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Effect of different pre and post emergence herbicides on yield productivity and economics of sesame (*Sesamum indicum* L.)

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Abstract
A field experiment was conducted at the Crop Research Centre, School of Agriculture, ITM University, Gwalior (M.P) during *Kharif* season 2022. The experiment was laid out in Randomized Block Design, replicated three times and consisted of twelve treatments. The herbicides were used individually as well as in combinations viz; T_1 Pendimethalin (30% EC) P.E @ 800 g ha^{-1}, T_2 Pendimethalin (30% EC) P.E @ 1000 g ha^{-1}, T_3 Pendimethalin (30% EC) P.E @ 1200 g ha^{-1}, T_4 Oxyfluorfen (23.5% EC) P.E @ 150 g ha^{-1}, T_5 Oxyfluorfen (23.5% EC) P.E @ 200 g ha^{-1}, T_6 Oxyfluorfen (23.5% EC) P.E @ 250 g ha^{-1}, T_7 Imazethapyr (10% SL) P.E @ 60 g ha^{-1}, T_8 Imazethapyr (10% SL) P.E @ 70 g ha^{-1}, T_9 Imazethapyr (10% SL) P.E @ 80 g ha^{-1} T_{10} Imazethapyr (10% SL) + Imazamox (10% SC) POE @ 35 +35 g ha^{-1} and T_{11} and T_{12} being weed free and weedy check respectively. The soil of experimental field was sandy loam having pH-7.35, Organic-carbon-0.48, Available NPK-235.2, 14.5 and 238.4 respectively. The crop was affected with different type of weed flora eg: *Dinerba retroflexa and Digitaria Sanguinalis* of Narrow leaf weeds, *Amaranthus Viridis and Euphorbia Hirta* of Broad leaf weeds, and *Cyperus rotundus* of sedges. The experimental results indicated that among the herbicidal treatments T_{10} Imazethapyr (10% SL) + Imazamox (10% SC) POE @ 35 +35 g ha^{-1} recorded the lowest weed density (10.57), Dry weight (6.44), Weed Index (5.84) when compared to others. However, highest Weed control efficiency (82.05) was recorded with T_{10} Imazethapyr (10% SL) + Imazamox (10% SC) POE @ 35 +35 g ha^{-1} followed by T_3 Pendimethalin (30% EC) P.E @ 1200 g ha^{-1}. Yield and like Grain yield (810.04 kg ha^{-1}), Stalk yield (2111.37 kg ha^{-1}), Harvest index were significantly higher with T_{10} Imazethapyr (10% SL) + Imazamox (10% SC) POE @ 35 +35 g ha^{-1}.

Keywords: Weeds, sesame, herbicides, yield, economics

Introduction
Oil seeds are essential for maintaining a diet that is nutritionally balanced. They contribute significantly to the agricultural economy and are not just a source of oil; they are also high in protein. Useful in a variety of different ways, such as as a feed for pets and in the form of cakes with oil extracted for use in organic farming. Due to its high oil content (between 29 and 62%), sesame is also known as the "queen of oil seeds". Sesame production is a different choice for small farmers as a cash crop in many poor countries since it requires less irrigation and less labor but is a crop that is highly resistant to biotic stress. Sesame oil has been advocated as having an essential role in supporting health, including decreasing cholesterol and blood pressure, offering neuroprotective properties against hypoxia or brain injury, and preventing serious illnesses like cancer. Sesame is cultivated on 20.0 lakh hectares in India, with a yearly harvest of 8.66 lakh tonnes and productivity of 405 kg/ha (Anonymous, 2020). India tops the list in terms of both area (29%), production (26%), and exports of goods (40% of total global trade). Despite it is regarded as a significant oilseed crop, its average production is rather low when compared to that of many other nations. Gujarat, Rajasthan, and Madhya Pradesh are the top four contributing states in the nation, each contributing roughly 8.0% of the total area.

With a total area of roughly 3.15 lakh hectares, Madhya Pradesh produces 1,26,053 tonnes of agricultural output annually and produces 0.40 tonnes of agricultural output per hectare. Furthermore, Gwalior has a production of 12,384 tonnes over an area of around 18,764 ha, with a productivity of 0.66 tonnes/hectare. Weeds are a major contributor to the very poor crop yield of sesame in the Gwalior region (660 kg/ha), which may be caused by a variety of biotic and abiotic causes. Due to the fact that sesame is mostly planted during the kharif/rainy season, weed development is greatly encouraged.

