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Research Paper

Effect of plant spacing and weed-management practices on growth, biomass and steviol glycosides of candyleaf under western Himalayas

SWATI WALIA[1] AND RAKESH KUMAR[2]

CSIR-Institute of Himalayan Bioresource Technology, Palampur, Himachal Pradesh 176 061

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ABSTRACT

A field experiment was conducted during 2015 and 2016 to study the effect of plant spacing and weed-management practices on development, yield and steviol glycosides of candyleaf [*Stevia rebaudiana* (Bertoni) Bertoni] in the western Himalayas. Treatments included 2 plant spacings (45 cm × 45 cm and 60 cm × 45 cm) and 5 weed-management practices [weedy check, weed-free, hand-weeding, pendimethalin at 1.5 kg/ha followed by 1 hand-weeding (HW) at 40 days after spray (DAS) and oxyfluorfen at 0.25 kg/ha followed by 1 HW at 40 DAS]. Weed population and weed dry biomass under different plant spacing remained unaffected during both the years. Number of leaves (1792.58), dry leaf biomass (1481.32 kg/ha) and total dry biomass (3914.65 kg/ha) were significantly high under narrow spacing. However, total steviol glycosides (%) were significantly high (11.05%) under wider row spacing. Weed population (9.39/m^2) and dry biomass of weeds (11.53 g/m^2) were significantly reduced by the application of oxyfluorfen. Significantly higher number of leaves (2010.83), dry leaf biomass (1498.90 kg/ha) and total dry biomass (4256.45 kg/ha) were obtained with oxyfluorfen during both the years. Steviol glycoside content (12.05%) was significantly higher in hand-weeded plots. A spacing of 45 cm × 45 cm with application of oxyfluorfen could manage weeds efficiently for the perennial crop of candyleaf – a natural sweetner under western Himalayas.

***Key words*: Candyleaf, Plant spacing, Steviol glycoside, Weed-management, Yield**

Candyleaf or sweet leaf is a natural sweetner. The leaves of this plant are used to extract a natural, non-caloric sugar substitute, 300–400 times sweeter than table sugar. It is a perennial herb native to north-eastern Paraguay in South America and is cultivated in many countries like Korea, Russia, China, India, Japan, USA etc. Stevia was introduced in India during 1993 and is now cultivated in numerous Indian states, viz. Punjab, Rajasthan, Uttar Pradesh, Gujarat, Karnataka, Odisha, Kerala, Maharashtra etc. Its leaves contain sweet-tasting compounds, namely stevioside (St) and rebaudioside A (Reb-A). It has antifungal, anti-bacterial, anti-inflammatory, anti-microbial, anti-oxidant, anti-diabetic properties and regulates hypertensive and hyperglycaemic effect (Sharma *et al.,* 2016). With growing number of diabetic patients there is an urgent need of natural non-caloric sweetener in food market. Use of elective counterfeit sweeteners, aspartame have undesirable reactions, *Stevia*, being 100% natural non-caloric and nonfermentable is gaining popularity. The Food Safety and Standards Authority of India (FSSAI) in 2012, endorsed the utilization of steviol glycoside as a synthetic sweetener in different nourishments.

Since, *Stevia* is a slow-growing crop, most weed species can grow faster than it and inhibit the plant growth by curtailing sunlight, nutrients and moisture and reduce the leaf yield. As an annual crop, it can be grown in temperate regions and as a perennial crop in tropical and subtropical regions for 4–5 years. When *Stevia* is grown as a perennial crop, it undergoes dormancy during winter season and regrows once the temperature rises in the first week of March in North Indian plains. The growth of the plant is slow during initial period and hence it is infested by several weeds due to application of farmyard manure (FYM). For higher biomass yield and steviol glycosides, control of weeds is indispensable in perennial crop of *Stevia*. There are few studies are on weed management in perennial crop of *Stevia*.

