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Effect of irrigation schedule and planting geometry on growth and yield of stevia (*Stevia rebaudiana* Bertoni.)*

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Abstract: A field experiment was conducted in medium black, clayey soil under irrigated conditions to assess the response of stevia to irrigation schedules and planting geometry. Highest dry leaf yield of stevia (cumulative of five cuttings) was obtained with irrigation scheduled at 1.2 IW/CPE (10.54 t ha^{-1}) which was on par with irrigation scheduled at 1.0 IW/CPE (10.32 t ha^{-1}) and significantly lower dry leaf yield was with irrigation scheduled at 0.8 IW/CPE (9.36 t ha^{-1}). Planting geometry of 30 cm x 20 cm recorded the highest cumulative total dry leaf yield (11.12 t ha^{-1}) which was comparable with the dry leaf yield obtained with the planting geometry of 30 cm x 30 cm (10.89 t ha^{-1}). Significantly lower dry leaf yield was recorded with planting geometry of 45 cm x 30 cm (8.73 t ha^{-1}). Interaction effects of irrigation schedules and planting geometry on dry leaf yield of stevia were not significant. Consumptive use of water was highest with irrigation scheduled at 1.2 IW/CPE (2373.2 mm) closely followed by 1.0 IW/CPE (1903.8 mm). The study revealed that irrigation schedule at 1.0 IW/CPE *i.e.*, irrigation at 60 mm cumulative pan evaporation (CPE) with planting geometry of 30 cm x 30 cm (1,11,111 plants ha^{-1}) was found optimum for higher stevia dry leaf yield and higher water use efficiency. Based on the average daily evaporation the irrigation interval of 9-10 days during *kharif,* 5-6 days during *summer* and 7-8 days during *rabi* season can be recommended in similar soil and agro climatic conditions.

Key words: Consumptive use, Evapotranspiration, Geometry, Irrigation, Stevia

Introduction

Stevia (*Stevia rebaudiana* Bertoni.) is a herbaceous perennial small bush with carbohydrate based compounds in its leaves, which are many times sweeter than cane sugar and sugarbeet. Dry leaves are the economic part in stevia plant. Stevia leaves have a sweet taste which is 20-30 times that of cane sugar but importantly without any calories. Hence, stevia is a potential natural source of no calorie sweetner, alternative to the synthetic sweetening agents *viz.*, saccharine, aspartame, asulfam-K, sucralose that are available in the market to the diet conscious consumers and diabetics. Cultivation of stevia crop made significant impact in the countries like Japan, China, Korea, Mexico, USA, Thailand, Malaysia, Indonesia, Australia, Canada and Russia (Brandel and Rosa, 1992) and efforts were made to initiate research work in India. Studies conducted so far could suggest few management approaches for improving productivity. 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 (Chalapathi *et al*., 1997 b). Stevia can be cultivated profitably wherever irrigation facilities are available. Some research work on nutrient requirement and planting geometry 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 ; Ramesh *et al., 2006*). In the absence of adequate information on the planting geometry, water requirement and optimum irrigation schedule to stevia in vertisols, the present investigation was undertaken to determine the optimum irrigation schedule and planting geometry for stevia to get higher dry leaf yield.

