Herbigation in okra (*Abelmoschus esculentus* (L.) Moench): An innovative weed management approach

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Abstract

A field experiment was conducted during 2019-20 at College of Agriculture, Kerala Agricultural University, Vellanikkara to assess the efficiency of oxyfluorfen through herbigation and conventional spraying in okra. The experiment was laid out in randomized block design with ten treatments and three replications. Among the treatments, conventional spraying with oxyfluorfen @ 0.15 kg ha^{-1} two days before sowing (DBS) followed by hand weeding (HW) at 30 days after sowing (DAS) and conventional spraying with oxyfluorfen @ 0.20 kg ha^{-1} two DBS followed by HW at 30 DAS recorded lesser weed dry weight and it was on par with hand weeded control. Herbigation treatments resulted in significant reduction in weed dry matter production and higher weed control efficiency at later stages of crop growth as compared to unweeded control. Even though, conventional spraying recorded lesser weed count and weed dry weight, the yield was less due to the scorching of crop foliage. Yield of 13.04 t ha^{-1} could be realized under hand weeded control and it was on par with herbigation of oxyfluorfen @ 0.15 kg ha^{-1} two DBS followed by HW at 60 DAS and conventional spraying with oxyfluorfen @ 0.15 kg ha^{-1} two DBS followed by HW at 60 DAS. Herbigation with oxyfluorfen @ 0.15 kg ha^{-1} two DBS followed by HW at 60 DAS resulted in higher gross income and B:C ratio which was closely followed by conventional spraying with oxyfluorfen @ 0.15 kg ha^{-1} two DBS followed by HW at 30 DAS.

Keywords: Herbigation, Okra, Oxyfluorfen, Weed control efficiency.

Introduction

Weeds are the most severe and wide spread biological constraints in crop production in India and weeds alone cause 33 per cent loss out of the total losses due to pests (Verma et al., 2015). Herbigation is the application of herbicide through irrigation water and can be done effectively through micro irrigation. Conventional method of herbicide application takes considerable time and is expensive due to the increasing cost of manual labour. Also, heavy wind at the time of spraying and improper application causes more herbicide loss, environmental pollution and drift injury to the nearby fields especially on sensitive crops. Herbigation ensures no additional costs of application. The extent of movement of herbicides through irrigation water is a function of solubility, adsorption, volatility and no herbicide residues are detected in both the soil and crop in herbigation (Hariharasudhan et al., 2017). Weed competition during early stage of crop growth significantly lowers crop yields. Heavy weed infestation in okra is mainly due to wider spacing, slower crop growth during early stages, high fertilizer uses and frequent irrigation. In this context, the present study was undertaken with a view to study the effect of herbigation through drip irrigation system in okra and also to evaluate the economic feasibility of the system.

Materials and Methods

The study was conducted at Water Management

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Research Unit, Vellanikkara, Thrissur from December 2019 to April 2020. The soil of the experimental site is sandy loam with acidic pH of 6.08, high in organic carbon (1.52%), low in available N (182.20 kg ha^{-1}), high in available P (76.14 kg ha^{-1}) and medium in available K (181.43 kg ha^{-1}). Okra variety Arka Anamika was used for the experiment in a plot size of 4 m × 2.4 m with a spacing of 60 cm × 30 cm and fertilizer application was done as per POP recommendation of KAU (KAU, 2016). The experiment was laid out in RBD with ten treatments and three replications. The treatments comprised of four herbigation and four conventional spraying, applied in two doses (0.15 kg ha^{-1} & 0.20 kg ha^{-1}) at two different times of application *i.e,* two DBS and 25 DAS, a hand weeded control and an unweeded control. The herbicide application and HW were done as per the treatments. Drip irrigation was installed in the field with a dripper discharge of 2 lph. Irrigation was given daily at 125% pan evaporation. Herbigation was done using fertilizer injector pump and different herbicides were given as per the treatment.

Growth and yield parameters observed were plant height, number of leaves and leaf area (at 30, 60 and 90 DAS), number of fruits per plant and fruit yield. Weed count and weed dry matter production was recorded at 20, 50 and 80 DAS. Weed control efficiency and weed index were worked out using the formulae suggested by Mani et al. (1973) and Gill and Vijayakumar (1969) respectively. The data were statistically analysed by using the technique of analysis of variance using the statistical package WASP 2.0.

