Pak. J. Bot., 58(1): 255-272, January 2026.

ARTICLE | DOI: http://dx.doi.org/10.30848/PJB2026-1(32)

ALLELOPATHIC EFFECTS OF SORGHUM (*SORGHUM BICOLOR* L.) AND NITROGEN MANAGEMENT ON WEED REDUCTION AND YIELD ENHANCEMENT OF SESAME (*SESAMUM INDICUM* L.)

MUHAMMAD SALEEM CHANG[1], MUHAMMAD NAWAZ KHANDHRO[1], BAKHAT-UN-NISA MANGAN[1], ZIA-UL-HASSAN SHAH[2] AND SIRAJ AHMED CHANNA[3]

[1]Department of Agronomy, Faculty of Crop Production, Sindh Agriculture University, Tandojam, Pakistan
[2]Department of Soil Science, Faculty of Crop Production, Sindh Agriculture University, Tandojam, Pakistan
[3]Department of Plant Breeding and Genetics, Faculty of Crop Production, Sindh Agriculture University, Tandojam, Pakistan

*Corresponding author's email: mschang@sau.edu.pk

Abstract

The current research study was conducted at Crop Sciences Research Institute (CSRI), Agriculture Research Centre, Tandojam. The consecutive study was assumed to assess the allelopathic effects of sorghum and nitrogen application strategies on suppression of weed and yield enhancement of the sesame crop. The field experiment was randomized complete block design (RCBD) factorial in three replications with net plot size of 5 m x 4 m (20 m^2). The experimental unit was accommodated with three factors i.e. weed control practices (control or without sorghum material, sorghum extract @ 40 L ha^{-1}, herbicide @ 1.0 L ha^{-1}, sorghum extract @ 20 L ha^{-1} + herbicide @ 0.5 L ha^{-1}, and hand weeding twice (30 and 55 days after sowing)), nitrogen application rates (50, 75 & 100 kg ha^{-1}) and nitrogen application schedules (two & three splits). The statistical analysis of the compiled data revealed that significant ($p<0.05$) effects of weed control practices, nitrogen application approaches and their interaction on weed reduction positively improved agronomic and qualitative traits of sesame than control (without sorghum material). Substantially, the findings of overall study revealed that sorghum extract @ 20 L ha^{-1} + Herbicide (AXIAL 330 ml +ally max 14 g) @ 0.5 L ha^{-1} integrated with nitrogen application rate (100 kg ha^{-1}), nitrogen application schedules (three splits) and their interaction exerted considerable inhibitory effects on weed observations, significantly enhanced the agronomic and qualitative traits of sesame crop under field conditions, followed by hand weeding twice (30 and 55 days after sowing) ranked 2nd in effectiveness. The findings of this study thus conferred that possible efforts must be taken to reduce the dose of herbicides and minimize the health hazards.

Key words: Phytotoxic; Nitrogen management; Herbicide; Hand weeding; Sesame; Extract

Introduction

Sesame (*Sesamum indicum* L.) member of family Padaliaceae considered one of the oldest and an important oilseed crop owing to its high oil quality as well as high content of micronutrient compounds (Somwanshi *et al*., 2018; Aliyu *et al*., 2023). Sesame crop has a life cycle of typically 70-150 days long depending upon variety and climate. Presently sesame is considered as an orphan crop in Pakistan (Amna *et al*., 2021). Sesame has rich edible oil content of 53-55% also contains carbohydrates, proteins, vitamins, minerals, fibre, tocopherols, and lignans (Wacal *et al*., 2021; Aremu *et al*., 2025). Sesame contains important primary unsaturated fatty acids are very helpful in reduction of low-density lipoprotein cholesterol, and triglyceride levels, and promoting an increment in high-density lipoprotein (Hadeel *et al*., 2019). As a nutrient rich crop plant sesame can be used for industrial as well as pharmaceutical aspects (Wei *et al*., 2022). Being a nutritive rich crop plant sesame has the status of being an “all-purpose nutrient bank” and the “crown of eight grains” (Haixia & Lu, 2015). Sesame meal contains about 5.9% N, 3.3% P_2O_5 and 1.5% K_2O making it as good fertilizer (Ma & Fang, 2019). Containing insecticide and fungicide properties the sesame can be used as synergist for insecticides (Sirato-Yasumoto *et al*., 2001), sesame oil also applied for protection of tree against termites (Fatima *et al*., 2021). Globally, sesame is cultivated in tropical, sub-tropical, and temperate regions and it can tolerate various climatic conditions and most significant oilseed crop in location with scarce soil and drought Furthermore, it has ability to thrive in several environmental conditions make it a profitable crop for diversified agro-system (Dola *et al*., (2022); Wahab *et al*., 2022; Baraki *et al*., 2020). Sesame can be cultivated in low fertile soils and can thrive under low water supply (up to 300 mm), high temperatures though it is considered as crop of present and future because of climatic resilience (Sene *et al*., 2018; Boureima & Diouf, 2010). In current era acute shortage of irrigation water is the burning issue of Pakistan thus sesame is the suitable choice as an edible oil seed crop. Being a short duration crop it can be fit as catch crop in Zaid Kharif crop. Sesame is a good cash crop due to high market value increased demand with its lower cost production (Anwar *et al*., 2012). In sesame crop major yield reducing factor and compete for moisture nutrient, space and photosynthetically active radiation ultimately suppress yield quality as well quantity is weed (Rajpurohit *et al*., 2017). The presence of weeds in crop field affect quantity as well as quality of produce which significantly causes

Received: 09-04-2024 | Revised: 12-03-2025 | Accepted: 07-04-2025 | Online: 30-09-2025

financial losses of farmers (Sarić-Krsmanović *et al*., 2019; Ali *et al*., 2017). Near about 80 % reduction of yield is observed in sesame due to its high sensitivity to weed infestation and inappropriate weed management practices (Rajpurohit *et al*., 2017). To avoid yield losses, the field should be kept weed free for 2-6 weeks after sowing because growth of sesame is slow during the first 3-4 weeks after emergence (Ghatak *et al*., 2000; Vafaei *et al*., 2013). If a poor and weeds emerge simultaneously, then weeds have competitive advantage because at seedling stage sesame crop is poor competitor as linked to weeds seedlings (Gnanavel & Anbhazhagan, 2006; Sagarka *et al*., 2013). In Pakistan main cause of lower crop yield is weed crop competition (Ullah *et al*., 2022). Farmers with limited resources cultivating sesame crop and use indigenous weed control measures specifically hand hoeing and pulling (Langham *et al*., 2007). Manual weed control measures may be conceded in case of persistent rains and unavailability of labor during critical period of weed crop competition and this complication pushes them to adopt chemical weed control measure. (Bhadauria *et al*., 2012). Consequently, for weed infestation our farmers use hazardous chemicals in minimal time interval (Khan *et al*., 2009a; Tang *et al*., 2010). Continuous and application of herbicides with high doses results resistance in several weeds that endanger the ecosystem. Stephenson, (2000) revealed that three million tons of herbicides per year collectively used by most agriculture system that shows that severity of the concerned matter. In the current era of agricultural practices such as, cultivation of crops bearing allelochemicals can counteract the undesirable effects on weed growth. Utilization of allelopathy as chief and eco-friend measure for weed control and is adopted as a diversified control option for farmers that have poor resources (Ayani *et al*., 2013). The allelochemical are secondary metabolites and have ability to inhibit the major activities of plants such as, protein synthesis, enzymatic activities and photosynthesis and suppress weeds also (Asaadawi *et al*., 2015; Uddin *et al*., 2014; Reicosky & Crovetto, 2014). The function of secondary metabolites including phenolic acids, durrin and sorgoleone is to make sorghum as allelopathic plant (Alsaadawi *et al*., 2015; Bjarnholt *et al*., 2018; Pan *et al*., 2018 and Uchimiya, 2020), amongst all sorgoleone(2-hydroxy-5-methoxy-3-[(8′Z, 11′Z)-8′,11′,14′-pentadecatriene]-p-benzoquinone has high hydrophobicity strongly absorbed by soil colloids, released slowly in soil solution and suppresses weeds growth for long time interval (Pan *et al*., 2018; Tibugari *et al*., 2019; Trezzi *et al*., 2006; Trezzi *et al*., 2016 and Dayan *et al*., 2010). Research studies revealed that sorghum herbage extract can be used as selective weeds control measure in wheat, maize and soybean (Cheema *et al*., 2008; Cheema *et al*., 2004). Sorghum (*Sorghum bicolor* L.) bearing the ability of high drought tolerance and is successfully cultivated well in tropical and subtropical climatic condition with low rainfall (Ali *et al*., 2023; Khalifa & Eltahir, 2023; Pinto *et al*., 2023; Rad *et al*., 2023; Tu *et al*., 2023). However, Ashraf & Akhlaq (2007), researched that in wheat crop field amongst separate spray application of roots, shoots and leaves extracts of sorghum, the sorghum root extract was found to be the effective treatment reduced the weed population. Similarly, Iqbal *et al*., (2010) found that 18 L ha^{-1} plants extract (Sorghum, Brassica and Sunflower) integrated with chemical herbicide as per label dose of 50 g a.i ha^{-1}) suppressed the weed population by 88%, weed fresh weight by 90%, dry weight by 95 % and significantly enhanced seed yield by 35% as compared to untreated and suggested that with integrated application of allelopathy extract and herbicides, weeds can be controlled up to 50%. Furthermore, weed control through sorghum allelopathy is crucial and sustainable constituent of integrated weed management scheme (Tibugari *et al*., 2020). Nitrogen is a primary nutrient and most important for obtaining the potential yield of crops on field level (Wang *et al*., 2016). Nitrogen the prominently most important component of protein and involved directly in crop plant metabolism. Protein takes part in essential functions required for growth and development of plants (Manzoor *et al*., 2023). Almost 50 % of all essential nutrients input is contributed by nitrogen only (Hansen *et al*., 2000; Akanbi *et al*., 2005). The nitrogen application efficiency in Pakistan is near about 40-50 % (Qureshi & Zia, 1998). Weed crop competition, and imbalance nutrient use efficacy are the most critical causes respectively. About 47% N, 42% P and 50% of K can be deprived by weeds at the time of crop nutrient uptake (Kumar & Singh, 1998). Judicious application of nitrogen is the crucial factor to achieve high yield of sesame crop (Anas *et al*., 2020), and with application of various doses Nitrogen can significantly affect crop-weed competition (Abouziena *et al*., 2007; Blackshaw & Brandt, 2008). Management of weed is prominently crucial for sustainable cropping scheme, in which cultivar, plant protection measures as well as optimum fertilization of nitrogen should be integrated to obtained potential yield with sustainable nitrogen efficacy (Rathke *et al*., 2006). Keeping in view of above researched findings on sustainable agro-measures, where crops and ecology overlap, will enable the significant utilization of ecofriendly environmental services for weed management in agricultural production and substantial reduce the frequency of resistance to agro-chemicals, this PhD research was designed to assess the phytotoxic efficacy of sorghum and nitrogen management on weed reduction and per acre yield of sesame under field conditions.

