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EVALUATION OF WEED CONTROL METHODS ON GROWTH PERFORMANCE OF BAMBARA GROUNDNUT (*Vigna subterranea* (L.) Verdc) LANDRACES IN SUDAN SAVANNA, NIGERIA

***[1,2]Musa, M., [2]Lado, A. and [1]Ibrahim, A. M.**

[1]Department of Agronomy, Federal University Dutsin-Ma Katsina State, Nigeria
[2]Department of Agronomy, Bayero University Kano

*Corresponding authors' email: mmuhammad1@fudutsinma.edu.ng

ABSTRACT

Two field trials were conducted at Teaching and Research Farms Faculty of Agriculture of both BUK and Dutsin-ma (FUDMA) during the 2021 and 2022 rainy season to study the herbicidal potentials of Tithonia diversifolia (hemsley) growth component of bambara groundnut (Vigna subterrenea (l.) verdc) landraces in Sudan savanna of Nigeria... The experiment consisted of three (3) Bambara groundnut landrace (Hawayen Zaki, Idon Bazawara and Ja) and nine (9) weed control methods which were factorially combined and laid out in a split plot design with landraces at the main plot while weed control methods at the sub-plot. Data on growth components were collected and subjected to analysis of variance for Split Plot Design (SPD). F-test was used to test for the level of significance, mean comparison was done using Student Newmans' Keul (SNK) at $P < 0.05$, Statistical analysis Software (SAS) version 9.1 was used to analyze the data. Landrace had no significant effect on plant height of bambara groundnut except at DTM in 2021 during the 9WAS sampling period, where hawayen zaki (24.39 cm) and ja (25.27 cm) landraces produced the tallest plant which were statically similar compared to idon bazawara (22.6 cm) landrace which produced the shortest plant. Weed control methods on the other hand significantly influenced plant height of bambara groundnut at both location, season and sampling periods. Where Pre-emergence application of Tithonia fb imazethapyr 0.5kg ai/ha at 6 WAS produced the tallest plant at both locations across all the sampling periods while the shortest plant was observed from the plots kept unweeded. Bambara groundnut landrace had no significant ($P > 0.05$) effect on CGR at DTM in both seasons, while significant effect was observed in 2022 season at BUK respectively. base on the findings of this research it is ascertained that hawayen zaki landrace can be recommended for optimizing bambara groundnut production in the study area while Pre-emergence application of pendimenthaline 2.0 kg ha-1followed by post emergence application of tithonia at 6 WAS can be employed as a weed control strategy in the study area.

Keywords: Bambara groundnut, Landrace, Growth, Herbicide, Weed control methods

INTRODUCTION

Bambara groundnut (Vigna subterranea L.) The crop belongs to the family fabacea it is also a legume crop originated from Africa it is cultivated across the semi-arid environment (sub-Saharan Africa region) (Hillocks et al., 2012). An estimated 330,000 t of Bambara grains are produced yearly from an area of roughly 250,000 ha worldwide (Majola et al., 2021). West Africa is the major producer of bambara groundnuts worldwide, with sub-Saharan Africa being the top producer (FAO, 2020). Bamshaiye et al. (2011) state that about 45% of Africa's entire production of Bambara groundnuts is produced in West Africa, and this region is thought to provide over 74% of the world's total production (FAO, 2020). The main producing countries are: Nigeria, Ghana, Chad, Niger, Togo and Benin (Food and Agricultural Organization (FAO), 2019). Nutritionally, it is the third most vital legume species in semi-arid Africa, after the cowpea (Vigna unguiculata) and groundnut (Arachis hypogaea) (Chai et al., 2017). Specifically, bambara groundnut contains 18–24% protein with high methionine and lysine contents, 4–12% crude oil, 51–70% carbohydrate, 3–12% fiber, and 3–5% ash (Mayes et al., 2019). The utilization constraints of Bambara groundnut include the knowledge gap in improved seed system, agronomic practices, processing, and utilization. Genetics, agronomy, and nutritional aspects of bambara groundnut and its food uses have recently been reviewed by other authors (Mayes et al., 2019; Azman et al., 2019; Nwadi et al, 2020; Oyeyinka, et al., 2018). Bambara groundnut is nutrient-dense legume which is sometimes termed a "complete food" due to its balanced macronutrient composition. It contains about 64.4% carbohydrate, 23.6% protein, 6.5% fat, and 5.5% fiber and is rich in minerals (Azman et al., 2019).

In Nigeria the cultivation of Bambara groundnut in the Sahel and Sudan Savannah zone has declined over the past two decades. Weed poses serious threat to crop production it causes losses in bambara groundnut. losses cause by weeds exceeds the one caused by other pests and diseases combined. Weeds compete with bambara groundnut and cause reduction in yield, deter growth and development of the crop due to excessive competition for growth and environmental resources. Yield loss in bambara groundnut due to weeds depended on the density and type of weed flora, and the loss ranged from 17 – 96% (Rajendran et al 1999). Bambara groundnut pod yield was reduced by 62% in a multispecies weed complex (Paulo et al., 2001). Oerke, (2006), reported that weeds could reduce global yields of major crops by around 34%. there is need for improved varieties for cultivation and yield optimization in the study area which is lacking. Hence this study tends to evalaute the effect of weed control methods on growth of bambaranut landraces in the study area.

MATERIALS AND METHODS

Experimental Sites

Field trials were conducted at Teaching and Research Farm of Faculty of Agriculture, Bayero University Kano (latitude 110 58'N, longitude 8025'E and 475m above sea level) and Teaching and Research farm of Faculty of Agriculture Federal University Dutsin-Ma (FUDMA) (latitude 120 08'N, longitude 80 32'E, 500 m above sea level) during the 2021 and 2022 rainy season.