Results and Discussion

Weed flora of experimental field consisted of grasses, sedges, and broad-leaved weeds. The main grass weeds observed were *Panicum maximum, Digitaria sanguinalis, Digitaria bicornis* and *Axonopus compressus.* The broad-leaved weeds were *Ageratum conyzoides, Euphorbia hirta, Mollugo disticha, Cleome burmanii, Trianthema portulacastrum, Alternanthera bettzickiana,* and *Synedrella nodiflora.* The sedges present were *Cyperus* spp., and *Bulbostylis barbata* in the experimental field.

In comparing herbigation and conventional spraying plots, the latter recorded lesser weed count and weed

Table 1. Effect of weed management practices on weed count and weed dry weight at 20, 50 and 80 DAS

Sl. No.	Treatments	Weed count (No.m^{-2})			Weed dry weight (kg ha^{1})		
		20 DAS	50 DAS	80 DAS	20 DAS	50 DAS	80 DAS
1	T_1 Herbigation with oxyfluorfen 23.5 EC @ 0.15 kg ha^{-1} 2 days before sowing fb hand weeding at 30 DAS	133.33^{bcd}	112.00^{c}	152.00^{b}	55.2^{bc}	110.0^{c}	200.0^{bc}
2	T_2 Herbigation with oxyfluorfen 23.5 EC @ 0.20 kg ha^{-1} 2 days before sowing fb hand weeding at 30 DAS	138.67^{bc}	93.33^{cd}	109.33^{bc}	51.5^{bc}	140.0^{c}	203.3^{bc}
3	T_3 Herbigation with oxyfluorfen 23.5 EC @ 0.15 kg ha^{-1} 2 days before sowing and 25 DAS fb hand weeding at 50 DAS	162.67^{ab}	222.67^{b}	132.00^{bc}	55.1^{bc}	320.0^{b}	240.0^{bc}
4	T_4 Herbigation with oxyfluorfen 23.5 EC @ 0.20 kg ha^{-1} 2 days before sowing and 25 DAS fb hand weeding at 50 DAS	145.33^{b}	241.33^{ab}	150.67^{b}	59.7^{b}	240.0^{bc}	206.7^{bc}
5	T_5 Conventional spraying with oxyfluorfen 23.5 EC @ 0.15 kg ha^{-1} 2 days before sowing fb hand weeding at 30 DAS	46.67^{cde}	76.00^{cd}	80.00^{cd}	28.1^{cd}	83.3^{c}	133.3^{c}
6	T_6 Conventional spraying with oxyfluorfen 23.5 EC @ 0.20 kg ha^{-1} 2 days before sowing fb hand weeding at 30 DAS	21.33^{e}	52.00^{cd}	49.33^{d}	8.1^{d}	116.7^{c}	296.7^{b}
7	T_7 Conventional spraying with oxyfluorfen 23.5 EC @ 0.15 kg ha^{-1} 2 days before sowing and 25 DAS fb hand weeding at 50 DAS	38.67^{de}	34.67^{d}	34.67^{d}	13.2^{d}	153.3^{c}	243.3^{bc}
8	T_8 Conventional spraying with oxyfluorfen 23.5 EC @ 0.20 kg ha^{-1} 2 days before sowing and 25 DAS fb hand weeding at 50 DAS	33.33^{e}	32.00^{d}	38.67^{d}	11.6^{d}	180.0^{bc}	253.3^{bc}
9	T_9 Hand weeded control	97.33^{bcde}	114.67^{c}	86.67^{cd}	13.8^{d}	126.7^{c}	126.7^{c}
10	T_{10} Unweeded control	256.00^{a}	298.67^{a}	380.00^{a}	93.2^{a}	840.0^{a}	1346.7^{a}

Mean value with common superscripts does not differ significantly.

dry weight throughout the crop growth period (Table 1). Observations taken at 50 DAS shows that in herbigated plots, the weed count was higher in treatments which were given second herbicide application at 25 DAS instead of HW at 30 DAS. It implies that the HW given at 30 days resulted in complete removal of weeds from the plots whereas the second herbicide application at 25 DAS only controlled the emergence of new weeds. The already germinated weeds were not affected and thus resulted in higher weed count as well as weed dry matter production. Herbigation with oxyfluorfen @ 0.15 kg ha^{-1} two DBS followed by HW at 30 DAS recorded minimum weed index (Table 2).

