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Yield and Yield Attributes of Sorghum Varieties (*Sorghum bicolor* [L]. Moench) As Influenced by Weed Control in Sudan and Northern Guinea Savanna Ecology of Nigeria

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Abstract: *A field experiment was carried out in two distinct agro-ecological zones of Nigeria during the 2020 rainy season to ascertain the production and yield-related characteristics of sorghum as impacted by location, variety, and weed control treatment. The experimental treatments included three varieties and eight weed control treatments. The treatments were replicated three times and arranged in a split plot design with varieties and weed control treatments assigned to the main and sub plots, respectively. Results obtained showed that stand count at harvest, panicle length, 1000 seed weight and grain yield were significantly greater in Bauchi than Kano. Application of pendimethalin at 1.5 kg a.i.ha^{-1} + SHW at 6 WAS and the tank mixture of pendimethalin at 1.5 + glyphosate at 1.5 kg a.i.ha^{-1} + SHW at 6 WAS significantly reduced weed population and enhanced yield and yield related characteristics of sorghum. The Zauna inuwa variety significantly gave higher panicle weight, grain yield, 1000 seed weight and stover yield compared with other varieties. Furthermore, weed density and dry weight were significantly greater under weedy check, although weed control efficiency was higher due to successful weed control acquired through the application of various weed control treatments compared to unweeded plots that were entirely infested by weeds. Farmers in both sites can therefore cultivate the zauna inuwa variety with either pendimethalin at 1.5 kg a.i.ha^{-1} + SHW at 6 WAS and the tank mixture of pendimethalin at 1.5 + glyphosate at 1.5 kg a.i.ha^{-1} + SHW at 6 WAS to boost sorghum production.*

Keywords: *Yield attributes, variety, weed control, Savanna regions, Nigeria*

INTRODUCTION

Sorghum (*Sorghum bicolor* L. Moench) is one of the main cereals farmed in Sudan and the Northern Guinea Savannah zones of Nigeria (GAIN, 2020, Sasu, 2022). It is a warm-season crop with a C4 photosynthetic pathway (Newman *et al*., 2013). In 2016, 63.9 metric tons of sorghum were reportedly produced globally (FAO, 2018). According to data from the global cereal output in 2016, sorghum is Nigeria's second-most significant cereal crop after maize (FAO, 2018). Importantly, Nigeria has the largest production in Africa, producing 6.9 million metric tons on

5.4 million hectares, or just 10.9% of the total amount produced globally (FAO, 2019; Sasu, 2022). The greatest staple crop in Nigeria is sorghum, which accounts for 50% of overall output and takes up around 45% of the country's total land area used for cereal crop cultivation (FAO 2019). According to Peterson (2009), sorghum is a staple diet for the majority of Nigerians who resides in the Sudan and Guinea Savannah zones. Sorghum is a dual-purpose crop that is farmed for both its grain and its highly prized stems (FAO, 2018; Duff *et al*., 2019). It is grown using an old-fashioned small-scale food production approach. Sorghum can grow anywhere between sea level and 2,500 meters above sea level, and it needs at least 250 mm of annual rainfall and temperatures between 10°C and 40°C (minimum & maximum) (Chemonics, 2010; USDA, 2017). Despite the savannas of Nigeria having dazzling potential, the production was calculated at 1.23 t ha^{-1}, which is quite low compared to the global average of 1.45 t ha^{-1} and the yield of the USA, which is 4.58 t ha^{-1} (FAO, 2019). Low yield in sorghum production is attributed to constraints such as pests and diseases, weeds, insufficient technological innovation, insufficient seeds, and a lack of capital to purchase inputs; drought stress; declining soil fertility (Mrema *et al*., 2017, 2020; Sani *et al*., 2013); and use of extensive traditional agronomic management practices (Leibman *et al*., 2014). Among the biotic restrictions, weed infestation is directly responsible for yield reduction in sorghum (15-97%) depending on cultivar, weed flora, and weed density (Thakur *et al*., 2016). To replace manual weeding with technology and boost agricultural yields, the use of herbicides in crop management has been suggested (Mahmood *et al*., 2015). More land can be used for the cultivation of sorghum by using herbicide to suppress weeds. Moreover, in this climate-changed environment, their output can also be increased by using appropriate cultivars with high grain and stover yields. Consequently, it is crucial to determine how weed control strategies affect the yield and yield characteristics of some sorghum cultivars in Nigeria's two distinct sorghum belts.

