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Impact of weed management strategies on dry matter production and yield in sesame (*Sesamum indicum* L.)

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Abstract
Sesame, 'the queen of oilseeds' occupies a major share of oilseed production in India. Slow growth during initial growth stages contributes to heavy weed infestation, leading to low yield and quality in sesame. The investigation was conducted at 'College of Agriculture, Raichur' to analyze different pre and post-emergence herbicides and inter-cultivation for weed management practices in Sesame (*Sesamum indicum* L.). The field experiment consisted of 8 different weed management treatments. Randomized Block Design (RBD) was used as the design with three replications. Preemergence application of alachlor 50 EC @ 0.75 kg ha^{-1} along with hand weeding at 30 DAS and inter-cultivation at 45 DAS gave significantly lower dry weight of weeds at 20, 40, 60 DAS and at harvest (0.73, 0.63, 0.85 and 1.80 g/m^2, respectively) followed by Post-emergence application of Quizalofop 5 EC @ 40 g ha^{-1} at 20 DAS along with Inter-Cultivation at 45 DAS. Concerning dry matter production and chlorophyll content, Preemergence application of alachlor 50 EC @ 0.75 kg ha^{-1} along with hand-weeding at 30 DAS and inter-cultivation at 45 DAS resulted in significantly higher values when compared to other treatments. Among the treatments, preemergence application of alachlor 50EC produced the highest yield of seeds (480 kg ha^{-1}).

Keywords: Weed management, sesame, alachlor, quizalofop ethyl, crop phytotoxicity

Introduction
Sesame, (*Sesamum indicum* L) is an erect annual plant belonging to Family Pedaliaceae. It is grown since antiquity for its oil extracted from seeds which is also used for food, flavouring and religious purposes. Sesame or 'gingelli' is called as 'til' in India and is labeled as the "Queen of Oilseeds". The seeds have high-quality ply-unsaturated stable fatty acids. The exquisite keeping quality makes it the most preferred oil in the preservation of pickles. The crop grows slow during its initial stages of growth, so when weeds sprout and proliferate, there is fierce competition amongst them for nutrients, light, moisture, and space. Therefore, weed-free environments are crucial to sesame yield, especially during its early growing stage. Sesame losses resulting from unchecked weed growth have been documented to reach 50%. (Dungarwal *et al*., 2006) [2]. In Sesame, it is imperative to uphold weed-free conditions starting from the second week following the germination and emergence of sesame. This must be sustained until the ninth week to prevent losses of greater than five percent in sesame output. (Karnas *et al*., 2019) [6]. The most crucial time for crop weed competition in sesame is between 15 and 30 DAS (Venkatakrishnan & Gnanamurthy, 1998) [15]. Though manual weeding is the usual and commonly followed practice to control weeds, labor cost, as well as the scarcity of labor, urges the need for alternative methods of weed management Pre- and post-emergence herbicides in conjunction with manual weeding lowered the cost of labor for controlling weeds, which in turn led to a decrease in the overall cost of cultivation and a maximum B:C (Gupta *et al.*, 2019) [3]. Manual hand weeding is time-consuming, tedious, costly, and difficult to adopt in large areas (Singh *et al.*, 2014) [13]. Adopting better techniques resulted in a considerable increase in crop output, yield-related attributes, and net returns to farmers (Chaudhary *et al.*, 2022) [1]. With the aim of suggesting alternating methods to hand weeding, the present study was done with an objective of assessing various integrated weed management strategies in Sesame.

Materials and Methods
The field experiment was conducted at the 'Agricultural College Farm', Raichur, Karnataka. The experimental site's soil was medium black soil with available N content of 223.25 kg ha^{-1} (Subbiah and Asija 1956) [14], available P2O5 of 33.41 kg ha^{-1} (Olsen *et al*. 1954) [9] and