Plant spacing plays an important role in maximizing crop development and yield, and also in competitive balance between weeds and crop. Kumar *et al.* (2014) re-

[2]**Corresponding author's Email:** rakeshkumar@ihbt.res.in
[1]Agrotechnology of Medicinal, Aromatic and Commercially Important Plants Division, Academy of Scientific and Innovative Research, New Delhi**;** CSIR- Institute of Himalayan Bioresource Technology, Palampur 176 061 Himachal Pradesh

corded higher leaf dry biomass at 45 cm × 10 cm spacing under mid-hill region of north-western Himalayas in candyleaf. Narrow spacing increases crop competitive ability and also constrains the time of competition between weeds and crops. It provides accessible moisture to the crop and stifles weed development by closing crop canopy sooner than wider spacing (Kumar *et al.*, 2014). Manual weeding is effective but is uneconomical due to higher labour cost; wherereas chemical weed management is considered quick, more effective, time and labour-saving method and economical method of reducing early weed competition and crop production losses (Azimah *et al.,* 2018).

It is necessary to develop a low-cost method of weed-management with either herbicides alone or their combination with mechanical methods. There is dearth of literature on weed-management practices in candyleaf, thus the current experiment was designed to study the effect of plant spacing and weed-management practices on growth, yield and steviol glycoside content of candyleaf grown as a perennial crop under western Himalayas.

MATERIALS AND METHODS

The field experiment was conducted during 2015 and 2016 at the experimental farm of the CSIR (Council of Scientific and Industrial Research)-Institute of Himalayan Bioresource Technology, Palampur (32º06´05"N, 76º34´10"E, 1,325 m above mean sea-level) India. The experimental field soil was acidic (*p*H 4.94) with clayey texture, electrical conductivity of 0.06 m mhos/cm, high in organic matter (0.8%), low in available nitrogen (175.96 kg/ha), medium in available phosphorus (10.58 kg/ha) and high in available potassium (310.01 kg/ha). The climate of the location (Palampur) remains warm and temperate, with a temperature range of 9.2–35.4°C during the summer and 3.0–20.7°C during winter, and average rainfall of 2,690 mm. *Stevia* crop was transplanted in 2012, while the experiment was conducted during 2015–2016. During 2015–2016, vermicompost @ 2 t/ha was applied in March. Fertilizers @ 100-50-50 kg N-P-K/ha through urea, single superphosphate and muriate of potash, respectively, were applied.

Experiment comprised 2 factors, i.e. plant spacing (per 10 m^2) and weed management. Plant spacing factor had two levels, viz. 45 cm × 45 cm (49 plants/10 m^2) and 60 cm × 45 cm (37 plants/10 m^2). Five weed-management practices, viz. weedy check, weed-free control, hand-weeding at 40, 60 and 90 days after hoeing, protected spray of pendimethalin (30% EC) at 1.5 kg/ha (pre-emergence) followed by 1 hand-weeding (HW) at 40 days after spray (DAS) and protected spray of oxyfluorfen (23.5% EC) at 0.25 kg/ha (pre-emergence) followed by 1 HW at 40 DAS). Protected spray of the herbicides was done on the soil surface with the help of hood to the spray pump. The experiment consisted of 10 treatments with 3 replicates. Beds were prepared 1 m apart from each other.

An iron square quadrat of size 0.25 m^2 was used to take observations on weed population and weed dry weight. Quadrat was thrown randomly at 2 places in each plot number of weeds were counted and converted to per m^2. Weeds were randomly pulled by hand, identified and categorized into 3 types, i.e. broad leaf weeds (BLW), grasses and sedges. Fresh and dry biomass of BLW, grasses and sedges and total annual weeds/m^2 was recorded. The total number of weeds were counted species-wise in each plot separately and analyzed after subjecting the original values to square-root transformation. To calculate dry weight, weeds were ripped out from 0.25 m^2 area; roots were washed, sun-dried before drying in hot-air oven at 70°C until persistent weight was reached. Weed-control efficiency (WCE), herbicide-efficiency index (HEI) and weed-persistence index (WPI) were calculated as:

$$\text{WCE} = \frac{\text{WDC} - \text{WDT}}{\text{WDC}} \times 100$$

where WDC, weed dry weight in control and WDT, weed dry weight in treatment

$$\text{HEI} = \frac{\frac{\text{YT} - \text{YC}}{\text{YC}} \times 100}{\frac{\text{WDT}}{\text{WDC}} \times 100}$$

where, YT, yield from treatment; YC, yield from control; WDT, weed dry weight in treatment; and WDC= weed dry weight in control.