MATERIALS AND METHODS

Field trials were conducted during 2020 rainy season at the Research and Teaching farm of the Faculty of Agriculture, Bayero University, Kano (Lat. 11^{O}.58” N and Long. 8^{O}.26’ E at an altitude of 460 meters *asl*) situated in the Sudan Savanna ecological zone and at the Abubakar Tafawa Balewa University Teaching and Research Farm, Gubi, (Lat. 10^{o} 45' N and Long. 9^{o}.82' E, 616m *asl*) situated in the Northern Guinea savanna ecological zone of Nigeria to evaluate the yield and yield attribute of sorghum varieties as influenced by weed control treatments and location. The experimental treatments were replicated three times in a split plot design comprising of three sorghum varieties viz-a-viz; ICSV-400, Local Kaura and SAMSORG 47 (Zauna Inuwa) and eight weed control measures (Weedy check, Hoe weeding at 3 & 6 WAS, Pendimethalin at 1.5 + Glyphosate 1.5 kg a.i.ha^{-1}, Pendimethalin at 2.0 kg a.i.ha^{-1}, Pendimethalin at 1.5 kg a.i.ha^{-1} + SHW at 6 WAS, Pendimethalin 1.5 kg a.i.ha^{-1}, Glyphosate 2.0 kg a.i.ha^{-1} + SHW at 6 WAS, Glyphosate 1.5 + Pendimethalin 1.5 kg a.i.ha^{-1} + SHW at 6 WAS). The varieties were placed on the main plots while weed control measures were placed on the sub plots. The land in both locations were cleared and prepared into ridges then marked into the required number of plots each of gross plot size of 3 m x 4 m (12 m^2) and net plot size of 1.5 m x 3m (4.5 m^2). The ally between main plots, sub-plots and replicates were 1.0 m, 0.5m and 1.5m and five (5) seeds were sown at the spacing of 75 cm × 25 cm inter and intra row spacing, respectively. Pre emergence herbicides (pendimethalin and glyphosate) were applied a day after sowing using a Knapsack sprayer while nutrients at the rate of 64 N, 30 P_2O_5 and 30 K_2O Kg ha^{-1}. Basal application of 30 N-30 P_2O_5-30 K_2O Kg using NPK 15:15:15 fertilizer was done at sowing while the remaining balance of 34 Kg N was side placed at 4 WAS using Urea (46% N). Weeding was carried out in plots with supplementary hoe weeding as well as hoe weeded plots. All other agronomic practices were duly observed and carried out as at when due. Data were collected on yield and yield attributes of sorghum such as stand count at harvest, panicle length, panicle weight, stover weight, 1000 seed weight, grain yield ha^{-1}, shelling percentage and on weed parameters such as weed density, weed dry weight and weed control efficiency using standard agronomic procedures. Data collected were subjected to analysis of variance (ANOVA) using Genstat (17^{th} Edition). Significant means were separated using the Student-Newman Keuls (SNK) at 5% probability level.

RESULTS

Table 1 presented the meteorological data for both locations during 2020 cropping season. The results showed that, a total rainfall of 1067.7 and 1749.3 mm was received with an average temperature (33.46^{o}C and 33.28 ^{o}C) and relative humidity (35.67% and 46.75%) were recorded in Kano and Bauchi respectively during 2020 season. Results of the physical and chemical analysis of soil of the experimental sites (Table 2) revealed that, the textural classes of the soil in two (2) locations were sandy loam. The result further indicated that, pH of the experimental sites was slightly acidic with a value of 6.37 and 5.94 for Kano and Bauchi respectively. Organic carbon on the other hand was found to be low with a value of 1.80 and 2.24g kg^{-1} for both locations, respectively. The total nitrogen content of the soil in Kano (0.24 gkg^{-1}) and Bauchi (0.99 gkg^{-1}) were high, while the available phosphorus was found to be low in Kano (4.87) but high in Bauchi (10.09).

Table 1: Mean monthly rainfall, temperature and relative humidity at Kano/Bauchi during 2020 rainy seasons

Months	Kano			Bauchi		
	Rainfall (mm)	Tempt. (ºC)	R.H (%)	Rainfall (mm)	Tempt. (ºC)	R.H (%)
January	0.0	25.7	12	0.0	34.3	23
February	0.0	26.9	12	0.0	34.7	24
March	0.0	43.8	18	0.0	37.6	48
April	0.0	44.6	25	13.7	37.7	36
May	14.3	40.0	31	13.7	37.7	36
June	101.4	36.7	48	239.7	32.2	69
July	323	33.4	51	428.2	31.3	71
August	219.8	29.8	63	593.5	29.5	75
September	254.4	31.9	55	273.9	31.8	67
October	154.8	34.9	68	186.6	28.9	82
November	0.00	28.4	25	0.0	31.1	30
December	0.00	25.4	20	0.0	32.6	29
Total	1067.7			1749.3		
Average		33.46	35.67		33.28	46.75

Source: Meteorological station, Department of Geography, BUK/Agro-Meteorological station, ATBU

Table 2: Physico-chemical properties of the soil at the experimental sites during 2020 rainy season

Soil composition	Location	
	Kano	Bauchi
Physical properties (%)		

Sand	64.23	58.36
Silt	21.39	26.26
Clay	14.40	15.38
Textural class	Sandy loam	Sandy loam
Chemical properties		
pH water (1:1)	6.37	5.94
pH CaCl (1:2)	6.28	5.81
Organic Carbon (g kg^{-1})	0.49	2.24
Total Nitrogen (g kg^{-1})	0.24	0.99
C:N	4.35	6.46
Available P (mg kg^{-1})	4.87	6.89
Exchangeable bases (C mol (+)/kg^{-1})		
Ca	1.76	2.23
Mg	0.44	0.97
K	0.19	0.39
Na	0.12	0.06
CEC (Cmol (+) kg^{-1})	2.75	5.12

The mean of combined analysis on the influence of location, weed control and variety on stand count at harvest, panicle length, panicle weight and stover weight of sorghum is shown in Table 3. Stand count at harvest and panicle length were significantly ($P \leq 0.05$) influenced by location while panicle weight and stover weight were not ($P \geq 0.05$) influenced by location. Results showed that stand count and panicle length were higher at Bauchi than at Kano. Weed control had a substantial effect on stand count at harvest, panicle length, panicle weight, and stover weight of sorghum. The weedy check significantly provided the lowest values of the above parameters as compared to the other weed control treatments, which produced significantly ($P \leq 0.01$) higher values though at par. The native Kaura variety had a much greater stand count and panicle length, whereas the Zauna Inuwa variety had a significantly larger panicle and stover weight. The interaction between variety and weed control was significant for panicle length, panicle weight, and stover weight. Panicle length was significantly ($P \leq 0.05$) higher with the local Kaura variety under pendimethalin at 1.5 kg a.i.ha^{-1} + SHW at 6 WAS compared with the rest of the interaction effects (Table 4). On the other hand, the interaction between variety and weed control on panicle weight shows that the Zauna Inuwa variety under pendimethalin at 1.5 kg a.i.ha^{-1} + SHW at 6 WAS significantly ($P \leq 0.05$) resulted in higher panicle weight, though at par with application of glyphosate at 2.0 kg a.i.ha^{-1} + SHW at 6 WAS and pendimethalin at 1.5 kg a.i.ha^{-1} in the same variety compared with the rest of the interaction effects (Table 5).

