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Sole and sequential application of herbicides and botanicals for weed management in summer sesame

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Abstract

Weed infestation poses a significant challenge in sesame cultivation, leading to yield losses and decreased economic returns for farmers. The present study comprehensively analyses various weed control approaches, including allelopathic interaction with integrating herbicides and hand-weeding practices. The experiment was conducted at the Agriculture Farm, SOA, Odisha, during the summer of 2023 with 10 weed management treatments in RBD with 3 replications. The objective was to study different weed management practices, including the sole and sequential application of herbicides and botanicals, to control diverse weeds and enhance summer sesame growth, yield and profitability. The dominance of *Digitaria sanguinalis* (L.) Scop., *Echinochloa colona* (L.) Link. and *Poa annua* L. among grassy weeds and *Melochia corchorifolia* L., *Cleome viscosa* L. and *Cassia tora* L. among the broadleaved weeds were evident in summer sesame. The execution of different treatments showed that integrated use of aqueous leaf extract of *Parthenium hysterophorus* at 5 % concentration, followed by quizalofop-p-ethyl at 50 g/ha, was found on par with hand-weeding and brought down the weed count and biomass, which in turn increased the growth of summer sesame. The maximum yield of (793 kg seed/ha and 3035 kg stalk/ha) was registered under twice hand weeding. It was comparable with the spraying of aqueous leaf extract of *Parthenium hysterophorus* at 5 % concentration followed by (*fb*) quizalofop-p-ethyl at 50 g/ha (772 kg seed/ha and 2968 kg stalk/ha). Economic analysis of sesame revealed that the maximum return (Rs. 37454/- per ha) and return/rupee (2.28) were recorded with aqueous leaf extract of *P. hysterophorus* at 5 % concentration *fb* quizalofop-p-ethyl at 50 g/ha treatment.

Keywords

Allelopathy; botanicals; integrated weed management; nerium; parthenium

Introduction

Sesame (*Sesamum indicum* L.) is prominent amongst the oilseeds for its high-quality oil and rich nutritional offerings. It is an annual herbaceous crop which belongs to the family Pedaliaceae. The flower is axillary and pedicellate and the fruit is known as a capsule. Sesame holds a wealth of nutritional benefits. These tiny seeds are the powerhouse of essential nutrients, boasting high concentrations of protein, healthy fats, dietary fibre and an array of fat-soluble vitamins and amino acids. It is also rich in minerals such as calcium and iron (1). Globally, the sesame is grown in an 11743 thousand (000) ha area with a production of 6016 thousand (000) M tons and 512 kg/ha productivity. India contributed around 1730 Thousand (000) ha in area, with a production and productivity of 746 Thousand M tons and 431 kg/ha in 2018 respectively. India produces nearly 12.4 % of sesame cultivation (2). Weed infestation in sesame cultivation can lead to substantial yield losses, hinder efficient harvesting and compromise the quality of the produce. Sesame is often cultivated in diverse agro-climatic conditions, infested with varying weed species. To achieve the required productivity, weed control is essential. If weeds are not effectively managed, they can severely affect the yield of crops by competing with sesame plants for resources such as nutrients, space, water and sunlight.

Cynodon dactylon (L.) Pers., *Echinochloa colona* (L.) Link., *Digitaria sanguinalis* (L.) Scop., *Dactyloctenium aegyptium* (L.) P. Beauv. Willd., *Cyperus rotundus* L., *Trianthema portulacastrum* L., *Spilanthes acmella* L., *Amaranthus viridis* L., *Phyllanthus niruri* L., *Commelina benghalensis* L., *Digera arvensis* Forsk. and *Malvastrum coromandalianum* Garcke. are commonly found as predominant weeds in sesame cultivation (3-5). Sesame experienced a significant reduction in seed yield, ranging from 50 % to 75 %, because of intense weed competition (6). Weed management is not only about protecting the crop yield but also about optimizing input costs. As the demand for this oilseed crop continues to rise, the challenges posed by weed infestations have become increasingly evident. Excessive reliance on chemical herbicides poses environmental risks in pursuing productive sesame cultivation. It leads to a shift in weed flora and the emergence of herbicide-resistant weed populations (7). Relying solely on a single method can have several drawbacks. At the same time, manual weeding has been a traditional practice in sesame cultivation, which requires a significant amount of labour and incurs substantial costs for farmers (8). Manual weeding is dependent on weather conditions. Wet conditions can delay and make manual weeding difficult, allowing weeds to establish and compete with the crop and keep the weed in an advantageous position (9).