Material and Methods

The research study was carried out in two consecutive years at Crop Science Research Institute, Agriculture Research Centre, Tandojam (GPS coordinates 25° 25' 41.268" N & 68° 31' 45.228 E), during Kharif 2022-23. The experiment was arranged as a factorial in three replicated randomized complete block design (RCBD), with net plot size of 5 m x 4 m (20 m^2). The experimental unit was accommodated with three factors which are as under:

Factor-A: Weed Control Practices (W)

$\mathbf{W_1}$ = Control (Untreated)
$\mathbf{W_2}$ = Sorghum extract @ 40 L ha^{-1}
$\mathbf{W_3}$ =Herbicide (AXIAL 330 ml + Ally mix 14 g) @ 1.0 L ha^{-1}
$\mathbf{W_4}$ = Sorghum extract@ 20 L ha^{-1} + Herbicide @ 0.5 L ha^{-1}
$\mathbf{W_5}$ = Hand Weeding Twice (30 and 55 days after sowing)

Factor-B: Nitrogen Application Rate (NR)

$\mathbf{NR_1}$ = 50 kg^{-1} (33% < recommended)
$\mathbf{NR_2}$ = 75 kg^{-1} (Recommended)
$\mathbf{NR_3}$ = 100 kg^{-1}(33% > recommended)

Factor-C: Nitrogen Application Schedules (NS)
NS_1 = Two splits (50% at sowing time + 50% at 2nd Irrigation)
NS_2 = Three splits (50% at sowing time + 25% at 2nd irrigation + 25% at 3rd irrigation)

Preparation and application of sorghum water extract: Healthy and diseases free mature sorghum plants were selected, sun dried, chopped and soaked into clean water with 1:10 w/v ratio for 24 hours. After filtration with muslin cloth extract was boiled at 100^0C on gas burner and reduced to 20 times and safely stored in airtight glass jars in laboratory at optimum room temperature. The filtered water extract of sorghum and selected herbicide were applied as per treatment with the help of hand sprayer (calibrated), (Knapsack) with standardized (T) jet nozzle with spray volume of 300 L ha^{-1}. (Awan *et al*., 2009; Iqbal & Cheema, 2008).

Cultural practices: All Cultural/Agronomic practices were adopted as per requirements of the sesame crop.

Observations recorded: The whole data of following parameters was recorded by adopting methodology developed by (Reedy, 2004; Alsaadawi *et al*., 2005; Inamullah *et al*., 2011).

Weed observations

Weed density (m^{-2}): The density of weeds was calculated by using formula:

$$\text{Weed density (m–2)} = \frac{\text{Total number of weeds (m–2) for known treatment}}{\text{Total number of replications}}$$

Weed control (%): it was calculated by adopting the formula given as under:

$$\text{Weed control (\%)} = \frac{\text{Check weed density – Given treatment density x 100}}{\text{Check weed density}}$$

Agronomic observations

Plant height (cm): From each experimental unit five mature plants were selected and measured with the help of measuring tape from ground level to the tip of plant separately.

Capsules plant^{-1}: The number of capsules from five randomly selected plants in plot was counted separately and their average capsule plant^{-1} was recorded.

Capsules weight plant^{-1} (g): The collected capsules from five randomly selected plants were weighed and averaged.

Seed index (1000-seeds wt., g): With the help of digital seed counter the sample of thousand seeds was taken from each plot and weighed on an electronic balance.

Biological yield (kg ha^{-1}): It was measured in kilograms, the central rows of plants having 1m^{-2} were harvested, air dried and weighed to record the biological yield kg ha^{-1}.

Seed yield (kg ha^{-1}): On maturity 1 m^{-2} area of each plot was harvested and threshed. The seeds were cleaned, dried and weighed to record the seed yield kg ha^{-1}.

Harvest index (%): It was determined by adopting the formula:

$$\text{Harvest index (\%)} = \frac{\text{Seed yield (kg ha – 1) x 100}}{\text{Biological yield (kg – 1)}}$$

Qualitative observations

Oil yield (kg ha^{-1}): Oil yield (kg ha^{-1}) was determined by applying the formula:

$$\text{Oil yield (kg – 1)} = \frac{\text{Oil content (\%) x Seed yield (kg ha – 1)}}{100}$$

Seed protein (%): Protein content (%) was calculated by multiplying the deducted value of nitrogen by protein constant 6.25 mg.

Statistical analysis

The overall collected data was subjected to analysis of variance (ANOVA) methodology using software Statistix version 8.1, 2006. For statistical significance P value less than 0.05 was considered and for comparison of treatment superiority the least significant difference (LSD) test was applied, where the observed results were found to be significant (Singh & Chaudhry, 1985).

Results

Weed traits

Weed density (m^{-2}): The analysis of collected data showed that the influence of various weed control measures, nitrogen application approaches, and combination were substantial (p<0.05) on weed density (m^{-2}). The data (Table 1 & Figs. 1-4) revealed that in case of weed management, combined application of sorghum extract @ 20 L ha^{-1} + Herbicide (AXIAL 330 ml + ally max 14 g) @ 0.5 L ha^{-1} (W_4) resulted in lowest (50.3 m^{-2}) weed density pursuing by hand weeding (twice; 30 & 55 DAS) (W_5) with weed density of 63.6 m^{-2}. Application of herbicide (AXIAL 330 ml + ally max 14 g) @ 1.0 L ha^{-1} (W_3) and sorghum extract @ 40 L ha^{-1}(W_2) ranked 3rd and 4th in effectiveness with weed density of 74.9 m^{-2} and 87.9 m^{-2}, respectively. Nevertheless, the highest (168.7 m^{-2}) weed density was documented under control (check) (W_1). As regards nitrogen application rates, minimum (84.4 m^{-2}) weed density was recorded @ 50 kg N ha^{-1} (R_1). Application of N @ 75 kg ha^{-1} (NR_2) gave weed density of 88.5 m^{-2}. Nonetheless, maximum (94.4 m^{-2}) weed density was recorded when N was applied @ 100 kg ha^{-1}(NR_3). In case nitrogen application schedules, the least (87.6 m^{-2}) weed density was noticed under three splits (NS_2), whereas the application of nitrogen in two splits (NS_1) resulted in greatest (90.6 m^{-2}) weed density. Furthermore, the results of interaction between weed control practices (W) × nitrogen application rates (NR) showed that lowermost (45.0 m^{-2}) weed density was documented under the interaction of sorghum extract @

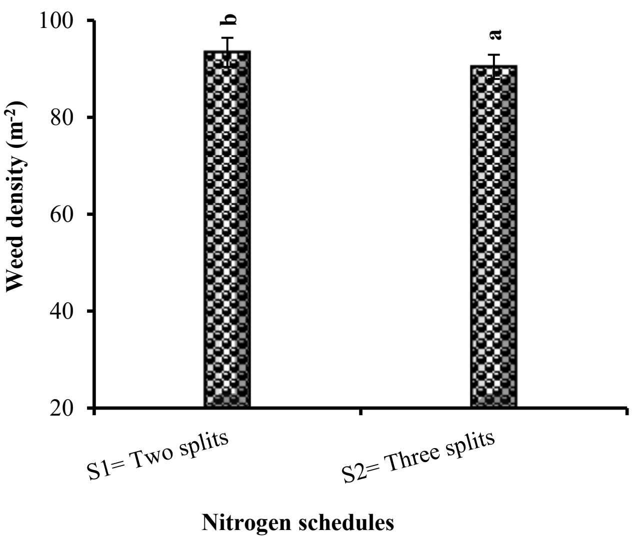
20 L ha^{-1} + Herbicide (AXIAL 330 ml + ally max 14 g) @ 0.5 L ha^{-1}(W_4) × application of N @ 50 kg ha^{-1} (NR_1). The interaction of weed control practices (W) × nitrogen application timings (TM) indicated that bottommost (48.8 m^{-2}) weed density was registered under the interaction of sorghum extract @ 20 L ha^{-1} + Herbicide (AXIAL 330 ml + ally max 14 g) @ 0.5 L ha^{-1} (W_4) × nitrogen application in three splits (NS_2). In case of interactive effects of nitrogen application rates (NR) × nitrogen application timings (TM), smallest (83.2 m^{-2}) values of weed density were recorded under the interaction of N application @ 50 kg ha^{-1} (NR_1) × N application in three splits (NS_2). Amongst interactive effects of weed control practices (W) × nitrogen application rates (R) × nitrogen application schedules (NS), lowest (42.6 m^{-2}) weed density was noted under the interaction of sorghum extract @ 20 L ha^{-1} + Herbicide (AXIAL 330 ml + ally max 14 g) @ 0.5 L ha^{-1} (W_4) × application of N @ 50 kg ha^{-1} (NR_1) × N application in three splits (NS_2).

Weed control (%): The observed data showed that impact of weed control practices, nitrogen application strategies and their interaction were significant (p<0.05) on weed control (%). The data (Table 2) revealed that in circumstance of weed control practices, integrated application of sorghum extract @ 20 L ha^{-1} + Herbicide (AXIAL 330 ml + ally max 14 g) @ 0.5 L ha^{-1} (W_4) resulted in highest (59.4 %) weed control followed by hand weeding twice; 30 and 55 days after sowing (W_5) with weed control of (40.7 %). Application of herbicide (AXIAL 330 ml + ally max 14 g) @ 1.0 L ha^{-1} (W_3) and sorghum extract @ 40 L ha^{-1} (W_2) ranked 3rd and 4th in efficiency with weed control of (28.3 %) and (14.6 %), correspondingly. Although, lower (0.0 %) weed control was observed under control (without sorghum material) (W_1). As per nitrogen application rates (NR), maximum (32.5 %) weed control was recorded @ 50 kg N ha^{-1} (NR_1). Application of N @ 75 kg ha^{-1} (NR_2) gave weed control of (28.6 %). However, minimum (24.6 %) weed control was noted when N was applied @ 100 kg ha^{-1} (NR_3). Amongst nitrogen application schedules (NS), the highest (29.7 %) weed control was noticed under three splits (NS_2), whereas application of nitrogen in two splits (NS_1) resulted in lowest (27.5 %) weed control. Furthermore, the outcomes of integration concerning weed control practices (W) × nitrogen application rates (NR) exhibited that maximum (65.4 %) weed control was documented under interaction of sorghum extract @ 20 L ha^{-1} + Herbicide (AXIAL 330 ml + ally max 14 g) @ 0.5 L ha^{-1} (W_4) × application of N @ 50 kg ha^{-1} (NR_1). The interaction of weed control practices (W) × nitrogen application schedules (NS) indicated that highest (61.3 %) weed control was registered under the interaction of sorghum extract @ 20 L ha^{-1} + Herbicide (AXIAL 330 ml + ally max 14 g) @ 0.5 L ha^{-1} (W_4) × nitrogen application in three splits (NS_2). In case of interactive effects of nitrogen application rates (NR) × nitrogen application schedules (NS), highest (33.7 %) values of weed control were recorded under the interaction of N application @ 50 kg ha^{-1} (R_1) × N application in three splits (NS_2). Amongst interactive effects of weed control practices (W) × nitrogen application rates (NR) × nitrogen application schedules (NS), highest (67.1 %) weed control was noted under the interaction of sorghum extract @ 20 L ha^{-1} + Herbicide (AXIAL 330 ml + ally max 14 g) @ 0.5 L ha^{-1} (W_4) × application of nitrogen @ 50 kg ha^{-1} (NR_1) × Nitrogen application in three splits (NS_2).

Table 1. Weed density (m^{-2}) is affected by sorghum extract and nitrogen application.