Table 3: Mean of combined analysis across locations on stand count, panicle length, panicle weight and stover yield of sorghum varieties as influenced by weed control during 2020 raining season

Treatments	Stand count at harvest	Panicle length (cm)	Panicle weight (kg ha^{-1})	Stover weight (kg ha^{-1})
Location (L)				
Bauchi	21.56^{a}	30.42^{a}	2794	2787
Kano	20.54^{b}	28.59^{b}	2750	2763
P of F	0.008	<.001	0.446	0.703
SE±	0.265	0.270	39.9	44.4
Weed control (W)				
Unweeded	17.33^{b}	20.34^{e}	1702^{d}	758^{d}
Hoe weeding at 3 and 6 WAS	21.72^{a}	29.56^{cd}	2879^{bc}	3717^{a}
Pendimethalin 1.5 kg a.i.ha^{-1}	21.06^{a}	29.54^{d}	2744^{bc}	2216^{c}
Pendimethalin 2.0 kg a.i.ha^{-1}	21.67^{a}	29.20^{d}	2884^{bc}	1973^{c}
Pendimethalin 1.5 + Glyphosate 1.5 kg a.i. ha^{-1}	22.06^{a}	30.67^{bcd}	2702^{c}	3046^{b}
Pendimethalin 1.5 kg a.i.ha^{-1} + SHW at 6 WAS	21.28^{a}	32.27^{ab}	2772^{bc}	3711^{a}
Glyphosate 2.0 kg a.i. ha^{-1} + SHW at 6WAS	21.72^{a}	31.42^{abc}	3052^{b}	3621^{a}
Pendimethalin + Glyphosate 1.5 kg a.iha^{-1} + SHW at 6 WAS	21.56^{a}	33.01^{a}	3440^{a}	3161^{b}
P of F	<.001	<.001	<.001	<.001
SE±	0.531	0.539	79.9	88.8
Variety (V)				
ICSV-400	17.79^{c}	22.02^{c}	2415^{b}	2423^{c}
Local Kaura	23.27^{a}	38.12^{a}	2515^{b}	2723^{b}
SAMSORG 47(Zauna Inuwa)	22.08^{b}	28.36^{b}	3386^{a}	3179^{a}
P of F	<.001	<.001	<.001	<.001
SE±	0.325	0.330	48.9	54.4
Interaction				
WC x V	0.926	<.001	<.001	0.008
WC x L	1.000	0.910	0.990	1.000
V x L	0.958	0.998	1.000	0.996
WC x V x L	1.000	1.000	1.000	1.000

Means followed by the same letter(s) in a column are not significantly different at 5% according to Student-Newman-Keuls test (SNK). WAS = Weeks after sowing, SHW = Supplementary hoe weeding

Table 4: Interaction effect of variety and weed control on panicle length of sorghum during 2020 rainy season combined location

	Weed control							
Variety	T1	T2	T3	T4	T5	T6	T7	T8
ICSV-400	15.98^{l}	22.43^{jk}	21.65^{jk}	23.40^{h-k}	22.40^{jk}	21.03^{i}	22.78^{ijk}	25.28^{ghi}
Local Kaura	23.85^{hij}	40.58^{b}	39.32^{b}	39.22^{b}	41.25^{b}	44.68^{a}	35.03^{c}	41.05^{b}
Zauna Inuwa	21.20^{k}	25.65^{gh}	27.67^{fg}	29.42^{ef}	29.73^{ef}	30.77^{de}	29.78^{ef}	32.70^{cd}
SE±				1.230				

T1 = Weedy check; T2 = Hoe weeding at 3 & 6 WAS; T3 = Pendimethalin at 1.5 + Glyphosate 1.5 kg a.i.ha^{-1}; T4 = Pendimethalin at 2.0 kg a.i.ha^{-1}; T5 = Pendimethalin 1.5 kg a.i.ha^{-1}; T6 = Pendimethalin at 1.5 kg a.i.ha^{-1} + SHW at 6 WAS; T7 = Glyphosate at 2.0 kg a.i.ha^{-1} + SHW at 6 WAS; T8 = Pendimethalin 1.5 + glyphosate 1.5 kg a.i.ha^{-1} + SHW at 6WAS.

Table 5: Interaction effect of variety and weed control on panicle weight of sorghum during 2020 rainy season combined location.

Variety	Weed control							
	T1	T2	T3	T4	T5	T6	T7	T8
ICSV-400	1575^{l}	2637^{ih}	2740^{fgh}	2393^{hi}	1970^{jk}	2438^{hi}	2471^{hi}	3097^{ef}
Local Kaura	1665^{kl}	2712^{f-i}	2331^{hi}	2650^{hi}	2608^{hi}	2448^{hi}	2668^{ghi}	3039^{efg}
Zauna Inuwa	1865^{kl}	3289de	3162^{e}	3219^{e}	3609^{cd}	4185^{a}	4019^{ab}	3737^{bc}
SE±				138.3				

T1 = Weedy check; T2 = Hoe weeding at 3 & 6 WAS; T3 = Pendimethalin at 1.5 + Glyphosate 1.5 kg a.i.ha^{-1}; T4 = Pendimethalin at 2.0 kg a.i.ha^{-1}; T5 = Pendimethalin 1.5 kg a.i.ha^{-1}; T6 = Pendimethalin at 1.5 kg a.i.ha^{-1} + SHW at 6 WAS; T7 = Glyphosate at 2.0 kg a.i.ha^{-1} + SHW at 6 WAS; T8 = Pendimethalin 1.5 + glyphosate 1.5 kg a.i.ha^{-1} + SHW at 6WAS.