Material and methods

The experiment was conducted at Water Management Research Center (WMRC), Belavatagi, (Ta: Navalagund, Dist: Dharwad), during 2003-04 to 2005-06. It is located in semi-arid tract of Karnataka at 15° 34' N latitude and 75° 21' E longitude with an altitude of 578 m above mean sea level. The soil type of the experimental site was medium black soil (Vertisols) with soil depth of more than 1.5 m having high water holding capacity (78%) and low infiltration rate (0.25 cm hr^{-1}). The annual total rainfall received during the years 2004-05 and 2005-06 were 481, 492 and 443 mm respectively, which were 13.5, 11.5 and 20.3 per cent lower than the average annual rainfall of past 30 years (556.0 mm). The experiment consisted irrigation schedules *viz.*, I_1 (0.8 IW/CPE), I_2 (1.0 IW/CPE) and I_3 (1.2 IW/CPE) as main plots and planting geometries of D_1 (30 cm x 20 cm), D_2 (30 cm x 30 cm), D_3 (45 cm x 30 cm) and D_4 (60 cm x 20 cm) as sub plots. The experiment was laid out in split plot design with three replications. Two months old stevia seedlings were planted at respective spacing as per treatment on 23rd November, 2003. A common dose of FYM @ 10 t ha^{-1} was uniformly applied to the experimental plots. Nutrient dosage of 300:150:100 kg N, P_2O_5 and K_2O ha^{-1} was applied in equal splits for five cuttings in year *i.e.* 60: 30: 20 kg N, P_2O_5 and K_2O ha^{-1} per cutting. Common irrigation with 60 mm depth was given on the next day of planting. Gap filling with planting new seedling was undertaken after 30 days of planting up to 60 days to maintain required plant

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population. The nutrients N, P and K were applied in the form of di-ammonium phosphate (DAP), urea and muriate of potash (MOP) respectively to both the experiments. Entire P and K fertilizers and 50 per cent N were applied a week after transplanting. Remaining 50 per cent N was applied in three equal splits at 30, 45 and 60 days after transplanting (DAT) for plant crop. But for the subsequent ratoon crops after the harvest of plant crop, 50 per cent each N, P and K was applied two days after harvest with irrigation to a depth of 60 mm. The remaining 50 per cent N was top dressed in two equal splits at 30 and 45 days of harvest of previous crop. This was followed and maintained for each cutting throughout the crop season during both the years. Irrigation was scheduled as per the IW/CPE treatments to a depth of 60 cm in each irrigation. Irrigation water was measured with Parshall Flume with a throat width of 7.5 cm. Soil moisture content at 0-15 cm and 15 cm -30 cm soil depths was worked out with gravimetric method in all the treatment plots of one replication at the time of planting, just before each irrigation, also after three days of irrigation and soon after the harvest of each crop. Based on the moisture content, the total consumptive use and water use efficiency were computed using appropriate formulae. First crop was harvested at 90 days after planting, whereas the succeeding crops were harvested at a regular interval of 70 days. Observations were recorded on the selected five plants just before harvest of the cop. The plants were cut uniformly 10 cm above the ground level and the green biomass was sun dried for a day, then shade dried for a week with periodic pulverization. The dried stevia leaves were stripped off from the stem and dried separately under sunlight for a day and stored in clean gunny bags. Totally five cuttings per year were taken in each experiment and the plots were maintained for two years.

Results and discussion

The data on plant height, number of branches plant^{-1} and number of leaves plant^{-1} at harvest as influenced by irrigation schedule and planting geometry are presented in Table 1. Plant height at harvest differed significantly due to irrigation levels. Irrigation schedule I_2 (1.0 IW/CPE) recorded significantly higher plant height (58.61 cm) which was on par with the irrigation schedule I_3 (1.2 IW/CPE) (60.08 cm), and irrigation schedule I_1 (0.8 IW/CPE) recorded significantly lower plant height (53.53 cm) in pooled data. Number of branches plant^{-1} and number of leaves plant^{-1} differed significantly due to irrigation. Pooled data

Table 1. Growth parameters of stevia at harvest as influenced by irrigation schedule and planting geometry

