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Growth Performance of Sorghum (*Sorghum bicolor* L. Moench) as Influenced by Variety and Weed Control Treatment in a Semi-Arid Ecology of Nigeria

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Abstract: *Field trials were conducted at two different locations during the 2020 rainy season to determine the growth performance of sorghum as impacted by variety and weed control in a semi-arid ecology of Nigeria. The experimental treatments comprised three varieties (var. ICSV-400, Local Kaura and Zauna inuwa [SAMSORG-47]) and eight weed control treatments (Weedy check, hoe weeding at 3 & 6 WAS, pendimethalin at 1.5 kg a.i.ha^{-1}, pendimethalin at 2.0 kg a.i.ha^{-1}, pendimethalin at 1.5 + glyphosate at 1.5 kg a.i.ha^{-1}, 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, glyphosate at 1.5 + pendimethalin at 1.5 kg a.i.ha^{-1} + SHW at 6 WAS. The treatments were arranged in a split plot design with varieties and weed control treatments assigned to the main and sub plots, and was replicated three times. Findings reveals that the application of glyphosate at 2.0 kg a.i.ha^{-1} + SHW at 6 WAS, glyphosate at 1.5 + pendimethalin 1.5 kg a.i.ha^{-1} + SHW at 6 WAS produced significantly ($P \leq 0.05$) more growth parameters (plant height, number of leaves plant^{-1}, leaf area and leaf area index) of sorghum. It also significantly ($P \leq 0.05$) produced shorter number of days to 50% booting, heading and flowering compared to other weed control treatments, while on the other hand, it also significantly ($P \leq 0.05$) recorded higher weed control index and treatment efficiency index of sorghum alongside Zauna inuwa and Kaura varieties by smothering the growth of weeds. Based on findings from this study, farmers in the Sudan and the Northern Guinea Savanna region of Nigeria can adopt the cultivation of the zauna inuwa (SAMSORG 47) variety with application of either glyphosate at 2.0 kg a.i.ha^{-1} + SHW at 6 WAS, glyphosate at 1.5 + pendimethalin 1.5 kg a.i.ha^{-1} + SHW at 6 WAS, for effective weed control in sorghum production to increase food supply for the teaming human population in both locations.*

Keywords: *Growth, varieties, sorghum, weed control, semi-arid*

INTRODUCTION

Sorghum (*Sorghum bicolor* L. Moench), which has a special adaptation to the climate of Africa, evolved there. According to Paterson (2008), it is the fifth-most significant cereal crop in the world and follows maize as the second-most significant cereal crop in Africa and Nigeria (Borrell *et al.,* 2014; FAOSTAT, 2015). In many developing nations in the semi-arid tropical regions of Africa, it is a staple food for small-scale farmers and is also grown as a forage crop (Mace *et al*., 2013). With an estimated 26 MT output in Sub-Saharan Africa, where Nigeria is the largest producer in Africa and second internationally after the United States, grain sorghum is cultivated on 42 million hectares worldwide (USDA, 2017). Because of its ability to grow in areas where maize does not do well, more of its grains are used as local food in a variety of ways, including semi-leavened bread, couscous, dumplings, fermented and non-fermented porridges, alcoholic and non-alcoholic beverages, and straws for livestock feed and house fencing (Abdelghafoor *et al*., 2011; Adegbola *et al*., 2013; Hariprasanna & Rakshit, 2016). In the manufacturing of syrup, sugar, and molasses among are other uses (Berenji *et al*., 2011; Cole *et al*., 2017; Jiang *et al*., 2020). Nevertheless, depending on the varieties grown in various ecologies, sorghum contributes significantly to the battle against hunger and food insecurity (Mathur *et al*., 2017). The increased market awareness of the crop as a result of its industrial potential in the milling, malting, and brewing industries has also brought about competition between grain for human consumption and grain for industrial usage (Ajeigbe *et al*., 2017; KFFC, 2018). Sorghum production is unfortunately constrained by a number of biotic (weeds, insect pests, illnesses, pathogens, choice of cultivar) and abiotic factors (marginal soils, unpredictable rainfall, tillage techniques, irrational/inadequate fertilizer use, etc.). One of the most severe biotic pressures is weed infestation from striga and other weed biotypes, which lowers grain yield and biomass and prevents the attainment of food security yields (Ball *et al*., 2019). Infestations of weeds are a barrier to any crop production venture (Gage & Schwartz, 2019; Nwosisi *et al*., 2019), compete favorably with crops for limited growth resources like moisture, nutrients, space, and light, and can also harbor pests and diseases that infest crops (Abraham *et al*., 2021; Tibugari *et al*., 2020), among other negative effects. However, according to a study by Ndjeunga *et al*. (2015), only roughly 20% of Nigeria's total sorghum production area is planted with improved cultivars. The need to overcome the limitations of weed infestation and cultivar selection becomes essential in order to raise demand for sorghum and assure food security. Therefore, the studies were conducted with the aim of evaluating the growth performance of some varieties of sorghum as influenced by weed control treatments in the Sudan and Northern Guinea Savanna ecologies of Nigeria.