Table 6 presents the mean of the combined analysis on the impact of location, weed control, and variety on the 1000 seed weight, grain yield, and shelling percentage of sorghum seeds. The location has a substantial influence on the grain output and weight of 1000 seeds of sorghum. Kano produced values that were significantly lower than those from Bauchi. Application of tank mixture of glyphosate 1.5 + pendimethalin 1.5 kg a.i.ha^{-1} + SHW at 6 WAS, glyphosate at 2.0 kg a.i.ha^{-1}, pendimethalin at 1.5 kg a.i.ha^{-1} + SHW at 6 WAS, and pendimethalin at 1.5 + glyphosate 1.5 kg a.i.ha^{-1} significantly highly ($P \leq 0.01$) increased 1000 seed weight compared to the other treatments that resulted in lower value. Similarly, the application of pendimethalin at 1.5 kg a.i.ha^{-1} + SHW at 6 WAS and tank mixture of glyphosate at 1.5 + pendimethalin at 1.5 kg a.i.ha^{-1} + SHW at 6 WAS significantly ($P \leq 0.01$) resulted in a higher grain yield compared with the rest of the treatments that resulted in lower grain yield. Shelling percentage was significantly higher in plots treated with tank mixture of glyphosate at 1.5 + pendimethalin at 1.5 kg a.i.ha^{-1} + SHW at 6 WAS though at par with pendimethalin at 1.5 kg a.i.ha^{-1} + SHW at 6 WAS, glyphosate at 2.0 kg a.i.ha^{-1} + SHW at 6 WAS as well as other treatments that resulted in decrease shelling percentage. However, weedy check significantly ($P \leq 0.01$) produced the lowest 1000 seed weight, grain yield and shelling percentage, respectively. The zauna inuwa variety significantly ($P \leq 0.01$) produced higher 1000 seed weight and grain yield compared with the rest of the varieties that resulted in decreased value. Similarly, Zauna Inuwa and Kaura significantly ($P \leq 0.01$) produced a higher shelling percentage than the ICSV-400 variety.

Table 6: Mean of combined analysis across locations on 1000 seed weight, grain yield and shelling percentage of sorghum varieties as influenced by weed control during 2020 raining season

Treatments	1000 seed weight (g)	Grain yield (kg ha^{-1})	Shelling percentage (%)
Location (L)			
Bauchi	36.15^{a}	2325^{a}	77.57
Kano	34.34^{b}	2170^{b}	76.51
P of F	<.001	0.039	1.000
SE±	0.290	24.5	0.926
Weed control (WC)			
Unweeded	22.54^{c}	884^{d}	47.56^{e}
Hoe weeding at 3 and 6 WAS	38.50^{a}	2329^{bc}	81.56^{c}
Pendimethalin 1.5 kg a.i.ha^{-1}	34.30^{b}	2208^{c}	81.00^{bcd}
Pendimethalin 2.0 kg a.i.ha^{-1}	33.84^{b}	2178^{c}	75.22^{cd}
Pendimethalin 1.5 + Glyphosate 1.5 kg a.i. ha^{-1}	37.89^{a}	2304^{bc}	75.67^{c}
Pendimethalin 1.5 kg a.i.ha^{-1} + SHW at 6 WAS	38.34^{a}	2647^{a}	86.89^{ab}
Glyphosate 2.0 kg a.i. ha^{-1} + SHW at 6 WAS	38.36^{a}	2426^{b}	81.44^{bc}
Glyphosate 1.5 + Pendimethalin 1.5 kg a.i.ha^{-1} + SHW at 6 WAS	38.16^{a}	2606^{a}	91.22^{a}
P of F	<.001	<.001	<.001
SE±	0.579	49.0	1.852
Variety (V)			
ICSV-400	32.72^{c}	1804^{c}	74.25^{b}
Local Kaura	35.75^{b}	2042^{b}	80.12^{a}
SAMSORG 47 (Zauna Inuwa)	37.25^{a}	2746^{a}	78.33^{a}
P of F	<.001	<.001	0.001
SE±	0.355	30.0	1.134
Interaction			
WC x V	0.009	<.001	<.001
WC x L	1.000	1.000	1.000
V x L	0.937	0.838	1.000
WC x V x L	1.000	1.000	1.000

Means followed by the same letter(s) in a column are not significantly different at 5% according to Student-Newman-Keuls test (SNK). WAS = Weeks after sowing, SHW = Supplementary hoe weeding.