Allelopathy is a biological phenomenon where certain plants release biochemicals, known as allelochemicals, into the environment. These allelochemicals can potentially influence crops' growth, development and germination, either inhibiting or promoting their growth (10). In *Parthenium hysterophorus*, the allelochemicals named sesquiterpene lactones and parthenin have herbicidal properties, which can impact the growth and development of weeds (11). Similarly, the flowering plant *Nerium oleander* L. is well-known for its flavonoid and glycoside compounds, among which oleandrine is the most prominent glycoside, which can be used as botanicals to control weeds at different concentrations (12). The aqueous extract of *P. hysterophorous* significantly reduced the germination of *Digitaria sanguinalis* (L.) Scop. and *Eleusine indica* (L.) Gaertn. (13). Similarly, the application of dry leaf extracts of *Nerium oleander* at different concentrations effectively affected the initiation and growth of *Cyperus rotundus* L. (14). In addition to their herbicidal activities, the allelopathic potential of *P. hysterophorus* and *N. oleander* has been exploited for control of fungal and bacterial diseases (15-17). These findings may shed light on using allelopathic approaches to an overall integrated weed management (IWM) strategy to manage weeds sustainably. Therefore, a field trial was conducted to investigate the competent IWM approach to manage weeds and enhance sesame's growth, yield and profitability during the summer season.

Materials and Methods

a. Experimental site:

The investigation was executed during the summer of 2023 at the Agriculture Farm, Binjhagiri, Chhatabar, Odisha, positioned at coordinates 20°15' N latitude, 85°40' E longitude and 58 m altitude above MSL. The soil of the experimental field exhibited a clayey texture, was deep and featured a slight slope from west to east, contributing to adequate drainage. It was characterized by acidic nature with a pH of 5.87. The soil content showed lower levels of soil organic carbon (0.36 %) as analyzed by the volumetric weight combustion method and available N (204.5 kg/ha) by alkaline permanganate method, while being moderate in both available P_2O_5 (21.27 kg/ha) and K_2O (131.1 kg/ha) by Bray's method no. 1 and flame photometer method respectively.

b. Treatments and crop management:

A randomised block design framed the field experiment consisting of 10 treatments with 3 replications. Sesame seeds of the '*Smarak*' variety were line sown with a 6 kg/ha seed rate at 30 cm x 10 cm spacing in the north-south direction. The treatments consist of solely applying pendimethalin, quizalofop-p-ethyl, *Parthenium hysterophorous* and *Nerium oleander* leaf extract at 5 and 10 % concentration. Further botanicals and herbicides were used for sequential application and compared with 2 hand weeding and weedy check. Pendimethalin, the aqueous leaf extract of *P. hysterophorous* and *N. oleander* were applied one day after sowing (DAS), whereas quizalofop-p-ethyl was applied at 20 DAS. The crop was supplied with nutrients of 40-20-20 kg of $N\text{-}P_2O_5\text{-}K_2O$ respectively, per ha, using urea, SSP and MOP. The complete dose of phosphorus, potassium and 50 % nitrogen was applied as a basal before the sowing. The remaining dose of N was top-dressed at 21 DAS under sufficient soil moisture.

c. Data collection and observation taken:

The observations on plant growth characteristics, including plant height and dry matter accumulation (DMA), were measured at the 40 DAS. The weed count and biomass were also documented at 40 DAS using two randomly selected quadrats, each measuring 50 cm x 50 cm within the sampling area of each plot. Weed samples were cut close to the ground level, sun-dried and oven-dried at 65 ± 5 °C until a constant weight was obtained to record biomass. The yield was measured from each plot's net plot area (5 m x 4 m) and recorded in kg/ha. The rate of increase in dry weight per unit of ground area per unit of time calculated crop growth rate (CGR). Weed control efficiency was computed using the dry weight of weeds. It was worked out from a reduction in weed dry weight due to the weed control method over the unweeded check. The weed index was a gain in crop yield due to weed control as a percentage of yield from weed-free crops. The significance of different sources of variation was tested by the "Error Mean Square Method" of Fisher Snedecor's "F" test at probability level 0.05. The analysis of variance method was followed for analyzing the experimental data statistically (18). The standard error of means (SEM ±) and the value of critical differences (C.D.) between means have been provided.

Results and Discussion

During the investigation, 8 weed species *viz. Digitaria sanguinalis* (L.) Scop., *Echinochloa colona* (L.) Link. and *Poa annua* L. and *Dactyloctenium aegyptium* (L.) P. Beauv. Willd. among the grasses; *Melochia corchorifolia* L., *Cleome viscosa* L. and *Cassia tora* L. among the broadleaved and *Cyperus iria* L. only sedge, were predominantly found in the experimental field. Similar grassy weeds were documented in sesame cultivation (4). The least density and weed biomass were observed in plots with twice hand weeding (T_9) (13 No./m^2 and 2.77 g/m^2). Among the integrated practices, the aqueous leaf extract of *P. hysterophorus* at 5 % concentration, *fb* quizalofop-p-ethyl at 50 g/ha (T_8) (18 No./m^2 and 4.53 g/m^2) exhibited lower weed density and biomass (Table 1). This was because of the reduction of the first flush of weeds by the Parthenium extract and later, weeds were controlled by the herbicide. Aqueous extract of *Parthenium hysterophorus* at 40 % resulted in a potent allelopathic interaction inhibiting germination, seedling growth and dry matter accumulation of *T. populnea* (19). Similarly, applying *P. hysterophorus* extracts remarkably reduced germination alongside the initiation of *Cyperus iria*, i.e., coleoptile and radicle length. They also found that the increase in the concentration of *P. hysterophorus* extract was exhibited in lower biomass and the *Cyperus iria* leaf area (20). The weed biomass was effectively reduced under the integrated application of aqueous leaf extract of *N. oleander* at 5 % conc. *fb* quizalofop-p-ethyl was significantly at par with the sole application of quizalofop-p-ethyl. Integrated weed management approach, including quizalofop, effectively lowered the weed biomass (21, 22). Apart from T_8 and T_9 treatments, the total weed density was reduced under the integrated application of aqueous leaf extract of *Nerium oleander* at 5 % concentration *fb* quizalofop-p-ethyl at 50 g/ha, which was closely followed by the sole application of quizalofop-p-ethyl at 50 g/ha, pendimethalin at 750 g/ha and aqueous leaf extract of *Parthenium hysterophorus* at 10 % concentration treatments in sesame during summer season (Table 1). Application of quizalofop-p- ethyl at 50 g/ha decreased the grassy weed population (7.33 no/0.25 m^2) (23). The application of pendimethalin at 1 kg/ha controlled most of the annual grasses and broad-leaved weeds during the germination of weed seeds. Still, pendimethalin at 750 g/ha failed to control *Commelina benghalensis* more effectively (24).