MATERIALS AND METHODS

Field experiment was carried out 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, 460m *above sea level*) and at the Abubakar Tafawa Balewa University, Bauchi Teaching and Research Farm, Gubi, (Lat. 10^{o} 45' N and Long. 9^{o}.82' E, 616m *above sea level*); situated in the Sudan and Northern Guinea savanna ecological zones, respectively. The experiments comprised of three sorghum varieties; ICSV-400, Local Kaura and Zauna inuwa (SAMSORG 47) and eight (8) weed control treatments; Weedy check (control), Hoe weeding at 3 & 6 WAS, Pendimethalin 1.5 + Glyphosate 1.5 kg a.i.ha^{-1}, Pendimethalin 2.0 kg a.i.ha^{-1}, Pendimethalin at 1.5 kg a.i.ha^{-1} + SHW at 6 WAS, pendimethalin 1.5 + Glyphosate 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 experimental treatments were replicated three times and arranged in a split plot design with variety assigned to the main plots while weed control treatment were assigned to 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 0.75m × 0.25 m 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 growth and weed parameters of sorghum varieties using standard agronomic procedures. The growth parameters recorded were plant height, number of leaves, leaf area, leaf area index, days to 50% booting, heading and flowering, leaf chlorophyll content and seedling vigor while the weed parameters include weed specie composition, treatment efficiency index, weed index and weed control index. Data collected were subjected to analysis of variance (ANOVA) using Genstat (17th edition). Significant means were separated using the Student-Newman Keuls (SNK) at 5% probability level.

RESULTS AND DISCUSSION

The physico-chemical analysis of the soil of the experimental sites revealed that the textural classes of the soil in two locations were sandy loam with a pH value of 6.37 and 5.94 (slightly acidic) 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}) was high, while the available phosphorus was found to be low in Kano (4.87) but high in Bauchi (10.09). The mean of the combined analysis on the influence of location, weed control and variety on plant height at 6, 8, 10 and 12 WAS of sorghum is shown in Table 1. Weed control was significant at 6, 8, 10 and 12 WAS, whereas variety was significant at 8, 10, and 12 WAS, but location and interaction effects were not significant ($P \geq 0.05$) during the sampling periods. At 6 WAS, the application of pendimethalin at 2.0 kg a.i.ha^{-1}, Pendimethalin 1.5 + Glyphosate at 1.5 kg a.i.ha^{-1}, pendimethalin at 1.5 kg a.i.ha^{-1} + SHW at 6 WAS, and Glyphosate 1.5 + Pendimethalin 1.5 kg a.i.ha^{-1} + SHW at 6 WAS significantly ($P \leq 0.05$) resulted in producing shorter plant compared to weedy check, hoe weeded at 3 and 6 WAS, pendimethalin at 1.5 kg a.i.ha^{-1}, and Glyphosate 2.0 kg a.i.ha^{-1} + SHW at 6 WAS that significantly ($P \leq 0.05$) produced taller plants. At 8 and 10 WAS, unweeded and hoe-weeded at 3 and 6 WAS significantly ($P \leq 0.05$) produced taller plants, though on par with the rest of the weed control treatments which produced shorter plants. Similarly, at 12 WAS, the unweeded significantly ($P \leq 0.05$) produced taller plants, which was comparable with the remaining treatments. Plant height may have grown in unweeded plots due to interspecific and intraspecific competition between sorghum and weeds for scarce growth resources. Growing taller is a strategy for competing with weed biotypes for moisture, space, and sunshine as a result of this struggle for survival and superiority. The phytotoxic action of the herbicide, especially pendimethalin, either alone or in combination with glyphosate, which is capable of lowering crop growth indices, might be responsible for decreases in plant height as observed in herbicidal treated plots. Nevertheless, as the season progresses, the phytotoxic effect becomes less, giving the crop a greater competitive edge and producing more robust plants. The results of Shittu (2015) and Shittu *et al*. (2021), who independently reported on the phytotoxicity of pendimethalin on sorghum and roselle, are corroborated by this finding. The ability of Kaura variety to produced significantly ($P \leq 0.05$) taller plants over other variety could be due to variation in growth habit as it is in their genetic makeup. Varieties ICSV-400 and Zauna inuwa attained their maximum heights and stopped increasing in height while Kaura continued to increase in height. This was in line with Abdulsalam *et al*. (2018) who attested to the fact that differences exist among sorghum varieties on the basis of height of the plants due to their inherent genetic composition. The ability of the Kaura variety to produce significantly ($P \leq 0.05$) taller plants than other varieties could be due to variation in growth habits which is traced to their genetic makeup. The ICSV-400 and Zauna inuwa varieties reached their top heights and ceased growing, whereas the Kaura variety kept growing. This was in line with the findings of Abdulsalam *et al*. (2018), who confirmed that differences in sorghum varieties' plant height occur due to their innate genetic makeup.

