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Research Paper

Effect of post-emergence herbicides on yield and economics of sesame (*Sesamum indicum*)

SOURAV GUPTA[1], S.S. KUSHWAH[2], RAJENDRA MANDLOI[3], JYOTIMALA SAHU[4], R.N. SHARMA[5] AND SUSHIL YADAV[6]

Rajamata Vijayaraje Scindia Krishi Vishwa Vidyalaya, Gwalior, Madhya Pradesh 474 002

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ABSTRACT

An experiment was conducted during the rainy (*kharif*) seasons of 2013 and 2014 at Gwalior, Madhya Pradesh, to study effect of post-emergence herbicides on yield and economics of sesame (*Sesamum indicum* L.). The experiment was laid out in a randomzied block design (RBD) replicated thrice, with 8 treatments. Sesame variety 'TKG 22' was grown by adopting recommended package of practices except weed-control measures which were applied as per treatments. Two hand-weedings at 20 and 40 days after sowing (DAS) gave significantly higher weed control efficiency (94.14%), followed by propaquizafop @ 125 g a.i./ha (69.51%) over rest of the weed-control treatments. Pooled results showed significantly higher growth and yield attributes and seed yield (718 kg/ha), stalk yield (3,243 kg/ha), gross income (₹73.4 × 10^3), net income (₹47.3 × 10^3) and benefit: cost ratio (2.82) under 2 hand-weeding at 20 and 40 DAS over rest of the weed-control treatments, followed by propaquizafop @ 50 g a.i./ha. Application of propaquizafop @ 125 g a.i./ha produced phytotoxicity on sesame plants and subsequently affected the growth attributes in crop; however, symptoms of chlorosis disappeared 25–30 days after application of herbicides.

Key words**:** Benefit: cost ratio, Gross income, Herbicides, Sesame, Weeds, Weed control efficiency, Yield

Sesame is popularly known as *til, tilli, gingelly* etc. one of the important edible oilseeds cultivated in India. Its oil content varies from 46 to 52%. Protein content in seed varies between 20 and 26%. It is grown in the rainy (*kharif*) season in Madhya Pradesh, during which it faces severe competitional stress from weeds. Narrow-leaf weeds infest the *kharif* crop severally than broad-leaf weeds in Gird Agro-climatic region of Madhya Pradesh.

Severe weed competition is one of the major constraints in lower productivity of sesame. The competitional stress of weeds on crop for nutrients, water, light and space is responsible for poor yield of sesame. Prevalence of high temperature with high relative humidity and frequent rainfall during the crop season coupled with slow plant growth particularly during early crop-growth stages favour luxuriant weed growth since seedling emergence which causes about 50–75% reduction in seed yield of sesame (Dungarwal *et al.*, 2003). The period from 15–30 days after sowing (DAS) is the most critical period of crop–weed competition in sesame (Venkatakrishan and Gnanamurthy, 1998). Therefore, it is essential to control weeds during the initial growth period. Though the conventional methods of weed control are very much effective but due to high wages and non-availability of labourers during the critical weeding season (15–30 DAS) and incessant protracted rains, use of post-emergence herbicides could be more time saving, economical and efficient to check early crop-weed competition. The research work on post-emergence herbicidal weed control in sesame is meager, particularly in Gird Agro-climatic region of Madhya Pradesh. Keeping this in view, an attempt was made to evaluate new post-emergence herbicidal molecules for the control of grassy weeds.