Meteorological Data
During the experimental period, records of rainfall, temperature, sunshine hour and relative humidity in the experimental sites (BUK and FUDMA research farms) were collected from the meteorological station of BUK and FUDMA respectively.

Determination of Soil Nutrient Status
Soil samples were collected randomly from the experimental sites at a depth of 0-30 cm the samples collected was bulked, sieved; oven dried and was subjected to physicochemical analysis. Soil samples were collected randomly from the experimental sites at a depth of 0-30 cm using soil auger. Routine soil analysis was carried out to determine particle size distribution by hydrometer method (Bouyocous, 1951). Soil pH, using pH meter as described by Walkley and Black (1934), total N was determined using Kjeldhal method as described by Bremner and Mulvaney (1982). Available P was determined by Bray 1 test (Bray and Kurtz, 1945). Exchangeable bases (Ca, Mg, k and Na) were extracted with IN Ammonium (NH4OAC) (Anderson and Ingram, 1993) Ca and Mg were determined using absorption spectrophotometer while K and Na was determined using flame photometer. Soil samples taken after the experiment from each plot and was subjected to pesticide residue analysis.

Treatments and Experimental Designs
The experiment consisted of three (3) Bambara groundnut landrace (hawayen zaki, idon bazawara, and jar gujjiya) which were sourced from dawanau seed market Kano and nine (9) weed control methods; Pre-emergence application of Tithonia, Pre-emergence application of Tithonia followed by (fb) Supplementary hoe weeding (SHW) at 6 weeks after sowing (WAS), Pre-emergence application of Tithonia followed by (fb) post-emergence application of Tithonia at 6 WAS, Pre-emergence application of Tithonia followed by (fb) imazethapyr 0.5kg ai/ha at 6 AWAS, Pre-emergence application of pendimenthaline 2.0 kg ai/ha followed by (fb) post-emergence application of Tithonia at 6 WAS, Pre-emergence application of pendimenthaline 2.0 kg ai/ha followed by (fb) imazethapyr 0.5kg ai/ha at 6 WAS, Pre-emergence application of pendimenthaline 2.0 kg ai/ha followed by (fb) supplementary hoe weeding (SHW) at 6 WAS, hoe weeding at 3and 6 WAS, Weedy check.These were factorially combined with three replications, and was laid out in a split plot design with landraces at the main plot while weed control methods at the sub-plot.

Preparation of the Tithonia Extract
Aqueous extract was prepared according to Hua et al., (2005) with little modification. Fresh Tithonia diversifolia plants was collected, cleanse and separate into leaves and shoots. The leaves were chopped into about 3-5cm and air dried at room temperature to constant weight. The dried leaves were milled into fine powder with A2 grinder and sieved through 10 mm sieve. 1000g of the powder of various parts was placed into 20 litre plastic bucket and was soaked in 20 litre of distilled water for 24 hours at room temperature to obtain the solution that was used as herbicide during the trial.

Cultural Practices
Land Preparation
The land was harrowed and ridged 75cm apart using tractor after which the plots were demarcated. A space of 1 m between the plots and 2 m between replicates was used as borders.

Sowing
Three seeds were sown per stand and later thinned to two seedlings per stand at 2 weeks after sowing (WAS). An intra-row spacing of 15cm was maintained.

Weed Control
This was carried out as per treatment basis.

Fertilizer Application
Fertilizer was applied to each plot at the rate of 30 Kg N: 500 kgha-1 P2O5 and 40kg k per hectare at sowing. All of N, K and half of P were applied basally a week after emergence using NPK 15:15:15 the remaining half of P was applied at 4 WAS Using SSP 18%.

Pest Control
Insect pest observed during the trial were controlled using cypermethrin 50 EC at the rate of 1 liter/ha using knapsack sprayer.

Harvesting
Harvesting was done manually at physiological maturity stage. This was done by digging up the whole plant using a hoe and hand picking of the pods from the soil.

Data Collection
Data on growth related component from 5 tag plants were collected per plant at 6 and 9 WAS

Crop Growth Parameters
Plant height (cm)
Five (5) randomly selected plants from the net plot were tagged and their heights were measured and recorded using a meter rule at 6, and 9 weeks after sowing.

Number of leaves per plant
The number of leaves from the 5 randomly selected tagged plants were counted and the average was taken per plot at 6 and 9 weeks after sowing (WAS).

Leaf area index (LAI)
This was taken using leaf area meter (L-P80 Ceptometer) at 6 and 9 (WAS).

Crop growth rate (CGR)
Crop growth rate was computed as suggested by Watson (1958) using the formula below.
$CGR = \frac{W2 - W1}{t_2 - t_1}$ g/wk.
Where; W1 and W2 = Total dry weights in gram/plant at time t2 and t1 weeks respectively.

Relative growth rate (RGR)
This was calculated using the formula described by Blackman (1919), at 6 and 9 (WAS),
$RGR = \frac{\text{Loge } W2 - \text{Loge } W1}{t_2 - t_1}$ g/g/wk.

Leaf chlorophyll content
The chlorophyll content of plant was measured from five selected tagged plants using Minolta SPAD chlorophyll meter and their mean will be recorded at 6 and 9 (WAS).

Total dry matter
Five plants were randomly selected from each plot and cut from the ground level at harvest. This were oven dried to a constant weight and the mean weight were recorded.

Nodule count

Five randomly selected plants per plot were uprooted at podding stage in order to expose the roots nodules, the roots were washed with clean water to remove the soils from the root, number of nodules, were counted and the average recorded from the plot.