The mean of combined analysis on the influence of location, weed control and variety on the number of leaves plant^{-1} at 6, 8, 10 and 12 WAS of sorghum is shown in Table 2. The number of leaves plant^{-1} had significant effect at 6 and 8 WAS only. Application of glyphosate at 2.0 kg a.i.ha^{-1} + SHW at 6 WAS significantly ($P \leq 0.05$) produced a greater number of leaves compared with pendimethalin at 2.0 kg a.i.ha^{-1}, which resulted in a less number of leaves plant^{-1} at 6 WAS. Additionally, at 8 WAS, the application of glyphosate at 2.0 kg a.i.ha^{-1} + SHW at 6 WAS significantly ($P \leq 0.05$) produced higher number leaves plant^{-1} although at par with the other weed control treatments. This was presumably owing to the phytotoxic action of pendimethalin rather than glyphosate on sorghum, which translates to less number of leaves at the early growth stages, yet the crop was able to detoxify the active ingredients and compete favorably with other herbicidal treatments. This is consistent with the findings of Bandyopadhyay and Choudhury (2009), who discovered that in light sandy loam soil, pendimethalin can penetrate to the root zone and exert phytotoxic effects in the presence of enough moisture. According to Zain *et al*. (2020), pendimethalin can inhibit plant root and shoot growth regardless of application rate. Zauna inuwa at 6, 10 and 12 WAS significantly ($P \leq 0.05$) produced a greater number of leaves than other varieties, while at 8 WAS, zauna inuwa and kaura varieties significantly ($P \leq 0.05$) recorded a greater number of leaves plant^{-1} than ICSV-400. There was no significant ($P \geq 0.05$) effect noticed with respect to location and interactions.

The results of a mean combined analysis on the effects of location, weed control, and variety on the leaf area and leaf area index of sorghum at 6, 8, 10, and 12 WAS are presented in Tables 3 and Table 4. The outcomes demonstrated that weed control was notable at 6, 8, and 12 WAS. Despite being at par, the remaining weed control treatments resulted in generating larger leaves compared with the unweeded which substantially ($P \leq 0.05$) produced smaller leaves. Sorghum's decreased leaf area and leaf area index can be attributed to unchecked weed competition for the available resources for growth, which forced the crop to divert its assimilates to grow taller in order to compete for space and sunlight at the expense of leaf area expansion. The phytotoxic action of pendimethalin, which was previously reported by Zain *et al*. (2020) and Shittu *et al*. (2021) on the number of leaves and plant height, respectively, while glyphosate was found to be less toxic, could be explained by the fact that glyphosate produced significantly ($P \leq 0.05$) larger leaves than pendimethalin rates and its combination. However, the crop was able to counteract pendimethalin's phytotoxicity as the season progressed, thereby performing similar to glyphosate either alone or in combination. A similar observation was noted by Hameed *et al*. (2017) and Jantar *et al.* (2017) and when they reported higher growth and yield performance of cotton and sorghum due to herbicide application, respectively. Zauna inuwa significantly ($P \leq 0.05$) produced larger leaves than the remaining varieties at 8, 10 and 12 WAS, respectively. Nonetheless, the genetic makeup of the variety's stay-green characteristics and lately maturity than other varieties make this conceivable. Similar to this, at 10 and 12 WAS, zauna inuwa and local kaura substantially ($P \leq 0.05$) generated larger leaf indices than ICSV-400. This is most likely because these varieties mature later than ICSV-400, which matured sooner. Thus, all growth indexes come to an end. Conley *et al*. (2005) and Thakur *et al*. (2009) discovered that greater leaf area provides a bigger surface for the interception of radiation and other growth resources, compensating for inter- and intra-crop competition and resulting in increased productivity. For leaf area and leaf area index, however, there were no location- and interaction-related effects that were significant ($P \geq 0.05$) across the sampling periods.

Table 5 shows the mean of the combined analysis on the impact of location, weed control, and variety on the number of days to 50% booting, heading, and flowering. The findings demonstrated that days to 50% booting, heading, and flowering had a substantial impact on weed control, variety, and location. Unweeded plots required considerably more days to reach the stages of 50% booting, heading, and flowering than alternative weed control treatments, which required fewer days to achieve these stages. This may be a result of weed competition in the weedy check plots, which hinders the sorghum from booting and flowering early, as well as weed suppression from other weed control treatments, which reduced weed populations and enhanced crop development and yield in sorghum during the study period. Pacanoski and Mehmeti (2019) and Kanataz *et al*. (2020) showed similar findings in wheat and soybean, respectively. Due to the variety's late maturation and longer time to reach the reproductive stage compared to its co-varieties ICSV-400 and Kaura, which reach the reproductive stage ealier, Zauna Inuwa substantially ($P \leq 0.05$) recorded the greatest days to 50% booting, heading, and flowering. This was consistent with the National Committee on Variety Naming, Registration, and Release of Nigeria's (2018) reports, which identified the variety as a late maturing one. In a similar vein, Gosh *et al*. (2015) also noted that the sorghum variety with the tallest plants and the most delayed maturation had the best yield. Sorghum has responded differently to the times of booting, heading, and flowering in each location. Sorghum grown in Kano significantly ($P \leq 0.05$) took a longer number of days to attain the 50% booting, heading, and flowering periods than those grown in Bauchi. This could be attributed to prevailing climatic conditions across the two locations. The genetic response of sorghum accessions to different agro-ecologies could be determined by the inherent and flower, which can also be influenced by varying climatic conditions across the savanna ecologies (temperature, late drought). Drought has been shown to reduce nutrient uptake by roots and induce nutrient deficiency by decreasing the diffusion rate of nutrients from soil to root, creating restricted transpiration rates and impairing active transport and membrane permeability, thus resulting in a longer number of days to resume physiological reproductive activities. Similar findings were reported by Msongaleli *et al*. (2015) and Reddy (2019) on sorghum.

