E-ISSN: 2618-0618
P-ISSN: 2618-060X

www.agronomyjournals.com
2024; SP-7(11): 574-577
Received: 02-08-2024
Accepted: 03-09-2024

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Integrated weed management in sunflower

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DOI: https://doi.org/10.33545/2618060X.2024.v7.i11Sh.2076

Abstract
Research was conducted at Instructional farm, OUAT, Bhubaneswar, during *summer*-2023, to study the effect of integrated weed management in sunflower. The experiment was laid out in a randomized block design with a total of eight treatments replicated thrice. The treatments included application of pre and post- emergence herbicides as well as mechanical and manual weed control methods. The dominant weed flora found in the experimental site included narrow leaved weeds like *Cynodon dactylon, Digitaria ciliaris, Digitaria sanguinalis, Sorghum halepense, Cyperus rotundus, Cyperus iria, Fimbristylis miliacea* and broad-leaved weeds like *Heliotropium indicum, Alternanthera philoxeroides, Spilanthes acmella* and *Amaranthus viridis.* Weed free treatment recorded highest seed yield (1980 kg/ha) and oil yield (752 kg/ha) which remained at par with One intercultivation at 20 DAS *fb* one hand weeding at 30 DAS, Two intercultivation at 20 & 40 DAS and Pendimethalin @1.0 kg/ha as PE *fb* One intercultivation at 30 DAS. The highest yield attributing characters i.e., head diameter (17.4 cm) and 100 seed weight (5.53g) along with highest plant height (190 cm), WCE (80.5%) were recorded in weed free. As compared to other weed management practices, Weed free recorded the highest gross return (Rs.133878/ha) and net return (Rs.57311/ha), but the highest B-C ratio (1.81) was recorded in Pendimethalin @1.0 kg/ha as PE *fb* One intercultivation at 30 DAS. Hence, Pendimethalin @1.0 kg/ha as PE *fb* One intercultivation at 30 DAS was the most remunerative weed management practice for achieving higher yield and monetary benefit during *summer* season.

Keywords: Sunflower, IWM

Introduction
One of the most significant oilseed crops in the world, the sunflower (*Helianthu annuus* L.), is a member of the Asteraceae family. The production of edible oil is the primary goal of sunflower cultivation. It includes oleic acid (42–57%) and linolenic acid (33–48%), which lowers low-density lipoprotein cholesterol, making it a good source of unsaturated fatty acids and lessens the risk of heart disease. Currently sunflower is grown in India on an area of 0.228 million ha with a production of 0.212 million tones and productivity of 0.93 t ha^{-1} (Indiastatagri, 2020) [2]. Weeds compete with sunflower for nutrients, moisture, light and space, thus reducing yields and decreasing the effectiveness of other inputs (Suresh and Reddy, 2010). Weeds can also act as hosts for harmful pathogens and pests. A dry-land crop like sunflower may have a yield loss of 60-90% due to intense competition. This costs growers money through decreased crop yields. Weeds that were not controlled reduce the sunflower yields by up to 62% (Sumathi *et al.* 2009) [7]. According to Raut *et al*. (2015) [6], the type of weed, its density, the timing of its emergence, the crop, as well as soil conditions, all affect yield. Herbicides are therefore, a very efficient and cost-effective method of controlling weeds. Pre-emergence and post-emergence herbicides can be used to manage weeds at crucial times of crop growth. Due to continuous application of herbicides, herbicide resistance is also causing problem now-a-days. The conventional method of weed control is laborious, insufficient and costly hence, neither herbicide nor cultivation practices are adequate for consistent and acceptable weed control. Therefore integrated weed management is the best for higher productivity, using pre and post emergent herbicides in combination with hand weeding or inter cultivation. Integrated Weed Management (IWM) is a sustainable approach to the management of weeds by combining all available weed control techniques, including preventative measures, monitoring, crop rotations, tillage, crop competition, mechanical and physical control, herbicide rotation, herbicide mixtures, biological control, nutrition, irrigation, flaming, etc. in a way that minimizes economic, health and environmental risks (Swanton *et al*., 2008) [9].