RESULTS AND DISCUSSION

Table 1 shows the effect of weed control methods on plant height of Bambara groundnut landraces during the 2021 rainy season. Plant height had no significant effect on bambara groundnut landrace in both seasons and at both locations throughout the sampling period. However, at 9 WAS during the 2021 wet season in Dutsin-Ma, there was a significant difference between the varieties where hawayen zaki landrace and ja landrace produces taller plants that were statistically at par while idon bazawara landrace produced the shortest plant. Weed control method significantly affected plant height at 6 WAS at both seasons and locations. At Dutsin-Ma in both seasons, supplementary hoe weeding at 3 and 6 WAS produced the tallest plant while weedy check control gave the shortest plant. Similarly, at 9 WAS, supplementary hoe weeding at 3 and 6 WAS produced the tallest plant while the shortest plant was obtained from weedy check plote. In 2022 at Dutsin-ma, tallest plants were obtained from supplementary hoe weeding at 3 and 6 WAS while the shortest plant was observed from the weedy check (W9). At 9 WAS, significantly tallest plants were produced by plots treated with supplementary hoe weeding at 3 and 6 WAS and was statistically at par with pre-emergence application of tithonia followed by supplementary hoe weeding at 6 WAS and pre-emergence application of pendimenthaline at 2.0 kg aiha-1 followed by post emergence application of tithonia at 6WAS, while weedy check gave the shortest plant.

At BUK, during the 2021 and 2022, there was a remarkable difference on plant height of bambara groundnut as affected by weed control methods (Table 1). At 6 WAS, pre-emergence application of tithonia followed by imazethapyr at 0.5 kg ai/ha gave the tallest plants and the result is statistically at par with plots weeded with pre-emergence application of pendimethaline at 2.0kg ai/ha followed by post emergence application of tithonia at 6 WAS while the shortest plant was observed on the weedy check control. Similarly, at 9 WAS in 2021 season the weedy check control plots significantly produced the shortest plants compared to other weed control methods in both seasons and at both locations. During the 2022, season at BUK, a significant increase in plant height (cm) was observed among different weed control methods (Table 1). Plots weeded with supplementary hoe weeding at 3 and 6 WAS) recorded tallest plant and was statistically similar with other results obtained in other weed control methods while weedy check control recorded the shortest. More so, at 9 WAS, manual hoe weeding at 3 and 6 WAS recorded the tallest plant which was statistically at par with the plots treated with pre-emergence application of tithonia followed by supplementary hoe weeding at 6WAS, pre-emergence application of pendimethaline at 2.0kg ai/ha followed by post emergence application of tithonia at 6 WAS and pre-emergence application of pendimenthaline 2.0 kg ai/ha followed by supplementary hoe weeding at 6 WAS, while shortest plant was recorded from the weedy check. Table 2 and 3 shows the interaction between weed control and bambara groundnut landraces on plant height (cm) at 6 WAS. All the landrace produced statistically similar plant at all methods of weed control except on weed check control. Idon bazawara landrace produced significantly shorter plant height than ja and idon bazawara at 6 WAS at Dutsin-ma in 2022 season. Pre-emergence application of tithonia followed by imazethapyr 0.5 kg at 6 WAS significantly produced taller plant while weedy check had the shortest. The height of Ja landrace did not change significantly with method of weed control at 6 WAS in 2022 at Dutsin-ma. However, manual hoe weeded green at 3 and 6 WAS has taller plant compared to un-weeded control.

Table 1: Plant Height (cm) at 6 and 9 was as Influenced by Weed Control Methods and Bambara Groundnut Landraces During the 2021wet Season at BUK and Dutsin-ma

Treatments	Plant Height (cm) at 6 and 9 WAS			
	BUK		DTM	
	6 WAS	9 WAS	6 WAS	9 WAS
Landraces(G)				
Hawayen zaki	22.38a	27.57a	19.10a	24.39a
Ja	22.42a	28.92a	19.19a	25.37a
Idon bazawara	21.21a	27.35a	18.97a	22.66b
p-value	0.166	0.287	0.9392	0.0088
SE±	0.505	0.753	0.438	0.602
Weed control(W)				
Pre emergence application of tithonia	22.07abc	27.36a	18.31cb	24.43b
Pre-emergence application of Tithonia fb Supplementary hoe weeding at 6 WAS,	20.22bc	26.86a	18.25cb	23.70b
Pre-emergence application of Tithonia fb post-emergence application of Tithonia at 6 WAS	22.09abc	28.67a	19.39b	22.91b
Pre-emergence application of Tithonia fb imazethapyr 0.5kg ai/ha at 6 AWAS	24.88a	30.24a	18.06cb	22.13b
Pre-emergence application of pendimenthaline 2.0 kg ai/ha fb post-emergence application of Tithonia at 6 WAS	23.84ab	31.88a	18.46cb	23.82b
Pre-emergence application of pendimenthaline 2.0 kg ai/ha fb imazethapyr 0.5kg ai/ha at 6 WAS,	21.59abc	27.23a	19.50b	23.10b
Pre-emergence application of pendimenthaline 2.0 kg ai/ha fb supplementary hoe weeding at 6 WAS,	21.48abc	30.38a	18.40cb	21.77b
Supplementary hoe weeding at 3and 6 WAS,	22.48abc	27.06a	25.35a	34.89a
Weedy check	19.35c	21.81b	16.07c	20.52b

Treatments	Plant Height (cm) at 6 and 9 WAS			
	BUK		DTM	
	6 WAS	9 WAS	6 WAS	9 WAS
p-value	0.0018	0.0001	<.0001	<.0001
SE±	0.875	1.304	0.760	1.043
Interaction				
G*W	0.0529	0.4296	0.8907	0.1540

Means followed by unlike letter(s) are statistically significant at 5 % level of probability

Table 2 shows the interaction between bambara groundnut variety and weed control methods on plant height at 9 WAS in Dutsin-ma during 2022 season. The results revealed that the varieties produced statistical similar height at both locations with all methods of weed control. However, the hawayen zaki significantly produced taller plant when weeds were control with pre-emergence application of Tithonia followed by post-emergence application of Tithonia at 6 WAS and manual hoe weedy at 3 and 6 WAS while weedy check of the same landrace produced the shortest plant. The height of Ja and idon bazawara landrace does not significantly change with the change of weed control methods.