MATERIALS AND METHODS

A field experiment was conducted at the Research Farm, College of Agriculture, Gwalior, Madhya Pradesh during the *kharif* seasons of 2013 and 2014 under the

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[1]**Corresponding authors Email:** souravgupta654@gmail.com
[1]Ph.D. Scholar, [2]Scientist, [5]Assistant Professor, [3,6]M.Sc. Scholar, Department of Agronomy, College of Agriculture, Rajamata Vijayaraje Scindia Krishi Vishwa Vidyalaya, Gwalior, Madhya Pradesh; [4]Ph.D. Scholar, Department of Agronomy, College of Agriculture, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur Madhya Pradesh

edaphic and climatic conditions of Gwalior (26°13' N, 78°14' E, 206 m above sea-level). It lies in the Northern tract of Madhya Pradesh, enjoying sub-tropical climate. The maximum temperature goes up to 46.6°C during summer and minimum as low as 0°C during winter under extreme cases. The average rainfall ranges between 75 and 80 cm most of which is received in the months of June, July and August with few showers in winter months. The weather condition was normal during the crop season with an average maximum and minimum temperature during growing period remained as 35.7°C and 20.6°C during 2013 and 37.6°C and 16.5°C during 2014, respectively. The total rainfall received during the rainy season of 2013 and 2014 from June to October was 871.0 mm and 508.2 mm respectively. The topography of the field was uniform with proper drainage. The soil of the experimental field was sandy clay loam (60.10% sand, 17.90% silt and 22.00% clay), neutral to alkaline in reaction (*p*H 7.5). The soil was low in organic carbon (0.39%), available nitrogen (180 kg/ha), medium in available phosphorus (14 kg/ha) and available potassium (235.2 kg/ha), and electrical conductivity 0.39 mmhos/cm.

The experiment was conducted in a randomized block design with 3 replications and 8 treatments. The treatments of weed-control include: propaquizafop 10% EC post-emergence: PoE @ 50 g a.i./ha T_1, propaquizafop 10% EC (PoE) @ 62.5 g a.i./ha; T_2, propaquizafop 10% EC PoE @ 100 g a.i./ha; T_3, propaquizafop 10% EC (PoE) @ 125 g a.i./ha; T_4, quizalofop-p-ethyl 5% EC (PoE) @ 50 g a.i./ha; T_5, fenoxaprop-p-ethyl 9% EC (PoE) @ 100 g a.i./ha; T_6, 2 hand-weedings at 20 and 40 days after sowing (DAS); T_7, and weedy check T_8.

The seed was treated with carbendazim @ 2 g/kg seed. The sesame variety 'TKG 22' was sown in gross plot size 5.0 m × 3.6 m with planting geometry 30 cm × 10 cm, behind the hand plough with a seed rate 5 kg/ha, keeping 3–4 cm depth in the first and third week of July in the 2013 and 2014 respectively. The nutrients were applied @ 60 kg N, 40 kg P_2O_5 and 20 kg K_2O/ha. All quantities of fertilizers (except nitrogen) were applied basal. Nitrogen fertilizer 50% was applied basal and 50% at 30 DAS. Urea was source of the nitrogen, single super phosphate was taken as a source of phosphorus and muriate of potash was used as the source of potassium. The required quantity of fertilizer for each plot was weighted and placed at a depth of 6–8 cm below the seed.

Herbicidal spray was done at 20 DAS in both the years. Weeds were counted by randomly placing quadrate of 1m² in each plot. Three quadrates were thrown in each plot and than an average values were worked out. The first observation was recorded at 20 DAS and later on studies pertaining to this character were carried out at 40, 60 DAS and harvest stage. The data pertaining to weed population were subjected to Log x, Log (x+1) and √x, √x+0.5 transformations as per requirement for statistical analysis. All recommended practices were followed during crop-growing season. The crop was harvested on 18 and 22 September during 2013 and 2014 respectively.

RESULTS AND DISCUSSION

Weed flora

The weed flora observed in the experimental field included *Cyperus rotundus* L., *Cynodon dactylon* L. Pers., *Echinochloa crus-galli* L. Beauv., *Echinochloa colona* (L.) Link., *Dinebra retroflexa Panz., Digitaria longiflora (Retz.) Pers.,* and *Dactylactenium aegyptium* (L.) Willd. as narrow-leaf weeds, while *Parthenium hysterophorus* L., *Commelina benghalensis* L., *Digera arvensis* Forsskal, *Alternanthera sessilis* (DC.), and *Celosia argentea* L. were broad-leaf weeds during both the years of study.