Table 5 shows the mean of the combined analysis on the influence of location, weed control, and variety on weed control index, treatment efficiency index and weed index of sorghum. The findings demonstrated that weed control considerably affected WCI, TEI, and WI, while variety significantly affected TEI and WI. Other weed control methods were closely followed by the application of Glyphosate at 1.5 + Pendimethalin 1.5 kg a.i.ha^{-1} + SHW at 6 WAS, which resulted in a much higher WCI. The weedy check, however, record a zero TEI and WCI. While other treatments produced lower WI, the unweeded (control) had a much greater WI than other treatments. Higher WCI and TEI values were achieved due to the efficacy of weed control treatments in significantly covering weed development when compared to unweeded plots that recorded zero index due to continuous weed competition. Mardhavi *et al*. (2013), Ehsas *et al*. (2014), and Kumar *et al*. (2017) reported similar findings in maize. Higher TEI was significantly ($P \leq 0.05$) produced by the Zauna inuwa and kaura varieties, whereas a higher weed index was notably produced by ICSV-400. Variation in sorghum cultivar genetic make-up may be responsible for Zauna inuwa and kaura producing larger leaf surfaces and growing taller for intercepting sunlight which can as well smoother growth of weeds within its vicinity than ICSV-400, which lacks such property. Separate reports on morphological variation in sorghum landraces were made by Muui (2015), Muhammad *et al*. (2017), and Mathur *et al*. (2017). Location did not appear to have any significant ($P \geq 0.05$) effects, however there was a significant interaction with TEI where Zauna inuwa in glyphosate at 1.5 + pendimethalin 1.5 kg a.i.ha^{-1} + SHW at 6 WAS significantly ($P \leq 0.05$) produced higher TEI though at par with Kaura in same treatment compared with the rest of the interaction effects. This is, however, possible due to the efficacy of the weed control treatments with varieties that are effective in smothering the growth of weeds, thereby enhancing the efficiency of the treatments. Galon *et al*. (2016) reported a similar finding concerning the selectivity and efficiency of herbicides in weed control on sweet sorghum varieties in Brazil. Similarly, Vinothini and Arthanari (2017) reported the efficacy of pre-emergence herbicide plus hand weeding for effective weed management on irrigated kodo millet in India.

CONCLUSION AND RECOMMENDATIONS

The application of all the weed control treatments comparable resulted in producing taller plants, while kaura varieties produced the tallest plant than other cultivar. The application of glyphosate at 2.0 kg a.i.ha^{-1} + SHW at 6 WAS, glyphosate at 1.5 + pendimethalin 1.5 kg a.i.ha^{-1} + SHW at 6 WAS produced significantly ($P \leq 0.05$) more number of leaves plant while Zauna inuwa variety had more number of leaves than other varieties under investigation. Similarly, the application of glyphosate at 1.5 + pendimethalin 1.5 kg a.i.ha^{-1} + SHW at 6 WAS significantly resulted in producing larger leaf area and leaf are index, shorter number of days to 50% booting, heading and flowering compared to other treatments, while on the other hand, it also significantly ($P \leq 0.05$) recorded higher weed control index and treatment efficiency index of sorghum alongside Zauna inuwa and Kaura varieties by smothering the growth of weeds. Based on findings from 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 glyphosate at 2.0 kg a.i.ha^{-1} + SHW at 6 WAS, glyphosate at 1.5 + pendimethalin 1.5 kg a.i.ha^{-1} + SHW at 6 WAS, for effective weed control in sorghum production to increase food supply for the teaming human population.

REFERENCES

Abduselam, F., Tegene, S., Legese, Z., Tadesse, F., Biri A, Tessema T, (2018). Evaluation of early maturing Sorghum (*Sorghum bicolor* L. Moench), for yield and yield components in the lowland of eastern Hararghe. *Asian Journal of Plant Science and Research,* 8 (1): 40-43.

Abraham, P., Banwo, O. O., Kashina, B. D., & Alegbejo, M. D. (2021). Detection of Weed Species Infected by Tomato ringspot virus in Field-grown Tomato in Sudan Savanna, Nigeria. *Nigerian Journal of Plant Protection*, 35 (2): 1-15.

Ajeigbe,H.A., Akinseye, F.M., Angarawai, I.I., Umma,S.A., Inuma,A.H., Adinoyi, A. and Abdulazeez, T. (2017). Enhancing Farmers Access to Technology and Market for increased Sorghum Productivity in the Selected Staple Crop Processing Zones. Proceedings of the 51st Annual Conference of the Agricultural Society of Nigeria, Abuja, Nigeria. 1068-1072.

Ball, M. G., Caldwell, B. A., DiTommaso, A., Drinkwater, L. E., Mohler, C. L., Smith, R. G., & Ryan, M. R. (2019). Weed community structure and soybean yields in a long-term organic cropping systems experiment. *Weed Science*, 67 (6): 673-681.

Bandyopadhyay, S. & Choudhury, P. P. (2009). Leaching behavior of pendimethalin causes toxicity towards different cultivars of *Brassica juncea* and *Brassica campestris* in sandy loam soil. *Interdisciplinary Toxicology*, 2 (4): 250-253. doi: 10.2478/v10102-009-0025-z

Berenji, J., Dahlberg, J., Sikora, V., Latković, D. (2011). Origin, History, Morphology, Production, Improvement, and Utilization of Broomcorn [*Sorghum bicolor* (L) Moench] in Serbia. *Economy Botany*, 65: 190-208

Borrell, A.K., Mullet, J.E., George-jaeggli, B., Oosterom, E. J. V (2014). Drought adaptation of stay-green sorghum is associated with canopy development, leaf anatomy, root growth, and water uptake. *Journal of Experimental Botany*, 1-13.