Table 2: Interaction Between Landraces and Weed Control Methods on Plant Height (cm) of Bambara Groundnut During the 2022 Wet Season at Dutsin-ma

Weed Control Methods	Landraces		
	Hawayen zaki	Ja	Idon bazawara
Pre emergence application of tithonia	23.27abc	20.45abc	22.97abc
Pre-emergence application of Tithonia fb Supplementary hoe weeding at 6 WAS,	23.36abc	22.31abc	23.74abc
Pre-emergence application of Tithonia fb post-emergence application of Tithonia at 6 WAS	25.41ab	23.75abc	22.15abc
Pre-emergence application of Tithonia fb imazethapyr 0.5kg ai/ha at 6 AWAS	26.03a	21.15abc	22.91abc
Pre-emergence application of pendimenthaline 2.0 kg ai/ha fb post-emergence application of Tithonia at 6 WAS	26.31a	25.33ab	24.10ab
Pre-emergence application of pendimenthaline 2.0 kg ai/ha fb imazethapyr 0.5kg ai/ha at 6 WAS,	22.90abc	22.76abc	23.30abc
Pre-emergence application of pendimenthaline 2.0 kg ai/ha fb supplementary hoe weeding at 6 WAS,	22.68abc	24.70ab	23.35abc
Supplementary hoe weeding at 3and 6 WAS,	25.95a	24.09ab	25.41ab
Weedy check	17.67bc	24.83ab	15.86c
SE±		1.45	

Means followed by unlike letter(s) are statistically significant at 5 % level of probability

Table 3 Shows Leaf area (cm2) Bambara groundnut Landrace had significant effect on leaf area at 6 WAS in both locations in 2021 in both seasons as well as at 9 WAS in 2021 season at BUK while non-significant effect was observed at other sampling period in both locations of seasons. Cream strip produced significantly wide LA than the other varieties in both seasons at both locations. Weed control methods had significant effect on LA in both season at both sampling periods at Dutsin-ma while at BUK non-significant effect was observed in both seasons at both sampling period. Manual hoe weeding at 6 and 9 WAS significantly produced large LA at both sampling period in both season at Dutsin-ma while the control had the lowest. The interaction between variety and weed control methods on LA was not significant at both sampling period of location in both seasons.

Table 3: Leaf area Height (cm) at 6 and 9 WAS as Influenced by Weed Control Methods and Bambara Groundnut Landraces During the 2021wet Season at BUK and Dutsin-ma

Treatments	Leaf area (cm) at 6 and 9 WAS			
	BUK		DTM	
	6 WAS	9 WAS	6 WAS	9 WAS
Landraces(G)				
Hawayen zaki	383.62a	550.86a	330.13a	485.91
Ja	285.38b	413.61b	330.79a	478.51
Idon bazawara	354.56ab	515.61ab	293.21b	439.93
p-value	0.029	0.042	0.0083	0.0765
SE±	25.902	38.763	9.370	15.022
Weed control(W)				
Pre emergence application of tithonia	378.17	551.69	344.74a	518.38a
Pre-emergence application of Tithonia fb Supplementary hoe weeding at 6 WAS,	401.46	601.08	336.17a	504.90a
Pre-emergence application of Tithonia fb post-emergence application of Tithonia at 6 WAS	355.20	518.13	294.19a	454.71a

Treatments	Leaf area (cm) at 6 and 9 WAS			
	BUK		DTM	
	6 WAS	9 WAS	6 WAS	9 WAS
Pre-emergence application of Tithonia fb imazethapyr 0.5kg ai/ha at 6 AWAS	409.54	546.59	294.56a	470.12a
Pre-emergence application of pendimenthaline 2.0 kg ai/ha fb post-emergence application of Tithonia at 6 WAS	337.58	477.04	346.31a	512.30a
Pre-emergence application of pendimenthaline 2.0 kg ai/ha fb imazethapyr 0.5kg ai/ha at 6 WAS,	312.43	459.58	322.77a	477.48a
Pre-emergence application of pendimenthaline 2.0 kg ai/ha fb supplementary hoe weeding at 6 WAS,	313.61	471.19	320.64a	479.59a
Supplementary hoe weeding at 3and 6 WAS,	321.89	460.19	324.63a	479.22a
Weedy check	240.81	354.70	278.36b	316.35b
p-value	0.235	0.360	0.0436	<.0001
SE±	44.864	67.140	16.228	26.019
Interaction				
G*W	0.182	0.193	0.286	0.603

Table 4: shows leaf chlorophyll content of bambara groundnut as influenced by weed control methods and bambara groundnut landraces during the 2021 and 20222 wet seasons at Dutsin-ma and BUK. Bambara groundnut landraces had no significant effect on leaf chlorophyll content at both seasons at both locations.