$$\text{WPI} = \frac{\text{WDT}}{\text{WDC}} \times \frac{\text{WCC}}{\text{WCT}}$$

where, WDT, weed dry weight in treatment; WDC, weed dry weight in control; WCC, weed count in the control; WCT, weed count in the treatment.

Different biometric observations such as plant spread, branches/plant, leaves/plant and chlorophyll-content index (CCI) were recorded from 5 selected plants/plot at harvesting stage (in June). Plant spread was taken in both north–south (N–S) and east–west (E–W) directions. Fresh and dry biomass was calculated from 5 random plants, that were uprooted and partitioned into leaf and stem. Harvesting was done at 50% flower bud stage, when the steviol glycosides (SG) concentration is highest. The stem samples were dried at 70ºC till complete drying, and the leaf samples were dried at 40ºC for 48 h in a hot-air oven. In order to measure CCI, Chlorophyll Content Meter 200 was used. The SG was extracted according to the procedure given by Kumar *et al.* (2014). Analysis of variance (ANOVA) was done to assess the difference between treatments by programming SYSTAT-12 of SYSTAT Software Inc., USA, which were separated by least-square difference (LSD) at 5% level. The weed number and weed dry weight information was examined after square root (x+1) transformation of the actual data (x) to enhance the homogeneity of difference (Shapiroe Wilk test). Design of the experiment was 2 factor factorial arrangement in randomized block design (RBD).

RESULTS AND DISCUSSION

Weed density

Prominent weeds present in the experimental field were *Cyperus* spp. *(C. rotundus* L., *C. iria* L. and *C. esculentus* L.*), Polygonum nepalense* (Meisn.) H. Gross, *Ipomoea purpurea* (L.) Roth., *Oxalis latifolia* Kunth*., Galinsoga parviflora* Cav., *Bidens pilosa* L., *Chenopodium album* L., *Cynodon dactylon* (L.) Pers., *Commelina benghalensis* L., *Eleusine compressa* Forssk. and *Amaranthus viridis* L. Plant spacing did not exert any significant effect on weed density (i.e. number of BLW, grasses and sedges), total weed density, weed-control efficiency, weed-persistence index and herbicide-efficiency index during 2015–16 (Table 1).

Significant variation in weed density was observed due to different weed-management practices. Significantly high weed density was observed in weedy check. Weed density of BLW, grasses and sedges and total weed density was significantly low in weed-free plots (Table 1). Oxyfluorfen at 0.25 kg/ha followed by 1 HW at 40 DAS recorded lowest BLW and total number of weeds as compared to the other weed-management practices. These results concur with those of others in suggesting that crops treated with oxyfluorfen successfully decrease BLW (Amador-Ramirez *et al.,* 2007). Pendimethalin at 1.5 kg/ha followed by 1 HW at 40 DAS resulted in significantly lower number of grasses. Likewise, sedges were significantly lowest in plots treated with oxyfluorfen at 0.25 kg/ha followed by 1 HW at 40 DAS as compared to weedy check but remained at par with pendimethalin at 1.5 kg/ha followed by 1 HW at 40 DAS and hand-weeded plot.

Phytotoxicity symptoms

The phytotoxicity of herbicides on *Stevia* plants was recorded at 12 and 24 DAS (days after spray). Pendimethalin caused no phytotoxicity but application of oxyfluorfen showed phytotoxicity symptoms (3.5–7.0%, i.e. more severe but not lasting based on European Weed Research Council recommendation) on *Stevia* plants by causing burning of upper leaf portion in the young leaves due to herbicidal drift on certain leaves but later the plants recovered and showed good growth.