available K2O content of 195.30 kg ha^{-1} and a pH of 8.21. Eight treatments and three replications were included in the Randomized Block Design (RBD) setup for the trial. In a 5.4 m × 4.5 m plot, sesame variety, DS-1, was seeded with a 30 cm x 15 cm spacing. 50 kg N, 25 kg P2O5, and 25 kg K2O ha^{-1} were used as the basal doses for fertilizing sesame. The crop was fertilized with 50 kg N, 25 kg P_2O_5 and 25 kg K_2O ha^{-1} as basal dose. T_1: Unweeded check, T_2: Weed free check (Hand weeding at 15 DAS along with intercultivation at 30 and 45 DAS) T_3: Recommended practice (Preemergence application of alachlor 50 EC @ 0.75 kg ha^{-1} along with hand weeding at 30 DAS along with intercultivation at 45 DAS), T_4: Preemergence application of Pendimeth 30 EC @ 1 kg ha^{-1} along with hand weeding at 30 DAS and intercultivation at 45 DAS, T_5: Preemergence application of Pendimeth 38.7 CS @ 1 kg ha^{-1} along with hand weeding at 30 DAS and intercultivation at 45 DAS, T_6: Preemergence application Butachlor 50 EC @ 1 kg ha^{-1} along with hand weeding at 30 DAS and IC at 45 DAS, T_7: Post emergence application of Quizalofop 5 EC @ 40 g ha^{-1} at 20 DAS along with intercultivation at 45 DAS, T_8: Post emergence application of Imazethapyr 10 SL @ 75 g ha^{-1} at 20 DAS along with intercultivation at 45 DAS. Using a hand backpack sprayer with a flat fan nozzle and a spray capacity of 750 l ha^{-1}, pre-emergence treatments (PE) of Alachlor 50 EC, Butachlor 50 EC, Pendimeth 30 EC, and Pendimeth 38.7 CS were given, and post-emergence treatments (PoE) of Quizalofop and Imazethapyr were sprayed at 20 DAS. Weed biomass and density were measured at 20, 40, and 60 DAS as well as at harvest using a 50 cm × 50 cm quadrate that was thrown at random at four locations within each plot. Prior to analysis, the dry matter and weed density data had been modified using square root transformation.

Results and Discussion

Effect on weeds: The dominant weed flora seen in the experimental field was mainly *Agropyron repens* (L.)., *Cyperus rotundus* L., *Cynodon dactylon* (L.) Pers, *Abutilon indicum* (L.) Sweet, *Acalypha indica*, *Ageratum conyzoides* L., *Commelina benghalensis* L., *Parthenium hysterophorus* L., *Phyllanthus maderaspetensis*, *Portulaca oleraceae*, *Tribulus terrestris* L., *Xanthium strumarium* L. Across all crop growth stages, the various weed control treatments led to a significant variation in the total dry weight of weeds.

At the 20-day-old crop stage (20 DAS), the recommended practice involving the Preemergence application of Alachlor 50 EC at a rate of 0.75 kg ha^{-1}, coupled with hand weeding at 30 DAS and inter cultivation at 45 DAS (T3), exhibited the most effective control of weed growth, recording the lowest total dry matter of weeds at 0.73 g/m^2 compared to other treatments. Notably, the treatment employing Preemergence application of Butachlor 50 EC at 1 kg ha$^-$, combined with hand-weeding at 30 DAS and inter cultivation at 45 DAS (T6), and preemergence application of Pendimeth 38.7 CS at 1 kg ha^{-1} along with hand-weeding at 30 DAS and inter cultivation at 45 DAS (T5), demonstrated comparable results with similarly low weed dry matter.

Conversely, the unweeded control group (T1) exhibited the highest total weed dry matter at 1.04 g/m^2, which was statistically equivalent to the treatment involving post-emergence application of Quizalofop 5 EC at 40 g ha^{-1} at 20 DAS, coupled with inter cultivation at 45 DAS (T7). The recommended practice (T3) displayed the lowest weed dry weight at both 40 and 60 DAS, followed closely by the treatment with Quizalofop 5 EC at 40 g ha^{-1} as a post-emergence application at 20 DAS, combined with inter cultivation at 45 DAS (T7), and these two treatments showed comparable results. The reduced weed dry weight in these treatments suggests a lower weed population, aligning with the findings reported by Joseph *et al*.(2006) [4].

During the harvest period, the lowest overall dry weight of weeds (1.80 g/m^2) was documented in the recommended practice (T3), which was comparable to the effectiveness of post emergence application of Quizalofop 5 EC applied at 40 g ha^{-1} at 20 DAS in conjunction with inter cultivation at 45 DAS (T7). Patnaik *et al*. (2020) [10] underscores the efficacy of Alachlor in their reports. Conversely, the highest total dry weight of weeds (1.80 g/m^2) was observed in the unweeded check (T1), with the subsequent highest weight seen in the treatment involving as a pre-emergence application of pendimeth 30 EC applied at 1 kg ha^{-1}, complemented by hand weeding at 30 DAS and inter cultivation at 45 DAS (T4). At harvest, all treatments exhibited an increase in dry weight of weeds due to the continual emergence of weeds during this period, a phenomenon similarly noted by Singh *et al*. (2004) [12].