Weed control methods significantly affected the chlorophyll content of bambara groundnut at both seasons in both locations except at BUK in 2021 season, where non-significant effect was observed. Weedy check control consistently recorded the lowest chlorophyll content in both seasons at both locations. However, manual hoe weeding at 3 and 6WAS gave highest chlorophyll content though statistically at a par with other weed control used except for weedy check that gave the least chlorophyll content.

The interaction between landrace and weed control method on chlorophyll content was not significant in both season at both locations except at Dutsin-ma in 2021 at 9WAS (Table 5). Cream landraces weeded with manual hoe weeding produced higher chlorophyll content which is statistically at par with the number of chlorophyll content produced by ja landrace under similar weeding method while the least chlorophyll content was recorded by cream landrace managed with weedy check control (Table 5). All landrace recorded significantly lower chlorophyll from un-weeded plots compared to other weed control method

Table 4: Chlorophyll Content at 6 and 9 WAS as Influenced by Weed Control Methods and Bambara Groundnut Landraces During the 2021wet Season at BUK and Dutsin-ma

Treatments	Chlorophyll Content at 6 and 9 WAS			
	BUK		DTM	
	6 WAS	9 WAS	6 WAS	9 WAS
Landraces(G)				
Hawayen zaki	22.01	31.59	25.07	33.86b
Ja	23.49	34.53	26.26	37.95a
Idon bazawara	23.82	35.75	26.94	38.27a
p-value	0.682	0.464	0.2947	0.0113
SE±	1.546	2.427	0.843	1.113
Weed control(W)				
Pre emergence application of tithonia	19.50	31.43	25.96b	37.88b
Pre-emergence application of Tithonia fb Supplementary hoe weeding at 6 WAS	23.51	35.27	26.49b	38.50b
Pre-emergence application of Tithonia fb post-emergence application of Tithonia at 6 WAS	24.24	36.35	26.38b	39.19b
Pre-emergence application of Tithonia fb imazethapyr 0.5kg ai/ha at 6 AWAS	24.42	31.60	27.22b	37.56b
Pre-emergence application of pendimenthaline 2.0 kg ai/ha fb post-emergence application of Tithonia at 6 WAS	22.91	33.49	27.43b	37.77b
Pre-emergence application of pendimenthaline 2.0 kg ai/ha fb imazethapyr 0.5kg ai/ha at 6 WAS,	21.06	31.59	27.04b	35.60b
Pre-emergence application of pendimenthaline 2.0 kg ai/ha fb supplementary hoe weeding at 6 WAS,	24.69	36.47	24.33b	33.70b
Supplementary hoe weeding at 3and 6 WAS,	22.86	32.69	34.66a	49.83a
Weedy check	24.78	36.73	15.31c	20.21c
p-value	0.886	0.967	<.0001	<.0001
SE±	2.677	4.204	1.460	1.928
Interaction				
G*W	0.415	0.464	0.274	0.0004

Means followed by unlike letter(s) are statistically significant at 5 % level of probability

Table 5: Interaction Between Bambara Groundnut and Weed Control Methods on Chlorophyll Content of Bambara Groundnut During the 2021 wet Season at Dutsin-ma

Weed Control Methods	Landraces		
	Hawayen Zaki	Ja	Idon Bazawara
Pre emergence application of tithonia	38.34bcde	36.31bcde	38.99bcd
Pre-emergence application of Tithonia fb Supplementary hoe weeding at 6 WAS,	33.713bcdef	38.32bcd	43.46bc
Pre-emergence application of Tithonia fb post-emergence application of Tithonia at 6 WAS	38.64bcde	39.25bcd	39.67bcd
Pre-emergence application of Tithonia fb imazethapyr 0.5kg ai/ha at 6 AWAS	31.91bcdef	44.02bc	36.75bcde
Pre-emergence application of pendimenthaline 2.0 kg ai/ha fb post-emergence application of Tithonia at 6 WAS	35.89bcde	41.91bc	35.52bcdef
Pre-emergence application of pendimenthaline 2.0 kg ai/ha fb imazethapyr 0.5kg ai/ha at 6 WAS,	41.54bc	33.45bcdef	31.81bcde
Pre-emergence application of pendimenthaline 2.0 kg ai/ha fb supplementary hoe weeding at 6 WAS,	28.05cdef	37.86bcde	35.19bcdef
Supplementary hoe weeding at 3and 6 WAS,	36.27bcde	47.53ab	65.67a
Weedy check	20.35ef	22.87def	17.41f
SE±		2.53	

Means followed by unlike letters are statistically significant at 5% percent level of probability

Table 6: - shows the effect of landraces and weed control methods on number of leaves of bambara groundnut at 6 and 9 WAS at BUK and Dutsin-ma in 2021 and 2022 rainy season. Bambara groundnut exhibited significant difference on number of leaves at 6 and 9 WAS only in Dutsin-ma in 2021. Hawayen zaki consistently gave the highest number of leaves though at a par with ja landrace at 6 WAS, while ja landrace gave the least number of leave for at sampling period. The landraces had no effect on number of leaves at 9 WAS in both season at both locations. Similarly, the landrace effect on number of leaves in 2022 at 6 WAS in BUK was not significant. Weed control method significantly affected the number of leaves at both sampling periods in both locations except in 2022 at Dutsin-ma where non-significant effect was observed. The weedy check control plot significantly and consistently recorded the lowest number of leaves than the other weed control methods at both sampling periods in both seasons at both locations. The interaction between variety and weed control method on number of leaves was significant only at Dutsin-ma in 2021 season at 9 WAS. The number of leaves of ja landrace weeded with pre-emergence application of tithonia was same with weedy check. Number of leaves of idon bazawara landrace was statistically the same with all methods of weed control except with pre-emergence application of pendimenthaline 2.0 kg ai/ha fb imazethapyr 0.5kg ai/ha which had the highest and manual at 6 and 9 WAS. The hawayen zaki had higher number of leaves when weeds were controlled at 6 and 9 WAS, while the lowest was observed with weedy check. For Ja landrace, higher leaves number were observed with pe-emergence application of tithonia fb SHW and the lowest was observed with pre-emergence application of tithonia. The cream landrace recorded a greater number of leaves with pre-emergence application of pendimenthaline at 2.0kg ai/ha fb imazethapyr (imazethapyr) 0.5kg ai/ha and lowest with the weedy check.

