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RESEARCH ARTICLE

Quality and profitability of sesame (*Sesamum indicum*) as influenced by weed management treatments in Kano, Sudan Savanna agro-ecological zone of Nigeria

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ABSTRACT

Weed control is an important component of crop management as it determines the crops productivity, quality and the profitability. A field trial was conducted in 2019 rainy season at Research and Training Farm of Centre for Dryland Agriculture, Bayero University Kano (BUK) (11°58'52.5" N and 008°24'48.6") and National Horticultural Research Institute at Bagauda, Kano (11°33'25.93" N and 008°23'11.97" E), Nigeria. The experiment was aimed at evaluating weed management strategies effect on quality and profitability of sesame production. Eleven weed management treatments were laid out in randomized complete block design replicated thrice. Weedy check recorded the largest number of broad-leaved, grasses and sedges weed species in both locations. The pre-emergence application (PE) of pendimethalin followed by (*fb*) a hoe weeding at 6 weeks after seeding (WAS) recorded the highest sesamum seed yield, seed oil contents and physical purity when compared to other weed control treatments at both locations. Hoe weeding twice at 3 and 6 WAS had the highest seed yield (1223 kg/ha and 1212 kg/ha), total variable cost ($973 and $963) and gross revenues ($1065 and $1056) than other weed control treatments, at both the locations. Hoe weeding twice at 3 and 6 WAS resulted into higher seed yield, but it is not economical due to labour cost involved. Pendimethalin 1.0kg/ha PE *fb* post-emergence application (PoE) of *Tithonia diversifolia* (Hemsl.) A. Gray leaf extract 5% w/v at 6 WAS had higher net return ($309 and $317) and benefit cost ratio (1.50 and 1.52) proving to be more economical and could therefore be recommended in the study area.

Keywords: Economics, Pendimethalin, Seed purity, Tithonia diversifolia, Sesame, Weed management

INTRODUCTION

Sesame (*Sesamum indicum* L.), is one of the most important oilseed crops due to its edible quality oil (Raikwar 2016). Apart from being an important oil seed source, sesame seed is a potential source of protein. It is rich in water soluble antioxidants such as sesamin, sesamol, sesamolin, and sesaminol glucosides which inhibit the development of rancidity in the oil (Langham 2008). The oil obtained from sesame is use in the industries as raw material for the production of detergent, scent, medications and edible oils (Yol *et al*. 2010).

The world's major sesame producing countries are China, India, Myanmar, Ethiopia and Nigeria. Worldwide, 6.55 million ton of sesame was produced in 2019 on an area of 12.82 million ha with an average yield of 510.8 kg/ha (FAOSTAT 2019) and Africa produced 4.00 million ton from 8.73 million ha with an average yield of 457.6 kg. Nigeria is the leading sesame producer in Africa, and the third major in the world, with about 0.48 million tons produced in 2019 and ranking third in the world.

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Weeds are one of the major constraints to sesame production. Weeds compete with sesame for resources leading to significant reduction (30%) in yield (Hossain *et al*. 2020, Babiker *et al*. 2014). Weed competition in sesame may reduce the size of sesame seeds and hence oil contents. Some weed seeds are morphologically similar with sesame seed and can adulterate sesame grains thereby decreasing its quality and oil contents. Sesame is now becoming an export crop and international market requires 99.99% purity (Vafaei *et al.* 2013) of sesame. To achieve this high percent purity, proper and efficient weed management is necessary and crucial.

To reduce the deleterious effect of unwanted plants on seed purity and oil content, farmers use varieties of weed control methods which may not necessarily be economical (Daramola *et al*. 2020). Previous studies were mostly aimed at identification of effective weed management strategies without considering their economic efficiency (Omovbude and Udensi 2012). Manual hoe weeding has been the traditional way of weed management in many crops production systems in Africa. Manual method is labour intensive, time consuming and became very expensive (Lins *et al.* 2021) in addition to non-availability of labour at time of critical needs due to shortage of labour during early crop growth stage when weeds must be controlled for higher quality and yield. The use of herbicide is the most cost effective compared to manual hoe weeding, but it may not control all weed species at the same time (Daramola *et al.* 2020), crop injury may occur and herbicide resistant weeds may emerge, if not properly used. If adulterated, herbicides may not provide efficient control. The use of *Tithonia diversifolia* (Hemsl.) A. Gray (*Tithonia*) leaf extract has been reported to be effective in weed control in many crops (Scavo and Mauromicale 2021). It is environmentally friendly and efficient in suppressing weed growth at relatively low cost. The plant is widely and freely available, and farmers may require lower technological and monitory input to prepare the extract and spray on their farms. The objective of this study was to evaluate the effect of using *Tithonia* leaf extract as a component of integrated weed management on quality and profitability of sesame production in Sudan savanna agro-ecological zone of Nigeria.