Effect on crops

At all growth stages, there were significant differences in dry matter production per plant among various weed control treatments. The weed-free check (T2) exhibited the highest dry matter production (2.91 g plant^{-1}) at 30 DAS, outperforming other treatments. Following closely were the pre-emergence application of alachlor 50 EC @ 0.75 kg ha^{-1} coupled with hand weeding at 30 DAS and inter-cultivation at 45 DAS, post-emergence application of Quizalofop 5 EC @ 40 g ha^{-1} at 20 DAS, and inter-cultivation at 45 DAS(T7) and preemergence application of Butachlor 50 EC @ 1 kg ha^{-1} coupled with hand-weeding at 30 DAS, and inter-cultivation at 45 DAS -(T6). The lowest dry matter production occurred with post-emergence application of imazethapyr 10 SL @ 75 g ha^{-1} at 20 DAS along with inter cultivation at 45 DAS (T8), attributed to the herbicide's phytotoxic effects.

At 60 DAS and harvest, post emergence application of Imazethapyr 10 SL @ 75 g ha^{-1} (T8) resulted in the lowest dry matter production (7.00 g plant^{-1} and 9.62 g plant^{-1}, respectively), followed by the unweeded check (T1). Weed-free check (T2) recorded the highest dry matter production (24.47 g plant^{-1} and 29.95 g plant^{-1}), followed by the recommended practice (Alachlor 50 EC @ 0.75 kg ha^{-1}, hand weeding at 30 DAS, and inter cultivation at 45 DAS - T3).

The chlorophyll content in sesame decreased with plant age, and significant differences were observed among weed control treatments. At 30 DAS, the weed-free check (T2) exhibited the highest chlorophyll content (45.69), followed by the recommended practice (T3) and post-emergence application of Quizalofop 5 EC @ 40 g ha^{-1} at 20 DAS along with inter cultivation at 45 DAS (T7), which were comparable. Imazethapyr 10 SL @ 75 g ha^{-1} (T8) recorded the lowest chlorophyll content (24.83) at 30 DAS, followed by the unweeded check (T1).

Similarly, at 60 DAS, Imazethapyr 10 SL @ 75 g ha^{-1} (T8) resulted in the lowest chlorophyll content (14.33), followed by the unweeded check (T1). The highest chlorophyll content was observed in the weed-free check (T2) (27.83), followed by the recommended practice (25.95).

Weed-free check recorded the highest number of capsules plant^{-1} (31.67), number of seeds capsule^{-1} (38.33), seed yield (588 kg ha^{-1}), and stalk yield (2520 kg ha^{-1}) followed by Alachlor 50 EC @ 0.75 kg ha^{-1} as pre-emergence application along with hand-weeding at 30 DAS and inter-cultivation at 45 DAS (T_3), quizalofop ethyl 5 EC @ 40 g ha^{-1} as Post-emergence application at 20 DAS and IC at 45 DAS. This can be due to the application of herbicide along with the cultural practices resulting in minimised crop weed competition and offering good environment for better plant growth and this resulted in better yield of sesame. Similar findings were reported by Nisha Bhadauria *et al.* (2012) [8] and Parvender Sheoran *et al.* (2012) [11]. In contrast, Imazethapyr 10 SL @ 75 g ha^{-1} (T8) recorded the lowest seed yield (86.00 kg ha^{-1}) due to severe phytotoxic effects. Joshi *et al* (2022) [5] reported the phytotoxic effect of Imazethapyr which causes the destruction of sesame growth. The unweeded check (T1) also resulted in low seed yield (179.67 kg ha^{-1}) due to weed competition, as reported by Narkhede *et al*. (2000) [7].