Table 6: Number of Leaves Per Plant at 6 and 9 WAS as Influenced by Weed Control Methods and Bambara Groundnut Landraces During the 2021wet Season at BUK and DTM

Treatments	Number of Leaves at 6 and 9 WAS			
	BUK		DTM	
	6 WAS	9 WAS	6 WAS	9 WAS
Landraces(G)				
Hawayen zaki	57.95	72.95	48.80a	69.40a
Ja	51.35	66.79	31.48b	53.49c
Idon bazawara	57.59	70.51	44.44a	60.36b
p-value	0.1741	0.254	<.0001	<.0001
SE±	2.763	2.610	1.649	1.954
Weed control(W)				
Pre emergence application of tithonia	64.02a	75.89a	46.42a	58.48a
Pre-emergence application of Tithonia fb Supplementary hoe weeding at 6 WAS,	50.73ab	67.98a	39.85ab	66.47a
Pre-emergence application of Tithonia fb post-emergence application of Tithonia at 6 WAS	56.27a	69.31a	45.88ab	62.70a
Pre-emergence application of Tithonia fb imazethapyr 0.5kg ai/ha at 6 AWAS	53.21ab	73.32a	39.61ab	64.01a
Pre-emergence application of pendimenthaline 2.0 kg ai/ha fb post-emergence application of Tithonia at 6 WAS	64.40a	77.52a	42.45ab	62.96a
Pre-emergence application of pendimenthaline 2.0 kg ai/ha fb imazethapyr 0.5kg ai/ha at 6 WAS,	63.09a	76.20a	43.73ab	67.15a

Treatments	Number of Leaves at 6 and 9 WAS			
	BUK		DTM	
	6 WAS	9 WAS	6 WAS	9 WAS
Pre-emergence application of pendimenthaline 2.0 kg ai/ha fb supplementary hoe weeding at 6 WAS,	60.33a	81.53a	42.27ab	66.27a
Supplementary hoe weeding at 3and 6 WAS,	53.10ab	68.11a	40.72ab	58.48a
Weedy check	35.56b	40.87b	33.23b	43.29b
p-value	0.0020	<.0001	0.077	0.0002
SE±	4.786	4.521	2.856	3.385
Interaction				
G*W	0.9713	0.4924	0.5140	<.0001

Means followed by unlike letter(s) are statistically significant at 5 % level of probability

Table 7 shows the effect of bambara groundnut variety and weed control treatment on crop growth rate at Dutsin-ma and BUK in 2021 and 2022 cropping season. Bambara groundnut Landrace had no significant effect on CGR at Dutsin-ma in both season as well as in 2021, while significant effect was observed in 2022 season at BUK. The cream landrace significantly supported higher crop growth rate which is statistically similar with hawayen zaki landrace but different from of ja landrace. The weed control treatment significantly influenced crop growth rate at Dutsin-ma in both season while non-significant effect was observed at BUK in both seasons. Weedy check control significantly recorded the lowest CGR compared to other weed control treatment in both seasons. The interaction between Bambara groundnut landrace and weed control method on CGR was significant only at Dutsin-ma in 2021 while non-significant was observed in other seasons at both locations.

The Relative Growth Rate (RGR) of bambara groundnut landraces as influenced by weed control methods in the Sudan savanna during the 2021 and 2022 wet season at BUK and Dutsin-ma is presented in table 7. Bambara groundnut hawayen zaki exhibited statistically similar RGR at both locations in both seasons.

Weed control methods had no effect on RGR in both season at Dutsin-ma as well as in 2022 at BUK while significant effect was observed in 2021 season at BUK. Weeding with Pre-emergence application of pendimenthaline 2.0 kg ai/ha fb post-emergence application of Tithonia at 6 WAS significantly recorded higher RGR which was significantly different from all other weed control method at BUK in 2021 season. The interaction between bambara groundnut landrace and weed control methods on RGR was not significant in both season at both locations.

Table 7: - shows the effect of variety and weed control method on nodule count and Bambara groundnut landrace significantly influenced nodule count at Dutsin-ma 2021 season while non-significant effect was observed in 2022 as well as at BUK in both seasons. The striped cream landrace significantly recorded high number of root nodule count which was significantly different from other landrace tested. Weed control method significantly affected nodule count in both season at Dutsin-ma as well as in 2022 season at BUK while non-significant effect was observed in 2021 at that location. Manual hoe weeding at 3 and 6 WAS recorded higher number of nodules than other weed control methods in 2021 at Dutsin-ma as well as at BUK in 2022 seasons while the weed check control had the lowest number of nodules at both location in both seasons. In 2022 season at Dutsin-ma, pre-emerge application at imazethapyr at 6 WAS significantly recorded higher nodule count than the other weed control method.