Weeds compete with the sesame crop for numerous input components, which reduces crop production. Sesame has a wide weed flora in Kharif season, The weeds associated with sesame in Madhya Pradesh are like grasses *Eleusine indica, Sataria glauca, Echinochloa crusgalli, Cynodon dactylon, Digitaria sanguinalis, Dinebra retroflexa* etc, sedges i.e, *Cyperus rotundus and Cyperus iria*, along with few broad-leaved weeds like *Cyanotis axillaris, Ageratum conizoides, Phyllanthus niruri, Amaranthus spinosus, Aeschinome indica, Celosia argentia, Portulaca oleracea, Euphorbia hirta*, etc.

Materials and Methods

The field experiment was carried out at the crop research centre, School of Agriculture, ITM University, Gwalior (M.P), during the *kharif* season of 2022. The research field is located in the Indo-Gangetic plains region of the subtropics at an elevation of 196 m above sea level with coordinates of 26° 21' N latitude and 78° 17' E longitude. The Sesame variety "Govinda" was used for the experiment following the spacing of 30 ×15 cm. The pre and post emergence herbicides were applied at next day after sowing and at 40 DAS for weeds and crop respectively with the help of manually operated Knapsack sprayer fitted with flat fan nozzle using 600 lit\ha of water. The crop was sown on 09-8-2022 with 5 kg ha^{-1} of sesame seeds. A recommended dose of fertilizers was 40:30:20 kg ha^{-1}, respectively was applied in the crop.

Treatment Details

The randomized block design was replicated three times and featured a total of twelve treatments. The treatments were T_1 Pendimethalin (30% EC) P.E @ 800 g ha^{-1}, T_2 Pendimethalin (30% EC) P.E @ 1000 g ha^{-1}, T_3 Pendimethalin (30% EC) P.E @ 1200 g ha^{-1}, T_4 Oxyfluorfen (23.5% EC) P.E @ 150 g ha^{-1}, T_5 Oxyfluorfen (23.5% EC) P.E @ 200 g ha^{-1}, T_6 Oxyfluorfen (23.5% EC) P.E @ 250 g ha^{-1}, T_7 Imazethapyr (10% SL) P.E @ 60 g ha^{-1}, T_8 Imazethapyr (10% SL) P.E @ 70 g ha^{-1}, T_9 Imazethapyr (10% SL) P.E @ 80 g ha^{-1} T_{10} Imazethapyr (10% SL) + Imazamox (10% SC) POE @ 35 +35 g ha^{-1} and T_{11} and T_{12} being weed free and weedy check respectively.

On November 6, 2022, the crop was harvested. Statistical information on weeds and crops was examined using randomized block designs and analysis of variance (ANOVA) techniques. The square root transformed data $\sqrt{x} + 0.5$ on weed density and dry matter were used in an ANOVA.

Using a common equation, weed control efficiency (WCE) was calculated. The cost of cultivation was subtracted from the gross return to determine the net return. By dividing the net return by the cost of cultivation, the benefit-cost ratio was obtained.

Formulae were used: Weed control efficiency & weed index

$$WCE\ (\%) = \frac{DMC - DMT}{DMC} 100$$

Where,
DMC = Dry matter of weeds in the un weeded check (control)
DMT = Dry matter of weeds in the treated plot.

Weed Index (WI)

$$WI\ (\%) = \frac{(X - Y)}{X} 100$$

Where,
X = Grain yield from weed-free check or maximum yield treatment (Complete removal of weeds)
Y = Grain yield from treatment for which weed index is to be calculated

Grain yield (kg ha^{-1})

After recording the weight of total biomass, the produce of each net plot was threshed, separated and clean grains were sun dried to obtain 12% moisture. The grain yield was recorded in kg/plot and finally the converted into kg ha^{-1}.

Stalk Yield (kg ha^{-1})

Stalk yield from net plot area was computed by subtracting the grain yield from the total produce harvested and then converted into kg ha^{-1}.

Harvest Index (%)

Harvest index is the economic yield per hectare represented as a proportion of harvested biomass production represented in percentage.

$$\text{Harvest index} = \frac{\text{Economic yield (seed yield)}}{\text{Biological yield (seed yield + Straw yield)}} \times 100$$

Result and Discussion

Sedges and Weeds with broad and narrow leaves covered the experimental field. At the 60 days stage, the main weed species were *Dinerba retroflexa* (13.26%), *Digitaria sanguinalis* (12.85%). *Amarantus viridis* (8.24%), *Euphorbia hirta* (9.27%), *Cyperus Rotundus* (47.16%), *and other weeds* (9.93%). In table no. 1, data on density, dry weight of total weeds, and weed control efficiency recorded at 60 days stage of crop growth have been given.

