Indian Journal of Agronomy **67** (1): 82–88 (March 2022)

Research Paper

Impact of weed management practices on weeds and okra crop

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Received: August 2020; Revised accepted: January 2022

ABSTRACT

A preliminary study was conducted during the summer of 2014 and 2015 at the N.M. College of Agriculture, Navsari Agricultural University, Navsari, Gujarat, India to evaluate the 10 treatments of weed-management, i.e. stale seedbed, pre- and post-emergence herbicides alone and in combination, integrated weed-management and hand-weeding in summer okra [*Abelmoschus esculentus* (L.) Moench]. Almost 73.2% of weed infestation was dominated by grasses and sedges, followed by broad-leaf weeds (26.8%). Uncontrolled weed growth caused significant reduction in mean green pod yield of okra by 67%. Weed-free plot [3 hand-weedings (HW) at 20, 40 and 60 days after sowing (DAS)] showed the maximum weed-control efficiency (WCE) (88.4%), resulting in higher green pod yield (16.8 t/ha) and net returns (₹105,233/ha). Statistically at par yields were also obtained from plots treated with not incorporated and 2 HW at 20 and 40 DAS (14.3 t/ha) and pendimethalin 1.0 kg/ha followed by (*fb*) quizalofop-ethyl 0.04 kg/ha at 30 DAS (13.9 t/ha) with net returns of ₹83,442 and ₹82,277/ha respectively. Application of pendimethalin 1.0 kg/ha (pre) *fb* quizalofop ethyl 0.04 kg/ha at 30 DAS supressed the weeds effectively (71.3% WCE) which not only reduced the drudgery of farm labour but also found practically more convenient and economically feasible weed-management option for higher production of okra fruit crop.

Key words: Okra, Oxyfluorfen, Pendimethalin, Quizalofop ethyl, Stale seedbed, Weed management

Okra [*Abelmoschus esculentus* (L.) Moench] is one of the most popular vegetables of India. It is grown throughout the tropical and subtropical regions and in the warmer parts of the temperate regions. Okra has good potential as a foreign-exchange crop and accounts for 60% of the export of fresh vegetables (Sah *et al.*, 2018). It is the lucrative vegetable used in many ways; immature fruits are consumed in the form of fry, boiled, curries etc., stems and roots for clearing of cane juice, possesses medicinal properties to treat inflammation of a mucous membrane, coughing, gonorrhea and (Kanaujia *et al.*, 2017). The crop is also used in paper industry as well as for the extraction of fibre. It is one of the most important fruit vegetable crops and a source of calorie (4,550 Kcal/kg) for human consumption (Babatunde *et al.*, 2007). Okra is rich in vitamins and mineral salts such as calcium, phosphorus, magnesium and iron and it is very valuable with regards to anti-carcinogenicity, human-immunity promotion and ageing prevention (AVRDC, 1991). India ranks first in the world, with 6.37 million tonnes of okra produced from over 0.52 million ha land and productivity of 12.3 t/ ha (NHB, 2020–21). Crop is infested by repeated flushes of diversified weed flora throughout its growing season and weed competition is especially greater in a direct-seeded vegetable like okra. The crop-weed competition remains maximum during the early growth stage which slows initial growth rate of the crop and consequently causes poor competitive ability. The uncontrolled weeds exert severe competition for nutrients, water and light, resulting in reduced pod yield of okra by 73–75% (Imoloame and Muinat, 2018), 78–85% (Sah *et al.*, 2018) and 61.99% (Dhivya *et al.,* 2021), depending on the type of weed flora, their intensity and stages. Continuous monitoring and refinement in management strategies is essential for alleviating adverse effects of weeds on agricultural productivity and environmental health (Rao and Nagmani, 2013). Hand-weeding is a predominant weed-control method used by farmers. However, it is very tedious, sometime inefficient, time-consuming and associated with high labour demands (Adigun *et al.*, 2018; Patel *et al.*, 2020). Besides, availability of labour for manual weeding is scarce and often too expensive (Adigun *et al.*, 2017). Hence, use of herbicide in sequence or in combination with other weed-management practices is more advis-

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able for farmers for season-long weed control. We hypothesized that, integration of physical and chemical (alone or sequential) weed-management practices could help improve weed-control efficiency, reduce the high cost associated with multiple hand-weeding and increase the yield of summer okra.