Weed biomass

Plant spacing did not show any significant effect on weed dry biomass of BLW, grasses and sedges and total dry biomass (Table 2). Application of oxyfluorfen at 0.25 kg/ha followed by 1 HW at 40 DAS resulted in significantly lower dry weight of BLW and sedges than pendimethalin at 1.5 kg/ha followed by 1 HW at 40 DAS, but remained at par with hand-weeding. Pendimethalin at 1.5 kg/ha followed by 1 HW recorded significantly lower grasses and total weed dry biomass than the other weed-management practices. Oxyfluorfen at 0.25 kg/ha followed by 1 HW at 40 DAS and hand weeding remained statistically at par with each other in case of total weed dry biomass (Table 2). These results confirm the findings of

Table 1. Effect of plant spacing and weed-control treatments on weed population infesting candyleaf during 2015–16 (pooled data of 2 years)

Treatment	Number of weeds/m²			Total number of weeds/m²
	BLW	Grasses	Sedges	
Plant spacing				
45 cm × 45 cm	6.51 (56.00)	5.60 (41.60)	4.32 (41.06)	10.30 (138.66)
60 cm × 45 cm	6.28 (50.66)	6.21 (51.73)	5.52 (45.33)	10.82 (147.73)
SEm±	0.50	0.52	0.90	0.53
CD (P=0.05)	NS	NS	NS	NS
Weed-management				
Weedy check	9.79 (96.00)	9.81 (96.00)	9.86 (104.00)	17.20 (296.00)
Weed-free	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)
Hand-weeding	6.88 (50.66)	7.56 (60.00)	6.31 (62.66)	12.95 (173.33)
Pendimethalin at 1.5 kg/ha + 1 HW at 40 DAS	9.62 (97.33)	4.31 (26.66)	4.30 (30.66)	12.27 (154.66)
Oxyfluorfen at 0.25 kg/ha + 1 HW at 40 DAS	4.71 (22.66)	6.85 (50.66)	3.14 (18.66)	9.39 (92.00)
SEm±	0.79	0.82	1.42	0.85
CD (P=0.05)	2.35	2.44	4.22	2.52

BLW, Broad-leaf weed; HW, hand-weeding; DAS, days after spray

Weed density data were subjected to square-root $\sqrt{(x + 1)}$ transformation before analysis and original values are shown in parentheses

Singh *et al.,* (2017) in turmeric.

Weed-control indices

Weed-control indices were influenced considerably due to weed management practices. The highest weed-control efficiency (WCE) was recorded in oxyfluorfen at 0.25 kg/ha followed by 1 HW at 40 DAS (19.6% and 65.6%) (Fig. 1). Similar results were reported in chile pepper by Amador-Ramirez *et al.* (2007), while Pandey *et al.* (2001) reported higher WCE in pendimethalin-treated plots in maize. However, higher weed-control efficiency was observed by Harrington *et al.* (2011) in *Stevia* with pendimethalin. Herbicide-efficiency index and weed persistence index were significantly higher in oxyfluorfen at 0.25 kg/ha followed by 1 HW at 40 DAS and pendimethalin at 1.5 kg/ha followed by 1 HW at 40 DAS.

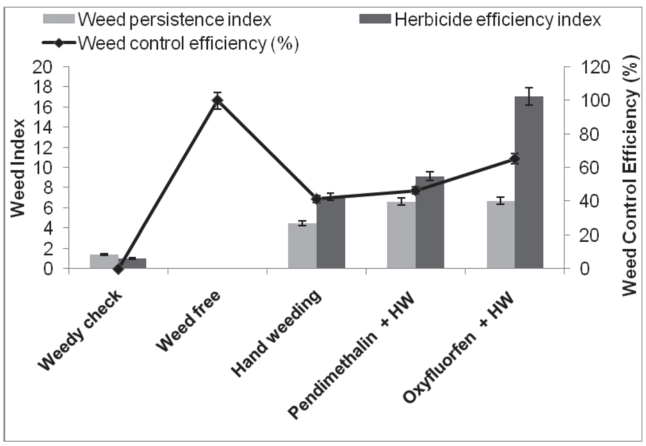

Fig. 1. Weed-control efficiency, herbicide-efficiency index and weed-persistence index of different weed-control treatments during 2015–16. Error bars represent LSD (Least significant difference) of 0.05