The interaction between variety and weed control on 1000 seed weight, grain yield, and shelling percentage was significant and presented in Table 7-9. Zauna inuwa in tank mixture of glyphosate at 1.5 + pendimethalin 1.5 + SHW at 6 WAS substantially produced ($P \leq 0.01$) higher 1000 seed weight, though at par with Kaura under the same circumstances; zauna inuwa under pendimethalin at 1.5 kg a.i.ha^{-1} + SHW at 6 WAS, glyphosate at 2.0 kg a.i.ha^{-1} + SHW at 6 WAS applied to Kaura and glyphosate at 2.0 kg a.i.ha^{-1} + SHW at 6 WAS applied to zauna inuwa. On the other hand, the interaction between variety and weed control (Table 8) on grain yield demonstrated that zauna inuwa when treated with tank mixture of glyphosate at 1.5 + pendimethalin at 1.5 + SHW at 6 WAS, pendimethalin at 1.5 + SHW at 6 WAS, glyphosate at 2.0 kg a.i.ha^{-1}, and pendimethalin at 1.5 kg a.i.ha^{-1} significantly ($P \leq 0.01$) produced higher grain yield compared to the other interaction effects. Table 9 presents the interaction between variety and weed control on shelling percentage were Zauna inuwa exposed to pendimethalin at 1.5 kg a.i.ha^{-1} + SHW at 6 WAS, glyphosate at 1.5 kg a.iha^{-1} + SHW at 6 WAS, glyphosate at 2.0 kg a.i.ha^{-1}, as well as kaura and zauna inuwa subjected to hoe weeding at 3 and 6 WAS, respectively, had higher shelling percentage than the remaining interaction effects.

Table 7: Interaction effect of variety and weed control on 1000 seed weight of sorghum during 2020 rainy season combined location.

	Weed control							
Variety	T1	T2	T3	T4	T5	T6	T7	T8
ICSV-400	18.80^{k}	31.62^{i}	32.53^{hi}	31.30^{i}	32.53^{hi}	35.60^{efg}	36.40^{d-g}	37.82^{b-f}
Local Kaura	23.45^{j}	38.30^{b-e}	35.13^{fgh}	35.28^{fgh}	37.15^{c-g}	39.90^{abc}	39.30^{abc}	40.12^{ab}
Zauna Inuwa	25.38^{j}	39.23^{abc}	34.95^{gh}	35.12^{fgh}	38.75^{bcd}	40.07^{ab}	39.25^{abc}	41.60^{a}
SE±				1.004				

T1 = Weedy check (control); T2 = Hoe weeding at 3 & 6 WAS; T3 = Pendimethalin at1.5 + Glyphosate 1.5 kg a.i.ha^{-1}; T4 = Pendimethalin at 2.0 kg a.i.ha^{-1}; T5 = Pendimethalin at 1.5 kg a.i.ha^{-1}; T6 = Pendimethalin at 1.5 kg a.i.ha^{-1} + SHW at 6 WAS; T7 = Glyphosate at 2.0 kg a.i.ha^{-1} + SHW at 6 WAS; T8 = Glyphosate at 1.5 + Pendimethalin 1.5 kg a.i.ha^{-1} + SHW at 6WAS.

Table 8: Interaction effect of variety and weed control on grain yield of sorghum during 2020 rainy season combined location.

	Weed control							
Variety	T1	T2	T3	T4	T5	T6	T7	T8
ICSV-400	725^{k}	2288^{def}	1767^{hi}	2128^{fg}	1929^{gh}	1929^{gh}	1686^{i}	2295^{def}
Kaura	759^{k}	2060^{fg}	2181^{ef}	2104^{fg}	2414^{cde}	2512^{bcd}	2104^{fg}	2215^{ef}
Zauna Inuwa	1168^{j}	2639^{bc}	2676^{b}	2511^{bcd}	3249^{a}	3301^{a}	3121^{a}	3370^{a}
SE±				84.9				

T1 = Weedy check (control); T2 = Hoe weeding at 3 & 6 WAS; T3 = Pendimethalin at1.5 + Glyphosate 1.5 kg a.i.ha^{-1}; T4 = Pendimethalin at 2.0 kg a.i.ha^{-1}; T5 = Pendimethalin at 1.5 kg a.i.ha^{-1}; T6 = Pendimethalin at 1.5 kg a.i.ha^{-1} + SHW at 6 WAS; T7 = Glyphosate at 2.0 kg a.i.ha^{-1} + SHW at 6 WAS; T8 = Glyphosate at 1.5 + Pendimethalin 1.5 kg a.i.ha^{-1} + SHW at 6 WAS

Table 9: Interaction effect of variety and weed control on shelling percentage of sorghum during 2020 rainy season combined location.

Variety	Weed control							
	T1	T2	T3	T4	T5	T6	T7	T8
ICSV-400	46.33^{i}	79.00^{c-g}	71.00^{gh}	73.67^{fgh}	77.67^{d-g}	85.00^{a-e}	81.67^{b-f}	81.67^{b-f}
Local Kaura	46.67^{i}	87.00^{abc}	73.33^{fgh}	76.00^{efg}	78.67^{c-g}	94.00^{a}	93.00a	92.67^{a}
Zauna Inuwa	49.67^{i}	86.67^{a-d}	66.33^{h}	77.00^{efg}	78.67^{c-g}	90.67^{ab}	86.33^{a-d}	89.00^{ab}
SE±				3.208				

T1 = Weedy check (control); T2 = Hoe weeding at 3 & 6 WAS; T3 = Pendimethalin at1.5 + Glyphosate 1.5 kg a.i.ha^{-1}; T4 = Pendimethalin at 2.0 kg a.i.ha^{-1}; T5 = Pendimethalin at 1.5 kg a.i.ha^{-1}; T6 = Pendimethalin at 1.5 kg a.i.ha^{-1} + SHW at 6 WAS; T7 = Glyphosate at 2.0 kg a.i.ha^{-1} + SHW at 6 WAS; T8 = Glyphosate at 1.5 + Pendimethalin 1.5 kg a.i.ha^{-1} + SHW at 6 WAS

Table 10 presents the mean of the combined analysis on the impact of location, weed control, and variety on weed density, weed dry weight and weed control efficiency of sorghum. The location has a substantial influence on weed density while weed dry weight and weed control efficiency was not significantly ($P > 0.05$) influenced by location. Kano produced values that were significantly lower than those from Bauchi. Weedy check resulted in significantly ($P \leq 0.01$) higher weed density and weed dry weight compared to other treatments, which resulted in lower values. In contrast to other treatments that had greater values, weedy check substantially produced the lowest weed control efficiency. Zauna inuwa considerably ($P \leq 0.05$) outperformed other varieties in terms of weed control efficiency.