MATERIALS AND METHODS

The experiment was conducted at College Farm, N.M. College of Agriculture, Navsari Agricultural University, Navsari, Gujarat, India, during summer 2014 and 2015, to found out the most suitable weed-management practices in summer okra. All the treatments were arranged in a randomised complete block design with three replications. Total 10 treatments, comprising stale seedbed by using glyphosate 1.0 g/ha (W_1), pendimethalin 1.0 kg/ha as pre-emergence (PE:W_2), oxyfluorfen 0.24 kg/ha as PE (W_3), pendimethalin 1.0 kg/ha as PE *fb* quizalofop ethyl 0.040 kg/ha at 30 days after sowing (DAS: W_4), oxyfluorfen 0.24 kg/ha as PE *fb* quizalofop ethyl 0.040 kg/ha at 30 days after sowing (DAS: W_5), quizalofop ethyl 0.040 kg/ha at 20 DAS *fb* hand-weeding (HW) at 40 DAS (W_6), HW + straw mulch 3 t/ha at 20 DAS (W_7), 2 HW at 20 and 40 DAS (W_8), 3 HW at 20, 40 and 60 DAS (Weed-free: W_9) and weedy check (control: W_{10}), were included for comparison. The soil was clay in texture, having 0.59% organic C, medium in available nitrogen (224 kg/ha) and phosphorus (40 kg/ha), fairly rich in available potassium (362 kg/ha) and slightly alkaline in reaction (*p*H 7.6) with normal electrical conductivity. The gross and net plot sizes in both years were: 4.5 m × 3.0 m and 2.7 m × 2.4 m respectively. Alleyways of 2 m and 1 m were left between blocks and adjacent plots respectively.

The seeds of okra was sown in the well-prepared beds by dibbling at 2 seeds/hill, later thinned after full emergence to 1 plant/hill. There were 10 rows in gross plot and 6 rows in net plot size with a uniform distance of 45 cm between rows and 30 cm distance between plant to plant. The sowing was done in first half of February during both years. Well-decomposed FYM 10 t/ha was uniformly applied to all the experimental units commonly. The field was fertilized with recommended doses of N : P : K (150 : 100 : 100 kg/ha). Nitrogen applied in 2 splits, half as basal along with full dose of phosphorus and potash and remaining half nitrogen was top dressed 30 days after sowing. The plant-protection measures were taken up to control pest and diseases as and when required. Recommended package of practices were adopted to raise the crop except weed control. In stale seedbed treatment to facilitate weed emergence, light irrigation was applied 25 days before sowing and the first flush of weeds was controlled by application of glyphosate 1.0 kg/ha using a knapsack sprayer, fitted with flat-fan nozzle with spray volume of 440 litres/ha. Pre emergence herbicides were applied a day after sowing and post-emergence herbicides were applied as per treatment with knapsack sprayer fitted, with flat fan nozzle and a spraying volume was 500 litres/ha. In each plot, 10 plants were tagged for taking all observations. First picking was started 52 days after sowing and subsequent pickings were done at alternate days. Pod yield was estimated on per plot basis and converted in pod yield per hectare in tonnes.

Data on weed density and weed dry matter (weed biomass) were collected using a 1 m × 1 m quadrat, placed randomly within each plot. Weeds sampled from the quadrat were counted and oven–dried at 65 °C for 72 h, after which they were weighed. Data on weed population were transformed through square root [$\sqrt{(x+1)}$] method before statistical analysis. Weed-control efficiency was calculated as per Mani *et al.* (1973) and weed index as suggested by Gill and Vijay (1969). Treatment-wise economics were calculated by considering prevailing market price. The data were subjected to Fisher's analysis of variance technique using "MSTATC" statistical software and $p \leq 0.05$ probabilities was applied to compare the differences among treatments' means.