The effectiveness of weed control was determined by how successfully weed populations were managed and how well weed control techniques outperformed weedy checks. This was greatly altered by various weed control techniques. Among all weed control methods, the higher weed control efficiency recorded with T_{11} weed-free was found to be more effective, followed by T_{10} Imazethapyr (10% SL) + Imazamox (10% SC) POE @ 35 +35 g ha^{-1} applied on 40 DAS followed by T_3 pendimethalin (30% EC) P.E @ 1200 g ha^{-1} applied on first DAS followed by T_2 Pendimethalin (30% EC) P.E @ 1000 g ha^{-1} applied on first DAS. The lowest weed control efficiency (WCE) recorded in weedy check treatment.

Among all weed control methods, the lower weed index recorded with T_{11} weed-free followed by T_{10} Imazethapyr (10% SL) + Imazamox (10% SC) POE @ 35 +35 g ha^{-1} applied on 40 DAS; T_3: Pendimethalin (30% EC) P.E @ 1000 g ha^{-1} applied on first DAS. The highest weed index (WI) recorded in weedy check treatment.

Table 1: Effect of different weed control treatments on weed density (no. m^{-2}), dry matter (g m^{-2}), Weed Control Efficiency (%), weed index at 60 DAS

S.no.	Treatment	Weed density (no. m^{-2})	Weed dry weight (g m^{-2})	WCE (%)	Weed Index (WI)
T_1	Pendimethalin (800 g ha^{-1}) @ P. E	14.25 (202.60)	9.29 (85.84)	62.47	25.76
T_2	Pendimethalin (1000 g ha^{-1}) @ P. E	12.79 (162.98)	8.01 (63.72)	72.14	11.67
T_3	Pendimethalin (1200 g ha^{-1}) @ P. E	11.32 (127.75)	6.67 (45.90)	79.93	8.23
T_4	Oxyfluorfen (150 g ha^{-1}) @ P. E	15.51 (240.02)	10.87 (117.75)	48.51	47.65
T_5	Oxyfluorfen (200 g ha^{-1}) @ P. E	14.01 (195.68)	8.83 (77.43)	66.14	19.53
T_6	Oxyfluorfen (250 g ha^{-1}) @ P. E	13.34 (177.53)	8.22 (67.09)	70.66	12.87
T_7	Imazethapyr (60 g ha^{-1}) @ P. E	15.76 (247.94)	10.57 (111.72)	51.15	49.26
T_8	Imazethapyr (70 g ha^{-1}) @ P. E	15.32 (234.20)	10.13 (102.20)	55.31	42.90
T_9	Imazethapyr (80 g ha^{-1}) @ P. E	14.61 (213.09)	9.46 (88.92)	61.12	29.94
T_{10}	Imazethapyr + Imazamox (35 + 35 g ha^{-1}) @ POE	10.57 (111.31)	6.44 (41.04)	82.05	5.84
T_{11}	Weed-Free check	0.71 (0.00)	0.71 (0.00)	100.00	0.00
T_{12}	Weedy Check	17.09 (291.73)	15.14 (228.69)	0.00	55.38
	S.Em ±	0.13	0.34	-	-
	CD @ 5%	0.40	1.01	-	-
Note: Fig. in parenthesis are the original values, X= $\sqrt{x}$ + 0.5 transformation					

The various weed management techniques had a substantial impact on the sesame yield characteristics. (Table 2).

Significantly higher yield was recorded in T_{11}: Weed-free (860.30 kg ha^{-1}). Which is at par with T_{10}: Imazethapyr (10% SL) + Imazamox (10% SC) POE @ 35 +35 g ha^{-1} applied on 40 DAS (810.04 Kg ha^{-1}) and T_3 Pendimethalin (30% EC) P.E @ 1200 g ha^{-1} applied on first DAS (789.52 kg ha^{-1}) and followed by T_2: Pendimethalin (30% EC) P.E @1000g ha^{-1} (759.88 kg ha^{-1}) and T_6: Oxyfluorfen (23.5% EC) P.E @ 250 g ha^{-1} (749.58 kg ha^{-1}). Significantly lower yield was recorded with the T_{12} weedy-check (383.90 kg ha^{-1}), because of a severe weed infestation.

Impact on economics of Sesame. (Table no. 3).