Applying twice hand weeding had 95.29 % weed control efficiency (WCE) among weed management treatments - *P. hysterophorus* at 5 % conc. *fb* quizalofop-p-ethyl recorded the maximum WCE (92.32 %) followed by *Nerium oleander* at 5 % at 1 DAS *fb* quizalofop-p-ethyl (80.41 %) (Fig. 1). The use of quizalofop-p- ethyl at 50 g/ha had weed control efficiency of 47.79 % (23). The maximum dry matter and CGR growth were registered under two-hand weeding, which was closely followed by aqueous leaf extract of *Parthenium hysterophorus* at 5 % *fb* quizalofop-p-ethyl at 50 g/ha (Table 1). The integrated weed management treatments exhibited the maximum dry matter accumulation of sesame, which was on par with the two-hand weeding (25)-however, the sole application of quizalofop-p-ethyl registered maximum growth parameters. In the present study, the application of both Parthenium and Nerium aqueous leaf extract at 10 %

Table 1. Weed and crop growth under various weed management treatments at 40 DAS.

Treatments	Weed growth		Crop growth		
	Population (no./m^2)	Biomass (g/m^2)	Plant height (cm)	DMA (g/m^2)	CGR (g/m^2/day)
T_1- Pendimethalin at 750 g/ha	6.09 (36.6)*d	3.60 (12.4)d	54.18ab	117.2bc	6.03b
T_2- Quizalofop-p-ethyl at 50 g/ha	6.02 (35.7)d	3.56 (12.1)d	55.00ab	126.1b	6.07b
T_3- ALEN at 5 %	8.15 (66.0)b	5.60 (30.8)b	48.11bc	102.4cd	5.19bc
T_4- ALEN at 10 %	7.07 (49.6)c	4.65 (21.1)c	45.08c	88.8d	4.62cd
T_5- ALEP at 5 %	6.95 (48.0)c	4.79 (22.5)c	48.36bc	103.7cd	5.38bc
T_6- ALEP at 10 %	6.39 (40.3)cd	4.39 (18.8)c	45.95c	91.5d	5.09bc
T_7- T_3 *fb* T_2	5.78 (33.1)d	3.45 (11.5)d	54.29ab	123.1b	5.90b
T_8- T_5 *fb* T_2	4.29 (18.0)e	2.23 (4.5)e	55.92a	145.4a	7.35a
T_9- Two HW	3.67 (13.0)e	1.80 (2.7)e	56.51a	147.0a	7.42a
T_{10}-Weedy check	10.0 3 (100.3)a	7.70 (58.9)a	34.94d	46.7e	3.46d
CD(P=0.05)	0.69	0.45	7.48	16.93	1.24

*The bracketed value is original, and the square root was transformed before analysis. Treatments with similar letters are not significantly different.

WCE: Weed control efficiency, DMA: Dry matter accumulation, CGR: Crop growth rate, ALEN: Aqueous leaf extract of *Nerium oleander,* ALEP: Aqueous leaf extract of *Parthenium hysterophorus,* H.W.: Hand weeding showed a phytotoxic effect and a significant decrement in the plant height of sesame. An increment in the concentration of *P. hysterophorus* extract notably hampered gingelly's initiation and seedling length (26).

The highest productivity (793 kg seed/ha and 3035 kg stalk/ha) was observed in hand-weeded plots, followed by plots treated with the *P. hysterophorus* leaf extract at 5 % concentration *fb* quizalofop (772 kg seed/ha and 2968 kg stalk/ha) (Table 2). The application of pre-emergence herbicide followed by quizalofop-p-ethyl documented significantly higher seed yield (1002 kg/ha) and stalk yield (3374 kg/ha) (5). In the present study, the subsequent best treatment in registering higher levels of seed and stalk yield was the sole application of quizalofop-p-ethyl at 50 g/ha at 15 DAS (727 kg seed/ha and 2629 kg stalk/ha^{-1}) which was at par with the aqueous leaf extract of *Nerium oleander* at 5 % concentration at 1 DAS *fb* quizalofop-p-ethyl at 50 g/ha at 15 DAS (709 kg seed/ha and 2626 kg stalk/ha) and lone application of pendimethalin at 750 g/ha^{-1} at 1 DAS (692 kg seed/ha and 2533 kg stalk/ha) (Table 2). The infestation of grassy weeds was higher than broadleaved and sedge weeds, which was effectively controlled by the sole application of quizalofop-p-ethyl. The post emergence application of quizalofop significantly improved the seed yield and plant growth parameters by effectively managing the weed population (27). Applying pendimethalin at 750 g/ha produced a much greater seed yield (5.463 q/ha) and caused low injury in sesame plants (28). The harvest index of sesame did not indicate any variation by the imposition of different weed management practices and remained relatively similar in all the treatments.