Table 8: - shows the interaction between bambara groundnut landrace and weed control treatment on CGR in 2021 season at Dutsin-ma. Across weed control methods, hawayen zaki weeded with pre-emergence application of pendimenthaine 2.0 kg ai/ha fb post emergence application of tithonia at 6 WAS significantly recorded the highest crop growth rate compared with other weed control with this variety while weedy check had the lowest. Ja landrace weeded with pre-emergence application of tithonia followed by post emergence application of tithonia had highest CGR compared to other methods with this landrace. Cream landrace had higher CGR with pre-emergence application of pendimenthaine 2.0 kg ai/ha followed by post emergence application of tithonia at 6 and 9 WAS compared to the weedy check. Weedy check control consistently recorded lower CGR in all the three landraces. Using pre-emergence application of tithonia followed by SHW at 6 WAS, Pre-emergence application of tithonia followed by by post emergence application of tithonia at 6 WAS, Pre-emergence application of Tithonia followed by imazethapyr 0.5kg ai/ha at 6 AWAS and Pre-emergence application of pendimenthaline 2.0 kg ai/ha followed by SHW at 6 WAS, as means of control had statistically similar crop growth rate in all the three landraces.

Table 9 shows the interaction between bambara groundnut landraces and weed control methods on nodule count at Dutsin-ma in 2021 season. Stripped cram landrace weeded at manually at 3 and 6 WAS significantly recorded higher nodule count than all other treatment combinations except with the same variety weeded with Pre-emergence application of pendimenthaline at 2.0 kg ai/ha fb imazethapyr 0.5kg ai/ha at 6 WAS, that are similar. Among the treatment combinations, ja landrace left unweeded significantly recorded the lowest number. All the landraces recorded statistically the same number of nodules when weeded with pre-emergence application of tithonia. However, stripped brown significantly recorded higher nodules number with manual hoe weeding at 3 and 6 WAS, Pre-emergence application of pendimenthaline at 2.0 kg ai/ha fb imazethapyr at 0.5kg ai/ha at 6 WAS, and Pre-emergence application of Tithonia followed by Supplementary hoe weeding at 6 WAS, compared to other landraces.

Table 7: Crop Growth Rate and Relative Growth Rate as Influenced by Weed Control Methods and Bambara Groundnut Landraces During the 2021 Wet Season at BUK and Dutsin-ma

Treatments	Crop Growth Rate		Relative Growth Rate		Root Nodules Content	
	BUK	DTM	BUK	DTM	BUK	DTM
Landraces(G)						
Hawayen zaki	13.29	2.82	13.29	2.82	30.26	33.09a
Ja	11.97	2.88	11.97	2.88	40.12	26.72b
Idon bazawara	12.92	2.86	12.92	2.86	36.88	22.38c
p-value	0.758	0.931	0.758	0.931	0.067	<.0001
SE±	1.289	0.115	1.289	0.115	2.969	0.630
Weed control(W)						
Pre emergence application of tithonia	10.26	2.47b	10.26	2.47b	38.67	24.29c
Pre-emergence application of Tithonia fb Supplementary hoe weeding at 6 WAS,	11.79	3.05a	11.79	3.05a	29.08	28.38bc
Pre-emergence application of Tithonia fb post-emergence application of Tithonia at 6 WAS	11.11	3.38a	11.11	3.38a	28.08	26.27bc
Pre-emergence application of Tithonia fb imazethapyr 0.5kg ai/ha at 6 AWAS	11.10	3.38a	11.10	3.38a	40.34	28.49bc
Pre-emergence application of pendimenthaline 2.0 kg ai/ha fb post-emergence application of Tithonia at 6 WAS	16.51	3.44a	16.51	3.44a	30.37	25.19bc
Pre-emergence application of pendimenthaline 2.0 kg ai/ha fb imazethapyr 0.5kg ai/ha at 6 WAS,	14.90	2.30b	14.90	2.30b	38.11	29.55b
Pre-emergence application of pendimenthaline 2.0 kg ai/ha fb supplementary hoe weeding at 6 WAS,	13.62	3.23a	13.62	3.23a	37.09	26.28bc
Supplementary hoe weeding at 3and 6 WAS,	14.06	3.32a	14.06	3.32a	37.45	40.13a
Weedy check	11.19	1.11c	11.19	1.11c	42.56	18.00d
p-value	0.5173	<.0001	0.5173	<.0001	0.4243	<.0001
SE±	2.232	0.199	2.232	0.199	5.143	1.091
Interaction						
G*W	0.4953	<.0001	0.4953	<.0001	0.3481	<.0001

Means followed by unlike letter(s) are statistically significant at 5 % level of probability

Table 8: Interaction Between Bambara Groundnut Landraces and Weed Control Methods on Crop Growth Rate (g/g/week) of Bambara Groundnut in Dutsin-ma in 2021 wet Season

Weed Control Methods	Landraces		
	Hawayen Zaki	Ja	Idon Bazawara
Pre emergence application of tithonia	1.92defg	3.81abcd	1.68efg
Pre-emergence application of Tithonia fb Supplementary hoe weeding at 6 WAS,	2.48bcdefg	3.02bcdef	3.65abcd
Pre-emergence application of Tithonia fb post-emergence application of Tithonia at 6 WAS	2.76bcdef	4.32ab	3.05bcdef
Pre-emergence application of Tithonia fb imazethapyr 0.5kg ai/ha at 6 AWAS	3.76abcd	2.90bcdef	3.48abcde
Pre-emergence application of pendimenthaline 2.0 kg ai/ha fb post-emergence application of Tithonia at 6 WAS	5.19a	1.42fg	3.73abcd
Pre-emergence application of pendimenthaline 2.0 kg ai/ha fb imazethapyr 0.5kg ai/ha at 6 WAS,	2.17cdefg	3.02bcdef	1.71efg
Pre-emergence application of pendimenthaline 2.0 kg ai/ha fb SHW at 6 WAS,	3.53abcde	2.97bcdef	3.19bcdef
Supplementary hoe weeding at 3and 6 WAS,	2.95bcdef	3.15bcdef	3.87abc
Weedy check	0.62g	1.32fg	1.40fg
SE±		0.34	