Materials and Methods

The field experiment was conducted during *spring* 2022-23 at Odisha University of Agriculture and Technology, Bhubaneswar, Odisha. The experimental site is located 64 kilometers from the Bay of Bengal at 20°27' North Latitude and 85°79' East Longitude, at an elevation of 25.9 m above mean sea level (MSL). It belongs to the East and South Eastern Coastal Plain Agroclimatic Zone of Odisha. The soil was sandy loam in texture, acidic in reaction (pH-5.9), having medium organic carbon (0.62%), medium available nitrogen (295.13 kg/ha), low available phosphorus (2.59 kg/ha) and medium available potassium status (262.29 kg/ha). The experiment was laid out in randomized block design with eight treatments and replicated thrice. The treatments were, T_1- Pendimethalin @1.0 kg/ha as PE *fb* One intercultivation at 30 DAS, T_2- Pendimethalin @1.0 kg/ha as PE *fb* Quizalofop Ethyl 10 EC @37.5g/ha as PoE at 20 DAS, T_3 - Oxyflurofen @0.025 kg/ha as PE *fb* One intercultivation at 30 DAS, T_4- Oxyflurofen @0.025 kg/ha as PE *fb* Quizalofop Ethyl 10 EC @37.5 g/ha as PoE at 20 DAS, T_5- Two intercultivation at 20 & 40 DAS, T_6- One intercultivation at 20 DAS *fb* one hand weeding at 30 DAS, T_7- Weed free (three hand weeding at 15,30 and 45 DAS), T_8- Unweeded control. The test hybrid DRSH-1 was sown on 06.01.2023 and harvested from 08.04.2023 to 10.04.2023. The crop was fertilized at the rate of 60 kg N, 80 kg P_2O_5 and 60 kg K_2O/ha in all the treatments. Half of nitrogen and full dose of P_2O_5 and K_2O were applied as single basal dose in the form of Urea, Single super phosphate (SSP) and Muriate of potash (MOP), respectively. Remaining half dose of nitrogen applied in two equal split at the time of earthing up and at the time of bud initiation stage. The seeds of DRSH-1 cultivar of sunflower were sown with a spacing of 60 cm × 30 cm. Weed density and weed dry weight at 30, 60 and 90 days after sowing were recorded from pre marked quadrants of $1m^2$area. The weed data were subjected to square root transformation ($\sqrt{x+1}$) to normalize the distribution. Weed growth attributes viz.,weed density (No/ m^2) and weed dry weight (g/ m^2), weed control efficiency (%) and weed index(%) were computed. Individual species wise weed counts were grouped into grasses, sedges and broad-leaved weeds and expressed as number/m^2. For the estimation of weed dry biomass the weed samples were uprooted, washed in tap water; sun dried and further dried at 70 ^{0}C in oven till constant weight. Thereafter, the dry weight of weeds was recorded in g/m^2. Weed control efficiency (%) and weed index (%) were calculated by using the formula: W.C.E (%) = (Wc-Wt/Wc) ×100, where, Wc = Dry matter of weeds in weedy check (control). Wt = Dry matter of weeds in weed control treatments and WI (%) =X- Y/X, where X=seed yield from minimum weed competition plot, Y= seed yield from treatment for which weed index is to be worked out. Seed yield were determined from the net plot area and were weighed in kg or gram and converted into kg/ha. Economics of different treatments was calculated by taking into account the prevailing market price of inputs and produce of the experimental year. Gross returns were worked out for each treatment based on quality and market prices of the produce. The net return was also worked out by deducting the cost incurred from the gross returns of the particular treatment. Benefit cost (B: C) ratio was calculated by dividing the gross return with cost of cultivation. The data were analyzed as per the analysis of variance (ANOVA) for randomized block design at 0.05 probability.

Results and Discussion

Weed flora

In the experimental field, 11 types of weeds belonging to 5 different families were present(table 1). The important narrow leaved weeds during spring 2023 in the experimental site were *Cynodon dactylon, Digitaria ciliaris, Digitaria sanguinalis, Sorghum halepense, Cyperus rotundus, Cyperus iria, Fimbristylis miliacea* and broad-leaved weeds were *Heliotropium indicum, Alternanthera philoxeroides, Spilanthes acmella* and *Amaranthus viridis.* Similar observations were found by Bharati *et al*. (2020) [1].

Table 1: Major weed flora in the experimental field observed during the crop period

Sl. no	Botanical name	Family	Common Name	Ontogeny	Group
1.	*Cynodon dactylon*	Poaceae	Bermuda grass	Perennial	Grass
2.	*Digitaria ciliaris*	Poaceae	Crabgrass	Annual	Grass
3.	*Digitaria sanguinalis*	Poaceae	Hairy crabgrass	Annual	Grass
4.	*Sorghum halepense*	Poaceae	Johnson grass	Perennial	Grass
5.	*Cyperus rotundus*	Cyperaceae	Nut grass	Perennial	Sedge
6.	*Cyperus iria*	Cyperaceae	Rice flat Sedge	Annual	Sedge
7.	*Fimbristylis miliacea*	Cyperaceae	Hoorah grass	Annual	Sedge
8.	*Heliotropium indicum*	Boraginaceae	Indian heliotrope	Annual	Broad Leaved
9.	*Alternanthera Philoxeroides*	Amaranthaceae	Alligator Weed	Perennial	Broad Leaved
10.	*Spilanthes acmella*	Asteraceae	Paracress	Perennial	Broad Leaved
11.	*Amaranthus viridis*	Amaranthaceae	Slender amaranth	Annual	Broad Leaved