Effect on weeds

Total weed population and dry weight were significantly reduced under the application of various weed control treatments over weedy check (2.10/m² and 156.33 g/m² respectively). The lowest total weed population and dry weight were noted with 2 hand-weeding at 20 and 40 DAS over rest of the weed control treatments. The next effective treatment was propaquizafop @ 125 g a.i./ha, followed by propaquizafop @ 100 g a.i./ha, which was statistically at par with treatments fenoxaprop-p-ethyl @ 100 g a.i./ha (Table 1). Similar results were also obtained by Kushwah and Vyas (2006) and Bhadauria *et al.* (2012).

Higher weed-control efficiency were observed under all treated plots compared to weedy check. The significantly highest weed-control efficiency was recorded in treatment 2 hand-weeding at 20 and 40 DAS over the remaining treatments. The next effective treatment was propaquizafop @ 125 g a.i./ha, followed by propaquizafop @ 100 g a.i./ha, fenoxaprop-p-ethyl @ 100 g a.i./ha, propaquizafop @ 62.5 g a.i./ha, propaquizafop @ 50 g a.i./ha and quizalofop-p-ethyl @ 50 g a.i./ha. This may be attributed to better control of weeds under the weed-control treatments which might have provided comparatively stress-free environment to better crop growth and development (Table 1). These findings are in close proximity of that reported by Benke *et al.* (2012).

Effect on crop

The weed-control practices significantly affected the growth attributes, viz. plant height, branches/plant and leaves/plant at all the crop-growth stages. The rate of increase in growth attributes was more during 20–40 DAS compared to 40–60 DAS, thereafter decreasing trend observed up to the harvesting stage. Two hand-weedings at 20 and 40 DAS resulted in significantly highest plant height, branches/plant and leaves/plant over rest of the weed-control treatments. The next effective treatment was propaquizafop @ 50 g a.i./ha, followed by quizalofop-p-ethyl @ 50 g a.i./ha and both these treatments were statistically at par with each other. Significant difference in growth attributes were obtained under the weed-control treatments owing to better micro-climatic situations created by these weed-control treatments for crop growth. Such congenial field conditions favoured the growth in crop plants over weedy check (Table 1). These observations are in agreement with Patel *et al.* (2011) and Benke *et al.* (2012).

Many morphological characters of the plant interacting with environment influence yield of crop. There is a good possibility of increasing the yield by exploiting some of the yield-attributing components, viz. plant population, capsules/plant, seeds/capsule, 1,000-seed weight and seed yield/plant. Plant population was not affected significantly by different weed-control treatments and its ranges from 8.06 to 9.56 plants/m row length. Significantly higher yield attributing characters, viz. capsules/plant, seeds/capsule, 1,000-seed weight and seed yield/plant, were recorded under treatment 2 hand-weeding at 20 and 40 DAS over rest of the weed control treatments. The next effective treatment for capsules/plant and seeds/capsule yield attributes was propaquizafop @ 50 g a.i./ha, followed by quizalofop-p-ethyl @ 50 g a.i./ha, and both treatments were statistically at par with each other. Similarly, the next

Table 1. Effect of weed-control practices on total weed population, total weed dry weight and weed-control efficiency, and growth attributes at 75 days after sowing (DAS) in sesame (pooled data of 2 years)