Weed-free check displayed the highest harvest index (0.19). The recommended practice (T3), post-emergence application of Quizalofop 5 EC @ 40 g ha^{-1} at 20 DAS, and inter-cultivation at 45 DAS (T7), pre-emergence application of Butachlor 50 EC @ 1 kg ha^{-1} along with hand weeding at 30 DAS, and inter-cultivation at 45 DAS (T6), pre-emergence application of Pendimeth 38.7 CS @ 1 kg ha^{-1} along with hand weeding at 30 DAS and inter cultivation at 45 DAS (T5), pre-emergence application of Pendimeth 30 EC @ 1 kg ha^{-1} coupled with hand weeding at 30 DAS and inter-cultivation at 45 DAS (T4) followed in descending order and were comparable. Post-emergence application of Imazethapyr 10 SL @ 75 g ha^{-1} at 20 DAS along with inter cultivation at 45 DAS and the unweeded check (T1) resulted in the lowest harvest index (0.10).

At the 20-day-old crop stage (20 DAS), the recommended practice involving the application of as a pre-emergence treatment of Alachlor 50 EC at a rate of 0.75 kg ha^{-1}, coupled with hand weeding at 30 DAS and inter cultivation at 45 DAS (T3), exhibited the most effective control of weed growth, recording the lowest total dry matter of weeds at 0.73 g/m^2 compared to other treatments. Notably, the treatment employing pre-emergence application of Butachlor 50 EC at 1 kg ha^{-1}, combined with hand-weeding at 30 DAS and inter cultivation at 45 DAS (T6), and pre-emergence application of Pendimeth 38.7 CS at 1 kg ha^{-1} along with hand-weeding at 30 DAS and inter cultivation at 45 DAS (T5), demonstrated comparable results with similarly low weed dry matter.

Conversely, the unweeded control group (T1) exhibited the highest total weed dry matter at 1.04 g/m^2, which was statistically equivalent to the treatment involving post-emergence application of Quizalofop 5 EC at 40 g ha^{-1} at 20 DAS, coupled with inter cultivation at 45 DAS (T7). The recommended practice (T3) displayed the lowest weed dry weight at both 40 and 60 DAS, followed closely by the treatment with post-emergence application Quizalofop 5 EC at 40 g ha^{-1} at 20 DAS, combined with inter cultivation at 45 DAS (T7), and these two treatments showed comparable results. The reduced weed dry weight in these treatments suggests a lower weed population, aligning with the findings reported by Joseph *et al*. in 2006 [4].

Table 1: Total dry weight of weeds in sesame at different stages of crop growth as influenced by weed control treatments

Tr. No.	Treatment	Total dry weight of weeds (g/m^2)			
		20 DAS	**40 DAS**	**60 DAS**	**At harvest**
T_1	Unweeded check	1.04 (9.07)	1.75 (53.67)	1.93 (83.19)	2.38 (238.87)
T_2	Weed free check (HW at 15 DAS + IC at 30 and 45 DAS)	0.30 (0.00)	0.30 (0.00)	0.30 (0.00)	0.30 (0.00)
T_3	Recommended practice (Alachlor 50 EC @ 0.75 kg ha^{-1}as PE application + HW at 30 DAS + IC at 45 DAS)	0.73 (3.40)	0.63 (2.23)	0.85 (5.03)	1.80 (61.53)
T_4	Pendimeth 30 EC @ 1 kg ha^{-1} as PE application + HW at 30 DAS + IC at 45 DAS	0.92 (6.33)	0.91 (6.1)	1.30 (17.87)	2.00 (97.37)
T_5	Pendimeth 38.7 CS @ 1 kg ha^{-1} as PE application + HW at 30 DAS + IC at 45 DAS	0.89 (5.77)	0.89 (5.73)	1.23 (14.80)	1.98 (93.85)
T_6	Butachlor 50 EC @ 1 kg ha^{-1} as PE application + HW at 30 DAS + IC at 45 DAS	0.85 (5.10)	0.83 (4.73)	1.06 (9.47)	1.93 (83.36)
T_7	Quizalofop 5 EC @ 40 g ha^{-1} as PoE application at 20 DAS + IC at 45 DAS	1.00 (8.10)	0.72 (3.23)	0.93 (6.47)	1.84 (69.67)
T_8	Imazethapyr 10 SL @ 75 g ha^{-1} as PoE application at 20 DAS + IC at 45 DAS	1.01 (8.27)	0.85 (5.1)	1.08 (10.10)	1.94 (85.10)
	S.Em.±	0.02	0.03	0.03	0.01
	C.D. at 5%	0.06	0.09	0.09	0.04

EC: Emulsifiable Concentrate CS: Capsular Suspension SL: Soluble Liquid HW: Hand Weeding IC: Intercultivation
DAS: Days After Sowing PE : Pre-emergence PoE: Post-emergence Pendimeth: Pendimethalin Quizalofop: Quizalofop ethyl
*Figures in parentheses indicate original values
Total weed count (x) data were transformed to log (x+2)