Cole, M. R., Eggleston, G., Petrie, E., Uchimiya, S. M., & Dalley, C. (2017). Cultivar and maturity effects on the quality attributes and ethanol potential of sweet sorghum. *Biomass and Bioenergy*, 96, 183–192. https://doi.org/10.1016/j.biombioe.2016.12.001.

Ehsas, J., Desai, L.J., Ahir, N. B and Joshi, J.R. (2016). Effect of integrated weed management on growth, production, and production attributes and weed parameters on summer maize (*Zea mays* L.) under South Gujarat condition. *International Journal of Science, Environment and Technology*, 5 (4): 2050-2056.

FAO (2015). Food and Agriculture Organization of the United Nations, FAOSTAT Retrieved from http://www.fao.org/faostat/en/#data/QC/visualize

Gage, K. L., & Schwartz-Lazaro, L. M. (2019). Shifting the paradigm: An ecological systems approach to weed management. *Agriculture*, 9, 179.

Galon, L., Fernandes, F.F., Andres, A., da Silva, A.F., Forte, C.T (2016). Selectivity and efficiency of herbicides in weed control on sweet sorghum. Pesq. Agropec. Trop., Goiânia, 46 (2): 123-131, Apr./Jun. 2016 v1 e-ISSN 1983-4063 - www.agro.ufg.br/pat - v

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

Hariprasanna, K., & Rakshit, S. (2016). Economic importance of sorghum. In S. Rakshit & Y. H. Wang (Eds.), The sorghum genome (pp. 1–25). Springer. https://doi.org/10.1007/978-3- 319-47789-3_1

Jantar, H.H., Adekpe, D. I., Bature, S. M., and Hussaini Y., (2017). Yield and Yield Attributes of Sweet Sorghum (*Sorghum bicolor* Subspecies s*accharatum* (L.) Moench. Varieties as Influenced by Weed Control Treatments and Plant Population in the Semi-Arid Region of Nigeria. *Bayero Journal of Pure and Applied Sciences*, 11(1): 67-73.

Jiang, Y., Zhang, H., Qi, X., & Wu, G. (2020). Structural characterization and antioxidant activity of condensed tannins fractionated from sorghum grain. *Journal of Cereal Science*, 92, 102918. https://doi.org/10.1016/j.jcs.2020.102918

Kanatas, P., Travlos, I., Papastylianou, P *et al*. (2020) Yield, quality and weed control in soybean crop as affected by several cultural and weed management practices. *Notulae Botanicae Horti Agrobotanici Cluj-Napoca*, 48(1):329– 41. doi: 10.15835/nbha48111823.

KFFC, Kansas Farm Food Connection (2018). What Are the Different Types of Sorghum? Retrievedfromhttp://kansasfarmfoodconnection.org/blog/2018/01/12/what-are thedifferent-types-of- sorghum.

Kumar, S., Prasad, D., Mandal, and R. Kumar, R (2017). Influence of integrated weed management practices on weed dynamics, productivity and nutrient uptake of rabi maize (*Zea mays* L.). *International Journal of Current Microbiology and Applied Sciences*, 6 (4) :1431-1440.

Mace, E. S., Tai S., Gliding, E. K., Like Y., Prentis, P. J., Bling L.,and Wang J., (2013). Whole-Genome Sequencing Reveals Untapped Genetic Potential in Africa's Indigenous Cereal Crop Sorghum. *Nature Communication,* 4, 2320.

Madhavi, M., Prakash, T.R., Srinivas, A and Yakadri, M. (2013). Integrated weed management in maize (*Zea mays* L.) for supporting food security in Andhra Pradesh, India. -e role of weed science in supporting food security by 2020. In: Proceedings of the 24th Asian-Pacific Weed Science Society Conference, vol. 2013, pp. 510–516, Bandung, Indonesia,

Mathur, S., Umakanth, A. V., Tonapi, V. A., Sharma, R., & Sharma, M. K. (2017). Sweet Sorghum as Biofuel Feedstock; *Sorghum bicolor* (L). Moench. *Theoretical and Applied Genetics,* 121,323-336.

Msongaleli, B. M., Rwehumbiza, F., Tumbo, S. D., & Kihupi, N. (2015). Impacts of climate variability and change on rainfed sorghum and maize: implications for food security policy in Tanzania. *Journal of Agricultural Science*, 7(5). http://hdl.handle.net/20.500.12661/3301

Muhammad Faiz Barchia, Marulak Simarmata, Santo Nicolas Simatupang, (2017). Prospects for Growing Sorghum (*Sorghum bicolor* L. Moench) at Marginal Dry Land in Coastal Areas Rretrieved with Organic Soil Amendments. *Asian Journal of Crop Science*, 9(4): 118-124

Muui, C. W. (2015) Identification and characterization of sorghum (*Sorghum bicolor* (L) Moench) landraces and improvement of on-farm seed production in eastern Kenya (PhD Thesis).

Ndjeunga, J., Mausch, K., and Simtowe. F. (2015). Assessing the effectiveness of Agricultural R&D for groundnut, pearl millet, pigeon pea, and sorghum in West and Central Africa and East and Southern Africa. In: Walker T.S., Alwang J., editor. Crop Improvement, adoption, and impact of improved varieties in food crops in Sub-Saharan Africa. Wallingford, UK: CABI; p. 123–147.