The plant height of okra was in the range from 48.07

Table 2. Effect of weed management practices in okra on weed control efficiency and weed index

Sl.No.		Treatments	Weed Control Efficiency (%)			Weed Index (%)
			20 DAS	50 DAS	80 DAS	
1	T_1	Herbigation with oxyfluorfen 23.5 EC @ 0.15 kg ha^{-1} 2 days before sowing fb hand weeding at 30 DAS	40.77	86.90	85.15	0.15
2	T_2	Herbigation with oxyfluorfen 23.5 EC @ 0.20 kg ha^{-1} 2 days before sowing fb hand weeding at 30 DAS	44.74	83.33	84.90	6.90
3	T_3	Herbigation with oxyfluorfen 23.5 EC @ 0.15 kg ha^{-1} 2 days before sowing and 25 DAS fb hand weeding at 50 DAS	40.88	61.90	82.18	40.26
4	T_4	Herbigation with oxyfluorfen 23.5 EC @ 0.20 kg ha^{-1} 2 days before sowing and 25 DAS fb hand weeding at 50 DAS	35.94	71.43	84.65	45.09
5	T_5	Conventional spraying with oxyfluorfen 23.5 EC @ 0.15 kg ha^{-1} 2 days before sowing fb hand weeding at 30 DAS	69.88	90.08	90.10	2.61
6	T_6	Conventional spraying with oxyfluorfen 23.5 EC @ 0.20 kg ha^{-1} 2 days before sowing fb hand weeding at 30 DAS	91.31	86.11	77.97	25.38
7	T_7	Conventional spraying with oxyfluorfen 23.5 EC @ 0.15 kg ha^{-1} 2 days before sowing and 25 DAS fb hand weeding at 50 DAS	85.82	81.75	81.93	21.32
8	T_8	Conventional spraying with oxyfluorfen 23.5 EC @ 0.20 kg ha^{-1} 2 days before sowing and 25 DAS fb hand weeding at 50 DAS	87.54	78.57	81.19	19.17
9	T_9	Hand weeded control	85.20	84.92	90.59	0.00
10	T_{10}	Unweeded control	0.00	0.00	0.00	58.97

Table 3. Effect of weed management practices on plant height of okra

Sl. No.		Treatments	Plant height (cm)	
			60 DAS	90 DAS
1	T_1	Herbigation with oxyfluorfen 23.5 EC @ 0.15 kg ha^{-1} 2 days before sowing fb hand weeding at 30 DAS	76.27^{a}	86.80^{a}
2	T_2	Herbigation with oxyfluorfen 23.5 EC @ 0.20 kg ha^{-1} 2 days before sowing fb hand weeding at 30 DAS	67.13^{a}	76.33^{ab}
3	T_3	Herbigation with oxyfluorfen 23.5 EC @ 0.15 kg ha^{-1} 2 days before sowing and 25 DAS fb hand weeding at 50 DAS	47.87^{b}	59.80^{bc}
4	T_4	Herbigation with oxyfluorfen 23.5 EC @ 0.20 kg ha^{-1} 2 days before sowing and 25 DAS fb hand weeding at 50 DAS	47.93^{b}	59.40^{bc}
5	T_5	Conventional spraying with oxyfluorfen 23.5 EC @ 0.15 kg ha^{-1} 2 days before sowing fb hand weeding at 30 DAS	73.73^{a}	83.80^{a}
6	T_6	Conventional spraying with oxyfluorfen 23.5 EC @ 0.20 kg ha^{-1} 2 days before sowing fb hand weeding at 30 DAS	68.07^{a}	78.53^{a}
7	T_7	Conventional spraying with oxyfluorfen 23.5 EC @ 0.15 kg ha^{-1} 2 days before sowing and 25 DAS fb hand weeding at 50 DAS	73.20^{a}	86.87^{a}
8	T_8	Conventional spraying with oxyfluorfen 23.5 EC @ 0.20 kg ha^{-1} 2 days before sowing and 25 DAS fb hand weeding at 50 DAS	66.93^{a}	79.20^{a}
9	T_9	Hand weeded control	60.73^{ab}	71.73^{abc}
10	T_{10}	Unweeded control	48.07^{b}	57.13^{c}