Treatment	Weed population/m²			Total weed-dry weight (g/m²)	Weed-control efficiency (%)	Plant height (cm)	Branches/ plant	Leaves/ plant	Plant population/m row length
	Narrow leaf	Broad leaf	Total						
Propaquizafop @ 50 g a.i./ha	1.57 (38.6)	1.36 (23.0)	1.78 (61.6)	56.8	63.6	136.0	3.47	132.7	9.00
Propaquizafop @ 62.5 g a.i./ha	1.55 (36.7)	1.37 (23.7)	1.77 (60.3)	53.4	65.8	133.6	3.30	125.6	8.95
Propaquizafop @ 100 g a.i./ha	1.48 (30.3)	1.37 (23.5)	1.73 (53.8)	48.8	68.7	130.3	3.03	116.2	9.11
Propaquizafop @ 125 g a.i./ha	1.42 (26.5)	1.34 (22.3)	1.69 (48.8)	47.7	69.5	129.6	2.80	114.5	9.11
Quizalofop-p-ethyl @ 50 g a.i./ha	1.58 (40.0)	1.36 (23.2)	1.79 (63.2)	58.6	62.5	135.4	3.37	130.3	9.00
Fenoxaprop-p-ethyl @ 100 g a.i./ha	1.50 (32.0)	1.35 (22.8)	1.73 (54.8)	50.4	67.7	130.4	3.00	115.8	9.11
2 hand-weeding at 20 and 40 DAS	0.97 (10.0)	0.55 (3.7)	1.12 (13.7)	9.2	94.1	147.4	4.13	144.5	9.56
Weedy check	2.01 (103.1)	1.38 (24.2)	2.10 (127.3)	156.3	-	114.7	2.10	101.4	8.06
SEm±	0.01	0.01	0.01	1.45	-	0.89	0.07	1.23	0.19
CD (P=0.05)	0.04	0.03	0.03	4.19	-	2.58	0.19	3.57	NS
Transformation	Log(x)	Log(x)	Log(x)	-	-	-	-	-	-

DAS, Days after sowing; figure in parentheses are original values of weed population; a.i., active ingradient

Table 2. Effect of weed-control practices on yield attributes, yield and economics of sesame at harvest (pooled data of 2 years)

Treatment	Capsules/ plant	Seeds/ capsule	1,000-seed weight (g)	Seed yield/ plant (g)	Seed yield /ha (kg)	Stalk yield/ha (kg)	Gross returns (× 10^3 ₹/ha)	Net returns (× 10^3 ₹/ha)	Benefit: cost ratio
Propaquizafop @ 50 g a.i./ha	44.8	44.9	2.87	5.78	517	2,785	53.1	33.3	2.68
Propaquizafop @ 62.5 g a.i./ha	43.5	44.3	2.82	5.48	485	2,691	49.8	29.7	2.48
Propaquizafop @ 100 g a.i./ha	40.4	42.5	2.74	4.70	427	2,476	43.9	23.2	2.12
Propaquizafop @ 125 g a.i./ha	39.5	42.0	2.71	4.49	407	2,413	41.9	20.7	1.98
Quizalofop-p-ethyl @ 50 g a.i./ha	44.1	44.4	2.77	5.44	495	2,722	50.8	30.4	2.49
Fenoxaprop-p-ethyl @ 100 g a.i./ha	40.7	42.8	2.74	4.77	432	2,479	44.4	23.6	2.14
2 hand-weedings at 20 and 40 DAS	50.9	49.0	3.01	7.53	718	3,243	73.4	47.3	2.82
Weedy check	32.6	36.6	2.49	3.02	233	1,972	24.3	5.8	1.31
SEm±	0.38	0.37	0.02	0.08	13.7	21.7			
CD (P=0.05)	1.11	1.08	0.06	0.23	39.7	62.9			

DAS, Days after sowing; a.i., active ingradient effective treatment for 1,000-seed weight and seed yield/plant parameter was propaquizafop @ 50 g a.i./ha, followed by propaquizafop @ 62.5 g a.i./ha, and both treatments were statistically at par with each other. The increase in yield attributes under different weed control treatments may also be attributed to increased availability of nutrients, water, light and space to crops as a result of effective weed-control. However, almost weed-free condition under treatment of 2 hand-weedings at 20 and 40 DAS enabled the crop plants to grow vigorously and produced more seeds/capsule, capsules/plant, test weight and seed yield/plant (Table 2). Such views were also reported by Singh *et al.* (2006).