Effect of different management practices on weed control

Weed population, weed dry weight, weed control efficiency and weed index were significantly influenced by different weed management practices (Table 2). At all the stages (30 DAS, 60 DAS and harvest), the highest weed population and weed dry weight was recorded under unweeded check as compared to other treatments. While weed free treatment attained significantly lower weed population which is followed by One intercultivation at 20 DAS *fb* One hand weeding at 30 DAS. This may be due to the effectiveness of intercultural operations and hand weeding, which both reduce weed populations. The similar results were observed by Nagamani *et al*. (2011) [5]. The weed free (three-hand weeding at 15, 30 and 45 DAS) treatment had the lowest weed dry weight at harvest which remained at par with one intercultivation at 20 DAS *fb* one hand weeding at 30 DAS. Similar findings were found by Kalaiyarasan and Vaiyapuri (2018) [3]. Weed control efficiency (WCE) was computed by taking into account total weed dry weight, which includes a range of weed species in different proportions, in order to prevent emphasising the effects of specific weed species. The weed free treatment in the current study indicated higher WCE (80.50%), because weeds were effectively controlled in a timely manner. The next best treatment was One intercultivation at 20 DAS *fb* One hand weeding at 30 DAS

(75.72%) followed by Two intercultivations at 20 and 40 DAS (68.03%) followed by Pendimethalin @1.0 kg/ha as PE *fb* one intercultivation at 30 DAS(66.13%). This was attributed to lower weed population, which resulted in reduction of total dry weight of weeds in these treatments due to better control of weeds by cultural methods and imposition of herbicides. Similar findings were recorded by Mahapatra *et al.* (2024) [4].

The extent of yield reduction due to weed competition as assessed through weed index (WI) has evidently indicated the suppressing effect of weed free check which had minimum weed competition and maximum seed yield. After weed free treatment, the lowest weed index was recorded in One intercultivation at 20 DAS *fb* one hand weeding at 30 DAS(6.77) followed by Two intercultivations at 20 and 40DAS (9.19) followed by Pendimethalin @1.0 kg/ha as PE *fb* one intercultivation at 30 DAS(10.05). The lower value of weed index was due to lower weed infestation resulting in lower weed biomass production. Similar results were found by Bharati *et al.* (2020) [1].

Table 2: Weed density, weed control efficiency (%) and weed index (%) as affected by different weed manage: ment methods

Treatment	Weed density (No./m^2)			Weed dry weight (g/m^2) at harvest	WCE (%)	Weed Index (%)
	30 DAS	60 DAS	Harvest			
Pendimethalin @1.0 kg/ha as PE *fb* One IC at 30 DAS	11.69* (125.14)	12.30 (139.24)	13.85 (178.10)	6.17* (32.14)	66.13	10.05
Pendimethalin @1.0 kg/ha as PE *fb* Quizalofop Ethyl 10 EC @37.5g/ha as PoE at 20 DAS	13.31 (164.03)	15.19 (215.87)	16.34 (251.03)	7.79 (53.18)	43.95	18.69
Oxyflurofen @0.025 kg/ha as PE *fb* One IC at 30 DAS	13.20 (161.33)	14.06 (184.00)	15.52 (225.66)	6.77 (39.29)	58.59	13.23
Oxyflurofen @0.025 kg/ha as PE *fb* Quizalofop Ethyl 10 EC @37.5 g/ha as PoE at 20 DAS	15.11 (213.36)	16.73 (263.52)	17.72 (296.37)	8.84 (69.53)	26.73	21.57
Two IC at 20 & 40 DAS	9.43 (79.67)	10.79 (105.79)	11.98 (131.72)	6.01 (30.34)	68.03	9.19
One IC at 20 DAS *fb* One hand weeding at 30 DAS	8.76 (68.22)	9.69 (84.51)	10.67 (103.43)	5.30 (23.04)	75.72	6.77
Weed free (three hand weeding at 15,30 and 45 DAS)	7.07 (43.18)	8.00 (56.19)	9.25 (76.64)	4.80 (18.50)	80.50	-
Unweeded control	17.11 (275.94)	18.51 (324.51)	19.59 (364.42)	10.24 (94.89)	-	49.39
SEm(±)	0.58	0.64	0.69	0.34	-	-
CD(p=0.05)	1.77	1.94	2.10	1.03	-	-

Figures in parentheses are original value,* Square root transformation value, IC – Inter cultivation