Treatment	Plant height at harvest (cm)			Number of branches plant^{-1}			Number of leaves plant^{-1}		
	2004-05	2005-06	Pooled	2004-05	2005-06	Pooled	2004-05	2005-06	Pooled
Irrigation schedule (M)									
I_1 (0.8 IW/CPE)	55.13	51.94	53.53	46.98	41.67	44.32	654.0	506.3	580.1
I_2 (1.0 IW/CPE)	60.15	57.08	58.61	51.36	46.63	48.99	692.2	553.2	622.7
I_3 (1.2 IW/CPE)	61.61	58.55	60.08	52.65	48.29	50.47	712.9	572.3	642.6
S.Em.±	0.35	0.36	0.32	0.30	0.59	0.41	5.5	5.9	2.8
C.D.(P=0.05)	1.37	1.42	1.24	1.19	2.31	1.60	21.7	23.2	10.9
Planting geometry (S)									
D_1 (30 cm x 20 cm)	62.13	60.19	61.16	46.06	40.75	43.40	657.2	510.5	583.9
D_2 (30 cm x 30 cm)	58.69	56.16	57.43	48.36	43.41	45.89	678.3	537.2	607.7
D_3 (45 cm x 30 cm)	56.65	52.63	54.64	55.88	52.18	54.03	721.6	578.3	650.0
D_4 (60 cm x 20 cm)	58.38	54.43	56.41	51.01	45.78	48.40	688.4	549.7	619.1
S.Em.±	0.89	0.87	0.71	0.76	0.85	0.72	12.7	16.9	14.0
C.D.(P=0.05)	2.64	2.58	2.10	2.24	2.51	2.13	37.7	NS	42.9
Interaction (M x S)									
I_1D_1	56.87	53.60	55.23	42.40	35.72	39.06	612.4	471.9	542.2
I_1D_2	54.99	52.61	53.80	45.08	38.53	41.81	637.6	496.3	566.9
I_1D_3	53.15	49.56	51.35	52.80	49.59	51.19	699.3	537.5	618.4
$I1D_4$	55.51	51.97	53.74	47.63	42.83	45.23	666.7	519.5	593.1
I_2D_1	64.23	63.09	63.66	46.43	42.45	44.44	670.5	518.6	594.5
I_2D_2	59.85	57.29	58.57	49.75	45.00	47.37	680.9	549.2	615.1
I_2D_3	57.35	53.14	55.24	56.73	52.20	54.47	724.8	588.3	656.6
I_2D_4	59.17	54.77	56.97	52.52	46.87	49.69	692.7	556.6	624.7
I_3D_1	65.29	63.88	64.59	49.35	44.07	46.71	688.8	540.9	614.8
I_3D_2	61.24	58.57	59.91	50.27	46.69	48.48	716.3	566.0	641.2
I_3D_3	59.45	55.19	57.32	58.09	54.75	56.42	740.8	609.0	674.9
I_3D_4	60.47	56.55	58.51	52.88	47.65	50.27	705.9	573.2	639.5
S.Em.±	1.38	1.35	1.10	1.17	1.40	1.15	19.8	26.0	21.2
C.D.(P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS

Note: 2004-05: average of first five cuttings 2005-06: average of next consecutive five cuttings Pooled : Average of 1 to 10 cuttings
NS: Non significant