MATERIALS AND METHODS

Two experiments were conducted during 2019 cropping season at Research and Training Farm of Centre for Dryland Agriculture, Bayero University Kano (BUK) and National Horticultural Research Institute, Bagauda, both in the Sudan savanna zone of Nigeria. The soil textural class was sandy clay at BUK and sandy clay loam at Bagauda. Soil pH, available phosphorus and organic carbon were higher at BUK than Bagauda. The experimental sites have the same Nitrogen contents. The two sites have equal amount of calcium ion in their soils. Magnesium and potassium ions were higher in BUK than Bagauda while more sodium ion and higher CEC were reported in Bagauda than BUK.

The experiment consisted of eleven weed management treatments, *viz.* hoe weeding twice at 3 and 6 weeks after sowing (WAS), pre-emergence application (PE) of pendimethalin at 1.0 kg/ha, pendimethalin at 1.5 kg/ha PE, *Tithonia* leaves extract (*Tithonia* LE) at 5% weight by volume (W/V), *Tithonia* LE at 10% (W/V), combined use of *Tithonia* LE at 5% (W/V) PE followed by (*fb*) post-emergence application (PoE) of the *Tithonia* LE 5% (W/V) at 6 WAS, *Tithonia* LE at 5% (W/V) *fb Tithonia* LE 10% (W/V) PoE at 6 WAS, pendimethalin at 1kg/ha PE *fb Tithonia* LE 5% (W/V) PoE at 6 WAS, pendimethalin at 1 kg/ha PE *fb Tithonia* LE 10% (W/V) PoE at 6 WAS, pendimethalin at 1.0 kg/ha PE *fb* hoe weeding at 6 WAS and weedy check. The experiment was laid out in a Randomized Complete Block Design replicated thrice. X-Sudan variety of sesame, obtained from Jigawa State Research Institute, Kazaure, was used. The gross plots were six ridges each of 3 m long, spaced at 0.75 m apart. The net plot was 4.5 m² consisting of the two innermost ridges.

Sesame seeds were mixed with fine sands (1:1) and a finger pinch of sesame sand mixture were placed in hole when the rainy season was fully established at 75 cm inter rows and 20 cm intra rows spacing. Nitrogen was applied at the rate of 60 kg/ha, phosphorus (P) at 20 kg/ha and potassium (K) at 20 kg/ha using NPK 15:15:15 and urea. The NPK was applied at 3 WAS and the urea at 6 WAS. Weeding was done as par the treatment.

The shoots of *Tithonia* were collected from bushes of surrounding area and air dried for seven days. The dried shoots were chopped into pieces with fodder cutter and milled with A2 grinder into fine powder and sieved. The powder was soaked in a ratio of 1 kg of powder to 10 liters of distilled water (for 24 hrs) to obtain 10% (w/v) concentration. The mixture was filtered through four layers of muslin cloth to obtain the water extract. One liter of this was diluted to make 5% (w/v) concentrations by adding 1 liter of distilled water.

One m^2 quadrat was laid out randomly in each of the plot at harvest and weeds within the quadrat were identified in-situ using Akobundu *et al.* (2016). Weeds that could not be identified immediately in the field were taken to the herbarium unit of the Department of plant biology, Bayero University, Kano Nigeria for identification. Weed species noted were counted and classified morphologically into broad-leaved, grasses and sedges. The sesame was harvested at maturity when the capsules turned yellow and the basal leaves started dropping. The stems were cut from the ground level using sickle. Stems from each plot were tied together to make bundle which were raised up and allowed to dry before threshing and winnowing to obtain pure seeds. The grain yields per plot were weighed using electric balance and extrapolated to grain yield in kg per hectare. Seed oil content **(%)** was strong-minded by using the Soxhlet extraction procedure as defined by Malik *et al.* (2003). Seed physical purity (%) was determined using the equation below (FAO and Africa Seeds 2018).

The cost of production (land preparation, land rent, sowing, cost of treatments application, cost of herbicides and pesticides, cost of seeds and harvest, *etc*.) were used for computation. The gross revenue was computed based on the prevailing market price of sesame in Kano at the time of harvest ($0.870588/kg).

$$\text{Seeds physical purity (\%)} = \frac{\text{Weight of the pure sesame seeds}}{Total\ weight\ of\ all\ components} X\ 100$$

Net returns was calculated as Gross revenue – Total cost while benefit cost ratio = Gross revenue / Total cost. Data generated on weed flora composition, oil content and seed purity were subjected to Analysis of variance using GENSTAT 17th edition. Significant means were compared using SNK at 5% level of probability.