Nwosisi, S., Nandwani, D., & Hui, D. (2019). Mulch treatment effect on weed biomass and yields of organic sweet potato cultivars. *Agronomy*, 9, 190.

Pacanoski Z, Mehmeti A. (2019). Pre-emergence grass weed control in winter wheat (*Triticum aestivum* L.) with soil applied premixed herbicides influenced by precipitations. *Agronomy Research*, 17 (6):2386-98. doi.org/10.15159/AR. 19.198
Paterson, A. H. (2008). Genomics of Sorghum. *International Journal of Plant Genomics,* 2008, 362451.

Reddy, P. S. (2019). Breeding for Abiotic Stress Resistance in Sorghum. In C. Aruna, K. B. R. S. Visarada, B. V. Bhat, & V. A. Tonapi (Eds.), Breeding sorghum for diverse end uses (pp. 325-340). Duxford. https://doi.org/ 10.1016/B978-0-08-101879-8.00020-6.

Shittu, E. A (2015). Tolerance of Selected Cereals and Legumes to Different Rates of Pendimethalin in Mubi and Gombe. Unpublished M.Sc Thesis, Adamawa State University, Mubi. 107pp.

Shittu, E.A., Fagam, A.S., Sabo, M.U., Abraham, P and Dantata, I.J. (2021). Calyxes Yield of Roselle (*Hibiscus sabdariffa* L.) as Influenced by Cultivar and Weed Control Practices in the Sudan Savanna, Nigeria. Pp 262-267. In: Lado, A., Daraja, Y.B., Dawaki, K.D., Jibril, H.J., Magaji, A.I., Yawale, M.A., Fulani, M.S and Garko, M.S. Theme-Sustainable Weed Management in a Changing Climate. *Proceedings of the 48th Annual Conference of the Weed Science Society of Nigeria (WSSN), Faculty of Agriculture and Agricultural Technology, Kano State University of Science and Technology, Wudil, Kano State, Nigeria. 1st-4th November, 2021,359 pp.*

Tibugari, H., Chiduza, C., & Mashingaidze, A. B. (2020). A survey of problem weeds of sorghum and their management in two sorghum-producing districts of Zimbabwe. *Cogent Social Sciences*, 6, 1738840.

USDA-NASS, (2017). USDA Quick Stats. Washington, DC: USDA-NASS. Retrieved from https://quickstats.nass.usda.gov/

Vinothini, G. & Arthanari, P. M. (2017). Pre emergence herbicide application and hand weeding for effective weed management in irrigated kodo millet (*Paspalum scrobiculatum* L.). *International Journal of Chemical Studies*, 5: 366-369.

Zain, S., Dafaallah, A. & Zaroug, M. (2020). Efficacy and selectivity of pendimethalin for weed control in soybean (*Glycine max* (L.) Merr.), Gezira State, Sudan. *Agricultural Science & Practice*, 7 (1): 59-68.

Table 1: Mean of combined analysis across locations on plant height at 6, 8, 10 and 12 WAS of sorghum varieties as influenced by weed control during 2020 rainy season

Treatments	Plant height (cm)			
	Weeks after sowing (WAS)			
	6	8	10	12
Weed Control (W)				
Unweeded	80.9a	120.2a	165.6a	181.8a
Hoe weeding at 3 and 6 WAS	80.9a	114.0a	160.5a	176.1ab
Pendimethalin 1.5 kg a.i.ha^{-1}	85.2a	90.1bcd	129.8ab	166.1ab
Pendimethalin 2.0 kg a.i.ha^{-1}	53.6b	86.9cd	120.3b	164.4ab
Pendimethalin 1.5 + Glyphosate at 1.5 kg a.i.ha^{-1}	57.8b	79.2d	136.3ab	158.0ab
Pendimethalin 1.5 kg a.i.ha^{-1} + SHW at 6 WAS	53.8b	103.0abc	158.4ab	154.8ab
Glyphosate 2.0 kg a.i.ha^{-1} + SHW at 6 WAS	94.1a	110.1ab	153.5ab	167.7ab
Glyphosate 1.5 + Pendimethalin 1.5 kg a.i.ha^{-1} + SHW at 6 WAS	53.8b	80.8cd	135.5ab	145.5b
P of F	<.001	<.001	0.008	0.043
SE±	4.39	6.01	9.71	8.06
Variety (V)				
ICSV-400	66.8	94.6b	129.7b	140.5b
Kaura	74.1	105.9a	169.8a	203.6a
Zauna Inuwa (SAMSORG 47)	69.6	93.6b	135.3b	145.0b
P of F	0.162	0.037	<.001	<.001
SE±	2.69	3.68	5.95	4.94
Location (L)				
Kano	68.9	96.4	143.4	161.6
Bauchi	71.5	99.6	146.5	164.5
P of F	0.410	0.453	0.656	0.603
SE±	2.20	3.01	4.86	4.03
Interaction				
V x W	0.470	0.606	0.913	0.772
V x L	0.991	0.996	1.000	0.999
W x L	1.000	1.000	1.000	1.000
W x V x L	1.000	1.000	1.000	1.000

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

Table 2: Mean of combined analysis across locations on number of leaves at 6, 8, 10 and 12 WAS of sorghum varieties as influenced by weed control during 2020 rainy season