RESULTS AND DISCUSSION

Effect on weeds

Weed flora composition: The weed flora covered 18 species spread over 7 plant families among which the Poaceae family had the highest number of species and infestation. *Echinochloa* spp., Bermuda grass [*Cynodon dactylon* (L.) Pers.], browntop millet [*Brachiaria ramosa* (L.) Stapf], fieldbind weed (*Convolvulus arvensis* L.), horse purslane (*Trianthema portulacastrum* L.), *Digera arvensis*, and nut grass (*Cyprus rotundus* L.) weeds which had high infestation in the early season were found with moderate infestation in the late season. The composition of narrow (grasses and sedge) and broad-leaf weeds in weedy check plot was 73.2 and 26.8 respectively. The crop experienced severe weed competition during investigation which might be due to favourable environmental conditions leading to vigorous growth of weeds.

Weed density: Implementations of various weed-management treatments had significant influence on weed density and weed dry weight during the crop growth (Tables 1, 2). Significantly higher density of monocot, dicot, sedges and total weeds was observed in weedy check, followed by oxyfluorfen 0.24 kg/ha alone at various growth stages, i.e. 20 and 40 days after sowing (DAS) and at harvesting. Uninterrupted growth of weeds with maximum utilization of the resource like moisture, nutrient, and sun light offered stiff competition to the crop and might have be the unavoidable reason for such result.

Table 1. Weed density at 20 and 40 days after sowing (DAS) as influenced by weed management in summer okra

Treatment	Dose (kg/ha)	Weed density/m²							
		20 DAS				40 DAS			
		Monocot	Dicot	Sedges	Total	Monocot	Dicot	Sedges	Total
Stale seed bed	-	4.41 (18.5)	3.67 (12.7)	4.34 (18.0)	7.07 (49.2)	5.56 (30.0)	4.87 (22.7)	5.27 (27.0)	8.98 (79.7)
Pendimethalin (PE)	1.0	5.01 (24.2)	3.81 (13.5)	4.74 (21.7)	7.75 (59.5)	5.57 (30.5)	4.64 (20.5)	5.17 (26.2)	8.82 (77.2)
Oxyfluorfen (PE)	0.24	5.36 (28.2)	4.77 (22.0)	5.29 (27.2)	8.81 (77.5)	6.00 (35.2)	5.48 (29.2)	6.26 (38.2)	10.18 (102.7)
Pendimethalin (PE) *fb* quizalofop ethyl at 30 DAS	1.0+0.04	4.48 (19.2)	4.18 (16.7)	5.27 (27.5)	7.99 (63.5)	3.45 (11.0)	4.51 (19.5)	4.43 (18.7)	7.08 (49.2)
Oxyfluorfen (PE) *fb* quizalofop ethyl at 30 DAS	0.24+0.04	5.44 (29.0)	4.92 (23.5)	5.70 (31.7)	9.22 (84.2)	4.84 (22.5)	5.33 (27.5)	5.07 (24.7)	8.70 (74.7)
Quizalofop ethyl at 20 DAS *fb* hand-weeding at 40 DAS	0.04	5.92 (34.5)	6.06 (36.0)	6.57 (42.2)	10.64 (112.7)	4.74 (21.7)	5.66 (31.0)	4.74 (21.5)	8.67 (74.2)
Hand-weeding *fb* straw mulch 3 t/ha at 20 DAS	–	6.00 (35.2)	5.59 (30.2)	6.26 (38.5)	10.24 (104.0)	4.30 (17.5)	4.50 (19.2)	5.19 (26.0)	7.98 (62.7)
2 hand-weeding at 20 and 40 DAS	–	6.22 (38.7)	5.75 (32.2)	6.37 (39.7)	10.57 (119.0)	3.88 (14.2)	4.35 (18.0)	4.87 (23.0)	7.48 (55.2)
Weed-free check (3 hand-weeding at 20, 40 and 60 DAS)	–	5.92 (34.0)	5.65 (31.0)	6.28 (38.5)	10.22 (103.5)	3.63 (12.2)	3.93 (14.7)	4.17 (16.5)	6.66 (43.5)
Weedy check (control)	–	6.89 (47.0)	6.07 (37.5)	6.63 (43.0)	11.29 (119.2)	6.77 (45.2)	5.95 (34.7)	6.47 (41.0)	11.02 (121.0)
SEm±		0.34	0.31	0.38	0.34	0.26	0.21	0.23	0.28
CD (P=0.05)		1.10	0.99	1.21	1.09	0.84	0.65	0.75	0.88