N Schedules	N Rates	Weed control practices					Mean
		W_1	W_2	W_3	W_4	W_5	
Two splits	50 kg ha^{-1}	165.0	82.6	71.3	47.5	61.4	85.5 e
	75 kg ha^{-1}	170.0	86.4	76.6	51.7	63.3	89.6 c
	100 kg ha^{-1}	174.6	102.9	80.0	56.2	69.5	96.6 a
	Mean	**169.8**	**90.6**	**76.0**	**51.8**	**64.8**	90.6 A
Three splits	50 kg ha^{-1}	162.3	81.0	70.3	42.6	59.9	83.2 f
	75 kg ha^{-1}	168.2	84.0	72.2	49.9	62.1	87.3 d
	100 kg ha^{-1}	172.3	90.4	78.7	53.9	65.4	92.2 b
	Mean	**167.6**	**85.1**	**73.8**	**48.8**	**62.5**	87.6 B
Averages	50 kg ha^{-1}	163.6 c	81.8 f	70.8 i	45.0 n	60.7 k	84.4 c
	75 kg ha^{-1}	169.1 b	85.2 e	74.4 h	50.8 m	62.7 k	88.5 b
	100 kg ha^{-1}	173.5 a	96.6 d	79.4 g	55.1 l	67.4 j	94.4 a
	Mean	**168.7 a**	**87.9 b**	**74.9 c**	**50.3 e**	**63.6 d**	-

Variables	P-value	SE	$LSD_{0.05}$
Weed Practices (W)	0.0000	0.6130	1.2270
N Rates (NR)	0.0000	0.4748	0.9504
N Schedules (NS)	0.0000	0.3877	0.7760
W x NR	0.0000	1.0617	2.1252
W x NS	0.0482	0.8669	1.7352
R x NS	0.0373	0.6715	1.3441
W x NR x NS	0.0004	1.5015	3.0055



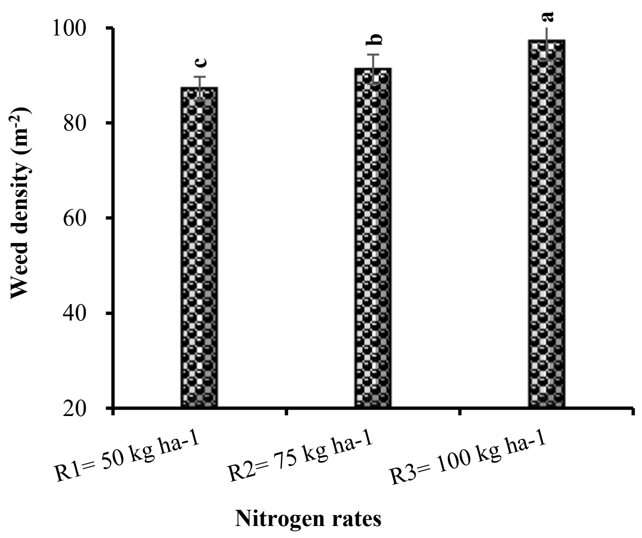


Fig. 1 & 2. Weed density (m^{-2}) of weeds associated with sesame under various nitrogen application schedules & rates.

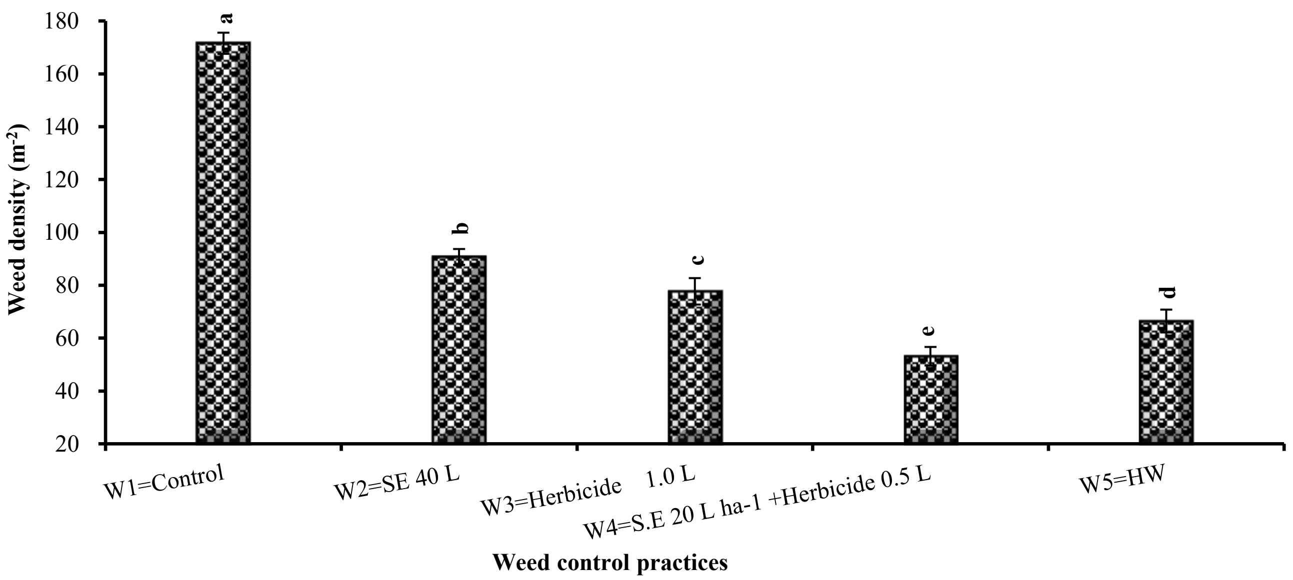


Fig. 3. Weed density (m^{-2}) of weeds associated with sesame under the influence of various weed control practices.

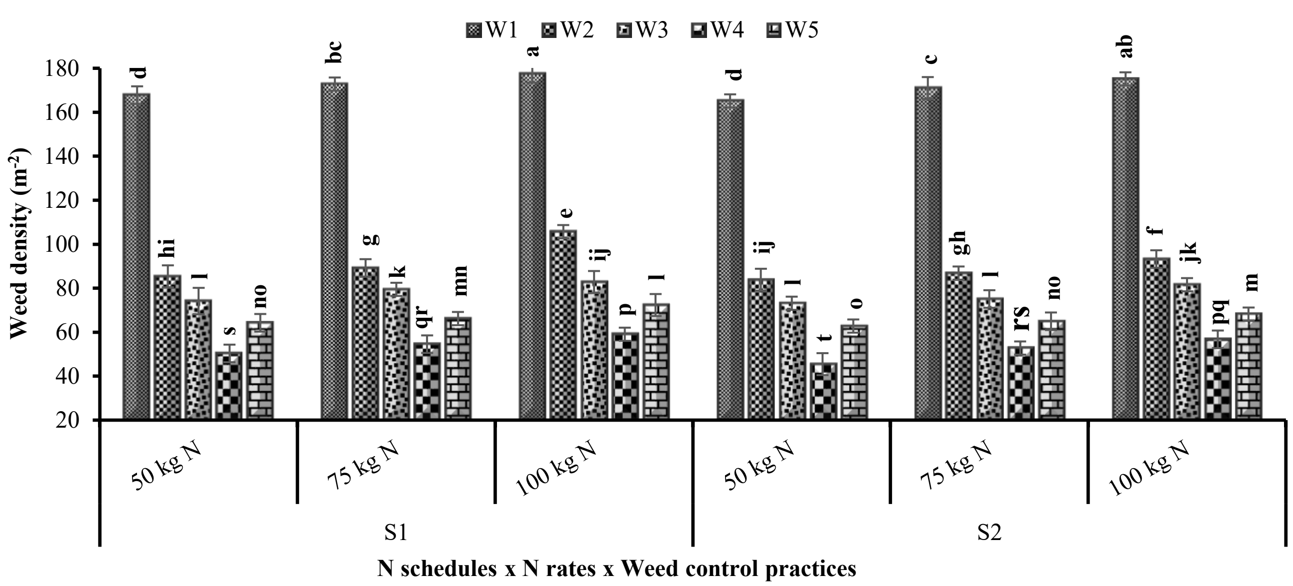


Fig. 4. Weed density (m^{-2}) of weeds associated with sesame under the influence of various nitrogen schedules, rates and weed control practices.

Table 2. Weed control (%) as affected by sorghum extract and nitrogen application.

N Schedules	N Rates	Weed control practices					Mean
		W_1	W_2	W_3	W_4	W_5	
Two splits	50 kg ha-1	0.0	18.3	31.4	63.6	43.4	31.3 b
	75 kg ha-1	0.0	13.3	26.9	57.6	39.3	27.4 d
	100 kg ha-1	0.0	8.6	23.5	50.9	35.9	23.8 f
	Mean	**0.0**	**13.4**	**27.3**	**57.4**	**39.5**	27.5 B
Three splits	50 kg ha-1	0.0	21.2	33.8	67.1	46.6	33.7 a
	75 kg ha-1	0.0	15.6	29.4	62.3	42.1	29.9 c
	100 kg ha-1	0.0	10.6	25.1	54.6	36.7	25.4e
	Mean	**0.0**	**15.8**	**29.4**	**61.3**	**41.8**	29.7 A
Averages	50 kg ha-1	0.0 m	19.7 j	32.6 g	65.4 a	45.0 d	32.5 a
	75 kg ha-1	0.0 m	14.4 k	28.1 h	59.9 b	40.7 e	28.6 b
	100 kg ha-1	0.0 m	9.6 l	24.3 i	52.8 c	36.3 f	24.6 c
	Mean	**0.0 f**	**14.6 d**	**28.3 c**	**59.4 a**	**40.7 b**	-

Variables	P-value	SE	$LSD_{0.05}$
Weed Practices (W)	0.0000	0.5514	1.1037
N Rates (NR)	0.0000	0.4271	0.8549
N Schedules (NS)	0.0000	0.3487	0.6980
W x NR	0.0000	0.9550	1.9116
W x NS	0.0178	0.7798	1.5608
NR x NS	0.5559	0.6040	1.2090
W x NR x NS	0.9914	1.3506	2.7035

Table 3. Plant height (cm) as affected by sorghum extract and nitrogen application.

N Schedules	N Rates	Weed control practices					Mean
		W_1	W_2	W_3	W_4	W_5	
Two splits	50 kg ha^{-1}	89.5	100.9	105.2	110.5	108.3	102.9 f
	75 kg ha^{-1}	92.4	112.8	114.1	122.1	118.3	111.9 d
	100 kg ha^{-1}	96.3	128.4	131.6	148.2	139.2	128.7 b
	Mean	**92.7**	**114.1**	**117.0**	**126.9**	**121.9**	114.5 B
Three splits	50 kg ha^{-1}	90.4	103.2	107.5	111.7	109.2	104.4 e
	75 kg ha^{-1}	93.3	113.5	116.3	124.8	120.0	113.6 c
	100 kg ha^{-1}	98.4	130.1	134.3	150.7	144.4	131.6 a
	Mean	**94.0**	**115.6**	**119.4**	**129.0**	**124.6**	116.5 A
Averages	50 kg ha^{-1}	89.9 o	102.0 l	106.3 k	111.0 i	108.7 j	103.6 c
	75 kg ha^{-1}	92.8 n	113.1 h	115.1 g	123.4 e	119.1 f	112.7 b
	100 kg ha^{-1}	97.3 m	129.2 d	132.9 c	149.4 a	141.8 b	130.1 a
	Mean	**93.3 e**	**114.8 d**	**118.1 c**	**127.9 a**	**123.2 b**	-

Variables	P-value	SE	$LSD_{0.05}$
Weed Practices (W)	0.0000	0.4624	0.9255
N Rates (NR)	0.0000	0.3581	0.7169
N Schedules (NS)	0.0000	0.2924	0.5853
W x NR	0.0000	0.8008	1.6030
W x NS	0.0000	0.6539	1.3089
NR x NS	0.57000	0.5065	1.0138
W x NR x NS	0.1295	1.1325	2.2670

Agronomic traits

Plant height (cm): The collected data revealed that the impacts of weed control practices, nitrogen application strategies and their interaction were significant (p<0.05) on plant height (cm). The data (Table 3) highlighted that in case of weed control measures, combined application of sorghum extract @ 20 L ha^{-1} + Herbicide (AXIAL 330 ml + ally max 14 g) @ 0.5 L ha^{-1} (W_4) resulted in highest (127.9 cm) plant height followed by hand weeding twice (30 and 55 days after sowing) (W_5) with plant height of (123.2 cm). Application of herbicide (AXIAL 330 ml + ally max 14 g) @ label dose 1.0 L ha^{-1} (W_3) and sorghum extract @ 40 L ha^{-1} (W_2) ranked 3rd and 4th in efficacy with plant height of 114.8 cm and 118.1 cm, respectively. whereas the lowest (93.3 cm) plant height was noticed under control (without sorghum material (W_1). As regards nitrogen application rates (NR) (111.0 cm) was observed @ 50 kg N ha-1 (NR_1). Application of N @ 75 kg ha^{-1} (NR_2) gave height of 123.4 cm. nonetheless, maximum (149.4 cm) height was observed when nitrogen was applied @ 100 kg ha^{-1} (NR_3). In case of nitrogen application schedules (NS), the highest (116.5 cm) height was perceived under three splits (NS_2), whereas the application of nitrogen in two splits (NS_1) resulted in lowest (114.5 cm) height. Moreover, the results of interaction between weed control practices (W) × N application rates (NR) exhibited that maximum (149.4 cm) plant height was recorded under the interaction of sorghum extract @ 20 L ha^{-1} + Herbicide (AXIAL 330 ml + ally max 14 g) @ 0.5 L (W_4) × application of N @ 100 kg ha^{-1} (NR_2). The interaction of weed control practices (W) × nitrogen application schedules (NS) shown that highest (129.0 cm) plant height was registered under the interaction of sorghum extract @ L ha^{-1} + Herbicide (AXIAL 330 ml + ally max 14 g) @ 0.5 L ha^{-1} (W_4) × nitrogen application in three splits (NS_2). In case of nitrogen application rates (NR) × nitrogen application schedules (NS), the highest (130.1 cm) plant height was noted under the interaction of N application @ 100 kg ha^{-1} (NR_3) × N application in three splits (NS_2). Amongst weed control practices (W) × nitrogen application rates (NR) × nitrogen application schedules (NS), highest (150.7 cm) plant height was noted under the interaction of sorghum extract @ 20 L ha^{-1} + Herbicide (AXIAL 330 ml + ally max 14 g) @ 0.5 L ha^{-1} (W_4) × application of N @ 100 kg ha^{-1} (NR_3) × N application in three splits (NS_2).