RESULTS AND DISCUSSION

Effect on weeds

A total of 24 weed species were identified in the experimental sites. Of these, 12 were broad-leaved, 10 grasses and only 2 sedges. Further analysis showed that there were more broad-leaved and grass weed species at Bagauda than BUK (**Table 1**) hence higher level of infestations due to variations in weed seed bank at the two sites as reported in rice by Duary and Mukherjee (2013).

Weed control treatment significantly ($p<0.05$) affected the weed flora composition in sesame field at BUK and Bagauda (**Table 2**). Weedy check recorded the largest number of broad-leaved, grasses and sedges in both locations as the experimental sites were rich in weed species occurrence and no any weed control measure was applied. The weeds emerged and competed severely with sesame crop as reported by Milberg and Hallgren (2004) and Hamma and Ibrahim (2013) who observed that weeds may grow faster than crops and successfully compete for available nutrients, water, space and sunlight if no control measures were applied. The lowest density of broad-leaved weeds was recoded with pendimethalin at 1.0 kg/ha *fb* supplementary hoe weeding at 6 WAS in both locations. This implied that these categories of weed can be managed using this method and minimized competition for nutrients, moisture and space between weeds and sesame. This highlights the superiority of integrated methods of weed control over other methods as reported by Bhadauria *et al.* (2012). Manual hoe weeding twice at 3 and 6 WAS had lower density of narrow leaved weed species at both locations. Less number of sedges was observed with manual hoe weeding at BUK and with pre- and

Table 1. Weeds species associated with sesame at BUK and Bagauda in 2019 rainy season

Species	Level of Infestation	
	BUK	Bagauda
Broad-leaf		
Ageratum conyzoides Linn.	*	***
Amaranthus spinosus Linn.	-	**
Aspilia bussei O.	**	*
Gomphrena celosioides Mart.	**	**
Hyptis lanceolata Poir.	*	**
Leucas martinicensis (Jacq.) Ait.f.	**	***
Mitracarpus villosus (Sw.) DC.	**	***
Neptunia oleracea Lour.		**
Oldenlandia herbacea (Linn.) Roxb.	**	-
Portulaca quadrifida Linn.	*	*
Senna occidentalis (L.) Link	*	**
Sesamum datum Thonning	-	**
Grasses		
Cenchrus biflorus Roxb.	*	
Dactyloctenium aegyptium (Linn.)P. Beauv	**	***
Digitaria horizontalis Willd	**	***
Echinochloa stagnina Beauv.	*	***
Eragrostis tremula Hochst. Ex Steud	**	***
Oryza longistaminata A. Chev.	**	***
Panicum laxum Sw.	**	**
Pennisetum pedicellatum Trin.	***	***
Pennisetum violaceum (Lam.) L. Rich.	*	**
Setaria pumila (Poir.)	*	***
Sedges		
Kyllinga bulbosa Beauv.	*	-
Cyperus difformis Linn	-	*

***=high infestation, **=moderate infestation, *=low infestation

Table 2. Effect of weed control treatments on the number of broad-leaved, narrow-leaved and sedge weeds at sesame harvest in BUK and Bagauda during 2019 rainy season

Treatment	BUK			Bagauda		
	Broad-leaved	Grasses	Sedges	Broad-leaved	Grasses	Sedges
Manual hoe weeding twice at 3 & 6 WAS	23.33cde	31.33f	00b	23.33c	74.00c	1.667ab
Pendimethalin at 1 kg/ha PE	33.33b	80.67b	1.00b	34.00bc	151.00b	00b
Pendimethalin at 1.5 kg/ha PE	34.33b	66.00c	3.00b	58b	96.00bc	4.667ab
Tithonia leaves extract at 5% (W/V)	37.33b	87.00b	0.333b	48.67bc	97.3bc	1.667ab
Tithonia leaves extract at 10% (W/V)	32.33b	83.00b	5.00ab	47.33bc	116.3bc	0.667b
Tithonia leaves extract at 5% (W/V) PE *fb Tithonia* leaves extract at 5% (W/V) PoE	32.33b	66.33c	00b	27.67bc	86.3bc	0.333b
Tithonia leaves extract at 5% (W/V) *fb Tithonia* leaves extract at 10% (W/V)	34.00b	57.00d	2.00b	24.33c	122.3bc	00b
Pendimethalin at 1.0 kg/ha PE *fb Tithonia* leaves extract at 5% (W/V)	24.33cd	57.00cd	0.333b	30.33bc	110.3bc	00b
Pendimethalin at 1.0 kg/ha PE *fb Tithonia* leaves extract at 10% (W/V)	28.33bc	52.00d	0.667b	34.67bc	127bc	00b
Pendimethalin at 1.0 kg/ha PE *fb* SHW at 6 WAS	17.33d	43.33e	0.333b	24.00c	92.70bc	00b
Weedy check	79.00a	116.00a	7.00a	119.33a	219.70a	7.333a
Level of probability	< 0.001	< 0.001	0.002	<.001	< 0.001	0.052
SE±	1.997	2.517	1.103	6.89	13.98	1.572