*Data in parentheses indicate original value of weeds and outside the bracket the transformed value of $\sqrt{X+1}$

At 20 DAS, stale seedbed technique and pre-emergence application of pendimethalin 1.0 kg/ha or oxyfluorfen 0.24 kg/ha significantly reduced the weed population in comparison to the weedy check and other weed-management practices those initiated 20 days after sowing. It undoubtedly indicated that, pre-emergence application of herbicides inhibited the growth of newly germinated weed seeds and/or seedlings. Thus, it significantly reduced the total weed population during the initial periods of crop growth. Further, at 40 DAS, weed-free [hand-weeding (HW) at 20, 40 and 60 DAS], HW at 20 and 40 DAS, HW + straw mulch 3 t/ha at 20 DAS and application of pendimethalin 1.0 kg/ha (PE) *fb* quizalofop-ethyl 0.04 kg/ha at 30 DAS were equally effective by significantly dropping down the monocot, dicot and sedges population, except HW + straw mulch 3 t/ha at 20 DAS that as failed to show significant influence on sedges. It clearly indicated that, pre- and post-emergence application of herbicides and hand-weeding at various stages significantly reduced the total weed population considerably that elevated the initial period of crop-weed competition. Further, the population of nut grass was not influenced much more due to different herbicidal application, because, perennial-nature and underground network of this weed; however, the treatments having hand-weeding directly influenced the sedges population. At harvesting, significantly lower monocot and sedge weed density were noticed under 3 hand-weeding at 20, 40 and 60 DAS, but found at par with 2 hand-weeding at 20 and 40 DAS and application of pendimethalin 1.0 kg/ha (PE) *fb* quizalofop-ethyl 0.04 kg/ha at 30 DAS. Moreover, dicot and total weeds density were minimum under both 2 (20 and 40 DAS) and 3 (20, 40 and 60 DAS) hand-weeding treatments. The possible reasons responsible for reduction in weed population under pendimethalin was that the pre-emergence applied herbicides absorbed by germinating weeds and inhibits early seedling growth shortly after seed germination by the disruption of cell-division. The weeds sustained to the above herbicide, germinated later on were knock down by hand-weeding practice or quizalofop ethyl application (narrow-leaf weeds) which ensured reduced population. Efficacy of the pre-emergence herbicides alone failed to contribute much in weed control because on fact that, application of herbicide inhibited the germination and emergence of weeds during initial growth stage of crop only but at later stages, these herbicides dissipated and deactivated in the soil and next flush of weeds appeared in such plots. Effectiveness of various herbicides against different weed species in okra crop have been reported by many workers including Sharma and Patel (2011), Mathukia *et al.* (2018) and Dhivya *et al.* (2021).