Growth parameters

Plant spacing did not show any significant effect on growth parameters of *Stevia* except number of branches and number of leaves (Table 3). *Stevia* planted in wider row spacing (60 cm × 45 cm) showed significantly higher number of branches than narrow row spacing (45 cm × 45 cm). However, number of leaves was significantly higher with 45 cm × 45 cm spacing. Number of branches was 13.92% higher in 60 cm × 45 cm spacing, while number of leaves was 19.14% higher in 45 cm × 45 cm. This is because in wider spacing plants grow and develop under reduced competition for environmental resources, especially light resulting in more lateral growth than upright growth with more branches and large-size leaves as compared to smaller size of leaves in the treatment with smaller spacing due to higher intraspecific competition among individuals resulting in more number of leaves. These results are in agreement with those of Kumar *et al.* (2016) in okra.

Number of branches was significantly higher in hand-weeding than the other weed-management practices but remained at par with oxyfluorfen at 0.25 kg/ha followed by 1 HW at 40 DAS and pendimethalin at 1.5 kg/ha followed by 1 HW at 40 DAS (Table 3). Significantly higher number of leaves was produced in plots applied with oxyfluorfen at 0.25 kg/ha followed by 1 HW at 40 DAS than the other weed management practices but remained at par with hand-weeding. Plant spread (N–S and E–W) was significantly higher in oxyfluorfen at 0.25 kg/ha followed by 1 HW at 40 DAS than the other weed-management practices. These results confirm the findings of Jadhav *et al.* (2015) in groundnut. The probable reasons for obtaining higher number of yield attributes, viz. branches, num-

Table 2. Effect of plant spacing and weed-control treatments on weed dry biomass during 2015–16 (pooled data of 2 years)

Treatment	Dry biomass (g/m^2)			Total dry biomass (g/m^2)
	BLW	Grasses	Sedges	
Plant spacing				
45 cm × 45 cm	8.05 (94.25)	6.44 (53.94)	4.11 (37.17)	11.73 (185.37)
60 cm × 45 cm	7.97 (133.83)	7.63 (87.89)	4.82 (35.97)	12.73 (257.71)
SEm±	0.79	0.43	0.50	0.44
CD (P=0.05)	NS	NS	NS	NS
Weed-management				
Weedy check	19.89 (425.40)	12.51 (169.49)	11.58 (135.68)	26.63 (730.58)
Weed-free	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)
Hand-weeding	6.35 (44.05)	8.05 (67.58)	4.09 (24.51)	11.60 (136.14)
Pendimethalin at 1.5 kg/ha + 1 HW at 40 DAS	8.38 (73.76)	3.81 (19.42)	3.32 (14.86)	10.39 (108.05)
Oxyfluorfen at 0.25 kg/ha + 1 HW at 40 DAS	4.43 (27.01)	9.81 (98.09)	2.31 (7.82)	11.53 (132.92)
SEm±	1.25	0.68	0.79	0.70
CD (P=0.05)	3.72	2.03	2.35	2.08

BLW, Broad-leaf weed; HW, hand-weeding; DAS, days after spray

Weed density data were subjected to square-root $\sqrt{(x + 1)}$ transformation before analysis and original values are shown in parentheses ber of leaves in oxyfluorfen-treated plot could be due to lesser weed competition faced by crop as herbicide application resulted in better weed control during initial stages of the crop growth. Plant spacing and herbicide treatments did not show any significant effect on CCI.

Biomass

Leaf biomass (fresh and dry) and total biomass (leaf and stem) were significantly higher in 45 cm × 45 cm spacing than 60 cm × 45 cm (Table 4). Narrow-spaced plots exhibited 31.0, 32.9 and 40.5% higher mean fresh leaf, dry leaf and total biomass, respectively, than wider spacing. The reason could be that closer spacing resulted in significantly taller plants credited to competition for light producing a noteworthy increment in leaf area and number which thus produces higher biomass.