Branches plant^{-1}: The analysis of collected data enlightens that the influence of weed management approaches, nitrogen application strategies and their interaction were significant ($p<0.05$) on branches plant^{-1}. The data (Table 4) indicated that in regards of weed control measures, integrated application of sorghum extract @ 20 L ha^{-1} + Herbicide (AXIAL 330 ml + ally max 14 g) @ 0.5 L ha^{-1} (W_4) resulted in highest (17.0) branches plant^{-1} pursued by hand weeding twice (W_5) with branches plant^{-1} of (16.1). Application of herbicide (AXIAL 330 ml + ally max 14 g) @ 1.0 L ha^{-1} (W_3) and sorghum extract @ 40 L ha^{-1} (W_2) ordered 3rd and 4th in effectiveness with branches plant^{-1} of 15.8 and 15.2, correspondingly. Although, lowest (11.1) branches plant^{-1} were recorded under control; untreated (W_1). In case nitrogen application rates (NR) (14.6) branches plant^{-1} were recorded @ 50 kg N ha^{-1} (NR_1). Application of N @ 75 kg ha^{-1} (NR_2) gave branches plant^{-1} of 16.6. Nonetheless, maximum (19.8) branches plant^{-1} were observed when nitrogen was applied @ 100 kg ha^{-1} (NR_3). As per nitrogen application schedules (NS), the highest (15.3) branches plant^{-1} were noticed under three splits (NS_2), whereas application of nitrogen in two splits (NS_1) resulted in lowest (14.8) branches plant^{-1}. Furthermore, the results of interaction between weed control practices (W) × N application rates (NR) showed that maximum (19.8) branches plant^{-1} were documented under the interaction of sorghum extract @ 20 L ha^{-1} + Herbicide (AXIAL 330 ml + ally max 14 g) @ 0.5 L (W_4) × application of N @ 100 kg ha^{-1} (NR_3). The interaction of weed control practices (W) × nitrogen application schedules (NS) indicated that highest (17.3) branches plant^{-1} were registered under the interaction of sorghum extract @ L ha^{-1} + Herbicide (AXIAL 330 ml + ally max 14 g) @ 0.5 L ha^{-1} (W_4) × nitrogen application in three splits (NS_2). In case of interactive effects of nitrogen application rates (NR) × nitrogen application schedules (NS), highest (17.2) values for branches plant^{-1} were recorded under the interaction of N application @ 100 kg ha^{-1} (NR_3) × N application in three splits (NS_2). Amongst interactive effects of weed control practices (W) × nitrogen application rates (NR) × nitrogen application schedules (NS), highest (20.5) branches plant^{-1} were noted under the interaction of sorghum extract @ 20 L ha^{-1} + Herbicide (AXIAL 330 ml + ally max 14 g) @ 0.5 L ha^{-1} (W_4) × application of N @ 100 kg ha^{-1} (NR_3) × N application in three splits (NS_2).

Table 4. Branches plant^{-1} as affected by sorghum extract and nitrogen application.

N Schedules	N Rates	Weed control practices					Mean
		W_1	W_2	W_3	W_4	W_5	
Two splits	50 kg ha^{-1}	9.0	13.3	13.7	14.5	14.1	12.9 f
	75 kg ha^{-1}	11.0	14.9	15.4	16.4	15.7	14.6 d
	100 kg ha^{-1}	12.0	17.0	17.7	19.2	18.3	16.8 b
	Mean	**10.6**	**15.0**	**15.6**	**16.7**	**16.0**	14.8 B
Three splits	50 kg ha^{-1}	10.0	13.5	13.9	14.7	14.3	13.2 e
	75 kg ha^{-1}	11.6	15.2	16.0	16.8	15.8	15.1 c
	100 kg ha^{-1}	12.8	17.5	17.8	20.5	18.8	17.5 a
	Mean	**11.5**	**15.4**	**15.9**	**17.3**	**16.3**	15.3 A
Averages	50 kg ha^{-1}	9.5 m	13.4 j	13.8 ij	14.6 h	14.2 hi	13.1 c
	75 kg ha^{-1}	11.3 l	15.0 g	15.7 f	16.6 e	15.7 f	14.9 b
	100 kg ha^{-1}	12.4 k	17.2 d	17.8 c	19.8 a	18.6 b	17.2 a
	Mean	**11.1 e**	**15.2 d**	**15.8 c**	**17.0 a**	**16.1 b**	-

Variables	P-value	SE	$LSD_{0.05}$
Weed Practices (W)	0.0000	0.1215	0.2432
N Rates (NR)	0.0000	0.0941	0.1884
N Schedules (NS)	0.0000	0.0769	0.1538
W x NR	0.0000	0.2105	0.4213
W x NS	0.1177	0.1718	0.344
R x NS	0.2388	0.1331	0.2665
W x NR x NS	0.2904	0.2976	0.5958

Table 5. Capsule plant^{-1} as affected by sorghum extract and nitrogen application.

N Schedules	N Rates	Weed control practices					Mean
		W_1	W_2	W_3	W_4	W_5	
Two splits	50 kg ha^{-1}	30.0	33.8	35.3	38.2	36.5	34.8 f
	75 kg ha^{-1}	31.1	39.4	40.7	42.0	40.9	38.8 d
	100 kg ha^{-1}	32.4	42.8	43.9	45.4	44.8	41.9 b
	Mean	**31.2**	**38.7**	**40.0**	**41.9**	**40.7**	38.5 B
Three splits	50 kg ha^{-1}	30.8	34.4	35.8	39. 0	37.3	39.1 c
	75 kg ha^{-1}	31.9	39.6	40.1	42.1	41.8	42.4 a
	100 kg ha^{-1}	33.1	43.6	44.4	46.2	45. 0	35.4 e
	Mean	**31.9**	**39.2**	**40.1**	**42.4**	**41.4**	39.0 A
Averages	50 kg ha^{-1}	32.8 m	34.1 l	35.5 k	38.6 i	36.9 j	35.1 c
	75 kg ha^{-1}	31.5 n	39.5 h	40.4 g	42.1 e	41.4 f	39.0 b
	100 kg ha^{-1}	30.4 o	43.2 d	44.1 c	45.8 a	44.9 b	42.2 a
	Mean	**31.5 e**	**38.9 d**	**40.0 c**	**42.1 a**	**41.0 b**	

Variables	P-value	SE	$LSD_{0.05}$
Weed Practices (W)	0.0000	0.1296	0.2593
N Rates (R)	0.0000	0.1004	0.2009
N Timings (TM)	0.0000	0.0819	0.1640
W x R	0.0000	0.2244	0.4492
W x TM	0.1454	0.1832	0.3668
R x TM	0.1603	0.1419	0.2841
W x R x TM	0.1823	0.3174	0.6353

Capsules plant^{-1}: The collected data regarding capsules plant^{-1} revealed that the effects of weed control practices, nitrogen application strategies and their interaction were significant (p<0.05) on capsule plant^{-1}. The data (Table 5) indicated that as in case of weed management practices, integrated application of sorghum extract @ 20 L ha^{-1} + Herbicide (AXIAL 330 ml + ally max 14 g) @ 0.5 L ha^{-1} (W_4) resulted in highest (42.1) capsules plant^{-1} followed by hand weeding twice (W_5) with capsules plant^{-1} of (41.0). Application of herbicide (AXIAL 330 ml + ally max 14 g) @ label dose 1.0 L ha^{-1} (W_3) and sorghum extract @ 40 L ha^{-1} (W_2) ranked 3rd and 4th in efficacy with capsules plant^{-1} of 40.0 and 38.9, respectively. Although, the lowest (31.5) capsules plant^{-1} were recorded under control (without sorghum material) (W_1). As regards of the nitrogen application rates (NR) (38.6) capsules plant^{-1} were recorded @ 50 kg N ha^{-1} (R_1). Application of N @ 75 kg ha^{-1} (NR_2) gave capsules plant^{-1} of 42.1. Nonetheless, maximum (45.8) capsules plant^{-1} were observed @ 100 kg N ha^{-1} (NR_3). In case of nitrogen application schedules (NS), the highest (39.0) capsules plant^{-1} were noticed under three splits (NS_2), whereas the application of nitrogen in two splits (NS_1) resulted in lowest (38.8) capsules plant^{-1}. Furthermore, the results of interaction between weed management practices (W) × N application rates (NR) showed that maximum (45.8) capsules plant^{-1} were documented under the interaction of sorghum extract @ 20 L ha^{-1} + Herbicide (AXIAL 330 ml + ally max 14 g) @ 0.5 L (W_4) × application of N @ 100 kg ha^{-1} (NR_3). The interaction of weed control practices (W) × nitrogen application schedules (NS) indicated that highest (42.4) capsules plant^{-1} were registered under the interaction of sorghum extract @ L ha^{-1} + Herbicide (AXIAL 330 ml + ally max 14 g) @ 0.5 L ha^{-1} (W_4) × nitrogen application in three splits (NS_2). In case of interactive effects of nitrogen application rates (NR) × nitrogen application schedules (NS), the highest (42.2) values for branches plant^{-1} were recorded under the interaction of N application @ 100 kg ha^{-1} (NR_3) × N application in three splits (NS_2). Amongst interactive effects of weed control practices (W) × nitrogen application rates (NR) × nitrogen application schedules (NS), highest (46.2) branches plant^{-1} were noted under the interaction of sorghum extract @ 20 L ha^{-1} + Herbicide (AXIAL 330 ml + ally max 14 g) @ 0.5 L ha^{-1} (W_4) × application of N @ 100 kg ha^{-1} (NR_3) × N application in three splits (NS_2).

