.

Nutrient content in plant

Drip irrigation increased N content by 14.1% than surface irrigation (Table 4). The effect of the quantity of irrigation water on N concentration was also significant. Application of irrigation at 100% PE had higher N content (1.31%) than 80% PE (1.13%) and 60% PE (0.96%). The level of fertilizer application affected the concentration significantly. However, 100% and 75% RD had highest N percent (1.14 to 1.17) than 50% RD (1.10). These results agree with those of Das *et al.* (2006). Phosphorus concentration did not differ significantly with irrigation methods but P content was in drip irrigation by 0.009% more than surface irrigation (Table 4). Neither, irrigation nor fertility levels influenced phosphorous content significantly. However, it decreased with reducing irrigation and fertilizer levels. The highest concentration (0.07%) was recorded with 100% RD as compared to 75% (0.067%) and 50% RD (0.064%). Drip irrigation recorded more K concentration (1.11%) than surface irrigation (1.0%). An increase in the irrigation water level from 60 to 100% PE increased the K content significantly. Irrigating the crop at 100% PE resulted in the highest K content (1.23%) than the other two levels. Fertility levels had no significant effect on K content.

Table 3. Effect of irrigation and fertility levels on active constituents of stevia (Pooled data of 2 years)

Treatment	Stevioside (%)	Rebaudioside A (%)	Dulcoside A (%)
Control	1.44	0.93	0.01
I_1F_1	7.06	4.83	0.10

Nutrient uptake

The N uptake was influenced by the method and level of irrigation and fertilizer application (Table 4). Drip irrigation helped the plants to take up 150 kg N/ha which was 16.8% higher than that of surface irrigation (128 kg/ha). The plants irrigated at 100% PE absorbed maximum amount of 181 kg N/ha followed by 150 kg/ha at 80% PE irrigation schedule and 119 kg/ha at 60% irrigation schedule. Fertility levels had significant effect on the nitrogen uptake. Maximum amount of 158 kg/ha was absorbed by the crop when it was fertilized with 100% RD followed by 75% RD (150 kg/ha) and 50% RD (141 kg/ha). Application of 75% RD accumulated 6.4% more N than 50% RD. Chalapathi *et. al*. (1999) reported that the application of 60-30-45 NPK kg/ha produced higher dry leaf yield and recorded higher nutrient uptake by stevia plant. Drip irrigation helped the crop to absorb 8.8 kg P/ha compared to 7.5 kg P/ha in surface irrigation. Irrigation at 100% PE helped to absorb 10.4 kg P/ha, which was 21.6% higher than 80% PE and 37.9% than that of 60% PE. Crop receiving irrigation at 80% PE accumulated 13.4% more P than that of 60% PE. Application of 100% RD resulted in accumulation of 9.5 kg P/ha, which was 6.8% and 15.4% higher than 75% RD (8.9 kg/ha) and 50% RD (8.2 kg/ha), respectively. Reduction of 25% fertilizer (F_2) reduced the P uptake by 6.3% and that of 50% by 13.3%.

Under drip method of irrigation stevia plants absorbed 12.75% more potassium (146 kg/ha) than the surface irrigation (129 kg/ha) (Table 4). Reduction in the quantity of irrigation decreased K uptake. Maximum K uptake was recorded with irrigation at 100% PE (172 kg/ha). It absorbed 18.2% and 41.5% more K than 80% and 60% PE, respectively. Application of full dose of fertilizer (100% RD) helped the crop to absorb maximum amount of K (151 kg/ha), which was 3.2% and 6.6% more than F_2 (146 kg/ha) and F_3 (141 kg/ha), respectively. Lowest amount of K was absorbed by F_3 (50% RD), which was 10 kg less than that of full dose of fertilizer (100% RD).