Weed dry weight: Weed-management practices significantly reduced the dry weight of weeds at 40 DAS and at harvesting. Adoption of 3 hand-weeding at 20, 40 and 60 DAS resulted in significantly less amount of weed dry matter (17.1 g/m^2 and 119.4 kg/ha), but found at par with 2 hand-weeding at 20 and 40 DAS (21.6 g/m^2 and 183.5 kg/ha) followed by pendimethalin 1.0 kg/ha (PE) *fb* quizalofop-ethyl 0.04 kg/ha at 30 DAS (24.8 g/m^2 and 281.5 kg/ha). Lower weed dry weight recorded in these treatments because of removing weed at regular interval through hand-weeding accounted for less count of monocots, dicots and sedges. Further, lower dry weight of weeds was registered with pendimethalin *fb* quizalofop ethyl because application of pendimethalin checks the germination of weed seeds and controls the establishment of many annual broad-leaf weeds and grasses, whereas, post emergence application of quizalofop ethyl controls the later-emerged grassy weeds which resulted in lower dry weight of weeds. Overall, response may be due to killing the weeds by itself with time and herbicide compound would be very active during the initial period of application; however, during later stage hand-weeding found to be superior to herbicide application might be owing to gradual decomposition of herbicide compound as the day proceeds. Significantly highest dry weight of weeds (46.1 g/m^2 and 1047.1 kg/ha) was recorded with weedy check because weeds were allow to grow in plot throughout the crop-growth period, ultimately increased the population of weeds and dry weight of weeds under this treatment. Our results confirm the findings of Mathukia *et al.* (2018), Patel *et al.* (2020) and Dhivya *et al.* (2021).

Weed indices: Different weed-management treatments exerted their remarkable effect on weed index and weed-control efficiency (WCE, Table 2). The range of WCE among different weed-management practices varied between 45.9 and 88.4% over the weedy check. The highest weed control efficiency (WCE) was recorded under weed free treatment (3 hand-weeding at 20, 40 and 60 DAS:

Table 2. Effect of weed-management, weed density, dry weight of weeds and weed indices in summer okra

Treatment	Dose (kg/ha)	Weed density/m^2 at harvest								Dry weed biomass		WCE (%)	WI (%)
		Monocot		Dicot		Sedges		Total		40 DAS (g/m^2)	Harvest (kg/ha)		
Stale seed bed	-	6.45	(40.7)	5.14	(25.5)	5.76	(32.2)	9.97	(98.5)	30.4	556.0	45.9	51.3
Pendimethalin (PE)	1.0	6.02	(35.2)	4.95	(23.5)	5.54	(30.0)	9.46	(88.7)	29.1	502.8	51.2	48.7
Oxyfluorfen (PE)	0.24	6.40	(40.0)	5.87	(33.5)	6.59	(42.5)	10.82	(116.0)	39.2	649.9	37.2	49.9
Pendimethalin (PE) *fb* quizalofop ethyl at 30 DAS	1.0+0.04	3.27	(9.7)	4.62	(20.5)	3.12	(8.7)	6.32	(39.0)	24.8	281.5	73.1	16.1
Oxyfluorfen (PE) *fb* quizalofop ethyl at 30 DAS	0.24+0.04	5.54	(29.7)	5.79	(32.7)	5.70	(31.5)	9.74	(94.0)	29.7	537.9	48.1	42.6
Quizalofop ethyl at 20 DAS *fb* hand-weeding at 40 DAS	0.04	3.56	(11.7)	4.39	(18.2)	4.66	(20.7)	7.19	(50.7)	30.1	299.6	70.9	24.8
Hand-weeding *fb* straw mulch 3 t/ha at 20 DAS	–	4.80	(22.2)	5.36	(27.7)	5.63	(30.7)	9.04	(80.7)	24.3	470.7	54.2	47.5
2 hand-weeding at 20 and 40 DAS	–	3.20	(9.2)	3.31	(10.0)	3.03	(8.25)	5.34	(27.5)	21.6	183.5	82.1	14.1
Weed-free check (3 hand-weeding at 20, 40 and 60 DAS)	–	2.64	(6.0)	2.77	(6.7)	2.95	(7.7)	4.63	(20.5)	17.1	119.4	88.4	0.0
Weedy check (control)	–	7.16	(51.0)	6.15	(37.2)	7.13	(50.7)	11.74	(139.0)	46.1	1047.1	0.0	67.0
SEm±		0.22		0.18		0.23		0.30		1.88	26.81	–	–
CD (P=0.05)		0.72		0.58		0.74		0.97		6.00	85.76	–	–