Capsule weight plant^{-1}(g): Analysis of the data highlighted that the effects of weed control practices, nitrogen application strategies and their interaction were noteworthy (p<0.05) on capsules weight plant^{-1}. The data (Table 6) indicated that in case of weed control practices, integrated application of sorghum extract @ 20 L ha^{-1} + Herbicide (AXIAL 330 ml + ally max 14 g) @ 0.5 L ha^{-1} (W_4) resulted in highest (22.2 g) capsules weight plant^{-1} followed by hand weeding twice; 30 and 55 DAS (W_5) with capsules weight plant^{-1} of (20.0 g). Application of herbicide (AXIAL 330 ml + ally max 14 g) @ label dose 1.0 L ha^{-1} (W_3) and sorghum extract @ 40 L ha^{-1} (W_2) ranked 3rd and 4th in efficacy with capsules weight plant^{-1} of 18.9 g and 17.6 g, respectively. Although, the lowest (10.9 g) capsules weight plant^{-1} was recorded under control (without sorghum material) (W_1). As regards nitrogen application rates (NR) (15.8 g) capsules weight plant^{-1} was recorded @ 50 kg N ha^{-1} (NR_1). Application of N @ 75 kg ha^{-1} (NR_2) gave capsules weight plant^{-1} of 21.3 g. Nonetheless, maximum (29.4 g) capsules weight plant^{-1} was observed @ 100 kg N ha^{-1} (NR_3). In regard to the application schedules of nitrogen (NS), the highest (12.2 g) capsules weight plant^{-1} was noticed in three splits (NS_2), whereas the application of nitrogen in two splits (NS_1) resulted in lowest (11.4 g) capsules weight plant^{-1}. Furthermore, the results of interaction between weed control practices (W) × N application rates (NR) showed that maximum (29.4 g) capsules weight plant^{-1} was documented under the interaction of sorghum extract @ 20 L ha^{-1} + Herbicide (AXIAL 330 ml + ally max 14 g) @ 0.5 L (W_4) × application of N @ 100 kg ha^{-1} (NR_3).

Interaction of weed control measures (W) × nitrogen application schedules (NS) indicated that highest (15.1 g) capsules weight plant^{-1} was registered under the interaction of sorghum extract @ L ha^{-1} + Herbicide (AXIAL 330 ml + ally max 14 g) @ 0.5 L ha^{-1} (W_4) × nitrogen application in three splits (NS_2). In case of interactive effects of nitrogen application rates (NR) × nitrogen application schedules (NS), highest (23.2 g) values for capsule weight plant^{-1} were recorded under the interaction of N application @ 100 kg ha^{-1} (R_3) × N application in three splits (NS_2). Amongst interactive effects of weed control practices (W) × nitrogen application rates (NR) × nitrogen application schedules (NS), highest (20.3 g) branches plant^{-1} was recoded under the interaction of sorghum extract @ 20 L ha^{-1} + Herbicide (AXIAL 330 ml + ally max 14 g) @ 0.5 L ha^{-1} (W_4) × application of N @ 100 kg ha^{-1} (NR_3) × N application in three splits (NS_2).

Table 6. Capsules weight plant^{-1} as affected by sorghum extract and nitrogen application.

N Schedules	N Rates	Weed control practices					Mean
		W_1	W_2	W_3	W_4	W_5	
Two splits	50 kg ha^{-1}	6.0	8.2	8.8	10.7	9.6	8.6 e
	75 kg ha^{-1}	7.0	11.2	12.0	14.0	13.0	11.4 d
	100 kg ha^{-1}	7.5	15.6	16.2	19.3	17.8	15.3 b
	Mean	**6.8**	**11.6**	**12.4**	**14.6**	**13.5**	11.8 B
Three splits	50 kg ha^{-1}	6.7	8.7	9.2	10.2	7.4	8.5 f
	75 kg ha^{-1}	10.0	11.6	12.4	14.6	13.4	12.4 c
	100 kg ha^{-1}	8.0	15.2	17.4	20.3	18.6	15.9 a
	Mean	**8.2**	**11.8**	**13.0**	**15.1**	**13.1**	12.2 A
Averages	50 kg ha^{-1}	9.3 o	12.6 l	13.4 j	15.8 i	13.3 k	12.9 c
	75 kg ha^{-1}	12.0 m	17.0 h	18.2 g	21.3 e	19.7 f	17.6 b
	100 kg ha^{-1}	11.5 n	23.2 d	24.9 c	29.4 a	27.1 b	23.2 a
	Mean	**10.9 e**	**17.6 d**	**18.9 c**	**22.2 a**	**20.0 b**	-

Variables	**P-value**	**SE**	**$LSD_{0.05}$**
Weed Practices (W)	0.0000	0.1180	0.2363
N Rates (R)	0.0000	0.0914	0.1830
N Timings (TM)	0.0000	0.0747	0.1494
W x R	0.0000	0.2045	0.4093
W x TM	0.0000	0.1669	0.3342
R x TM	0.0000	0.1293	0.2588
W x R x TM	0.0000	0.2891	0.5788

Table 7. Seed index (%) as affected by sorghum extract and nitrogen application.

N Schedules	N Rates	Weed control practices					Mean
		W_1	W_2	W_3	W_4	W_5	
Two splits	50 kg ha^{-1}	0.9	1.6	1.8	2.2	2.0	1.7 e
	75 kg ha^{-1}	1.2	2.4	2.5	3.0	2.7	2.3 d
	100 kg ha^{-1}	1.5	3.3	3.5	3.9	3.7	3.1 b
	Mean	**1.2**	**2.4**	**2.6**	**3.0**	**2.8**	2.4 B
Three splits	50 kg ha^{-1}	1.0	1.7	1.9	2.1	2.0	1.7 e
	75 kg ha^{-1}	1.3	2.4	2.7	3.2	2.9	2.5 c
	100 kg ha^{-1}	1.4	3.4	3.6	3.9	3.8	3.2 a
	Mean	**1.2**	**2.5**	**2.7**	**3.1**	**2.9**	2.5 A
Averages	50 kg ha^{-1}	1.0 o	1.6 l	1.8 k	2.2 i	2.0 j	1.7 c
	75 kg ha^{-1}	1.2 n	2.4 h	2.6 g	3.1 e	2.8 f	2.4 b
	100 kg ha^{-1}	1.5 m	3.3 d	3.5 c	3.9 a	3.7 b	3.2 a
	Mean	**1.2 e**	**2.4 d**	**2.6 c**	**3.0 a**	**2.8 b**	-

Variables	**P-value**	**SE**	**$LSD_{0.05}$**
Weed Practices (W)	0.0000	0.027	0.0540
N Rates (R)	0.0000	0.0209	0.0418
N Timings (TM)	0.0000	0.0171	0.0341
W x R	0.2021	0.0467	0.0935
W x TM	0.7599	0.0381	0.0764
R x TM	0.0312	0.0295	0.0591
W x R x TM	0.1057	0.0661	0.1323

Table 8. Biological yield (kg ha^{-1}) as impacted by sorghum extract and nitrogen application.

N Schedules	N Rates	Weed control practices					Mean
		W_1	W_2	W_3	W_4	W_5	
Two splits	50 kg ha^{-1}	2294.3	2358.3	2429.0	2612.0	2506.3	2440.0 e
	75 kg ha^{-1}	2320.0	2695.7	2783.3	2946.0	2899.3	2728.9 d
	100 kg ha^{-1}	2330.0	3043.3	3125.7	3406.0	3238.0	3028.6 b
	Mean	**2314.8**	**2699.1**	**2779.3**	**2988**	**2881.2**	2732.5 B
Three splits	50 kg ha^{-1}	2299.3	2396.7	2476.9	2650.0	2545.6	2473.7 e
	75 kg ha^{-1}	2326.7	2730.0	2826.0	3009.3	2930.0	2764.4 c
	100 kg ha^{-1}	2340.0	3103.3	3181.3	3427.0	3341.7	3078.7 a
	Mean	**2322.0**	**2743.3**	**2828.1**	**3028.8**	**2939.1**	2772.3 A
Averages	50 kg ha^{-1}	2296.8 m	2377.5 l	2452.9 k	2631.0 i	2526.0 j	2456.8 c
	75 kg ha^{-1}	2323.3 lm	2712.8 h	2804.7 g	2977.7 e	2914.7 f	2746.6 b
	100 kg ha^{-1}	2335.0 lm	3073.3 d	3153.5 c	3416.5 a	3289.8 b	3053.6 a
	Mean	**2318.4 e**	**2721.2 d**	**2803.7 c**	**3008.4 a**	**2910.2 b**	

Variables	**P-value**	**SE**	**$LSD_{0.05}$**
Weed Practices (W)	0.0000	15.846	31.72
N Rates (R)	0.0000	12.275	24.57
N Timings (TM)	0.0000	10.022	20.061
W x R	0.0000	27.447	54.94
W x TM	0.7663	22.41	44.859
R x TM	0.1132	17.359	34.747
W x R x TM	0.8893	38.815	77.698

Table 9. Seed yield (kg ha^{-1}) as influenced by sorghum extract and nitrogen application.

N Schedules	N Rates	Weed control practices					Mean
		W_1	W_2	W_3	W_4	W_5	
Two splits	50 kg ha^{-1}	700	917	938	992	956	901 e
	75 kg ha^{-1}	824	1030	1064	1133	1090	1028 c
	100 kg ha^{-1}	889	1172	1183	1203	1193	1128 a
	Mean	**804**	**1040**	**1062**	**1109**	**1080**	1019 B
Three splits	50 kg ha^{-1}	744	931	944	1003	980	920 d
	75 kg ha^{-1}	840	1054	1084	1162	1122	1052 b
	100 kg ha^{-1}	901	1179	1186	1206	1197	1134 a
	Mean	**828**	**1054**	**1071**	**1124**	**1100**	1035 A
Averages	50 kg ha^{-1}	722 l	924 i	941 i	998 g	968 h	910 c
	75 kg ha^{-1}	832 k	1042 f	1074 e	1148 c	1106 d	1040 b
	100 kg ha^{-1}	895j	1175 b	1185 ab	1205 a	1195 ab	1131 a
	Mean	**816 e**	**1047 d**	**1067 c**	**1117 a**	**1090 b**	-

Variables	**P-value**	**SE**	**$LSD_{0.05}$**
Weed Practices (W)	0.0000	5.8225	11.655
N Rates (R)	0.0000	4.5101	9.0279
N Timings (TM)	0.0000	3.6825	7.3713
W x R	0.0000	10.085	20.187
W x TM	0.7663	8.2343	16.483
R x TM	0.1132	6.3782	12.767
W x R x TM	0.8893	14.262	28.549

Seed Index (%): Analysis of data revealed that the impact of weed control practices, nitrogen application approaches and their integration were noteworthy ($p<0.05$) on seed index. The data (Table 7) indicated that in case of weed control practices, integrated application of sorghum extract @ 20 L ha^{-1} + Herbicide (AXIAL 330 ml + ally max 14 g) @ 0.5 L ha^{-1} (W_4) resulted in highest (3.0%) seed index pursued by hand weeding twice; 30 and 55 days after sowing (W_5) with seed index of (2.8%). Application of herbicide (AXIAL 330 ml + ally max 14 g) @ label dose 1.0 L ha^{-1} (W_3) and sorghum extract @ 40 L ha^{-1} (W_2) ranked 3rd and 4th in efficacy with seed index of 2.6% and 2.4%, respectively. Although, the lowest (1.2 %) seed index was recorded under control (without sorghum material) (W_1). As regards nitrogen application rates (NR) (2.2%) seed index was recorded @ 50 kg N ha^{-1} (NR_1). Application of N @ 75 kg ha^{-1} (NR_2) gave seed index of 3.1%. Nonetheless, maximum (3.9%) seed index was observed when nitrogen was applied @ 100 kg ha^{-1} (NR_3). In case of nitrogen application schedules (NS), the highest (2.5%) seed index was noticed under three splits (NS_2), whereas the application of nitrogen in two splits (NS_1) resulted in lowest (2.4%) seed index. Furthermore, the results of interaction between weed control practices (W) × N application rates (NR) showed that maximum (3.9%) seed index was documented under the interaction of sorghum extract @ 20 L ha^{-1} + Herbicide (AXIAL 330 ml + ally max 14 g) @ 0.5 L (W_4) × application of N @ 100 kg ha^{-1} (NR_2). The interaction of weed control practices (W) × nitrogen application schedules (NS) indicated that the highest (3.1%) seed index was registered under the interaction of sorghum extract @ L ha^{-1} + Herbicide (AXIAL 330 ml + ally max 14 g) @ 0.5 L ha^{-1} (W_4) × nitrogen application in three splits (NS_2). In case of interactive effects of nitrogen application rates (NR) × nitrogen application schedules (TM), the highest (3.2%) values for seed index were recorded under the interaction of N application @ 100 kg ha^{-1} (NR_2) × N application in three splits (NS_2). Amongst interactive effects of weed control practices (W) × nitrogen application rates (NR) × nitrogen application schedules (NS), highest (3.9%) seed index were noted under the interaction of sorghum extract @ 20 L ha^{-1} + Herbicide (AXIAL 330 ml + ally max 14 g) @ 0.5 L ha^{-1} (W_4) × application of N @ 100 kg ha^{-1} (NR_3) × N application in three splits (NS_2).