Table 10: Mean of combined analysis across locations on weed density, weight dry weight and weed control efficiency of sorghum varieties as influenced by weed control during 2020 raining season

Treatments	Weed density ($n\ m^{-2}$)	Weed dry weight ($g\ m^{-2}$)	Weed control efficiency (%)
Location (L)			
Bauchi	21.75^{a}	119.1	49.9
Kano	18.00^{b}	115.1	51.2
P of F	<.001	0.735	1.000
SE±	0.309	8.41	2.11
Weed control (WC)			
Unweeded	36.00^{a}	219.8^{a}	0.00^{d}
Hoe weeding at 3 and 6 WAS	17.94^{bc}	89.5^{b}	55.56^{ab}
Pendimethalin 1.5 kg $a.i.ha^{-1}$	20.39^{b}	118.3^{b}	49.33^{bc}
Pendimethalin 2.0 kg $a.i.ha^{-1}$	18.72^{bc}	106.2^{b}	51.56^{bc}
Pendimethalin 1.5 + Glyphosate 1.5 kg a.i. ha^{-1}	20.22^{b}	114.5^{b}	54.22^{bc}
Pendimethalin 1.5 kg $a.i.ha^{-1}$ + SHW at 6 WAS	19.44^{bc}	112.4^{b}	58.00^{a}
Glyphosate 2.0 kg a.i. ha^{-1} + SHW at 6 WAS	18.72^{bc}	94.2^{b}	65.44^{a}
Glyphosate 1.5 + Pendimethalin 1.5 kg $a.i.ha^{-1}$ + SHW at 6 WAS	17.56^{c}	81.7^{b}	65.11^{a}
P of F	<.001	<.001	<.001
SE±	0.619	16.83	4.22
Variety (V)			
ICSV-400	20.17	113.0	45.7^{c}
Local Kaura	20.10	127.8	49.1^{b}
SAMSORG 47 (Zauna Inuwa)	19.35	110.5	54.9^{a}
P of F	0.246	0.443	0.042
SE±	0.379	10.31	2.58
Interaction			
WC x V	0.299	0.797	0.145
WC x L	0.921	1.000	1.000
V x L	0.503	1.000	1.000
WC x V x L	0.977	1.000	1.000

Means followed by the same letter(s) in a column are not significantly different at 5% according to Student-Newman-Keuls test (SNK). WAS = Weeks after sowing, SHW = Supplementary hoe weeding

DISCUSSION

The ability of Bauchi to significantly outperform Kano in terms of stand count at harvest, panicle length, 1000 seed weight, and grain yield may be attributed to favorable climatic conditions that facilitate nutrient uptake and favor a greater stand count, larger panicles, which are directly related to grain yield, and higher 1000 seed weight. A drop in several crop qualities may be related to the climate change effect that caused the intermittent drought in Kano. This result supports the findings of Poudel and Shaw (2016), who claimed that throughout the crop growth period, field crop productivity is lost due to drought stress by roughly 30–70%. Similar to this, Li and Cui (2013) claimed that drought stress can cause a buildup of abscisic acid (ABA) in guard cells to cause stomatal closure, which may lead to aberrant metabolism that lowers crop performance resulting in loss of crop stand (Hasanuzzaman *et al*., 2013). The two locations' different fertility status could potentially be a contributing factor (Shang *et al*., 2014; Wang, 2014). The increase in yield and yield attributes of sorghum could be attributed to effective weed management achieved by the treatments, particularly pendimethalin at 1.5 kg a.i.ha^{-1} + SHW at 6 WAS, glyphosate at 2.0 kg a.i.ha^{-1} + SHW at 6 WAS, tank mixture of pendimethalin at 1.5 + glyphosate at 1.5 kg a.i.ha^{-1} + SHW at 6 WAS, which provides a favorable environment for growth and photosynthetic efficiency of sorghum towards utilizing the assimilates, which is reflected in the increased leaf chlorophyll content, panicle length, panicle weight, stalk weight, 1000 seed weight, grain yield and shelling percentage compared to weedy check, which consistently recorded the least values. This was in accordance with Hossain *et al*. (2016) findings, which claimed that weed control is the most important and crucial environmental element that influences panicle length and weight. Similar work was also reported on rice and cotton, respectively, by Dubey *et al*. (2017) and Cahoon *et al.* (2015). But because weed infestation continued unabated, weedy checks had a negative impact on stand count and yield-related characteristics. This finding is consistent with observations made by Ferdous *et al*. (2017) and Zohaib *et al*. (2016), who noticed a drop in crop growth due to weed infestation and the allelopathic effect of weeds on crops, which led to a reduction in stand count. When compared to Kaura and Zauna inuwa, which are late maturing varieties, ICSV-400 has less capacity to maximize photosynthates for the generation of dry matter. Awori *et al*. (2015), Gosh *et al*. (2015), and Faiz *et al*. (2017) reported evidence that yield attribute disparities in sorghum cultivars. The significant interaction observed on panicle length of Kaura variety treated with pendimethalin 1.5 kg a.i.ha^{-1} + SHW at 6 WAS could be attributed to the superiority of Kaura variety based on the tallness of the plant and the efficacy of the treatment in providing season-long weed control, which allows the variety to explore its genetic potential. Similarly, significant interaction was noted in panicle weight, 1000 seed weight, and grain yield with zauna inuwa under application of pendimethalin at 1.5 kg a.i.ha^{-1} + SHW at 6 WAS, glyphosate at 2.0 kg a.i.ha^{-1} + SHW at 6 WAS, and hoe weeding at 3 and 6 WAS in zauna inuwa and kaura, respectively. These findings corroborate the work of Rao *et al*. (2007) and McDonald (2021), who reported higher yields due to efficient weed management in rice and soybean, respectively. Gosh *et al*. (2015) also reported increased yield attributes of sorghum varieties that produced taller plants compared to shorter varieties. Effective weed management, as reported by Khaliq *et al*. (2012) and Sharma (2013) could be responsible for decreases in weed density and weed dry weight as well as an improvement in weed control efficiency. Similarly, Peer *et al*. (2013) discovered comparable results in other crops where herbicide paired with hoe weeding provided adequate weed control efficiency by reducing weed density, dry matter, and weed index. Imoloame (2017) found that combining herbicide rates with one additional hoe weeding improved weed control in maize.