*Data in parentheses indicate original value of weeds and outside the bracket the transformed value of $\sqrt{X+1}$

WCE, Weed-control efficiency; WI, weed index; DAS, days after sowing

88.4%), followed by 2 hand-weeding at 20 and 40 DAS (82.1%) and application of pendimethalin 1.0 kg/ha (PE) *fb* quizalofop-ethyl 0.04 kg/ha at 30 DAS (73.1%).

Weed index is the indication of reduction in crop yield due to presence of weeds in comparison with weed-free check, which is an ideal parameter to judge the bioefficacy of a particular herbicide or weed-management practices in the associated crop (Yadav *et al.,* 2016). The weed index among different treatments was found to be in the range of 0–67%. The maximum reduction in crop yield due to presence of weeds by 67% was found under weedy check plot, followed by stale seedbed (51.3%). Hand-weeding at 20 and 40 DAS (14.1%) and application of pendimethalin 1.0 kg/ha (PE) *fb* quizalofop-ethyl 0.04 kg/ha at 30 DAS (16.1%) was also found more effective in controlling the weeds in the okra crop as next 2 superior treatments after weed-free cheek. These findings are in line with those of Patel *et al.* (2004), Shivalingappa *et al.* (2014), and Dhivya *et al.* (2021).

Effect on crop

Various yield attributes, viz. diameter, weight and length of fruit, play vital role in increasing the productivity of okra crop which were favourably influenced by the weed-management treatments (Table 3). Significantly, higher value of all said parameters was recorded under weed-free (HW at 20, 40 and 60 DAS), while lower was recorded in the weedy check. In case of okra, fruit diameter, weight and length, it was found at par with treatments of 2 HW at 20 and 40 DAS, combination of pre- and post-emergence herbicides (pendimethalin 1.0 kg/ha *fb* quizalofop ethyl 0.04 kg/ha) and integrated weed-management practices. In general for most of the yield parameters, all the weed-management practices performed significantly superior to weedy check except stale-seedbed technique and alone application of pendimethalin and oxyfluorfen herbicides for stem diameter. Growth is the function of photosynthetic activity of the okra plant and its capacity to utilize available nutrients. Therefore, it was due to favourable environment in the root zone, resulting in absorption of more water and nutrients from soil and good control of weeds which ultimately resulted in less crop-weed competition throughout the growth of crop. Thus, enhanced availability of nutrients, water, light and space, which might have accelerated the photosynthetic rate, thereby increasing the supply of carbohydrates, which ultimately resulted in increase in plant height, number of leaves, and dry-matter accumulation which reflected in term of higher fruit length, fruit diameter and average fruit weight. Our findings support the observations of Pandey and Mishra (2013) and Shivalingappa *et al.* (2014) and Patel *et al.* (2018).

Higher fresh fruit yield (16.8, 14.3 and 13.9 t/ha respectively) were obtained under treatment 3 hand-weeding at 20, 40 and 60 DAS, which was followed by treatments 2 HW at 20 and 40 DAS and pendimethalin 1.0 kg/ha as pre-emergence + quizalofop ethyl 0.040 kg/ha at 30 DAS. Improved yield under these treatments may be owing to better control of weeds from the initial stage by periodical removal of weeds either by hand-weeding or combined application of pre and post-emergence herbicide, as evident by reduced crop-weed competition under these treatments; thus saved a huge amount of nutrients for crop which led to profuse growth enabling the crop to utilize more soil moisture and nutrients from deeper soil layers. All these favourable effects of weed management treatments resulted in significant increase in various yield-determining characters, providing better source sink relationship. The significantly higher values of yield attributes coupled with higher

Table 3. Effect of weed management on yield and its attributes, production efficiency and monetary efficiency of summer okra