Biological yield (kg ha^{-1}): The analyzed data revealed that the effects of weed control approaches, nitrogen application strategies and integrations were very significant (p<0.05) on biological yield. The data (Table 8) indicated that in case of weed management approaches, integrated application of sorghum extract @ 20 L ha^{-1} + Herbicide (AXIAL 330 ml + ally max 14 g) @ 0.5 L ha^{-1} (W_4) resulted in highest (3008.4 kg ha^{-1}) biological yield trailed by hand weeding twice 30 and 55 DAS (W_5) biological yield of (2910.2 kg ha^{-1}). Combination of herbicide (AXIAL 330 ml + ally max 14 g) @ 1.0 L ha^{-1} (W_3) and sorghum extract @ 40 L ha^{-1} (W_2) ranked 3rd and 4th in efficacy with 2803.7 kg ha^{-1} and 2721.2 kg ha^{-1} of biological yield respectively. Although, the lowest biological yield (2318.4 kg ha^{-1}) was recorded in control (without sorghum) (W_1). As regards nitrogen application rates (NR) (2631.0 kg ha^{-1}) biological yield was recorded @ 50 kg N ha^{-1} (NR_1). Nitrogen application @ 75 kg ha^{-1} (NR_2) gave (2977.7 kg ha^{-1}) biological yield. Nonetheless, maximum biological yield of 3416.5 kg ha^{-1} was noted @ 100 kg N ha^{-1} (NR_3). In case of nitrogen application schedules (NS), highest biological yield (2772.3 kg ha^{-1}) was noticed under three splits (NS_2), whereas the application of nitrogen in two splits (NS_1) produced the lowest (2732.5 kg ha^{-1}) biological yield. Furthermore, the results of interaction between weed control practices (W) × N application rates (NR) showed that maximum biological yield of 3416.5 kg ha^{-1} noted under the interaction of sorghum extract @ 20 L ha^{-1} + Herbicide (AXIAL 330 ml + ally max 14 g) @ 0.5 L (W_4) × application of N @ 100 kg ha^{-1} (NR_3). The interaction of weed control practices (W) × nitrogen application schedules (NS) indicated that highest (3028.8 kg ha^{-1}) biological yield was registered under the interaction of sorghum extract @ L ha^{-1} + Herbicide (AXIAL 330 ml + ally max 14 g) @ 0.5 L ha^{-1} (W_4) × nitrogen application in three splits (NS_2). In case of interactive effects of nitrogen application rates (NR) × nitrogen application schedules (TM), the highest (3053.6 kg ha) values for biological yield were recorded under the interaction of N application @ 100 kg ha^{-1} (NR_3) × N application in three splits (NS_2). Amongst interactive effects of weed control practices (W) × nitrogen application rates (NR) × nitrogen application schedules (NS), highest (3427.0 kg ha^{-1}) biological yield was observed under the integration of sorghum extract @ 20 L ha^{-1} + Herbicide (AXIAL 330 ml + ally max 14 g) @ 0.5 L ha^{-1} (W_4) × application of N @ 100 kg ha^{-1} (NR_3) × N application in three splits (NS_2).

Seed yield (kg ha^{-1}): The data revealed that the effects of weed control approaches, nitrogen application strategies and their integration were significant (p<0.05) on seed yield. The data (Table 9, Figs. 5-8) indicated that in case of weed control measures, integrated application of sorghum extract @ 20 L ha^{-1} + Herbicide (AXIAL 330 ml + ally max 14 g) @ 0.5 L ha^{-1} (W_4) resulted in highest (1117 kg ha^{-1}) seed yield followed by hand weeding twice; 30 and 55 days after sowing (W_5) seed yield of (1090 kg ha^{-1}). The label dose of herbicide (AXIAL 330 ml + ally max 14 g) @ 1.0 L ha^{-1} (W_3) and the extract of sorghum @ 40 L ha^{-1} (W_2) ranked 3rd and 4th in efficacy with seed yield of 1067 kg ha^{-1} and 1047 kg ha^{-1} respectively. Although, lowest (816 kg ha^{-1}) seed yield was recorded under control (without sorghum material) (W_1). As regards nitrogen application rates (NR) seed yield of 998 kg ha^{-1} was noted @ 50 kg N ha^{-1} (NR_1). Nitrogen application @ 75 kg ha^{-1} (NR_2) gave seed yield of 1148 kg ha^{-1}. Nonetheless, maximum (1205 kg ha^{-1}) seed yield was observed @ 100 kg N ha^{-1} (NR_3). Under Nitrogen application schedules (NS), highest (1035 kg ha^{-1}) biological yield was noticed in three splits (NS_2), whereas the application of nitrogen in two splits (NS_1) resulted in lowest (1019 kg ha^{-1}) seed yield. Furthermore, the results of interaction between weed control practices (W) × N application rates (NR) showed that maximum (1205 kg ha^{-1}) seed yield was documented under the interaction of sorghum extract @ 20 L ha^{-1} + Herbicide (AXIAL 330 ml + ally max 14 g) @ 0.5 L (W_4) × application of N @ 100 kg ha^{-1} (NR_3). The interaction of weed control practices (W) × nitrogen application schedules (NS) indicated that highest (1124 kg ha^{-1}) seed yield was registered under the interaction of sorghum extract @ L ha^{-1} + Herbicide (AXIAL 330 ml + ally max 14 g) @ 0.5 L ha^{-1} (W_4) × nitrogen application in three splits (NS_2). In case of interactive effects of nitrogen application rates (NR) × nitrogen application schedules (NS), highest (1131 kg ha) values for seed yield were recorded under the interaction of N application @ 100 kg ha^{-1} (NR_2) × N application in three splits (NS_2). Amongst interactive effects of weed control practices (W) × nitrogen application rates (RR) × nitrogen application schedules (NS), highest (1206 kg ha^{-1}) seed yield was noted under the interaction of sorghum extract @ 20 L ha^{-1} + Herbicide (AXIAL 330 ml + ally max 14 g) @ 0.5 L ha^{-1} (W_4) × application of N @ 100 kg ha^{-1} (NR_3) × N application in three splits (NS_2).

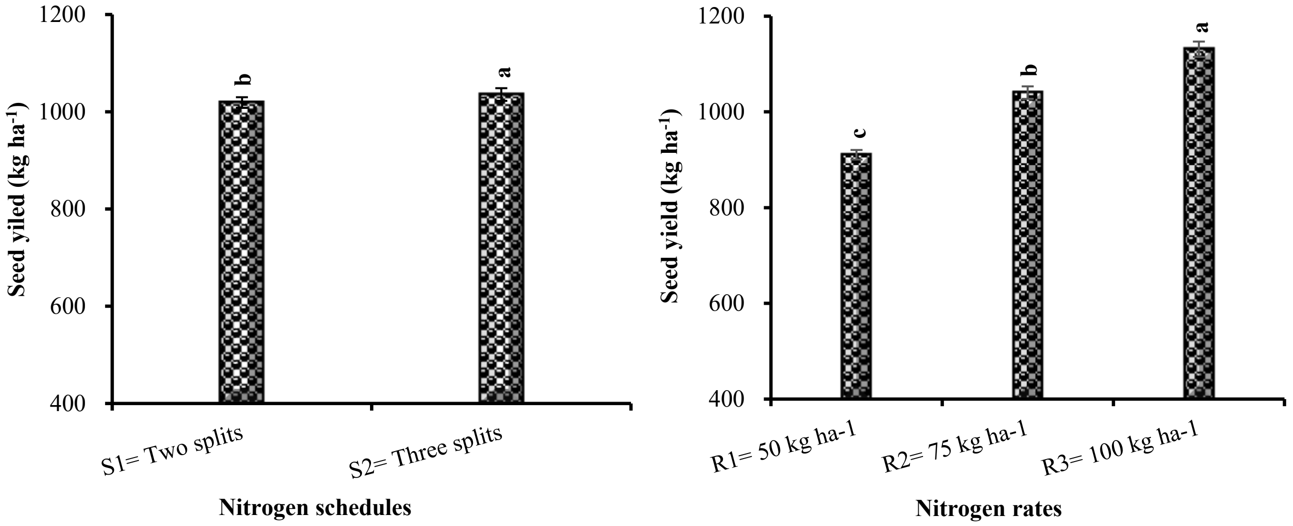


Fig. 5 & 6. Seed yield (kg ha^{-1}) of sesame under various nitrogen application schedules and rates.

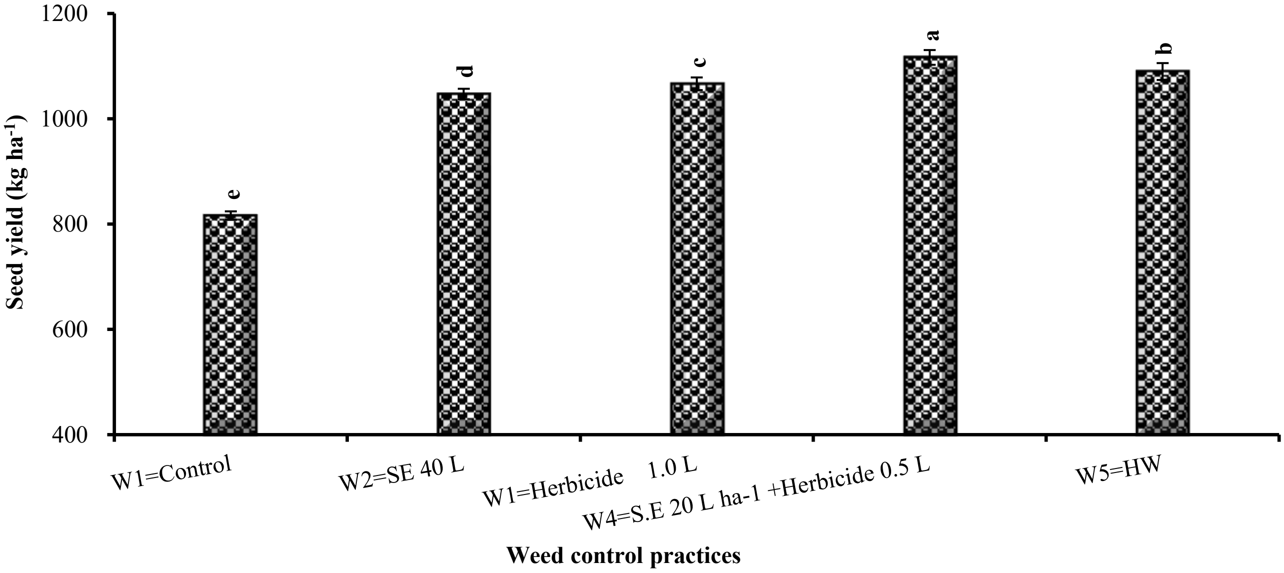


Fig. 7. Seed yield (kg ha^{-1}) of sesame under various weed control practices.