CONCLUSION AND RECOMMENDATION

Applying pendimethalin at 1.5 kg a.i.ha^{-1} *fb* SHW at 6 WAS and the tank mixture of pendimethalin at 1.5 + glyphosate at 1.5 kg a.i.ha^{-1} *fb* SHW at 6 WAS were all found to have considerably reduced weed population and boosted yield and yield-related parameters of sorghum in both locations. The Zauna inuwa variety produced the maximum panicle weight, grain yield, 1000 seed weight, and stover yield. Based on the results of this study, farmers in the Sudan and the Northern Guinea Savanna region of Nigeria can adopt the cultivation of the zauna inuwa variety with application of either pendimethalin at 1.5 kg a.i.ha^{-1} *fb* SHW at 6 WAS and tank mix application of pendimethalin at 1.5 + glyphosate 1.5 + kg a.i.ha^{-1} *fb* SHW at 6 WAS for sustainable weed control in sorghum towards ensuring food security.

REFERENCES

Awori, E., Kuyowa, M., Basirika, A., Dradiku, F., Kahunza, R., Oriba, A., Edonia, C., Olupot, R and Mukalazo, J. (2015): Performance of Elite Sorghum Varieties in the West Nile Agro Ecological Zones. *Uganda Journal of Agricultural Sciences*, 16 (1): 139-148. DOI: 10.4314/ujas.v16i1.12

Cahoon, C.W., York, A.C., Jordan, D.L., Everman, W.J., Seagroves, R.W., Braswell, L.R., and Jennings, K.M. (2015). Weed control in cotton by combinations of microencapsulated acetochlor and various residual herbicides applied pre- emergence. *Weed Technology*, 29:740-750.

Chemonics (2010). Staple Foods Value Chain Analysis Country Report – Kenya. For USAID

Dubey, R., Singh, D., & Mishra, A. (2017). Effect of weed management practices and establishment methods on growth, productivity and economics of rice. *International Journal of Current Microbiology and Applied Sciences*, 6 (3); 65-72. https://doi.org/10.20546/ijcmas.2017.603.006

Duff, J., Bice, D., Hoeffner, I., & Weinheimer, J. (2019). The sorghum industry and its market perspective. In I. A. Cimpilli & P. V. V. Prasad (Eds.), Sorghum: A state of the art and future perspectives (Vol. 58, pp. 503–514). https://doi.org/10.2134/agronmonogr58.c23.

Faiz, M, B., Santo, M. S., Santo, N, S. (2017). Prospects for Growing Sorghum (*Sorghum bicolor* L. Moench) at Marginal Dry Land in Coastal Areas Retrieved with Organic Soil Amendments. *Asian Journal of Crop Science*, 9(4): 118-124.

FAO (2018). Food and Agricultural Organization of the United Nations, Sorghum and Millet in Human Nutrition. FAO Food and Nutrition Series, No 27, Rome, Italy.

FAO. (2019). FAO Statistical Database (online). Food and Agricultural Organization of the United Nations. Rome. http:// www.fao.org/faostat/en/#data/QC accessed 10 June 2021.

Ferdous, J., M. H. Ali., M. S. Islam., I. F. Chowdhury., M. N. Haque and S. M. Masum. (2017). Growth and yield of soybean as affected by irrigation and weed control methods. *Bangladesh Journal of Weed Science*, 6 :17-26.

GAIN. (2020). Grain and Feed Update -Nigeria. Report by Global Agricultural Research Network (GAIN), Foreign Agriculture Service, United State Department for Agriculture.https://apps.fas.usda.gov/newgainapi/api/Report/DownloadReportByFileName?fileName = Grain%20and%20Feed%20Updat e_Lagos_Nigeria_09-16- 2020.

Ghosh S. C., Akram S., Ahsan S. M., Al asif A., Shahriyar S., (2015). Morpho-physiological and Yield Performance of Grain Sorghum Genotypes. *Asian Journal of Medical and Biological Research*, 1: 271-284.

Hasanuzzaman, M., Nahar, K., Alam, M.M., Roychowdhury, R., Fujita, M. (2013). Physiological, biochemical and molecular mechanisms of heat stress tolerance in plants. *International Journal of Molecular Sciences*, 14:9643-9684.