Table 2: Dry matter production and chlorophyll content of sesame at different growth stages as influenced by weed control treatments

Tr. No.	Treatment	Dry matter production (g plant^{-1})			Chlorophyll content (SPAD meter values)	
		30 DAS	60 DAS	At harvest	30 DAS	60 DAS
T_1	Unweeded check	0.94	12.37	16.24	32.20	16.37
T_2	Weed free check (HW at 15 DAS + IC at 30 and 45 DAS)	2.91	24.47	29.95	45.69	27.83
T_3	Recommended practice (Alachlor 50 EC @ 0.75 kg ha^{-1}as PE application + HW at 30 DAS + IC at 45 DAS)	2.07	21.30	26.80	44.10	25.95
T_4	Pendimeth 30 EC @ 1 kg ha^{-1} as PE application + HW at 30 DAS + IC at 45 DAS	1.48	18.62	22.87	37.85	19.77
T_5	Pendimeth 38.7 CS @ 1 kg ha^{-1} as PE application + HW at 30 DAS + IC at 45 DAS	1.57	19.01	23.68	39.40	20.67
T_6	Butachlor 50 EC @ 1 kg ha^{-1} as PE application + HW at 30 DAS + IC at 45 DAS	1.73	19.76	25.13	40.33	21.52
T_7	Quizalofop 5 EC @ 40 g ha^{-1} as PoE application at 20 DAS + IC at 45 DAS	1.84	20.10	25.45	41.96	23.84
T_8	Imazethapyr 10 SL @ 75 g ha^{-1} as PoE application at 20 DAS + IC at 45 DAS	0.53	7.00	9.62	24.83	14.33
	S.Em.±	0.16	0.4	0.46	1.50	0.68
	C.D. at 5%	0.48	1.20	1.41	4.56	2.07

EC: Emulsifiable Concentrate CS: Capsular Suspension SL: Soluble Liquid HW: Hand Weeding IC: Intercultivation
DAS: Days After Sowing PE: Pre-emergence PoE: Post-emergence

Table 3: Number of capsules per plant, number of seeds per capsule, seed yield, stalk yield and harvest index of sesame as influenced by weed control treatments

Tr. No.	Treatment	Number of capsules per plant	Number of seeds per capsule	Seed yield (kg ha^{-1})	Stalk yield (kg ha^{-1})	Harvest index
T_1	Unweeded check	18.00	23.00	180	1267	0.12
T_2	Weed free check (HW at 15 DAS + IC at 30 and 45 DAS)	31.67	38.33	588	2520	0.19
T_3	Recommended practice (Alachlor 50 EC @ 0.75 kg ha^{-1}as PE application + HW at 30 DAS + IC at 45 DAS)	29.00	34.33	480	2356	0.16
T_4	Pendimeth 30 EC @ 1 kg ha^{-1} as PE application + HW at 30 DAS + IC at 45 DAS	21.67	26.67	273	1683	0.14
T_5	Pendimeth 38.7 CS @ 1 kg ha^{-1} as PE application + HW at 30 DAS + IC at 45 DAS	22.67	27.33	283	1750	0.14
T_6	Butachlor 50 EC @ 1 kg ha^{-1} as PE application + HW at 30 DAS + IC at 45 DAS	25.67	29.00	367	2100	0.15
T_7	Quizalofop 5 EC @ 40 g ha^{-1} as PoE application at 20 DAS + IC at 45 DAS	27.00	31.33	410	2239	0.15
T_8	Imazethapyr 10 SL @ 75 g ha^{-1} as PoE application at 20 DAS + IC at 45 DAS	13.73	19.00	86	713	0.10
	S.Em.±	0.88	1.20	25	48	0.01
	C.D. at 5%	2.68	3.64	75	145	0.02

EC: Emulsifiable Concentrate CS: Capsular Suspension SL: Soluble Liquid HW: Hand Weeding IC: Intercultivation
DAS: Days After Sowing PE: Pre-emergence PoE: Post-emergence

Conclusion
In conclusion, the preemergence application of Alachlor 50 EC @ 0.75 kg ha^{-1} along with Hand Weeding at 30 DAS and inter-cultivation at 45 DAS was seen to be more effective in controlling weeds and increasing the growth of sesame.

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