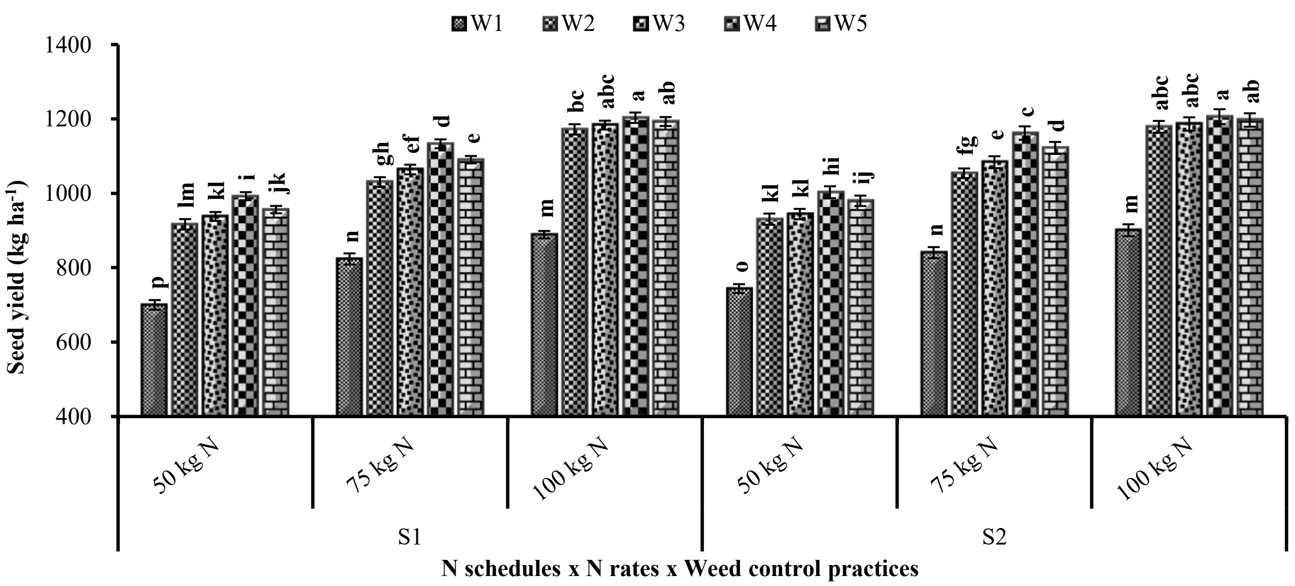


Fig. 8. Seed yield (kg ha^{-1}) of sesame under various nitrogen schedules, rates and weed control practices.

Table 10. Harvest index (%) as affected by sorghum extract and nitrogen application.

N Schedules	N Rates	Weed control practices					Mean
		W_1	W_2	W_3	W_4	W_5	
Two splits	50 kg ha^{-1}	30.4	35.9	36.2	37.1	36.7	35.3 d
	75 kg ha^{-1}	33.9	37.5	37.9	38.6	38.2	37.2 b
	100 kg ha^{-1}	34.8	38.8	39.2	39.8	39.6	38.4 a
	Mean	**33.0**	**37.4**	**37.7**	**38.5**	**38.2**	37.0 B
Three splits	50 kg ha^{-1}	32.0	36.0	36.3	37.3	37.0	35.7 c
	75 kg ha^{-1}	34.6	37.8	38.0	38.7	38.4	37.5 b
	100 kg ha^{-1}	35.8	39.0	39.3	40.7	39.6	38.8 a
	Mean	**34.1**	**37.6**	**37.8**	**38.9**	**38.3**	37.3 A
Averages	50 kg ha^{-1}	31.2 l	36.0 i	36.2 hi	37.2 fg	36.9 gh	35.5 c
	75 kg ha^{-1}	34.2 k	37.6 ef	37.9 e	38.6 cd	38.3 de	37.3 b
	100 kg ha^{-1}	35.3 j	38.9 cd	39.2 bc	40.2 a	39.6 ab	38.6 a
	Mean	**33.6 d**	**37.5 c**	**37.8 c**	**38.7 a**	**38.2 b**	-

Variables	P-value	SE	$LSD_{0.05}$
Weed Practices (W)	0.0000	0.1877	0.3757
N Rates (R)	0.0000	0.1454	0.291
N Timings (TM)	0.0020	0.1187	0.2376
W x R	0.0210	0.3251	0.6508
W x TM	0.0568	0.2654	0.5313
R x TM	0.8304	0.2056	0.4116
W x R x TM	0.8634	0.4598	0.9203

Harvest index (%): The analysis of collected data showed that the effects of weed control practices, nitrogen application strategies and their interaction were noteworthy (p<0.05) on harvest index. The data (Table 10) indicated that in case of weed control measure, integrated application of sorghum extract @ 20 L ha^{-1} + Herbicide (AXIAL 330 ml + ally max 14 g) @ 0.5 L ha^{-1} (W_4) resulted in highest (38.7 %) harvest index trailed by hand weeding twice 30 and 55 DAS (W_5) harvest index of (38.2%). Application of herbicide (AXIAL 330 ml + ally max 14 g) @ label dose 1.0 L ha^{-1} (W_3) and sorghum extract @ 40 L ha^{-1} (W_2) ranked 3rd and 4th in efficacy with harvest index of 37.8% and 37.5% respectively. Although, the lowest (33.6 %) harvest index was recorded under control (without sorghum material) (W_1). As regards nitrogen application rates (NR) (37.2%) harvest index was recorded @ 50 kg N ha^{-1} (NR_1). Nitrogen applied @ 75 kg ha^{-1} (NR_2) gave harvest index of 38.6%. Nonetheless, maximum (40.2%) harvest index was observed under the application of nitrogen @ 100 kg ha^{-1} (NR_3). However, as per nitrogen application schedules (NS), the highest (37.3 %) harvest index was noticed under three splits (NS_2), whereas the application of nitrogen in two splits (NS_1) resulted in lowest (37.0%) harvest index. Furthermore, the results of interaction between weed control practices (W) × N application rates (NR) showed that maximum (40.2 %) harvest index was documented under the interaction of sorghum extract @ 20 L ha^{-1} + Herbicide (AXIAL 330 ml + ally max 14 g) @ 0.5 L (W_4) × application of N @ 100 kg ha^{-1} (NR_2). The interaction of weed control practices (W) × nitrogen application schedules (NS) indicated that highest (38.9 %) harvest index was registered under the interaction of sorghum extract @ L ha^{-1} + Herbicide (AXIAL 330 ml + ally max 14 g) @ 0.5 L ha^{-1} (W_4) × nitrogen application in three splits (NS_2). In case of interactive effects of nitrogen application rates (NR) × nitrogen application schedules (NS), highest (38.6%) values for seed yield were recorded under the interaction of N application @ 100 kg ha^{-1} (NR_3) × N application in three splits (NS_2). Amongst interactive effects of weed control practices (W) × nitrogen application rates (NR) × nitrogen application schedules (NS), highest (40.7%) harvest index was noted under the interaction of sorghum extract @ 20 L ha^{-1} + Herbicide (AXIAL 330 ml + ally max 14 g) @ 0.5 L ha^{-1} (W_4) × application of N @ 100 kg ha^{-1} (NR_3) × N application in three splits (NS_2).

Qualitative traits

Oil yield (kg ha^{-1}): The collected data revealed that the effects of weed control practices, nitrogen application strategies and their interaction were significant (p<0.05) on oil yield (kg ha^{-1}). The data (Table 11) indicated that in case of weed control approaches, integrated application of the extract of sorghum @ 20 L ha^{-1} + Herbicide (AXIAL 330 ml + ally max 14 g) @ 0.5 L ha^{-1} (W_4) resulted in highest (471.8 kg ha^{-1}) seed yield perused by hand weeding twice; 30 and 55 DAS (W_5) oil yield of (470.7 kg ha^{-1}). Application of herbicide (AXIAL 330 ml + ally max 14 g) @ label dose 1.0 L ha^{-1} (W_3) and sorghum extract @ 40 L ha^{-1} (W_2) ranked 3rd and 4th in efficacy with oil yield of 466.6 kg ha^{-1} and 464.3 kg ha^{-1}. Although, the lowest (401.7 kg ha^{-1}) oil yield was recorded under control (without sorghum material) (W_1). As regards nitrogen application rates (NR) the oil yield of (452.1 kg ha^{-1}) recorded @ 50 kg N ha^{-1} (NR_1). The nitrogen applied @ 75 kg ha^{-1} (NR_2) gave oil yield of 468.1 kg ha^{-1}. Nonetheless, maximum (495.3 kg ha^{-1}) oil yield was observed under application of N @ 100 kg ha^{-1} (NR_3). In context of the nitrogen application schedules, the highest (458.5 kg ha^{-1}) oil yield was noticed under three splits (NS_2), whereas the application of nitrogen in two splits (TM_1) resulted in lowest (451.6 kg ha^{-1}) oil yield. Furthermore, the results of interaction between weed control practices (W) × N application rates (NR) showed that maximum oil yield of 495.3 kg ha^{-1} was recorded under interaction of sorghum extract @ 20 L ha^{-1} + Herbicide (AXIAL 330 ml + ally max 14 g) @ 0.5 L (W_4) × application of N @ 100 kg ha^{-1} (NR_3). Interaction of weed management approaches (W) × nitrogen application schedules (NS) indicated that the highest (473.6 kg ha^{-1}) oil yield was observed under the interaction of sorghum extract @ L ha^{-1} + Herbicide (AXIAL 330 ml + ally max 14 g) @ 0.5 L ha^{-1} (W_4) × nitrogen application in three splits (NS_2). In case of interactive effects of nitrogen application rates (NR) × nitrogen application schedules (NS), the highest (480.1 kg ha^{-1}) values for seed yield were recorded under the interaction of N application @ 100 kg ha^{-1} (NR_3) × N application in three splits (NS_2). Amongst interactive effects of weed control practices (W) × nitrogen application rates (NR) × nitrogen application schedules (NS), highest (499.9 kg ha^{-1}) oil yield was noted under the interaction of sorghum extract @ 20 L ha^{-1} + Herbicide (AXIAL 330 ml + ally max 14 g) @ 0.5 L ha^{-1} (W_4) × application of N @ 100 kg ha^{-1} (NR_1) × N application in three splits (NS_2).

Table 11. Oil yield (kg ha^{-1}) as affected by sorghum extract and nitrogen application.

N Schedules	N Rates	Weed control practices					Mean
		W_1	W_2	W_3	W_4	W_5	
Two splits	50 kg ha^{-1}	351.8	440.6	439.3	452.3	443.9	425.6 e
	75 kg ha^{-1}	403.8	454.0	469.8	467.2	465.5	432.8 d
	100 kg ha^{-1}	439.4	478.3	488.2	490.7	489.5	477.2 a
	Mean	**398.3**	**457.6**	**465.7**	**470.1**	**466.3**	451.6 B
Three splits	50 kg ha^{-1}	368.6	442.5	442.3	451.8	458.8	452.1 c
	75 kg ha^{-1}	408.2	471.8	468.4	469.0	481.2	459.7 b
	100 kg ha^{-1}	438.9	498.7	491.5	499.9	485.6	482.9 a
	Mean	**405.2**	**471.0**	**467.4**	**473.6**	**475.2**	458.5 A
Averages	50 kg ha^{-1}	360.2 g	441.5 cde	440.8 de	452.1 c	451.3 cd	429.2 c
	75 kg ha^{-1}	406.0 f	462.9 b	469.1 b	468.1 b	473.3 b	455.9 b
	100 kg ha^{-1}	439.1 e	488.5 a	489.9 a	495.3 a	487.5 a	480.1 a
	Mean	**401.7 c**	**464.3 b**	**466.6 ab**	**471.8 a**	**470.7 a**	**-**

Variables	P-value	SE	$LSD_{0.05}$
Weed Practices (W)	0.0000	3.0801	6.1656
N Rates (R)	0.0000	2.3859	4.7758
N Timings (TM)	0.0009	1.948	3.8994
W x R	0.0001	5.335	10.679
W x TM	0.3569	4.356	8.7194
R x TM	0.9129	3.3741	6.754
W x R x TM	0.1964	7.5448	15.102

Table 12. Seed protein content (%) as affected by sorghum extract and nitrogen application.