Treatments	Number of leaves plant^{-1}			
	Weeks after sowing (WAS)			
	6	8	10	12
Weed Control (W)				
Unweeded	6.67b	7.50abc	8.89	8.94
Hoe weeding at 3 and 6 WAS	7.00b	8.33ab	8.61	9.11
Pendimethalin at 1.5 kg a.i.ha^{-1}	5.44c	6.89c	8.89	8.78
Pendimethalin at 2.0 kga.i.ha^{-1}	5.44c	7.11bc	8.67	9.56
Pendimethalin at 1.5 + Glyphosate 1.5 kg a.i.ha^{-1}	5.56c	7.00bc	8.28	8.89
Pendimethalin at 1.5 kg a.i.ha^{-1} + SHW at 6 WAS	4.89c	6.67c	8.06	8.44
Glyphosate at 2.0 kg a.i.ha^{-1} + SHW at 6 WAS	7.56a	8.67a	9.28	9.61
Glyphosate at 1.5 + Pendimethalin 1.5 kg a.i.ha^{-1} + SHW at 6 WAS	6.56b	7.89abc	8.22	8.44
P of F	<.001	<.001	0.395	0.122
SE±	0.184	0.344	0.415	0.341
Variety (V)				
ICSV-400	5.79b	6.81b	7.17c	6.83c
Kaura	5.63b	7.58a	8.71b	8.23b
Zauna Inuwa (SAMSORG 47)	7.00a	8.12a	9.96a	11.85a
P of F	<.001	<.001	<.001	<.001
SE±	0.113	0.210	0.254	0.209
Location (L)				
Kano	6.14	7.51	8.58	8.90
Bauchi	6.14	7.50	8.64	9.04
P of F	1.000	0.955	0.850	0.566
SE±	0.092	0.172	0.207	0.170
Interaction				
V x W	0.011	0.455	0.992	0.019
V x L	1.000	0.997	0.991	0.785
W x L	1.000	1.000	1.000	1.000
W 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 3: Mean of combined analysis across locations on leaf area (cm) at 6, 8, 10 and 12 WAS of sorghum varieties as influenced by weed control during 2020 rainy season

Treatments	Leaf area (cm^2)			
	Weeks after sowing (WAS)			
	6	8	10	12
Weed Control (W)				
Unweeded	107.9d	245.6c	371.0	325.0b
Hoe weeding at 3 and 6 WAS	234.0ab	401.4a	441.0	466.0a
Pendimethalin at 1.5 kg a.i.ha^{-1}	250.7ab	347.0abc	390.0	411.0ab
Pendimethalin at 2.0 kg a.i.ha^{-1}	209.0abc	310.9ab	431.0	474.0a
Pendimethalin at 1.5 + Glyphosate 1.5 kg a.i.ha^{-1}	187.5bcd	263.0bc	362.0	405.0ab
Pendimethalin at 1.5 kg a.i.ha^{-1} + SHW at 6 WAS	134.6cd	291.8abc	365.0	419.0ab
Glyphosate at 2.0 kg a.i.ha^{-1} + SHW at 6 WAS	286.2.0a	371.7ab	431.0	508.0a
Glyphosate at 1.5 + Pendimethalin 1.5 kg a.i.ha^{-1} + SHW at 6 WAS	119.0cd	264.9bc	367.0	404.ab
P of F	<.001	<.001	0.691	0.002
SE±	24.27	28.11	41.9	30.4
Variety (V)				
ICSV-400	180.0	268.1b	346.0b	320.0c
Kaura	183.0	307.5b	282.0b	381.0b
Zauna Inuwa (SAMSORG 47)	210.7	360.5a	555.0a	578.0a
P of F	0.279	0.001	<.001	<.001
SE±	14.86	17.22	25.7	18.6
Location (L)				
Kano	190.1	310.9	393.	425.
Bauchi	192.3	313.2	396	428.
P of F	0.900	0.909	0.926	0.900
SE±	12.13	14.06	21.0	15.2
Interaction				
V x W	0.187	0.144	0.919	0.513
V x L	0.999	0.995	0.999	1.000
W x L	1.000	1.000	1.000	1.000
W 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: Mean of combined analysis across locations on leaf area index at 6, 8, 10 and 12 WAS of sorghum varieties as influenced by weed control during 2020 rainy season

Treatments	Leaf area index			
	Weeks after sowing (WAS)			
	6	8	10	12
Weed Control (W)				
Unweeded	1.57d	2.26c	2.69c	2.78c
Hoe weeding at 3 and 6 WAS	2.82ab	3.66ab	4.19a	4.73a
Pendimethalin at 1.5 kg a.i.ha^{-1}	3.25a	4.09a	4.33a	4.59ab
Pendimethalin at 2.0 kg a.i.ha^{-1}	2.08cd	3.15b	3.69ab	4.43ab
Pendimethalin at 1.5 + Glyphosate 1.5 kg a.i.ha^{-1}	1.98cd	2.82bc	3.49ab	4.05b
Pendimethalin at 1.5 kg a.i.ha^{-1} + SHW at 6 WAS	2.52bc	3.14b	3.89ab	4.48ab
Glyphosate at 2.0 kg a.i.ha^{-1} + SHW at 6 WAS	2.90ab	3.60ab	4.28a	4.74a
Glyphosate at 1.5 + Pendimethalin 1.5 kg a.i.ha^{-1} + SHW at 6 WAS	2.50abc	3.23b	3.94ab	4.67ab
P of F	<.001	<. 001	0.006	0.016
SE±	0.192	0.223	0.215	0.199
Variety (V)				
ICSV-400	2.42	3.09	3.57b	3.90b
Kaura	2.45	3.32	3.99a	4.60a
Zauna Inuwa (SAMSORG 47)	2.49	3.33	4.20a	4.84a
P of F	0.922	0.381	0.005	<.001
SE±	0.118	0.136	0.132	0.122
Location (L)				
Kano	2.39	3.18	3.886	4.364
Bauchi	2.52	3.32	3.890	4.526
P of F	0.363	0.375	0.978	0.250
SE±	0.096	0.111	0.108	0.099
Interaction				
V x W	0.952	0.981	0.918	0.904
V x L	1.000	0.985	0.999	0.994
W x L	1.000	1.000	1.000	1.000
W 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 5: Mean of combined analysis across locations on number of days to 50% booting, heading and flowering of sorghum varieties as influenced by weed control during 2020 rainy season