Among weed-management practices, fresh leaf biomass and dry leaf biomass (kg/ha) were significantly higher in oxyfluorfen at 0.25 kg/ha fb 1 HW at 40 DAS than weedy check but remained at par with pendimethalin at 1.5 kg/ha followed by 1 HW at 40 DAS and hand-weeding (Table 4). Total dry biomass (kg/ha) was significantly higher in oxyfluorfen at 0.25 kg/ha followed by 1 HW at 40 DAS compared to the other treatments but remained statistically at par with hand-weeding. Pandey *et al.* (2001) also reported similar findings in maize. Plant spacing and herbicide treatments did not show any significant effect on leaf : stem ratio.

Table 3. Effect of plant spacing and weed-control treatments on growth parameters of candyleaf during 2015–16 (pooled data of 2 years)

Treatment	Number of branches/ plant	Number of leaves/ plant	Plant spread (cm)		CCI at harvest
			N–S	E–W	
Plant spacing					
45 cm × 45 cm	26.79	1792.58	37.26	37.43	22.28
60 cm × 45 cm	30.52	1504.82	38.28	38.14	22.03
SEm±	0.86	81.83	1.09	0.89	0.51
CD (P=0.05)	2.56	243.04	NS	NS	NS
Weed-management					
Weedy check	10.23	204.26	20.61	18.70	21.59
Weed-free	41.90	2583.73	45.70	45.67	21.62
Hand-weeding	31.44	1866.48	40.78	42.79	22.52
Pendimethalin at 1.5 kg/ha + 1 HW at 40 DAS	29.01	1578.20	37.45	37.75	21.84
Oxyfluorfen at 0.25 kg/ha + 1 HW at 40 DAS	30.70	2010.83	44.30	44.03	23.19
SEm±	1.36	129.39	1.73	1.41	0.81
CD (P=0.05)	4.05	384.28	5.14	4.21	NS

N–S, North–south; E–W, east–west; CCI, chlorophyll content index; HW, hand weeding; DAS, days after spray

Table 4. Effect of plant spacing and weed-control treatments on yield parameters of candyleaf during 2015–16 (pooled data of 2 years)

Treatment	Fresh leaf biomass (kg/ha)	Dry leaf biomass (kg/ha)	Total dry biomass (kg/ha)	Leaf/stem ratio
Plant spacing				
45 cm × 45 cm	6,248.98	1,481.32	3,914.65	0.82
60 cm × 45 cm	4,768.00	1,114.65	2,784.02	0.71
SEm±	226.10	54.00	120.20	0.03
CD (P=0.05)	671.35	136.81	356.97	NS
Weed-management				
Weedy check	1,186.19	239.38	712.11	0.81
Weed-free	8,320.85	2,008.21	4,906.93	0.75
Hand-weeding	5,876.58	1,369.99	3,843.32	0.78
Pendimethalin at 1.5 kg/ha + 1 HW at 40 DAS	5,999.71	1,377.43	3,028.02	0.85
Oxyfluorfen at 0.25 kg/ha + 1 HW at 40 DAS	6,159.13	1,498.90	4,256.45	0.65
SEm±	357.40	86.00	190.10	0.05
CD (P=0.05)	1,061.51	257.42	564.42	NS

HW, hand-weeding; DAS, days after spray

Steviol glycosides

Plant spacing did not show any significant effect on Reb-A% and Reb-A/St ratio except St (%), total St+Reb-A and total SG yield (%) (Table 5). The St% and total SG concentration (St+Reb-A%) were significantly higher in wider spacing than narrow spacing, while opposite trend was observed in case of total SG yield (kg/ha). Although Reb-A% did not show any significant effect but was found higher in wider spacing. These findings concur with those of Kumar *et al*. (2014), who had reported that wider spacing recorded higher concentration of marker compound in *S. rebaudiana*. Hand-weeding recorded significantly higher St (%), Reb-A (%), total steviol glycoside concentration (St+Reb-A%) and total SG yield (kg/ha) in comparison to the other weed-management practices but remained at par with pendimethalin at 1.5 kg/ha followed by 1 HW at 40 DAS which was similar to findings of Angelini *et al.* (2018) (Table 5, Fig. 2).