All the weed-control treatments significantly increased the seed yield (kg/ha) and stalk yield (kg/ha) over weedy check. The significantly higher seed yield/ha and stalk yield/ha were recorded under treatment 2 hand-weedings at 20 and 40 DAS over rest of the weed control treatments. The next effective treatment was propaquizafop @ 50 g a.i./ha, followed by quizalofop-p-ethyl @ 50 g a.i./ha and both the treatments were statistically at par with each other. All these weed-control treatments resulted in 74.68 to 208.15% increase in seed yield/ha and 22.36 to 64.45% increase in stalk yield/ha over the weedy check. The unchecked weeds of weedy check plot reduced the seed yield by 67.55% and stalk yield by 39.19% when compared to seed and stalk yield/ha of treatment of 2 hand-weedings at 20 and 40 DAS (Table 2). The superiority of all weed-control treatments over weedy check under increasing seed yield (kg/ha) and stalk yield (kg/ha) also corroborate the findings of Kushwah and Vyas (2005) and Benke *et al.* (2012).

Phytotoxic effect

The application of propaquizafop @ 125 g a.i./ha, propaquizafop @ 100 g a.i./ha and fenoxaprop-p-ethyl @ 100 g a.i./ha were found effective weed-control treatments over rest of the herbicidal weed control treatments, but had phytotoxic effects on growth of sesame, viz. chlorosis and AC-Case inhibitor (Inhibition of fatty acid synthesis pre-

Table 3. 0 to 10 scale for observation for the specific parameters like chlorosis, necrosis, wilting, scorching, hyponasty and epinasty

Score	Phytotoxicity (%)	Score	Phytotoxicity (%)
0	No phytotoxicity	6	51–60
1	0–10	7	61–70
2	11–20	8	71–80
3	21–30	9	81–90
4	31–40	10	91–100
5	41–50	-	-

Table 4. Phytotoxicity symptoms in seasame on 10 point scale at 1, 3, 5, 7 and 10 days after application of different post-emergence herbicides

Parameter	Chlorosis					Necrosis					Wilting					Scorching					Hyponasty					Epinasty				
Treatment	Days of observations																													
	1	3	5	7	10	1	3	5	7	10	1	3	5	7	10	1	3	5	7	10	1	3	5	7	10	1	3	5	7	10
Propaquizafop @ 50 g a.i./ha	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Propaquizafop @ 62.5 g a.i./ha	0	1	2	3	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Propaquizafop @ 100 g a.i./ha	0	2	3	4	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Propaquizafop @ 125 g a.i./ha	0	3	4	6	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Quizalofop-p-ethyl @ 50 g a.i./ha	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

sumably blocks the production of phospholipids used in building new membranes required for cell growth) resulting significantly reduced growth and yield attributes and subsequently significant decrease in yield (Tables 3 and 4). These views were also earlier confirmed by Nadeem *et al.* (2009).

Economic analysis

The choice of any weed-control method ultimately depends on economics and efficiency in controlling weeds. The cost of chemical weed control is actually less than that of manual weeding. This has been a major incentive to many farmers for switching over to herbicides. The highest total cost of cultivation was incurred for treatment involving 2 hand-weedings at 20 and 40 DAS, followed by propaquizafop @ 125 g a.i./ha. All the weed-control treatments resulted in higher gross income over weedy check. The highest gross income, net income and benefit: cost ratio were obtained under 2 hand-weedings at 20 and 40 DAS, and followed by propaquizafop @ 50 g a.i./ha (Table 2). Under all the weed-control treatments, benefit: cost ratio were found low due to abnormal weather conditions during crop-growth period. Vijayalaxmi *et al.* (2012) also reported such findings.

On the basis of 2-year studies, it may be concluded that 2 hand-weedings at 20 and 40 DAS proved most remunerative. Simultaneously, in case of labourer scarcity post-emergence application of propaquizafop @ 50 g a.i./ha may be practiced for managing the grassy weeds economically. However, quizalofop-p-ethyl @ 50 g a.i./ha also gave effective and economical weed control, statistically being at par with propaquizafop @ 50 g a.i./ha.

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