Effect on crop growth and yield

The maximum plant height (190 cm.) was recorded in weed free (three hand weeding at 15, 30 and 45 DAS) at harvest which remained at par with one intercultivation at 20DAS *fb* one hand weeding at 30DAS and Two IC at 20 and 40 DAS. The largest head diameter (17.4 cm) was observed in weed free (three hand weeding at 15,30 and 45 DAS). The smallest head diameter (10.5 cm) was recorded with control. The impact of integrated weed control on 100 seed weight was determined to be non-significant. The highest 100 seed weight (5.53g) was recorded in Weed free (three hand weeding at 15, 30 and 45 DAS) treatment followed by One intercultivation at 20 DAS *fb* one hand weeding at 30 DAS (5.38 g), Two intercultivation at 20 & 40 DAS (5.36 g) and Pendimethalin @1.0 kg/ha as PE *fb* one intercultivation at 30 DAS (5.23 g). The lowest 100 seed weight (4.72g) was recorded with Unweeded control.

The seed yield varied significantly as a result of different integrated weed management practices. The highest seed yield (1980 kg/ha) was observed in Weed free (three hand weeding at 15, 30 and 45 DAS) which is at par with One intercultivation at 20 DAS *fb* one hand weeding at 30 DAS (1846 kg/ha), Two intercultivation at 20 & 40 DAS (1798 kg/ha) and Pendimethalin @1.0 kg/ha as PE *fb* one intercultivation at 30 DAS (1781 kg/ha). The lowest seed yield (1002 kg/ha) was recorded with control because of highest removal of nutrients and moisture by weed and severe crop weed competition resulting in poor source- sink relationship with poor yield components. Similar type of results were also reported by Sumathi *et al.* (2009) [7].

Table 3: Effect of weed control methods on growth, yield and economics of sunflower

Treatment	Plant height (cm)	Head diameter (cm)	100 seed wt. (g)	Seed Yield (kg/ha)	Oil yield (kg/ha)	Gross return (₹/ha)	Net return (₹/ha)	B: C ratio
Pendimethalin @1.0 kg/ha as PE *fb* One IC at 30 DAS	164	15.8	5.23	1781	682	120395	53923	1.81
Pendimethalin @1.0 kg/ha as PE *fb* Quizalofop Ethyl 10 EC @37.5g/ha as PoE at 20 DAS	156	15.2	5.07	1610	629	108854	46177	1.74
Oxyflurofen @0.025 kg/ha as PE *fb* One IC at 30 DAS	158	15.7	5.14	1718	660	116131	50619	1.77
Oxyflurofen @0.025 kg/ha as PE *fb* Quizalofop Ethyl 10 EC @37.5 g/ha as PoE at 20 DAS	153	14.1	4.93	1553	604	105000	43283	1.70
Two IC at 20 & 40 DAS	170	16.2	5.36	1798	684	121522	53280	1.78
One IC at 20 DAS *fb* One hand weeding at 30 DAS	176	17.0	5.38	1846	703	124814	54907	1.79
Weed free (three hand weeding at 15,30 and 45 DAS)	190	17.4	5.53	1980	752	133878	57311	1.75
Unweeded control	129	10.5	4.72	1002	379	67710	7793	1.13
SEm(±)	6.3	0.59	0.29	69.0	26.9	-	-	-
CD(p=0.05)	19.0	1.8	NS	209	82	-	-	-

The highest oil yield (752 kg/ha) was observed in Weed free (three hand weeding at 15, 30 and 45 DAS) which was at par with One intercultivation at 20 DAS *fb* one hand weeding at 30 DAS (703 kg/ha), Two intercultivation at 20 & 40 DAS (684 kg/ha) and Pendimethalin @1.0 kg/ha as PE *fb* one intercultivation at 30 DAS (682 kg/ha). The lowest oil yield (379 kg/ha) was recorded with control. Tadavi *et al*. (2017) [10] observed similar findings of highest oil yield with the weed free treatment.

Effect on economics

Weed free (three hand weedings at 15, 30 and 45 DAS) resulted in highest gross return (Rs.133878/ha) and net return (Rs.57311/ha) and unweeded control produced the lowest net return (Rs.7793/ha). Pendimethalin @1.0 kg/ha as PE *fb* one intercultivation at 30 DAS resulted in highest BC ratio (1.81). Similar results were reported by Tadavi *et al.* (2017) [10].

Conclusion

Weed free (Three hand weeding at 15, 30 and 45 DAS) treatment recorded the highest weed control efficiency, seed yield, gross and net returns, but the B:C ratio is highest in pendimethalin @1.0 kg/ha as PE *fb* one intercultivation at 30 DAS. Hence, the treatment, pendimethalin @1.0 kg/ha as PE *fb* one intercultivation at 30 DAS can be regarded as the efficient and economical integrated weed management practice for increasing sunflower yield.

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