Economics

Cost of cultivation was significantly higher in narrow spacing while significantly higher gross returns, net returns and benefit: cost ratio were found in wider spacing. Among the weed-management practices, oxyfluorfen at 0.25 kgs/ha followed by 1 HW at 40 DAS recorded significantly higher cost of cultivation, gross returns, net returns and benefit: cost ratio but remained at par with pendimethalin at 1.5 kg/ha followed by 1 HW at 40 DAS

Table 5. Effect of plant spacing and weed-control treatments on steviol glycoside concentration (%) of candyleaf after harvest during 2015–16 (pooled data of 2 years)

Treatment	St %	Reb-A %	Total % (St + Reb-A)	Total SG yield (kg/ha)	Reb-A/St ratio
Plant spacing					
45 cm × 45 cm	6.45	2.90	9.35	133.45	0.50
60 cm × 45 cm	7.55	3.45	11.05	117.35	0.50
SEm±	0.30	0.30	0.40	7.95	0.10
CD (P=0.05)	1.30	NS	1.30	25.6	NS
Weed-management					
Weedy check	6.65	3.80	10.45	20.20	0.55
Weed-free	5.80	2.50	8.35	162.35	0.50
Hand-weeding	8.25	3.80	12.05	168.30	0.50
Pendimethalin at 1.5 kg/ha + 1 HW at 40 DAS	7.50	3.35	10.85	153.45	0.50
Oxyfluorfen at 0.25 kg/ha + 1 HW at 40 DAS	6.70	2.50	9.25	122.65	0.35
SEm±	0.50	0.50	0.60	12.60	0.10
CD (P=0.05)	1.40	1.10	1.30	37.45	NS

St, Stevioside; Reb-A, rebaudioside; SG, steviol glycoside; HW, hand-weeding; DAS, days after spray

Table 6. Effect of plant spacing and weed-control treatments on economics of candyleaf during 2015–16 (pooled data of 2 years)

Treatment	Cost of cultivation (× 10^4 ₹/ha)	Gross return (× 10^4 ₹/ha)	Net return (× 10^4 ₹/ha)	Benefit: cost ratio
Plant spacing				
45 cm × 45 cm	10.37	22.21	11.84	1.05
60 cm × 45 cm	10.58	16.71	6.34	0.52
SEm±	0.25E-05	0.82	0.82	0.07
CD (P=0.05)	0.24E-05	2.44	2.44	0.23
Weed-management				
Weedy check	8.03	3.59	–4.44	–0.55
Weed-free	12.52	30.12	17.60	1.41
Hand-weeding	10.27	20.54	10.27	1.00
Pendimethalin at 1.5 kg/ha + 1 HW at 40 DAS	10.52	20.66	10.13	0.96
Oxyfluorfen at 0.25 kg/ha + 1 HW at 40 DAS	10.53	22.42	11.88	1.12
SEm±	0.41E-05	1.30	1.30	0.12
CD (P=0.05)	0.38E-05	3.86	3.86	0.36