revealed that irrigation schedule I_2 recorded significantly higher number of branches and leaves plant^{-1} (48.99 & 622.7) closely followed by irrigation schedule I_3 (50.47 & 642.6). The plant height at harvest differed significantly due to planting geometry. Lower number of branches and leaves plant^{-1} was recorded with irrigation schedule I_1 (44.32 & 580.1). Similar trend was also observed in the individual year data. Closer spacing D_1 (30 cm x 20 cm) resulted in higher plant height (61.16 cm) as compared to wider spacing of D_2 (57.43 cm), D_3 (54.64) and D_4 (56.41) in pooled data. Number of branches and leaves plant^{-1} differed significantly due to planting geometry. Significantly more number of branches and leaves plant^{-1} was obtained with planting geometry D_3 (54.03 & 650) followed by planting geometry D_4 (48.4 & 619.1) and D_2 (45.89 & 607.7), which were on par to each other in pooled data. Lower number of branches and leaves plant^{-1} was recorded with planting geometry D_1 (43.4 & 583.9). The interaction effects of irrigation schedule and planting geometry on these growth parameters were non-significant (Table 1). Higher number of branches plant^{-1} with irrigation scheduled at 1.0 IW/CPE was comparable with irrigation schedule of 1.2 IW/CPE. This lead to higher number of leaves plant^{-1} ultimately contributing to higher dry leaf yield. Lower number of leaves plant^{-1} was recorded with 0.8 IW/CPE. The number of branches and leaves plant^{-1} obtained with higher irrigation schedule at 1.2 IW/CPE were on par with the irrigation scheduled at 1.0 IW/CPE in pooled analysis and in individual cuttings. The growth parameters *viz*., plant height, number of branches plant^{-1} and leaves plant^{-1} at harvest were higher with the irrigation schedule of 1.0 IW/CPE, which resulted in higher economic yield. Ramesh *et al.* (2006) also reported more number of branches and leaves plant^{-1} of stevia with adequate irrigation. Donalisio *et al.* (1982) in Brazil also reported the higher dry leaf yield of stevia under irrigation due to better plant growth with higher number of branches and leaves plant^{-1}. Shock (1982) reported that the crop is much sensitive and susceptible to water stress during the crop growth period.

The data on fresh biomass, fresh leaf yield and dry leaf yield as influenced by irrigation schedule and planting geometry is presented in Table 2. Irrigation schedules significantly influenced the fresh biomass, fresh leaf yield and dry leaf yield of stevia. Higher levels of irrigation i.e., from 0.8 IW/CPE to 1.2 IW/CPE increased linearly the fresh biomass, fresh leaf yield and leaf yield in individual year as well as pooled. However, the irrigation schedule beyond 1.0 IW/CPE did not increase the yield

Table 2. Fresh biomass and dry leaf yield of stevia as influenced by irrigation schedule and planting geometry

Treatments	Fresh biomass yield (t ha^{-1})			Fresh leaf yield (t ha^{-1})			Dry leaf yield (t ha^{-1})		
	2004-05	2005-06	Pooled	2004-05	2005-06	Pooled	2004-05	2005-06	Pooled
Irrigation schedule(M)									
I_1 (0.8 IW/CPE)	132.55	114.91	123.71	54.96	39.76	47.36	10.06	8.67	9.36
I_2 (1.0 IW/CPE)	147.49	130.31	138.78	61.83	46.00	53.92	11.00	9.64	10.32
I_3 (1.2 IW/CPE)	149.21	130.87	140.20	65.11	48.61	56.86	11.36	9.73	10.54
S.Em±	2.48	1.69	1.79	0.86	0.70	0.81	0.15	0.11	0.10
C.D.(P=0.05)	9.73	6.65	7.01	3.39	2.71	3.10	0.60	0.44	0.40
Planting geometry (S)									
D_1 (30 cm x 20 cm)	159.24	139.25	149.27	65.22	49.05	57.14	11.95	10.28	11.12
D_2 (30 cm x 30 cm)	154.06	134.60	144.34	64.69	47.75	56.22	11.65	10.13	10.89
D_3 (45 cm x 30 cm)	123.51	109.06	116.27	53.80	40.39	47.10	9.32	8.13	8.73
D_4 (60 cm x 20 cm)	135.53	118.53	127.04	58.82	41.97	50.40	10.30	8.84	9.57
S.Em±	2.74	2.25	1.72	1.07	0.74	0.75	0.29	0.12	0.12
C.D.(P=0.05)	8.13	6.68	5.09	3.17	2.19	2.23	0.84	0.35	0.36
Interaction (M x S)									
I_1D_1	144.73	131.94	138.25	57.29	43.27	50.28	11.05	9.70	10.37
I_1D_2	144.14	120.22	132.18	60.73	42.31	51.52	10.91	9.46	10.19
I_1D_3	114.56	97.66	106.12	48.47	35.47	41.97	8.69	7.33	8.01
$I1D_4$	126.76	109.80	118.29	53.36	38.01	45.68	9.58	8.19	8.89
I_2D_1	167.59	144.19	155.40	67.62	52.46	60.04	12.18	10.54	11.36
I_2D_2	158.47	142.90	150.68	65.31	49.29	57.30	11.81	10.52	11.17
I_2D_3	127.87	113.26	120.54	54.51	39.83	47.17	9.62	8.49	9.06
I_2D_4	136.04	120.90	128.49	59.87	42.43	51.15	10.39	8.99	9.69
I_3D_1	165.40	141.62	154.17	70.76	51.43	61.09	12.62	10.60	11.61
I_3D_2	159.57	140.69	150.14	68.03	51.65	59.84	12.23	10.42	11.33
I_3D_3	128.10	116.27	122.15	58.42	45.87	52.15	9.65	8.57	9.11
I_3D_4	143.79	124.89	134.34	63.23	45.48	54.35	10.92	9.33	10.12
SEm±	4.80	3.77	3.13	2.19	1.53	1.34	0.38	0.21	0.21
C.D.(P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS

2004-05: average of first five cuttings   2005-06: average of next consecutive five cuttings   Pooled : Average of 1 to 10 cuttings
NS: Non significant

significantly. Irrigation scheduled at 1.0 IW/CPE *i.e.,* irrigation at 60 mm cumulative pan evaporation (CPE) resulted in higher fresh biomass(138.78 t ha^{-1}), fresh leaf yield (53.92 t ha^{-1}) and dry leaf yield (10.32 t ha^{-1}), which was on par with irrigation scheduled at 1.2 IW/CPE in pooled data. Jordan Moler (1984) also reported higher dry leaf yield of stevia (4300 kg ha^{-1}) under irrigated conditions than in rainfed conditions (1500-2000 kg ha^{-1}). Lower irrigation frequency of 0.8 IW/CPE *i.e.,* irrigation at 75 mm cumulative pan evaporation (CPE) resulted in significantly lower dry leaf yield (9.36 t ha^{-1}), indicating frequent irrigations for higher dry leaf yield. Similar trend was recorded with the individual year also (Table 2). Dry leaf yield varied significantly due to planting geometry in cumulative total of individual year and in pooled data. The highest dry leaf yield was recorded with the planting geometry D_1 (11.12 t ha^{-1}) which was on par with D_2 (10.89 t ha^{-1}), closely followed by D_4 (9.57 t ha^{-1}) and the lowest dry leaf yield was with D_3 (8.73 t ha^{-1}) in pooled data. The data on cumulative total dry leaf yield during 2004 and 2005 revealed that the planting geometry D_1 recorded the highest dry leaf yield (11.95 t ha^{-1} and 10.28 t ha^{-1}) which were closely followed by D_2 (11.65 t ha^{-1} and 10.13 t ha^{-1}) and the lowest dry leaf yield was with D_3 (9.32 t ha^{-1} and 8.13 t ha^{-1}). The interaction effects of irrigation schedule and planting geometry on fresh biomass, fresh leaf yield and dry leaf yield of stevia were non-significant during 2004, 2005 and in pooled data (Table 2).

Irrigation schedules had significant effect on the gross returns, net returns and B:C in pooled and individual year data (Table 3). Irrigation schedule I_3 recorded the highest gross returns (₹ 10,54,892 ha^{-1}), net returns (₹ 6,93,211 ha^{-1}), which was on par with the gross and net returns of I_2 (₹ 10,38,958 and ₹ 6,83,371 ha^{-1} respectively), but both were significantly higher than the gross and net returns of I_1 (₹ 9,36,408 and ₹ 5,93,349 ha^{-1} respectively). Planting geometry influenced the gross and net returns significantly. Planting geometry D_2 resulted in significantly higher gross and net returns (₹ 10,92,922 and ₹ 7,27,716 ha^{-1} respectively), closely followed by D_1 (₹ 11,19,933 and ₹ 6,68,694 ha^{-1} respectively) and the lowest gross and net returns with D_3 (₹ 8,71,000 and ₹ 58,3541 ha^{-1}). During 2004 also higher net returns were obtained with planting geometry D_2 (₹ 6, 26,048 ha^{-1}) closely followed by D_4 (₹ 5,84,272 ha^{-1}) and the lowest net returns were with D_1 (₹ 4,95,383 ha^{-1}). However, during 2005 the highest net returns were with D_1 (₹ 8, 41,950 ha^{-1}) which was on par with net returns of D_2 (₹ 8,29,350 ha^{-1}) and the lowest