Means followed by the same letter(s) in a column are not significantly different at 5% level of probability using Students-Newman-Keuls (SNK) Test. SE±= standard error of mean, SHW= Supplementary Hoe Weeding, WAS= Weeks After Sowing, *fb* = followed by post-emergence application of *Tithonia* LE at Bagauda.

Effect on seed yield, sesame oil yield and seed purity

The weed control treatment had significant influence on oil contents at BUK, while non-significant effect was observed at Bagauda (**Table 3**). Pendimethalin at 1.0 kg/ha PE *fb* hoe weeding at 6 WAS recorded higher oil contents than the other weed control methods. The lowest oil contents were obtained with weedy check due to severe competition between the crops and weeds which caused a reduction in photosynthetic processes and seed size as reported by Ahmed *et al.* (2014).

The highest physical purity of seeds was recorded with pendimethalin PE *fb* hoe weeding at 6 WAS, in both locations. Weedy check had the most contaminated sesame seeds in both locations. Weeds grow vegetatively faster than the crop and when dried their leaves contaminate the sesame seed resulting in lowest percent purity with crop in weedy check compared to weed controlled treated crop. Higher seed purity in plots with combined application of pendimethalin and hoe weeding could be ascribed to the lower weed density which might have reduced the contamination of sesame seeds with inert materials from weed. These finding support the observations of Farooq *et al.* (2011).

Total variable cost, gross profit, net profit and benefit cost ratio

The higher total variable cost and gross profit from plots were manual hoe weeding twice at 3 and 6 WAS as well as the combined use of pendimethalin at 1 kg/ha PE *fb* hoe weeding at 6 WAS (**Table 4**). However, higher net profit and cost-benefit ratio were observed with pendimethalin PE *fb Tithonia* LE PoE at various rates in both the locations. *Tithonia* LE at 5 and 10% w/v PE recorded higher gross and net profit as well as cost benefit ratio than pendimethalin at 1 and 1.5 kg/ha PE in both locations.

The manual hoe-weeding had resulted in higher yield, higher variable cost and lower profit compared to other weed management treatments due to higher cost of labour involved. The labor availability at the time of higher demand is also an issue of great concern as reported by Omovbude and Udensi (2012). The higher net profit and cost benefit ratio observed with pendimethalin at 1.0 kg/ha PE *fb Tithonia* LE at 5 and 10% w/v PoE at 6WAS was due to lower variable cost of these treatments combinations as reported by Daramola *et al.* (2020) in okra. The advantage of the use of the bio-herbicide may be in the unreported environmental cost benefit as the use of *Tithonia* LE in weed control is environmentally friendly because unlike synthetic herbicides, *Tithonia* LE is biodegradable (Scavo and Mauromicale 2021). This study also confirmed that the combined application of pendimethalin and *Tithonia* LE, at rate higher than 5% w/v may not be necessary because it reduces the net profit. This might possibly be associated with the fact that there may be an antagonistic effect at higher rate.

Manual hoe weeding twice adequately controlled weeds and produced higher sesame grain yield but it is not economical. The combined application of pendimethalin at 1.0 kg/ha PE *fb Tithonia* LE at 5 and 10% (w/v) PoE at 6WAS produces pure seeds with higher oil content and proved to be profitable than all other weed control measures studied and can therefore be recommended in sesame cultivated in the study area.