HW, hand-weeding; DAS, days after spray

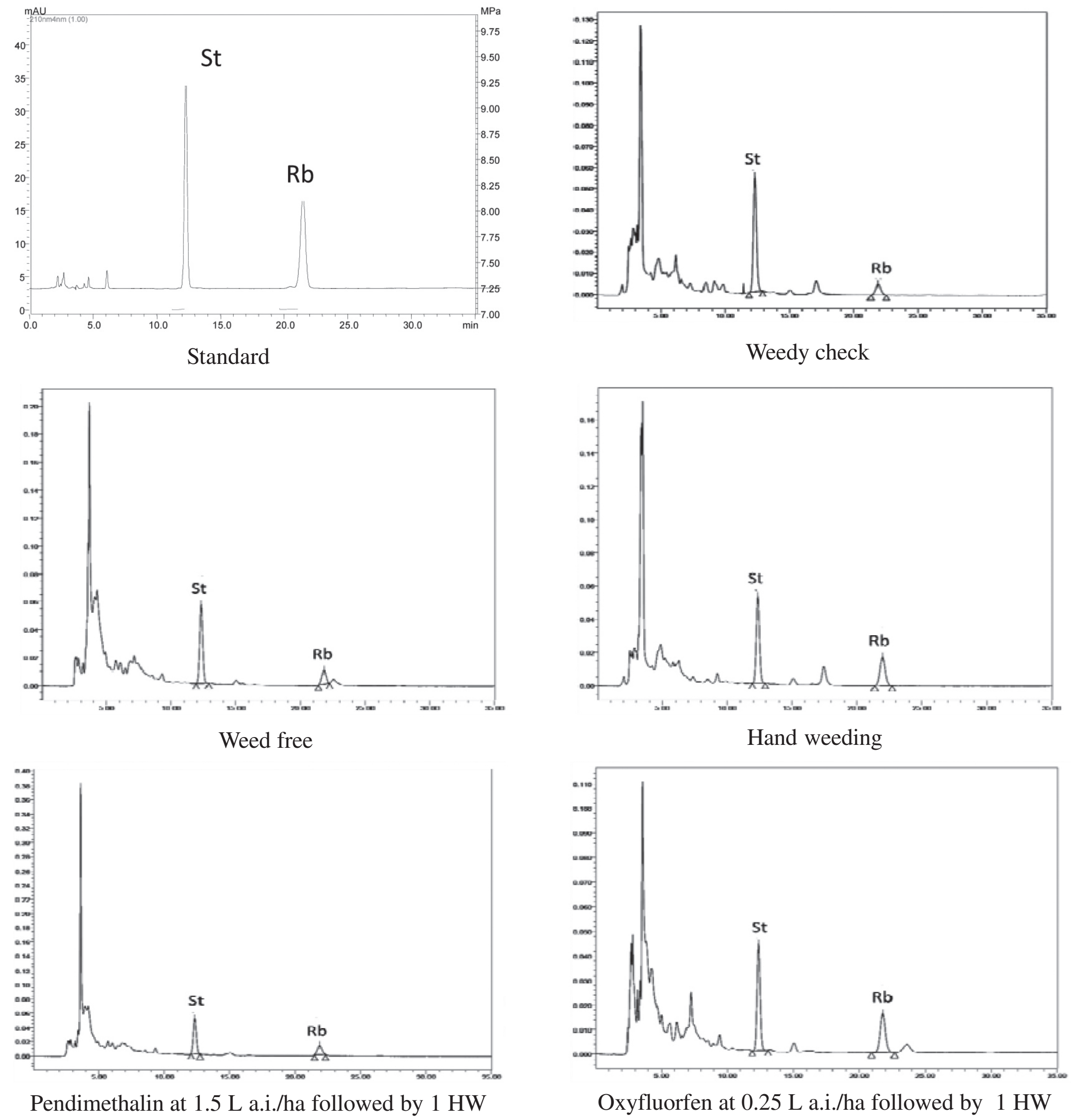

Fig. 2. Steviol glycosides accumulation in different weed-control treatments as compared to standard at harvest. St, Stevioside; Rb, Rebaudioside

and hand-weeding (Table 6). Singh *et al.* (2017) also noticed that application of oxyfluorfen resulted in significantly higher net returns and benefit: cost ratio.

Thus in candyleaf or sweet leaf, weed-management practices were effective in minimizing weed density and biomass. Application of oxyfluorfen at 0.25 kg/ha followed by 1 HW at 40 DAS along with 45 cm × 45 cm spacing is best for the production of higher leaf biomass and steviol glycosides in perennial candyleaf crop grown under western Himalayas.

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