N Schedules	N Rates	Weed control practices					Mean
		W_1	W_2	W_3	W_4	W_5	
Two splits	50 kg ha^{-1}	4.9	9.1	11.0	11.9	10.6	9.5 f
	75 kg ha^{-1}	7.6	13.1	14.2	16.6	15.6	9.9 e
	100 kg ha^{-1}	8.3	17.5	18.0	21.8	19.0	16.9 b
	Mean	**7.0**	**13.2**	**14.4**	**16.7**	**15.0**	13.3 B
Three splits	50 kg ha^{-1}	6.0	9.6	10.1	12.5	11.5	13.4 d
	75 kg ha^{-1}	7.9	13.8	14.8	17.0	16.0	13.9 c
	100 kg ha^{-1}	8.5	18.2	18.5	22.2	20.4	17.6 a
	Mean	**7.5**	**13.9**	**14.5**	**17.2**	**16.0**	13.8 A
Averages	50 kg ha^{-1}	5.5 l	9.3 j	10.5 i	12.2 h	11.1 i	9.7 c
	75 kg ha^{-1}	7.8 k	13.4 g	14.5 f	16.8 d	15.8 e	13.7 b
	100 kg ha^{-1}	8.4 k	17.8 c	18.2 c	22.0 a	19.7 b	17.2 a
	Mean	**7.2 e**	**13.5 d**	**14.4 c**	**17.0 a**	**15.5 b**	-

Variables	P-value	SE	$LSD_{0.05}$
Weed Practices (W)	0.0000	0.2007	0.4018
N Rates (R)	0.0000	0.1555	0.3113
N Timings (TM)	0.0001	0.127	0.2541
W x R	0.0000	0.3477	0.6960
W x TM	0.3567	0.2839	0.5683
R x TM	0.8030	0.2199	0.4402
W x R x TM	0.3103	0.4917	0.9843

Seed protein content (%): The collected data indicated that the effects of weed control practices, nitrogen application strategies and their interaction were substantial (p<0.05) on seed protein content. The data (Table 12) indicated that in case of weed management approaches, integrated application of sorghum extract @ 20 L ha^{-1} + Herbicide (AXIAL 330 ml + ally max 14 g) @ 0.5 L ha^{-1} (W_4) resulted in highest (17.0%) seed protein content followed by hand weeding twice (30 and 55 DAS) (W_5) seed protein content of (15.5%). Application of herbicide (AXIAL 330 ml + ally max 14 g) @ label dose 1.0 L ha^{-1} (W_3) and sorghum extract @ 40 L ha^{-1} (W_2) ranked 3rd and 4th in efficacy with seed protein content of 14.4% and 13.5% respectively. Although, lowest (7.2%) seed protein content was recorded under control; untreated (W_1). As regards nitrogen application rates (NR) (12.2%) seed protein content was recorded @ 50 kg N ha^{-1} (NR_1). Application of N @ 75 kg ha^{-1} (NR_2) gave seed protein content of 16.8 %. Nonetheless, maximum (22.0%) seed protein content was observed when nitrogen was applied @ 100 kg ha^{-1} (NR_3). In case of nitrogen application schedules (NS), highest (13.8 %) seed protein content was noticed under three splits (NS_2), whereas the application of nitrogen in two splits (NS_1) resulted in lowest (13.3%) seed protein content. Furthermore, the results of interaction between weed control practices (W) × N application rates (NR) showed that maximum (22.0%) seed protein content was documented in the interaction of sorghum extract @ 20 L ha^{-1} + Herbicide (AXIAL 330 ml + ally max 14 g) @ 0.5 L (W_4) × application of N @ 100 kg ha^{-1} (NR_3). Integration of weed control measures (W) × nitrogen application schedules (NS) indicated that highest (17.2%) seed protein content was recorded in the interaction of sorghum extract @ L ha^{-1} + Herbicide (AXIAL 330 ml + ally max 14 g) @ 0.5 L ha^{-1} (W_4) × nitrogen application in three splits (NS_2). In case of interactive effects of nitrogen application rates (NR) × nitrogen application schedules (NS), highest (17.2%) values for seed protein content were recorded under the interaction of N application @ 100 kg ha^{-1} (NR_3) × N application in three splits (NS_2). Amongst interactive effects of weed control practices (W) × nitrogen application rates (R) × nitrogen application schedules (NS), highest (22.2%) seed protein content was observed in combination of sorghum extract @ 20 L ha^{-1} + Herbicide (AXIAL 330 ml + ally max 14 g) @ 0.5 L ha^{-1} (W_4) × application of N @ 100 kg ha^{-1} (NR_3) × N application in three splits (NS_2).

Discussion

The ultimate goal of ecological weed control approaches must be suppressing or diversifying the weed-crop competition favors the crop plants (Shahzad *et al*., 2016). Incorporation of phytotoxic crop plant residues is a sustainable and eco-friendly approach reduces the weed infestation and act as green concept for sustaining the health of soil (Singh *et al*., 2008). Our significant research study revealed a substantial improvement in environment and the reduction of weed with potential incorporation of sorghum extract and nitrogen application strategies. In the current era science and technology research are finding sustainable sources of managing the weeds at an optimal level to enhance the growth and development of field crops. In pursuance of the statement the findings of this research signify that sorghum plant extract substantially reduced the weed density (m^{-2}) and weed control (%) of weeds associated with sesame as compared to control (without sorghum material). The results verify that sorghum extract has strong phytotoxic potential that can significantly reduce the growth and development of weeds up to certain limits. These findings are strongly supported by Hubert *et al*., (2023) elaborated that the secondary metabolites such as phenolic and sorgoleone show allelopathic effects on several weed species. Although Tibugari & Chiduza, (2022) observed the negative effects of sorghum significantly when applied the aqueous extract of sorghum. Young plants of sorghum release substantial amount of sorgoleone as high as 0.5 mg g^1 of roots fresh weight potentially suppresses the weed growth without disturbing the crop species (Besançon *et al*., 2020). Amongst the applied treatments such sorghum extract @ 20 L ha^{-1} + herbicide (AXIAL 330 ml + ally mix 14 g) @ L ha^{-1}, hand weeding twice (30 & 55 days after sowing), herbicide (AXIAL 330 ml + ally mix 14 g) @ label dose 1.0 L ha^{-1}, sorghum extract @ 40 ml ha^{-1} and control (without sorghum material) were found most sustainable weed management strategies in sesame. It is also observed from the findings of research experiment that many weeds have developed resistance against certain herbicides commonly applied for control of weeds, but these are not effective against certain weeds associated with sesame crop field. Although when sorghum extract was applied in combination with half dose of herbicides had improved the effectiveness of applied herbicide and significantly effective against many troublesome weeds of sesame field. (Cheema & Khaliq, 2000) elaborated that sorghum is among the substantially used crops whose water extracts applied as potential bio-herbicide. The water extract of sorghum inhibited the growth of most common weeds of wheat crop including, *Chenopodium album, Phalaris minor, Fumaria indica and rumex dentatus,* correspondingly reduced the weed population (15-17%) and dry weight by 19-49%. Application of herbicides as well as fertilizers boost up the production cost and greenhouse gasses emission significantly damage the environment. Nitrogen is the fundamental primarily essential for plants growth and development and has vital role in most of plant metabolic processes Fathi, (2022). Correspondingly, research study conducted by Kamani *et al*., (2022) he observed that with increment in nitrogen application levels led to greater seed yield. Ahmadu *et al*., (2022) signified that nitrogen with high dose treatment resulted in an increase in grain yield. According to the results of Sehgal *et al*., 2021, seed yield of 651 and 801 kg ha^{-1} obtained by applying 30 and 60 kg ha^{-1}. Improved agronomic and qualitative traits of sesame may be attributable to the fact that sorghum extract significantly inhibited weed growth resulting in less weed crop competition for growth resources and available resource were substantially utilized by sesame crop for better growth and yield enhancement. The findings are supported by Tibugari & Chiduza, (2022) who proposed that phytotoxic potential of sorghum and its applied as concentrated extract significantly suppressed weeds as well as enhanced crop yield substantially. Haq *et al*., (2023) similarly observed better yield and yield attributes with application of 90 kg N ha^{-1}. There have been findings of higher seed yields in correlation with higher nitrogen rates (Ali *et al*., 2022). Jabran, 2017, highlighted that allelopathic properties of sorghum may be used in several ways to manage the weeds of agricultural settings. Hghanian *et al*., (2019), revealed that the notable variation in nitrogen levels, weed competition, and sesame variety had an impact on yield attributes. In capsules $plant^{-1}$, seed index, and harvest index of sesame, there were substantial interfaces between nitrogen and sesame varieties. In case of weed intervention decreased the number of capsules $plant^{-1}$ by 23%. Competition from weeds, cultivars, and nitrogen had a considerable influence on grain and biological yield; as a result, the 100 kg N treatment produced the highest grain yield (158.06 gm^{-2}). The greatest degree of nitrogen treatment boosted biological yield by 31% as compared to the control (no nitrogen). Suhbarao *et al*., (2009) investigated that allelochemicals reduce the process of ammonium-oxidizing bacteria (AOB) by inhibiting the ammonium mono-oxygenases and hydroxylamine oxidoreductase biocatalyst enzyme. Jabran *et al*., (2012) also point outed that allelochemicals significantly influence biological nitrification inhibition (BNI), nutrient acquisition. Elakkiyapriya *et al*., (2022), observed that hand weeding with two herbal supplements Ageratum conizoides and Ocimum sanctum each taken at two levels. In comparison to the twice hand weeding and unweeded control, these treatments were used. Weed dimethyl phthalate had the lowest weed density (9.92, 9.88) of all the treatments (4.96, 13.54 g m^2 In a pre-emergence treatment of metribuzin at 100 g a.i.ha^{-1} on 3 DAS plus an early post-emergence application of imazethapyr at 30 g a.i/ha^{-1} on 10 DAS and HW on 20 DAS, highest seed production of 684 kg ha^{-1} and stalk produce (2069 kg ha^{-1}). As per findings of Ambika & Sundari (2019), a combination of alachlor 1.5 kg ha^{-1} on DAS 3 and applications of quizalofop ethyl 0.05 kg ha^{-1} on DAS 21 was an effective measure for controlling weeds and maximising the yield of irrigated sesame. Uncontrolled weeds in unruly areas decreased the production of sesame seeds by 50%. application of quizalofop-p-ethyl 40 g ha^{-1} at 20 days after sowing and serial administration of before it emerged application of inoculation 750 g/ha PE were persuaded by quizalofop-p-ethyl 40 g ha^{-1} at 20 DAS and the maximum weed control efficiency, sesame seed produce, net profit, and benefit cost benefit ratio. According to the findings of Cheema *et al*., (2012) with reduced dose of chemical herbicide water extract have been applied as potential herbicide in mixture. 52, and 42% upturn in yield of maize with 3% water extract of sorghum, moringa and brassica findings as foliar application observed by Jahangeer (2011). Iqbal & Cheema (2008) revealed their research findings that application of sorghum water extract as per-emergence integrated with 1/3 dose of S-metolachlor was very successful in suppressing the purple nutsedge potentially as compared to recommended dose. Considering the sorghum water extract in integration with reduced dose of herbicide in interaction of nitrogen application strategies will be economical approach for sustainable weed management and getting higher sesame yield.

Conclusion

The current PhD research study strongly favors building up the justifiable and sustainable management approaches through environmentally friendly weed control practices and nitrogen management strategies for weed management and yield enhancement of sesame. The findings of overall study strongly suggested that sorghum extract @ 20 L ha^{-1} + Herbicide (AXIAL 330 ml ha^{-1} + ally max 14 g) @ 0.5 L ha^{-1} in combination with nitrogen application rates (100 kg ha^{-1}) and schedules (three splits) exerted highest inhibitory effects on weed traits and significantly enhanced the agronomic and qualitative traits of sesame crop under field conditions. Growers' capacity should be built up regarding sustainable and eco-friendly weed management measures to control weeds by applying these integrated approaches with efficient nitrogen application strategies for obtaining the potential yield of sesame crop.

Acknowledgments

This is an original research article prepared from PhD dissertation of main author submitted at Sindh Agriculture University Tandojam, Pakistan.

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