The weedy check plot registered % maximum weed index (W.I.) of 81.70 %. The lowest W.I. was observed in 2 hand weeding treatments followed by the integrated application of *Parthenium hysterophorus* at 5 % concentration *fb* quizalofop (2.64 %) and sole application of quizalofop-p-ethyl (8.25 %) (Fig. 2).

The higher net return of Rs. 37454/ha and return/rupee (2.28) were recorded with the application of aqueous leaf extract of *Parthenium hysterophorus* at 5 % concentration *fb* quizalofop-p-ethyl at 50 g/ha. It was followed by applying quizalofop-p-ethyl with net return and return/rupee of Rs. 35107/ha and 2.27 respectively (Table 2). The net returns as well as the B:C ratio, were higher with the treatment of weed-free check, found to be significantly at par with the integrated application involving quizalofop as a postemergence herbicide (29). The lowest net return was noticed in weedy plots (Table 2). The lowest return values are documented in the weedy check plot due to the inability of the sesame crop to perform under higher weed competition (30).

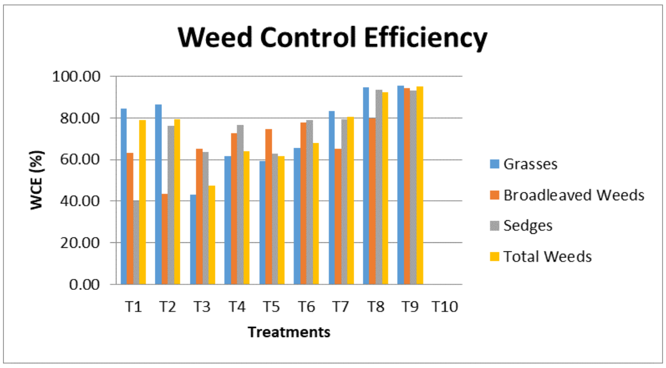

Fig. 1. Effect of weed management on weed control efficiency (%) of summer sesame at 40 DAS.

T_1- Pendimethalin at 750 g/ha, T_2- Quizalofop-p-ethyl at 50 g/ha, T_3- ALEN at 5 %, T_4- ALEN at 10 %, T_5- ALEP at 5 %, T_6- ALEP at 10 %, T_7- T_3 *fb* T_2, T_8- T_5 *fb* T_2, T_9- Two HW, T_{10}-Weedy check.

* ALEN: Aqueous leaf extract of *Nerium oleander,* ALEP: Aqueous leaf extract of *Parthenium hysterophorus,* H.W.: Hand weeding

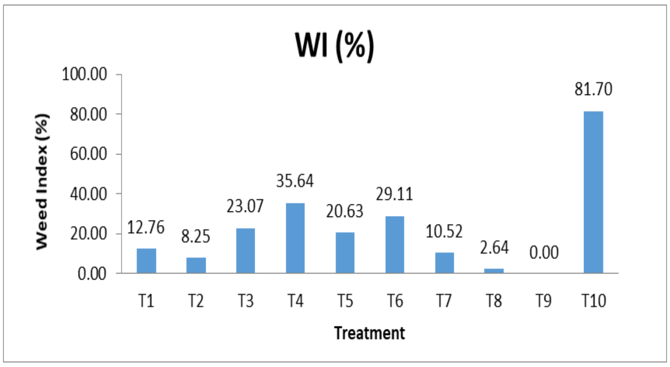

Fig. 2. Weed index (%) of sesame under different weed management treatments.