Nutrient status in soil at harvest

The maximum available N in soil was obtained under drip fertigation method (Table 5). Surface irrigation method recorded lower N content by 6.7% and 6.0% in first and second year, respectively over drip fertigation. Significantly maximum amount of N was recorded with irrigation at 60% PE. On an average, the reduction in soil N content with irrigation at 100% and 80% PE was 9.6% and 9.0%, respectively over 60% PE, which indicated efficient utilization of nitrogen in soil at greater moisture availability. Application of varying amounts of fertilizers through drip system influenced N content significantly. On an average, of two years about 1.0% and 2.1% less N content was estimated in 75% and 50% RD, respectively over 100% RD treatment. The highest increase in soil available N with NPK application might be due to positive interactions among themselves and decrease at the later period may be explained by the dilution effect due to higher biomass production. Maximum available P in soil was observed in drip method and magnitude of increase was 2% and 3.2% in first and second year, respectively over surface irrigation (Table 5). The highest available P of 21.0 kg/ha and 23.0 kg/ha in 1st and 2nd year was obtained with 100% RD application while least with 50% RD of fertilizers. Available K amount in soil was not affected by both irrigation methods and fertilizer levels but influenced significantly by irrigation levels. The maximum available K in soil was observed with irrigation at 60% PE (4.4%) followed by 80% (4.9%) compared to100% PE, respectively. These findings are in close conformity with the results of

Table 4. Effect of irrigation and fertility levels on N, P and K content (%) and their uptake by stevia (Pooled data of 2 years)

Treatment	Nutrient content in plant (%)			Nutrient uptake (kg/ha)		
	N	P	K	N uptake	P uptake	K uptake
Method of irrigation						
Control	0.99	0.058	1.00	128	7.5	129
DF	1.13	0.067	1.11	150	8.8	146
SEm±	0.025	0.01	0.02	1.0	0.08	0.07
CD (P=0.05)	0.070	NS	0.06	3.0	0.25	0.2
Irrigation (I)						
I_1 = 100% PE	1.31	0.075	1.23	181	10.4	172
I_2 = 80% PE	1.13	0.064	1.09	150	8.5	145
I_3 = 60% PE	0.96	0.061	0.99	119	7.5	121
SEm±	0.04	0.02	0.045	2.0	0.10	0.01
CD (P=0.05)	0.12	NS	0.14	5.1	0.40	0.03
Fertility (F)						
F_1= 100% RD	1.17	0.070	1.12	158	9.5	151
F_2 = 75% RD	1.14	0.067	1.10	150	8.9	146
F_3 = 50% RD	1.10	0.064	1.09	141	8.2	141
SEm±	0.04	0.02	0.05	2.0	0.10	0.01
CD (P=0.05)	0.12	NS	NS	5.1	0.40	0.03

NS = Not significant

Table 5. Effect of irrigation and fertility on N, P and K availability in soil after harvest

Treatment	Nitrogen (kg/ha)		Phosphorus (kg/ha)		Potassium (kg/ha)	
	2005-06	2006-07	2005-06	2006-07	2005-06	2006-07
Method of irrigation						
Control	164	167	20.2	21.8	187	187
DF	175	177	20.6	22.5	190	188
SEm±	0.26	0.46	0.06	0.099	0.51	1.12
CD (P=0.05)	0.76	1.38	0.18	0.295	NS	NS
Irrigation regimes						
I_1=100% PE	170	169	20.5	21.5	183	182
I_2=80% PE	171	171	20.5	22.5	191	190
I_3=60% PE	185	191	20.8	23.6	191	191
SEm±	0.44	0.81	1.17	0.17	1.95	1.95
CD(P=0.05)	1.32	2.39	NS	0.51	5.78	5.78
Fertilizers						
F_1=100% RD	177	179	21.0	23.0	189	189
F_2=75% RD	176	178	20.6	22.7	188	187
F_3=50% RD	174	175	20.1	21.9	188	187
SEm±	0.44	0.81	0.15	0.17	1.95	1.95
CD(P=0.05)	1.32	2.39	0.44	0.51	NS	NS
Initial	159	161	21	22	183	184

NS = Not significant, Recommended fertilizer dose: 110-45-45 kg N-P_2O_5-K_2O/ha

Das *et al*. (2006).

It could be concluded that medicinal crop stevia gave maximum fresh leaf (9.13 t/ha), dry leaf (2.90 t/ha), biomass (35.00 t/ha) yields and stevioside content (7.06%) with drip irrigation at 100% PE and application of 100% RD of fertilizer. The application of irrigation and fertilizer through drip has been found to increase nutrient contents both in soil and plants over the surface irrigation, suggesting a balanced fertilization is required for deriving optimum growth, yield and nutrition of the stevia plant. The stevia crop took up 150 kg N, 8.8 kg P and 146 kg K/ha with drip irrigation as compared to surface irrigation.

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