Hossain, M. M., Begum, M., Rahman, M. M., & Akanda, M. M. (2016). Weed management on direct-seeded rice system; A review. *Progressive Agriculture*, 27 (1): 1-8. https://doi.org/10.3329/pa.v27i1.27526

Imoloame, E. O. (2017) Evaluation of herbicide mixtures and manual weed control method in maize (*Zea mays* L.) production in the Southern Guinea agroecology of Nigeria. *Cogent Food & Agriculture*, (3), 1-17.

Khaliq, A., Matloob, A., Mahmood, S., Abbas, R. N., & Khan, M. B. (2012). Seeding density and herbicide tank mixture furnish better weed control and improve growth, yield and quality of direct of direct seeded fine rice. *International Journal of Agriculture & Biology*, 14 (4): 499-508.

Leibman, M., Shryock, J.J., Clements, M.J., All, M. A, Loida, P.J, Mcclerren, A.L, Mckiness, Z.P., Phillips, J.R., Rice, E.A., Stark, S.B. (2014). Comparative analysis of maize (*Zea mays*) crop performance: natural variation, incremental improvements and economic impacts. *Plant Biotechnology Journal*, 12:941-950.

Li, W and Cui, X. (2014). A special issue on plant stress biology: From model species to crops. *Molecular Plant*, 7:755-757.

Mahmood, A., Khaliq, A., Ihsan, M. Z., Naeem, M., Daur, I., Matloob, A., & El-Nakhlawy, F. S. (2015). Estimation of weed dry biomass and grain yield as a function of growth and yield traits under allelopathic weed management in maize. *Planta Daninha*, 33, 23-31.

McDonald, S.T., Striegel, A., Chahal, P.S, Jha, P., Rees, J.M., Proctor, C.A, Jhala, A.J. (2021). Effect of row spacing and herbicide programs for control of glyphosate-resistant Palmer amaranth (*Amaranthus palmeri*) in dicamba/glyphosate-resistant soybean. *Weed Technology*, 35: 790-801. doi: 10.1017/wet.2021.36. .

Mrema E, Shimelis H, Laing M, Bucheyeki T. (2017). Farmers' Perceptions of Sorghum Production Constraints and Striga Control Practices in Semi-Arid Areas of Tanzania. *International Journal of Pest Management*, 63 (2):146-156.

Mrema E, Shimelis H, Laing M, Mwadzingeni L. (2020). Integrated Management of '*Striga hermonthica*' and '*S. asiatica*' in sorghum: A Review. *Australian Journal of Crop Science*, 14 (1) :36-45.

Newman, Y., Erickson, J., Vermerris, W and Wright, D (2013). Forage sorghum (*Sorghum bicolor* L.): Overview and Management. Agronomy Dept, Florida Cooperative

Extension Services, Institute of Food and Agricultural Science, University of Florida.

Paterson, A. H., Bowers, J. E., Bruggmann, R, Dubchak, I., Grimwood, J., Gundlach, H., Haberer, G., Hellsten, U., Mitros, T. Poliakov, A. (2009). The *Sorghum bicolor* genome and the diversification of grasses. *Nature*, 457:(7229):551–556. doi:10.1038/nature07723.

Peer, F. A., Hassan, B., Lone, B. A., Qayoom, S., Ahmad, L., Kh, B. A., … Singh, G. (2013). Effect of weed control methods on yield and yield attributes of soybean. *African Journal of Agricultural Research*, 8(48), 6135–6141. doi:10.5897/AJAR11.1172

Poudel, S. and Shaw, R. (2016). The relationships between climate variability and crop yield in a mountainous environment: A case study in Lamjung District, Nepal. *Climate*, 4 (13):1- 19. DOI: 10.3390/cli4010013

Rao, A.N., Johnson, D.E., Sivaprasad, B., Ladha, K.L and Mortimer, A.M. (2007). Weed management in direct-seeded rice. *Advances in Agronomy*, Volume 93 Copyright 2007, Elsevier Inc. All rights reserved. 0065-2113/07 $35.00 DOI: 10.1016/S0065-2113(06)93004-1

Sani, R. M., Haruna, R. and Sirajo, S. (2013). Economics of Sorghum (*Sorghum bicolor* (L) Moench) Production in Bauchi Local Government Area of Bauchi State, Nigeria. 4th International Conference of the African Association of Agricultural Economists, Hammamet, Tunisia (No. 309-2016-5156).

Sasu, D.D. (2022). Production of sorghum in Nigeria 2010-2021.Research Expert covering primarily society and agricultural topics for Africa, particularly Ghana and Nigeria. Published February, 2022.

Shang, Q., Ling, N., Feng, X., Yang, X., Wu, P., Zou J, et al. (2018) Soil fertility and its significance to crop productivity and sustainability in typical agroecosystem: A summary of long-term fertilizer experiments in China. *Plant and Soil*, 381:13-23. DOI: 10.1007/s11104-014-2089-6.

Sharma, M. (2013). Weed dynamics and yield of dry direct seeded rice under different weed management practices at Rampur, Chitwan. Tribhuvan University.

Thakur, N.S., Kushwaha, B.B., Girothia, O.P., Sinha, N.K and Mishra, J.S. (2016). Effect of integrated weed management on growth and yields of rainy season sorghum. *Indian Journal of Agronomy*, 61(2): 217-222.

Wang, C.H. (2014). Farming methods effects on the soil fertility and crop production under a rice-vegetables cropping sequences. *Journal of Plant Nutrition*, 37:1498-1513. DOI: 10.1080/01904167.2014.881876

United States Department of Agriculture (2017). Grain: World Markets and Trade Report 2017/foreign Agricultural Services. 44p.

Zohaib, A., Abbas, T and Tabassum, T (2016). Weeds Cause Losses in Field Crops through Allelopathy. *Notulea Scientia Biologia*, 8(1): 47-56.