T_1- Pendimethalin at 750 g/ha, T_2- Quizalofop-p-ethyl at 50 g/ha, T_3- ALEN at 5 %, T_4- ALEN at 10 %, T_5- ALEP at 5 %, T_6- ALEP at 10 %, T_7- T_3 *fb* T_2, T_8- T_5 *fb* T_2, T_9- Two HW, T_{10}-Weedy check.

* ALEN: Aqueous leaf extract of *Nerium oleander,* ALEP: Aqueous leaf extract of *Parthenium hysterophorus,* H.W.: Hand weeding

Table 2. Effect of weed management on yield and economics of sesame.

Treatments	Yield (kg/ha)		Harvest Index (%)	Economics	
	Seed	Stalk		Net return (Rs. /ha)	Return/ Rupee invested
T_1- Pendimethalin at 750 g/ha	692.12c	2533.76cd	21.58a	30669	2.05
T_2- Quizalofop-p-ethyl at 50 g/ha	727.88bc	2629.51bc	21.76a	35107	2.27
T_3- ALEN at 5 %	610.30de	2179.82de	21.89a	25704	1.95
T_4- ALEN at 10 %	510.61f	1846.18e	21.80a	16496	1.60
T_5- ALEP at 5 %	629.70d	2195.58de	22.30a	27379	2.01
T_6- ALEP at 10 %	562.42ef	2051.94e	21.57a	20970	1.76
T_7- T_3 *fb* T_2	709.88c	2626.79bc	21.29a	32053	2.10
T_8- T_5 *fb* T_2	772.42ab	2968.30ab	20.68a	37454	2.28
T_9- Two HW	793.33a	3035.27a	20.74a	16009	1.30
T_{10}-Weedy check	145.15g	599.51f	19.39a	-12961	0.49
CD (P=0.05)	62.35	374.17	NS	-	-

Treatments with similar letters are not significantly different.

WI: Weed index, ALEN: Aqueous leaf extract of *Nerium oleander,* ALEP: Aqueous leaf extract of *Parthenium hysterophorus,* H.W.: Hand weeding

Conclusion

The aqueous leaf extract of *Parthenium hysterophorus* at 5 % concentration *fb* quizalofop-p-ethyl at 50 g/ha significantly reduced the weed densities and biomass. The seed and stalk yield of the treatment were 772 and 2968 kg/ha respectively. Economic analysis of sesame revealed that the maximum return (Rs. 37454/- per ha) and return/ rupee (2.28) was recorded with the application of *Parthenium hysterophorus extract* at 5 % concentration at 1 DAS *fb* quizalofop-p-ethyl at 50 g/ha at 20 DAS. Thus, integration of aqueous leaf extract of *Parthenium hysterophorus* at 5 % concentration at 1 DAS sequenced with the early postemergence application of quizalofop-p-ethyl at 50 g/ha proved to be a viable option for managing the weed infestation and has the potential to strengthen the growth, yield and profit in summer sesame. Future research should delve deeply into the role of botanicals in weed management, as their potential benefits are not yet fully understood. Detailed studies are needed to assess their effectiveness, mechanisms of action and any possible side effects or interactions with crops and soil ecosystems. By exploring various plant extracts and their properties, researchers can uncover novel solutions for controlling weed growth, improving crop yields and promoting ecological balance.

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Authors' contributions

SH carried out the field experiment and collected and analyzed the data. SD conceptualized and supervised the experiment and prepared the manuscript. UJ participated in the data collection and drafted the manuscript. All authors read and approved the final manuscript.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interest to declare.

Ethical issues: None

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