Treatments	Days to 50% booting	Days to 50% heading	Days to 50% flowering
Weed Control (W)			
Unweeded	91.78a	95.78a	97.72a
Hoe weeding at 3 and 6 WAS	80.61c	84.83c	87.72c
Pendimethalin at 1.5 kg a.i.ha^{-1}	85.61b	90.22b	92.17b
Pendimethalin at 2.0 kg a.i.ha^{-1}	82.39c	87.39bc	89.22bc
Pendimethalin at 1.5 + Glyphosate 1.5 kg a.i.ha^{-1}	82.28bc	87.00bc	89.94bc
Pendimethalin at 1.5 kg a.i.ha^{-1} + SHW at 6 WAS	81.83bc	86.67bc	88.00c
Glyphosate at 2.0 kg a.i.ha^{-1} + SHW at 6 WAS	80.61c	85.61c	87.39c
Glyphosate at 1.5 + Pendimethalin 1.5 kg a.i.ha^{-1} + SHW at 6 WAS	80.33c	85.56c	87.72c
P of F	<.001	<.001	<.001
SE±	1.075	1.080	1.024
Variety (V)			
ICSV-400	72.04b	78.10b	80.73b
Kaura	72.94b	76.46b	79.77b
Zauna Inuwa (SAMSORG 47)	104.62a	109.08a	110.46a
P of F	<.001	<.001	<.001
SE±	0.658	0.662	0.627
Location (L)			
Kano	84.00a	88.92a	90.82a
Bauchi	82.40b	86.85b	89.15b
P of F	0.038	0.008	0.024
SE±	0.538	0.540	0.512
Interaction			
V x W	0.293	0.338	0.356
V x L	0.992	0.994	0.825
W x L	1.000	1.000	0.993
W 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

Table 6: Mean of combined analysis across locations on weed control index, treatment efficiency index and weed index of sorghum varieties as influenced by weed control during 2020 rainy season

Treatments	Weed control index (%)	Treatment efficiency index (%)	Weed index (%)
Weed Control (W)			
Unweeded	-	-	64.89a
Hoe weeding at 3 and 6 WAS	79.89b	5.94b	-_
Pendimethalin at 1.5 kg a.i.ha^{-1}	50.89c	4.13b	35.11c
Pendimethalin at 2.0 kg a.i.ha^{-1}	52.56c	4.60b	34.44c
Pendimethalin at 1.5 + Glyphosate 1.5 kg a.i.ha^{-1}	58.00c	4.56b	38.44b
Pendimethalin at 1.5 kg a.i.ha^{-1} + SHW at 6 WAS	67.33b	4.70b	19.56d
Glyphosate at 2.0 kg a.i.ha^{-1} + SHW at 6 WAS	52.56c	6.36b	18.89d
Glyphosate at 1.5 + Pendimethalin 1.5 kg a.i.ha^{-1} + SHW at 6 WAS	77.22a	8.25a	15.56e
P of F	<.001	<.001	<.001
SE±	2.160	0.593	0.938
Variety (V)			
ICSV-400	60.14	3.29b	35.38a
Kaura	64.57	5.82a	31.19b
Zauna Inuwa (SAMSORG 47)	63.19	5.34a	30.67b
Level of probability	0.229	<.001	0.042
SE±	1.536	0.363	1.021
Location (L)			
Kano	49.9	4.45	33.2
Bauchi	49.9	5.18	32.8
P of F	1.000	0.087	1.000
SE±	1.441	0.297	1.344
Interaction			
V x W	0.627	<.001	0.510
V x L	1.000	0.981	1.000
W x L	1.000	0.999	1.000
W 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.

Table 6: Interaction effect of variety and weed control on treatment efficiency index of sorghum during 2020 rainy season combined location

	Weed control							
Variety	T1	T2	T3	T4	T5	T6	T7	T8
ICSV-400	_	4.4d-g	3.1fg	3.3efg	3.7d-g	4.0d-g	4.5d-g	5.7def
Kaura	_	5.7def	4.8d-g	4.8d-g	5.3d-g	6.0cde	8.8bc	13.1ab
Zauna inuwa	_	8.0bc	4.8d-g	4.9d-g	5.3d-g	6.23cd	6.3cd	14.1a
SE±				1.027				

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 = Glyphosate at 1.5 + Pendimethalin 1.5 kg a.i.ha^{-1} + SHW at 6WAS.