Among all the herbicide treatments, the highest net return was recorded with T_{10}: Imazethapyr (10% SL) + Imazamox (10% SC) POE @ 35 + 35 g ha^{-1} applied on 40 DAS (70776.24 ha^{-1}), which is at par with T_3: Pendimethalin (30% EC) P.E @ 1200 g ha^{-1} applied on first DAS (68323.88 ha^{-1}), followed by; T_2: Pendimethalin (30% EC) P.E @1000g ha^{-1} (65798.50 ha^{-1}) and; T_6: Oxyfluorfen (23.5% EC) P.E @ 250 g ha^{-1} (63963.71 ha^{-1}); lowest return was recorded in T_{12}; weedy check the (20600.69 ha^{-1}). The benefit-cost ratio recorded a higher value in T_{10}: Imazethapyr (10% SL) + Imazamox (10% SC) POE @ 35 +35 g ha^{-1} (INR 2.25), followed by T_3: Pendimethalin (30% EC) P.E @ 1200 g ha^{-1} (INR 2.18), followed by T_2: Pendimethalin (30% EC) P.E @1000g ha^{-1} (INR 2.12) and followed by T_6: Oxyfluorfen (23.5% EC) P.E @ 250 g ha^{-1} (INR 2.02).

Table 2: Effect of different treatments on yield of Sesame

S. no.	Treatment	Grain yield (kg ha^{-1})	Stalk yield (kg ha^{-1})	Harvest index
T_1	Pendimethalin (800 g ha^{-1}) @ P. E	638.69	1756.79	26.66
T_2	Pendimethalin (1000 g ha^{-1}) @ P. E	759.88	2051.40	26.96
T_3	Pendimethalin (1200 g ha^{-1}) @ P. E	789.52	2059.17	27.72
T_4	Oxyfluorfen (150 g ha^{-1}) @ P. E	450.35	1285.82	25.94
T_5	Oxyfluorfen (200 g ha^{-1}) @ P. E	692.31	1893.00	26.78
T_6	Oxyfluorfen (250 g ha^{-1}) @ P. E	749.58	2031.75	26.95
T_7	Imazethapyr (60 g ha^{-1}) @ P. E	436.51	1249.19	25.90
T_8	Imazethapyr (70 g ha^{-1}) @ P. E	491.23	1401.37	26.62
T_9	Imazethapyr (80 g ha^{-1}) @ P. E	602.71	1713.07	26.06
T_{10}	Imazethapyr + Imazamox (35 + 35 g ha^{-1}) @ POE	810.04	2111.37	27.73
T_{11}	Weed-Free check	860.32	2223.41	27.90
T_{12}	Weedy Check	383.90	1101.37	25.85
	SEm±	32.52	92.96	0.54
	C.D. at 5%	95.37	272.65	NS

Table 3: Effect of different treatments on economics of Sesame

S. no.	Treatment	Gross returns (INR ha $^{-1}$)	Net returns (INR ha $^{-1}$)	B-C ratio (INR re^{-1} Invested)
T_1	Pendimethalin (800 g ha^{-1}) @ P. E	81757.40	51134.40	1.67
T_2	Pendimethalin (1000 g ha^{-1}) @ P. E	96805.62	65798.50	2.12
T_3	Pendimethalin (1200 g ha^{-1}) @ P. E	99715.12	68323.88	2.18
T_4	Oxyfluorfen (150 g ha^{-1}) @ P. E	58213.94	27602.67	0.90
T_5	Oxyfluorfen (200 g ha^{-1}) @ P. E	88486.03	57366.51	1.84
T_6	Oxyfluorfen (250 g ha^{-1}) @ P. E	95591.48	63963.71	2.02
T_7	Imazethapyr (60 g ha^{-1}) @ P. E	56459.49	26580.97	0.89
T_8	Imazethapyr (70 g ha^{-1}) @ P. E	63484.10	33473.57	1.12
T_9	Imazethapyr (80 g ha^{-1}) @ P. E	77814.55	47672.03	1.58
T_{10}	Imazethapyr + Imazamox (35 + 35 g ha^{-1}) @ POE	102290.76	70776.24	2.25
T_{11}	Weed-Free check	108409.64	65323.12	1.52
T_{12}	Weedy Check	49687.21	20600.69	0.71
	SEm+	--	--	--
	C.D. at 5%	--	--	--

Conclusion

Post and pre-emergence application of herbicides may help the sesame crop with higher crop production and net returns. When compared with other treatments using Imazethapyr (10% SL) + Imazamox (10% SC) POE @ 35 + 35 g ha^{-1} showed superior results in terms of reducing weed density and dry weight of weeds.

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