Mean value with common superscripts does not differ significantly.

cm to 76.27 cm and 57.13 cm to 86.87 cm at 60 DAS and at 90 DAS respectively and the number of leaves increased from 60 DAS to 90 DAS (Table 3). Herbigation with oxyfluorfen @ 0.15 kg ha^{-1} two DBS followed by HW at 30 DAS recorded tallest plants throughout the crop growth period. More number of leaves was observed in conventional spraying with oxyfluorfen @ 0.15 kg ha^{-1} two DBS followed by HW at 30 DAS. The lowest plant height and number of leaves was recorded in unweeded control, which may be due to severe weed infestation. Reduction in plant height due to weed competition in okra was reported by Narayanan et al. (2020). This might be due to the higher weed count and weed dry matter production during the crop growth period. Similar findings were reported by Olabode et al. (2006). According to them, the probable reason for more days taken by plants in unweeded control for flowering is because of higher competition from weeds.

The leaf area in okra was influenced greatly by the application of oxyfluorfen. The leaf area was higher in herbicide treated (both herbigation and conventional spraying) plots. Among them, herbigation @ 0.15 kg ha^{-1} two DBS followed by HW at 60 DAS recorded highest leaf area and it was on par with hand weeded control. The minimum leaf area was recorded in unweeded control. These results were in line and agreement with the findings by Konyeha et al. (2013) in okra.

Fruit yield per plant and number of fruits per plant was significantly higher in herbigation @ 0.15 kg ha^{-1} two DBS followed by HW at 30 DAS and it was found on par with conventional spraying @ 0.15 kg ha^{-1} two DBS followed by HW at 30 DAS and hand weeded control. Unweeded control recorded the lowest number of fruits and fruit yield per plant. Various treatments significantly influenced the yield (Table 4). Hand weeded control recorded highest yield (13.04 t ha^{-1}). It was on par with herbigation @ 0.15 kg ha^{-1} two DBS followed by HW at 30 DAS, herbigation @ 0.20 kg ha^{-1}two DBS followed by HW at 30 DAS and conventional spraying @ 0.15 kg ha^{-1} two DBS followed by HW at 30 DAS was the best treatment. The unweeded control recorded the lowest yield and it was only 5.35 tonnes/ha. Even though conventional spraying recorded lesser weed count and weed dry weight, the yield was less due to the scorching of crop foliage.

Table 4. Effect of weed management practices on yield attributes and yield of okra

Sl. No	Treatments	Number of fruits per plant	Fruit yield per plant (g)	Fruit yield (t/ha^{-1})
1	T_1 Herbigation with oxyfluorfen 23.5 EC @ 0.15 kg ha^{-1} 2 days before sowing fb hand weeding at 30 DAS	17.8^{a}	243.90^{a}	13.02^{a}
2	T_2 Herbigation with oxyfluorfen 23.5 EC @ 0.20 kg ha^{-1} 2 days before sowing fb hand weeding at 30 DAS	15.85^{ab}	218.50^{abc}	12.14^{abc}
3	T_3 Herbigation with oxyfluorfen 23.5 EC @ 0.15 kg ha^{-1} 2 days before sowing and 25 DAS fb hand weeding at 50 DAS	12.53^{bcd}	140.30^{ef}	7.79^{de}
4	T_4 Herbigation with oxyfluorfen 23.5 EC @ 0.20 kg ha^{-1} 2 days before sowing and 25 DAS fb hand weeding at 50 DAS	10.60^{cd}	128.90^{fg}	7.16^{ef}
5	T_5 Conventional spraying with oxyfluorfen 23.5 EC @ 0.15 kg ha^{-1} 2 days before sowing fb hand weeding at 30 DAS	16.15^{ab}	228.54^{ab}	12.70^{ab}
6	T_6 Conventional spraying with oxyfluorfen 23.5 EC @ 0.20 kg ha^{-1} 2 days before sowing fb hand weeding at 30 DAS	12.59^{bcd}	175.14^{de}	9.73^{cd}
7	T_7 Conventional spraying with oxyfluorfen 23.5 EC @ 0.15 kg ha^{-1} 2 days before sowing and 25 DAS fb hand weeding at 50 DAS	14.05^{abc}	184.70^{cd}	10.26^{c}
8	T_8 Conventional spraying with oxyfluorfen 23.5 EC @ 0.20 kg ha^{-1} 2 days before sowing and 25 DAS fb hand weeding at 50 DAS	14.70^{ab}	189.74^{bcd}	10.54^{bc}
9	T_9 Hand weeded control	15.92^{ab}	220.32^{ab}	13.04^{a}
10	T_{10} Unweeded control	9.31^{d}	96.30^{g}	5.35^{f}