Table 3. Economics of stevia as influenced by irrigation schedule and planting geometry

Treatments	Gross returns (₹ ha^{-1})			Cost of cultivation (₹ ha^{-1})			Net returns (₹ ha^{-1})			Benefit :Cost		
	04-05	05-06	Pooled	04-05	05-06	Pooled	04-05	05-06	Pooled	04-05	05-06	Pooled
Irrigation schedule(M)												
I_1 (0.8 IW/CPE)	1005842	866975	936408	515972	170198	343085	489870	696778	593349	1.95	5.09	2.73
I_2 (1.0 IW/CPE)	1110733	967133	1038958	528711	182463	355587	582022	784670	683371	2.10	5.29	2.92
I_3 (1.2 IW/CPE)	1137192	972550	1054892	536606	186755	361680	600586	785795	693211	2.12	5.20	2.91
S.Em±	18344	11400	11909	1835	1140	1192	16510	10260	10717	0.03	0.030	0.022
C.D.(P=0.05)	72029	44764	46760	7204	4476	4679	64824	40287	42081	0.10	0.118	0.085
Planting geometry (S)												
D_1 (30 cm x 20 cm)	1208478	1031333	1119933	713095	189383	451239	495383	841950	668694	1.69	5.44	2.48
D_2 (30 cm x 30 cm)	1168478	1017333	1092922	542429	187983	365206	626048	829350	727716	2.15	5.41	2.99
D_3 (45 cm x 30 cm)	931933	810022	871000	407666	167252	287459	524267	642770	583541	2.28	4.84	3.03
D_4 (60 cm x 20 cm)	1029467	883522	956522	445195	174602	309899	584272	708920	646624	2.31	5.06	3.09
S.Em±	23927	11793	12216	2393	1179	1222	21535	10614	10994	0.04	0.033	0.021
C.D.(P=0.05)	71092	35038.2	36295	7109	3504	3629	63983	31534	32665	0.11	0.099	0.064
Interaction (M x S)												
I_1D_1	1104900	969900	1037433	699488	180490	439989	405412	789410	597444	1.58	5.37	2.36
I_1D_2	1091200	946100	1018667	531452	178110	354781	559748	767990	663886	2.05	5.31	2.87
I_1D_3	869433	732733	801100	398168	156773	277470	471266	575960	523630	2.18	4.67	2.89
I1D_4	957833	819167	888533	434781	165417	300099	523053	653750	588435	2.20	4.95	2.96
I_2D_1	1251767	1064033	1157933	716424	192153	454288	535343	871880	703645	1.75	5.54	2.55
I_2D_2	1190867	1064233	1127567	543671	192173	367922	647195	872060	759644	2.19	5.54	3.06
I_2D_3	961467	841600	901567	409620	169910	289765	551846	671690	611802	2.35	4.95	3.11
I_2D_4	1038833	898667	968767	445131	175617	310374	593703	723050	658393	2.33	5.12	3.12
I_3D_1	1268767	1060067	1164433	723374	195507	459440	545393	864560	704993	1.75	5.42	2.53
I_3D_2	1223367	1041667	1132533	552165	193667	372916	671201	848000	759617	2.22	5.38	3.04
I_3D_3	964900	855733	910333	415210	175073	295142	549690	680660	615191	2.32	4.89	3.08
I_3D_4	1091733	932733	1012267	455673	182773	319223	636060	749960	693044	2.40	5.10	3.17
S.Em±	47934	26511	27590	4794	2651	2760	43141	23860	24830	0.07	0.072	0.049
C.D.(P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