Means followed by unlike letters are statistically significant at 5% percent level of probability

Table 9: Interaction Between Bambara Groundnut Landraces and Weed Control Methods on Root Nodules Count of Bambara Groundnut in Dutsin-ma in 2021 Wet Season

Weed Control Methods	Landraces		
	Hawayen Zaki	Ja	Idon Bazawara
Pre emergence application of tithonia	26.67defgh	22.19ghij	24.00fghi
Pre-emergence application of Tithonia fb Supplementary hoe weeding at 6 WAS,	36.99bcd	22.47ghij	25.67efghi
Pre-emergence application of Tithonia fb post-emergence application of Tithonia at 6 WAS	27.60cdefgh	30.21cdefg	21.00ghij
Pre-emergence application of Tithonia fb imazethapyr 0.5kg ai/ha at 6 AWAS	36.48bcd	33.00cdef	16.00ij
Pre-emergence application of pendimenthaline 2.0 kg ai/ha fb post-emergence application of Tithonia at 6 WAS	23.33fghi	34.56bcde	17.67ijh
Pre-emergence application of pendimenthaline 2.0 kg ai/ha fb imazethapyr 0.5kg ai/ha at 6 WAS,	43.66ab	24.67efghi	20.33ghij
Pre-emergence application of pendimenthaline 2.0 kg ai/ha fb supplementary hoe weeding at 6 WAS,	30.19cdefg	23.00fghij	25.67efghi
Supplementary hoe weeding at 3and 6 WAS,	49.60a	37.37bc	33.42bcdef
Weedy check	23.33fghi	13.00j	17.67hij
SE±		1.89	

Means followed by unlike letters are statistically significant at 5% percent level of probability

Discussion

The results indicate that Bambara groundnut variety Hawayen zaki and Ja exhibit statistical similarity in some of the growth parameters such as plant height, number of leaves per plant, leaf area (LA), chlrophyll content, crop growth rate CGR), relative growth rate (RGR) and root nodules content (RNC) except some areas where Hawayen zaki was found to be significant ($P<0.05$) to all other varieties measured The genetic makeup of the crop may be the reason for the difference displayed by Hawayen zaki. However, the similarities between Hawayen zaki and Ja variety on growth could be interpreted as evidence of their similarity in terms of growth performance, and their high potential ability to utilize photosynthesis and assimilation over Idon bazawara variety. It is also similar to the findings of Aliyu et al. (2021) whom observed that certain landraces consistently showed larger leaf areas, which were linked to improved light capture and photosynthetic efficiency.However, the poor growth performance recorded from Idon bazawara could be attributed to its slow growth rate, short status and lower number of leaves compares to others and poorly competes with weeds. This implies that this landrace could not be used as a tool of weed management in bambara groundnut and cultivation. This finding corroborates with report of Mbasso et al. (2020), that Landraces-environmental interaction plays a critical role in determining the competitive ability of crop landraces against weed. The lower number of weed and low weed dry matter observe on hawayen zaki landraces indicated that the landrace could be used in suppressing weed growth. The ability of these landraces to suppress weed growth could be as a result of the fact that it is taller than other two varieties; it has higher number of leaves and higher growth rate. Azman et al., (2019). has earlier reported that taller growing plant provides complete ground cover which help in suppressing weed growth and development.

Similarly, the results on various weed control managements on Growth parameter like chlorophyll content, number of leaves and CGR were at maximum when supplementary hoe weeding at 3 and 6 WAS, pre-emergence application of pendimenthalin 2.0 kg ai/ha followed by post emergence application of tithonia at 6 weeks after sowing were deployed on Bambara groundnut field. The reasons for this tremendous variation aforementioned as opposed to the weedy check is no surprising because supplementary weeding is known to reduce on weed species population irrespective of their type and nature of damage they inflate on host plants. These might have an opening for the host plants to grow luxuriantly due to absences of weed- crop competition for some period of time as indicated in number of leaves, nodules count and CGR. This finding corroborates with that of Chikoye et al. (2019), weed species composition in any given location is a result of these environmental and agronomic factors who separately reported that un-weeded control plot recorded significantly higher weed density and dry weight. The manual hoe weeding at 3 and 6 WAS as well as pre-emergence application of tithonia had lower weed cover score, weed dry weight and weed density. This implies that these methods of weed control significantly reduced the number of weed that germinate, emerged and grow which lead to significance weed reduction both in number and dry weight. This suggested that these methods of weed control could be employed as a tool of weed management in bambara groundnut.

CONCLUSION

This study investigated the herbicidal potentials of Tithonia diversifolia and its efficacy as a weed control measure for enhancing the growth, yield, and yield components of Bambara groundnut landraces in the Sudan Savannah of Nigeria. The findings reveal that Tithonia diversifolia, when applied as a pre-emergence or post-emergence bioherbicide, effectively suppressed weed growth while providing additional nutrients, thereby improving crop performance. Manual hoe weeding, though labor-intensive, also demonstrated significant weed suppression and supported robust crop growth. Among the three Bambara groundnut landraces evaluated, "hawayen zaki" consistently showed superior performance in suppressing weed growth due to its taller stature and higher leaf area, making it a potential candidate for integrated weed management systems. "ja" and "idon bazawara" landraces exhibited moderate weed tolerance but were limited by slower growth and lower competitiveness.

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