Treatment	Dose (kg/ha)	Diameter (cm)	Fruit Weight (g)	Length (cm)	Fruit yield (t/ha)	Efficacy	
						Production (kg/ha/day)	Monetary (₹/ha/day)
Stale seed bed	–	1.47	11.05	11.10	8.0	75.5	224.3
Pendimethalin (PE)	1.0	1.43	11.23	11.89	8.5	80.2	276.8
Oxyfluorfen (PE)	0.24	1.41	10.17	11.07	8.3	78.3	269.9
Pendimethalin (PE) *fb* quizalofop ethyl at 30 DAS	1.0+0.04	1.69	11.30	12.25	13.9	131.1	776.2
Oxyfluorfen (PE) *fb* quizalofop ethyl at 30 DAS	0.24+0.04	1.58	10.38	12.10	9.6	90.6	371.9
Quizalofop ethyl at 20 DAS *fb* hand-weeding at 40 DAS	0.04	1.66	11.23	12.23	12.5	117.9	627.4
Hand-weeding *fb* straw mulch 3 t/ha at 20 DAS	–	1.59	10.87	11.03	8.7	82.1	224.5
2 hand-weeding at 20 and 40 DAS	–	1.67	11.51	12.19	14.3	134.9	787.2
Weed-free check (3 hand-weeding at 20, 40 and 60 DAS)	–	1.74	12.61	13.63	16.8	158.5	992.8
Weedy check (control)	–	1.30	8.83	7.31	5.5	51.9	12.3
SEm±		0.07	0.47	0.49	0.90		
CD (P=0.05)		0.21	1.50	1.55	2.9		

crop dry-matter obtained under these treatments could be the most probable reason of higher fruit yield.

Undoubtedly, weedy check gave significantly lowest fruit yield (5.5 t/ha) of okra crop (Table 3). In the presence of weeds, though the vegetative growth of the crop attained a level but sink was not sufficient to accumulate the meaningful food assimilates translocation towards seed formation. Besides, the most severe crop-weed competition throughout the season due to unrestricted weed growth under weedy check plots encouraged the depletion of nutrients and moisture by weeds, thus adversely affecting the crop growth. It also declined the translocation of photosynthates towards seed formation affecting yield attributes adversely, which turn reduced the yield to the lowest level. The findings are in closely vicinity of those reported by Sharma and Patel (2011), Patel *et al.* (2020) and Dhivya *et al.* (2021) with respect to okra yield.