Mean value with common superscripts does not differ significantly.

Table 5. Effect of treatments on Benefit: Cost ratio

Sl. No.	Treatments	Cost of cultivation (Rs/ha)	Gross Income (Rs/ha)	B:C ratio
1	T_1 Herbigation with oxyfluorfen 23.5 EC @ 0.15 kg ha^{-1} 2 days before sowing fb hand weeding at 30 DAS	132253	260400	1.97
2	T_2 Herbigation with oxyfluorfen 23.5 EC @ 0.20 kg ha^{-1} 2 days before sowing fb hand weeding at 30 DAS	132773	242800	1.83
3	T_3 Herbigation with oxyfluorfen 23.5 EC @ 0.15 kg ha^{-1} 2 days before sowing and 25 DAS fb hand weeding at 50 DAS	133785	155800	1.17
4	T_4 Herbigation with oxyfluorfen 23.5 EC @ 0.20 kg ha^{-1} 2 days before sowing and 25 DAS fb hand weeding at 50 DAS	134806	143200	1.06
5	T_5 Conventional spraying with oxyfluorfen 23.5 EC @ 0.15 kg ha^{-1} 2 days before sowing fb hand weeding at 30 DAS	134653	254000	1.89
6	T_6 Conventional spraying with oxyfluorfen 23.5 EC @ 0.20 kg ha^{-1} 2 days before sowing fb hand weeding at 30 DAS	135164	194600	1.44
7	T_7 Conventional spraying with oxyfluorfen 23.5 EC @ 0.15 kg ha^{-1} 2 days before sowing and 25 DAS fb hand weeding at 50 DAS	136185	205200	1.51
8	T_8 Conventional spraying with oxyfluorfen 23.5 EC @ 0.20 kg ha^{-1} 2 days before sowing and 25 DAS fb hand weeding at 50 DAS	137025	210800	1.54
9	T_9 Hand weeded control	141521	260800	1.84
10	T_{10} Unweeded control	126521	107000	0.85

The highest B: C ratio of 1.97 was obtained for herbigation with oxyfluorfen @ 0.15 kg ha^{-1}two DBS followed by HW at 30 DAS (Table 5). Conventional spraying with oxyfluorfen 23.5 EC @ 0.15 kg ha^{-1} two DBS followed by HW at 30 DAS recorded a B: C ratio of 1.89 which was the next best treatment. The B: C ratio for herbigation with oxyfluorfen 23.5 EC @ 0.20 kg ha^{-1} two DBS followed by HW at 30 DAS was 1.83, whereas that for HW was 1.84. The yield from plots with herbigation @ 0.15 kg ha^{-1}two DBS followed by HW at 30 DAS and conventional spraying with oxyfluorfen @ 0.15 kg ha^{-1}two DBS followed by HW at 30 DAS was on par with hand weeded control. This indicates the possibility of reducing number of HW by employing the use of herbicides along with HW.

The result of the study revealed that herbigation with oxyfluorfen @ 0.15 kg ha^{-1}two DBS followed by HW at 30 DAS resulted in higher gross income and B:C ratio which was closely followed by conventional spraying with oxyfluorfen @ 0.15 kg ha^{-1}two DBS followed by HW at 30 DAS. The farmers can adopt either herbigation or conventional spraying of oxyfluorfen according to their convenience because both treatments performed equally well in terms of yield. Herbigation can be implemented in fields were already fertigation is carried out because it does not involve any additional costs.

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