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Table 3. Effect of weed management treatments on sesame oil content and physical seed purity (%) at BUK and Bagauda during 2019 rainy season

Treatment	Oil content (%)		Physical seed purity (%)	
	BUK	Bagauda	BUK	Bagauda
Manual hoe weeding twice at 3 and 6 WAS	51.60a	52.28	98.73a	98.33a
Pendimethalin at 1 kg/ha PE	48.33a	47.80	95.87ab	96.33a
Pendimethalin at 1.5 kg/ha PE	47.75a	48.94	96.50ab	95.53ab
Tithonia leaves extract at 5% (W/V)	48.38a	48.53	96.95ab	94.29ab
Tithonia leaves extract at 10% (W/V)	47.35 a	49.45	97.00ab	95.44ab
Tithonia leaves extract at 5% (W/V) *fb Tithonia* leaves extract at 5% (W/V)	52.95a	51.15	97.89ab	97.67a
Tithonia leaves extract at 5% (W/V) *fb Tithonia* leaves extract at 10% (W/V)	49.21a	50.78	98.15a	98.27a
Pendimethalin at 1 kg/ha PE *fb Tithonia* leaves extract at 5% (W/V)	50.00a	51.74	98.33a	96.70a
Pendimethalin at 1 kg/ha PE *fb Tithonia* leaves extract at 10% (W/V)	49.10a	49.17	98.81a	96.46a
Pendimethalin at 1 kg/ha PE *fb* SHW at 6 WAS	53.82a	52.82	98.96a	98.67a
Weedy check	40.41b	47.35	94.85b	91.76b
Level of probability	< 0.001	0.681	0.006	0.005
SE±	1.454	2.151	0.691	1.036

Means followed by the same letter(s) in a column are not significantly different at 5% level of probability using Students-Newman-Keuls (SNK) Test. SE±= standard error of mean, SHW= Supplementary Hoe Weeding, WAS= Weeks After Sowing, *fb* = followed by

Table 4. Effect of weed management treatments in sesame on cost benefit and return at BUK and Bagauda during 2019 rainy season

Treatment	Total yield (kg/ha)	Total Variable cost ($)	Gross revenue ($)	Net revenue or loss ($)	Benefit cost ratio
BUK 2019					
Manual hoe weeding twice at 3 and 6 WAS	1224	973.16	1065.51	92.35	1.09
Pendimethalin at 1 kg/ha PE	739	575.42	643.28	67.85	1.12
Pendimethalin at 1.5 kg/ha PE	789	588.37	686.89	98.53	1.16
Tithonia leaves extract at 5% (W/V)	800	528.10	696.64	168.54	1.32
Tithonia leaves extract at 10% (W/V)	819	598.69	713.36	114.67	1.19
Tithonia leaves extract at 5% (W/V) *fb Tithonia* leaves extract at 5% (W/V)	871	598.69	758.63	159.94	1.27
Tithonia leaves extract at 5% (W/V) *fb Tithonia* leaves extract at 10% (WV)	920	645.75	800.94	155.19	1.24
Pendimethalin at 1 kg/ha PE *fb Tithonia* leaves extract at 5% (W/V)	1069	622.48	931.09	308.61	1.50
Pendimethalin at 1 kg/ha PE *fb Tithonia* leaves extract at 10% (W/V)	1121	669.28	976.10	306.82	1.46
Pendimethalin at 1 kg/ha PE *fb* SHW at 6 WAS	1160	782.65	1009.62	226.96	1.29
Weedy check	389	504.57	338.57	-166.00	0.67
Bagauda 2019					
Manual hoe weeding at 3 and 6 WAS	1213	962.64	1055.94	93.296	1.10
Pendimethalin at 1 kg/ha PE	736	563.59	641.01	77.423	1.14
Pendimethalin at 1.5 kg/ha PE	788	577.26	686.02	108.76	1.19
Tithonia leaves extract at 5% (W/V)	798	540.15	694.99	154.84	1.29
Tithonia leaves extract at 10% (W/V)	815	587.21	709.53	122.32	1.21
Tithonia leaves extract at 5% (W/V) fb *Tithonia* leaves extract at 5% (WV)	864	587.21	752.19	164.98	1.28
Tithonia leaves extract at 5% (W/V) fb *Tithonia* leaves extract at 10% (WV)	919	634.27	800.33	166.06	1.26
Pendimethalin at 1 kg/ha PE fb *Tithonia* leaves extract at 5% (W/V)	1066	610.65	927.96	317.31	1.52
Pendimethalin at 1 kg/ha PE fb *Tithonia* leaves extract at 10% (W/V)	1114	657.71	969.49	311.78	1.47
Pendimethalin at 1 kg/ha PE fb SHW at 6 WAS	1151	773.96	1002.13	228.17	1.29
Weedy check	375	493.09	326.73	-166.36	0.66

SHW= Supplementary Hoe Weeding, WAS= Weeks After Sowing, *fb* = followed by, PE = pre-emergence application; Price at time of harvest = $0.870588/kg

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