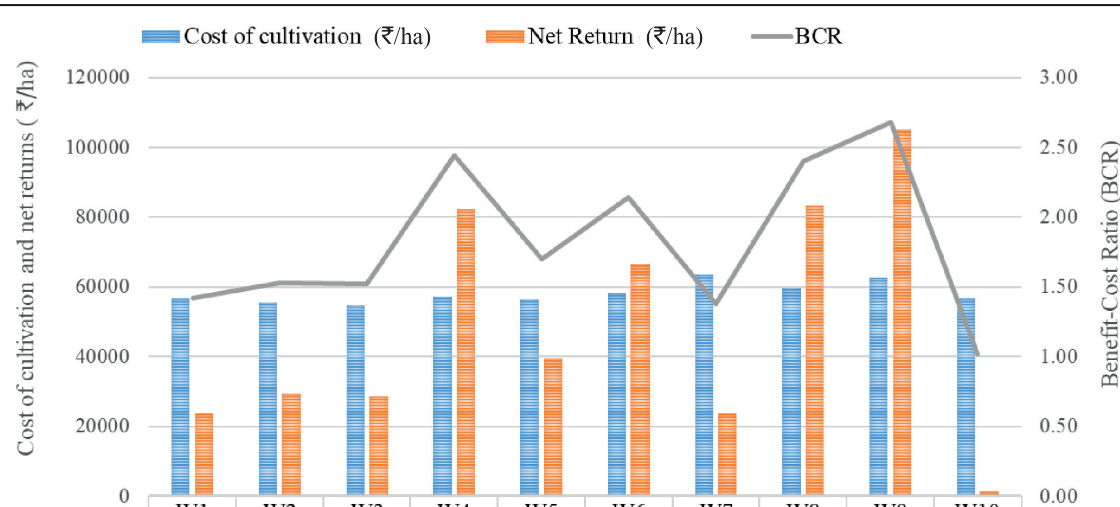
Production and monetary efficiency

The weed-management practices significantly influenced the production efficiency and monetary efficiency of okra (Table 3). The maximum production efficacy (158.5 kg/ha/day) and monetary efficiency (992.8 ₹/ha/day) were obtained with 3 hand-weeding at 20, 40 and 60 DAS, followed by 2 hand-weeding at 20 and 40 DAS (134.9 kg/ha/day and 787.2 ₹/ha/day) and application of pendimethalin 1.0 kg/ha *fb* quizalofop ethyl 0.040 kg/ha at 30 DAS (131.1 kg/ha/day and 776.2 ₹/ha/day).

Economics

All the weed-management treatments resulted in numerically higher net returns and benefit: cost (B : C) ratio over the weedy check, obviously owing to higher seed yield under these treatments (Fig. 1). Three hand-weeding at 20, 40 and 60 DAS secured maximum net realization of ₹105,233/ha with highest B: C ratio of 2.68, which was closely followed by pendimethalin 1.0 kg/ha *fb* quizalofop ethyl 0.040 kg/ha at 30 DAS with net realization of ₹82,277/ha and B : C ratio of 2.44, 2 hand-weeding at 20 and 40 DAS with net realization of ₹83,442/ha and B: C ratio of 2.40 and weed-free check required more labour for manual weeding when compared with herbicides application, resulting in the higher cost of cultivation as reported by Patel *et al.* (2018), Patel *et al.* (2020) and Dhivya *et al.* (2021). The lowest seed yield due to unrestricted weed growth in weedy-check treatment was eventually reflected in the lowest net returns (₹1,303/ha) and B : C ratio (1.02). The results are in agreement with those reported by Kumar *et al.* (2011), Pandey and Mishra (2013) and Mathukia *et al.* (2018).

It can be concluded that, hand-weeding at 20 and 40 DAS provided broad-spectrum weed control with higher production of okra fruit crop. Besides, sequential application of pendimethalin 1.0 kg /ha as pre-emergence *fb*



	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10
Cost of cultivation (₹/ha)	56706	55571	54722	57151	56302	58186	63356	59606	62606	56706
Net Return (₹/ha)	23772	29346	28611	82277	39421	66505	23799	83442	105233	1303
BCR	1.42	1.53	1.52	2.44	1.70	2.14	1.38	2.40	2.68	1.02

[W_1, Stale seedbed; W_2, pendimethalin 1.0 kg/ha pre-emergence; W_3, oxyfluorfen 0.24 kg/ha pre-emergence; W_4, pendimethalin1.0 kg/ha as pre-emergence *fb* quizalofop ethyl 0.040 kg/ha at 30 DAS); W_5, oxyfluorfen 0.24 kg/ha as pre-emergence *fb* quizalofop ethyl 0.040 kg/ha at 30 DAS; W_6, quizalofop ethyl 0.040 kg/ha at 20 DAS *fb* One hand weeding at 40 DAS; W_7, one hand-weeding *fb* straw mulch 3 t/ha at 20 DAS; W_8, 2 hand-weeding at 20 and 40 DAS; W_9, 3 hand-weeding at 20, 40 and 60 DAS and W_{10}, weedy-check (control)]

Fig. 1. Cost of cultivation (₹/ha), net return (₹/ha) and benefit : cost ratio of summer okra crop as influenced by weed-management

quizalofop ethyl 0.04 kg/ha at 30 DAS may be advised as better alternative weed management options, where labourers are scarce and costly.

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