04-05: average of first five cuttings 05-06: average of next consecutive five cuttings Pooled : Average of 1 to 10 cuttings

NS: Non significant Seedling cost: Rs.3 per seedling Selling price : Rs. 100 per kg dry stevia leaf net returns were with D_3 (₹ 6,42,770 ha^{-1}). Interaction effects of irrigation schedules and planting geometry on grass returns and net returns were non-significant. Combination of I_2D_2 recorded the highest net returns (₹ 7,59,644 ha^{-1}) closely followed by I_3D_2 (₹ 7,59,617 ha^{-1}) and the lowest net returns were with I_1D_1 (₹ 5,23,630 ha^{-1}). Benefit cost ratio (B:C) was significantly influenced by the irrigation schedules. Irrigation schedule I_2 recorded the highest B:C (2.92) closely followed by I_3 (2.91) and both were significantly superior over I_1 (2.73). Highest B:C were recorded during 2005 in all the treatments. Irrigation schedule I_2 recorded the highest B:C (5.29) followed by I_3 (5.2) and I_1 (5.09) during 2005 (Table 3). Planting geometry significantly influenced the B:C. In pooled data the planting geometry D_2 recorded the highest B:C (2.99) closely followed by D_4 (3.09) . The interaction effects of irrigation schedules and planting geometry on benefit cost ratio were non-significant.

Consumptive use (CU) of water increased progressively with increase in frequency of irrigation in each cutting, seasonal cumulative total and in pooled data (Table 4). Irrigation schedule I_3 recorded the highest CU of 2531.7, 2214.7 and 2373.2 mm as seasonal cumulative total during 2004-05, 2005-06 and in pooled respectively, followed by irrigation schedule I_2 (2141.1 mm, 1935.7 mm and 2038.4 mm) and I_1 (2011.7 mm 1795.9 mm and 1903.8 mm). Planting geometry D_1 recorded the highest CU (2146.5 mm), closely followed by D_4 (2117.0 mm) and D_2 (2113.0 mm) in pooled data. The data of cumulative total of CU during 2004 and 2005 revealed that the higher CU was with D_1 (2258.5 mm and 2034.5 mm) closely followed by D4 (2229.5 mm and 2004.5 mm) and D_2 (2222.5 mm, and 2003.0 mm). Treatment combination I_3D_1 recorded the highest CU (2403.5 mm) closely followed by I_3D_4 (2374.7 mm), I_3D_2 (2369.5 mm) and I_3D_3 (2345.1 mm) in pooled data. Similar trend was seen in the cumulative total of 2004 and 2005 (Table 3). The research carried out at Brazil indicated higher water consumption during the entire crop growth period and irrigation at 117% Ete was 13% better than 100% Ete in terms of stevia yield and the average crop evapotranspiration (Ete) measured as 5.75 mm day^{-1} (Fronza and Folegatti, 2002). Andolfi *et al.* (2002) in Canada also reported that stevia crop requires liberal watering after transplanting and before and after harvesting of the leaves.

Higher water use efficiency (WUE) of 5.15, 5.06 and 5.23 kg ha^{-1}mm was recorded with irrigation schedule I_2 in pooled data and mean of 2004 and 2005 respectively closely followed by irrigation schedule I_1 (4.86 kg ha^{-1}mm, 5.02 kg ha^{-1}mm and 4.71 kg ha^{-1}mm). Irrigation schedule I_3 recorded the lowest WUE (4.65 kg ha^{-1}mm, 4.66 kg ha^{-1}mm and 4.65 kg ha^{-1}mm). Planting geometry D_1 recorded highest WUE (5.27 kg ha^{-1}mm) closely followed by D_2 (5.26 kg ha^{-1}mm) and the lowest WUE was with D_3 (4.28 kg ha^{-1}mm). Combination of I_2D_2 *i.e.* irrigation schedule 1.0 IW/CPE with planting geometry of 30 cm x 30 cm recorded the highest WUE (5.58 kg ha^{-1}mm) closely followed by I_2D_1 (5.56 kg ha^{-1}mm) in pooled data and the lowest WUE was in I_3D_3

Table 4. Consumptive use of water and water use efficiency of stevia as influenced by irrigation schedule and planting geometry

Treatments	Consumptive use (mm)			Water use efficiency (kg ha^{-1} mm)		
	2004-05	2005-06	Pooled	2004-05	2005-06	Pooled
Irrigation schedule (M)						
I_1 (0.8 IW/CPE)	2011.7	1795.9	1903.8	5.02	4.71	4.86
I_2 (1.0 IW/CPE)	2141.1	1935.7	2038.4	5.23	5.06	5.15
I_3 (1.2 IW/CPE)	2531.7	2214.7	2373.2	4.66	4.65	4.65
Planting geometry (S)						
D_1 (30 cm x 20 cm)	2258.5	2034.6	2146.55	5.36	5.18	5.27
D_2 (30 cm x 30 cm)	2222.3	2003.3	2112.8	5.32	5.20	5.26
D_3 (45 cm x 30 cm)	2202.3	1974.1	2088.2	4.31	4.24	4.28
D_4 (60 cm x 20 cm)	2229.4	2004.4	2116.9	4.71	4.50	4.61
Interaction (M x S)						
I_1D_1	2041.7	1892.7	1967.2	5.41	5.19	5.30
I_1D_2	2005.4	1861.0	1933.2	5.45	5.15	5.30
I_1D_3	1985.5	1831.6	1908.6	4.41	4.04	4.22
I1D_4	2014.1	1598.3	931.1	4.79	4.42	4.61
I_2D_1	2172.5	1965.8	2069.1	5.69	5.44	5.56
I_2D_2	2136.2	1935.1	2035.6	5.62	5.55	5.58
I_2D_3	2116.3	1905.7	2011.0	4.65	4.55	4.60
I_2D_4	2139.7	1936.3	2038.0	4.96	4.70	4.83
I_3D_1	2561.5	2245.4	2403.5	5.11	4.99	5.05
I_3D_2	2525.2	2213.7	2369.5	5.03	4.99	5.01
I_3D_3	2505.4	2184.9	2345.1	4.00	4.17	4.08
I_3D_4	2534.5	2214.9	2374.7	4.50	4.44	4.47

2004-05: average of first five cuttings 2005-06: average of next consecutive five cuttings Pooled : Average of 1 to 10 cuttings
NS: Non significant CU: Consumptive use WUE : Water use efficiency

(4.08 kg ha^{-1}mm). Similar trend was seen in each cutting and in mean data of 2004 and 2005 (Table 3). Higher leaf yield obtained and optimum quantity of water utilized in this treatment resulted in higher WUE compared to higher levels of irrigation. Similarly, Goenadi (1983) in Indonesia reported higher water use efficiency of stevia wherein the average water requirement per day was 2.33 mm plant^{-1}.

Based on the study it is concluded that irrigation schedule at 1.0 IW/CPE *i.e.*, irrigation at 60 mm cumulative pan evaporation (CPE) found optimum for higher fresh biomass, fresh leaf yield and dry leaf yield of stevia with higher water use efficiency in vertisols. Planting geometry of 30 cm x 30 cm (1, 11,111 plants ha^{-1}) was found economically optimum resulting in higher stevia dry leaf yield. Based on the average daily evaporation the irrigation interval of 9-10 days during *kharif*, 5-6 days during *summer* and 7-8 days during *rabi* season can be recommended in similar soil and agro climatic conditions.

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