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Growth and yield performance of Bambara groundnut (Vigna subterranea) genotypes under varying periods of weed interference in Nigeria

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Bambara groundnut (*Vigna subterranea*) is a climate-resilient, underutilized legume with high nutritional value. However, weed interference during critical growth stages remains a major limitation to its productivity. This study assessed the critical period of weed interference in two Bambara groundnut genotypes (cream round and brown round) under Sudan Savanna conditions during the 2020 wet season. The experiment, conducted at two locations (BUK and Guringawa), used a randomized complete block design with three replications. Treatments involved maintaining plots either weed-free or weed-infested for 3, 6, 9, and 12 weeks after sowing (WAS), followed by the opposite condition until harvest. Weed interference had significant effects on multiple agronomic traits. At BUK, plots kept weed-infested for 12 WAS recorded the highest weed cover score (4.83) and weed dry biomass (61.3 g/m^2), while weed-free plots for 12 WAS had the lowest weed cover (1.00) and biomass (14.5 g/m^2), and the highest weed control index (52.0%). Similarly, leaf area index peaked at 5.6 under 12 WAS weed-free conditions but dropped sharply to 0.5 when infested for the same duration. Stand count at harvest rose to 25,9 plants ha^{-1} under 12 WAS weed-free but declined to 5,6 plants ha^{-1} under prolonged infestation. Yield traits followed the same pattern: total dry matter, number of pods, and kernel yield per plant were highest in 12 WAS weed-free plots (19.4 g, 33.8 pods, 25.7 g, respectively) and lowest when weed-infested for 12 WAS (3.36 g, 11.6 pods, 12.7 g, respectively). Genotypic effects were largely non-significant, though cream and brown types differed slightly in vigor and leaf number at BUK. Maintaining a weed-free period of at least 12 WAS significantly enhanced Bambara groundnut growth, physiological traits, and yield components, underscoring the need for early and sustained weed control in semi-arid farming systems.

Key words: Bambara groundnut, genotypes, critical period, weed interference, susceptibility

INTRODUCTION

Bambara groundnut (Vigna subterranea [L.] Verdc.) is a drought-tolerant tropical legume cultivated for centuries across Africa. It is well known for thriving in marginal soils and low-input farming systems. Despite its resilience and nutritional value, bambaranut remains significantly underutilized when compared to other legumes like peanuts and soybeans (Olanrewaju et al., 2022). The crop is highly nutritious, containing 20-25% protein, 55-60% carbohydrates, essential minerals (e.g., calcium, iron, magnesium, phosphorus, potassium, zinc), and vitamins (A, B1, B2, B6, C, and E). It also provides dietary fiber, antioxidants, and 4-12% oil content, making it beneficial for human health and food security (Gonné et al., 2013; Mayes et al., 2019). Its health benefits include enhanced digestive health, glycemic control, weight management, and reduced risk of chronic diseases (Adeleke et al., 2018; Tan et al., 2020). Additionally, its culinary versatility allows it to be consumed in various forms such as porridges, soups, stews, and baked goods (Halimi et al., 2019).

Owing to its adaptability and nutritional profile, bambaranut is considered a promising crop for sustainable agriculture, particularly in the climate-vulnerable Sudan Savanna region of Nigeria (FAO et al., 2020; Soumare et al., 2022). However, its yield potential is often compromised by biotic constraints particularly weed interference which severely limits productivity.

Weeds compete with crops for vital resources such as nutrients, water, light, and space, reducing plant growth, leaf expansion, dry matter accumulation, and yield (El-Metwally and Saudy, 2021; Saudy et al., 2021, 2022; Iddrisu et al., 2024). In fact, weeds can absorb 30-40% of applied nutrients in farmed areas (Kumar et al., 2021), causing groundnut yield losses ranging from 15-75% (Saudy et al., 2021), with some infestations leading to reductions as high as 78% (Hare et al., 2019). Moreover, limited access to timely intercultural operations in bambaranut restricts effective peg penetration and pod development, compounding the problem (Khan et al., 2021a).

Farmers often rely on pre-emergence herbicides for early weed suppression, but these measures typically do not offer season-long control. As a result, late-emerging weeds escape treatment and continue to interfere with crop growth (Regar et al., 2021; Shittu et al., 2023, 2024; Shittu, 2025). This emphasizes the need to understand the Critical Period of Weed Competition (CPWC), a specific window in the crop's phenological development during which weed control is essential to avoid substantial yield loss (Ramesh et al., 2021; Hooks et al., 2021).

Although CPWC has been studied in other legumes like groundnut, where the stage between flowering and pod formation is especially vulnerable, empirical data for bambaranut remains scarce (Korav et al., 2020a, 2020b; Latif et al., 2021). This lack of knowledge presents a key barrier to designing targeted, resource-efficient weed management strategies that align with bambara groundnut's growth dynamics. Given its potential to improve food and nutrition security in marginal environments, understanding the CPWC in bambaranut is critical. Doing so will support evidence-based recommendations for weed control, reduce yield losses, and ultimately encourage the wider adoption of this underutilized yet valuable crop.

Therefore, this study aims to determine the critical period during which bambaranut genotypes are most susceptible to weed interference under the agro-ecological conditions of the Sudan Savanna in Nigeria.

The main objective of this study is to determine the critical period of weed interference in bambaranut genotypes in the Sudan Savanna ecology of Nigeria while the specific objectives are to:

- Evaluate the growth and yield response of different bambaranut genotypes under varying periods of weed interference.

- Identify the period(s) during which weed interference has the most significant effect on bambaranut productivity.

- Recommend optimal weed management timing to enhance bambaranut yield in the Sudan Savanna region.

MATERIALS AND METHODS

Experimental site

The experiment was conducted during the 2020 wet season at two locations in Kano State, Nigeria: the Teaching and Research Farm of the Faculty of Agriculture, Bayero University Kano (Latitude 11° 58" N, Longitude 8° 33" E), and Guringawa in Kumbotso Local Government Area (Latitude 11° 56" N, Longitude 8° 31" E). At each site, composite soil samples were collected from the 0–15 cm depth using a soil auger. The samples were air-dried, sieved through a 2 mm mesh, and analyzed for their physical and chemical properties following the procedures described by Black (1965).

Treatment and experimental design

The experiment followed a factorial arrangement involving two factors: bambaranut genotype and weed interference period. Two genotypes (cream round and brown round) were used. Weed interference was structured into two sets of treatments:

• In the first set, plots were kept weed-free for 3, 6, 9, or 12 weeks after sowing (WAS), after which they were allowed to remain weed-infested until harvest.

• In the second set, plots were weed-infested for 3, 6, 9, or 12 WAS, followed by a weed-free period until harvest.

These weed interference durations were factorially combined with the two bambaranut genotypes and arranged in a Randomized Complete Block Design (RCBD) with three replications.

Cultural practices

Land preparation

The experimental sites were cleared manually, ploughed, harrowed and ridged. The field was marked into plot sizes. Each gross plot consisted of six ridges of 3 m long. The net plot consisted of four ridges of 3 m long (9.0 m2).

Seed treatment

The seeds were dressed with Dress force (Imidacloprid 20 % + Metalaxyl-M 20 % + Tebuconazole 2 % WS) at 20 g per kg of seeds as a seed protectant. The seeds were sown at 3 cm depth with two seeds per hole using 20 cm intra row spacing on a ridged of 75 cm. Similarly, weeding was carried out as per treatment.

Fertilizer was applied to each plot at the rate of 20 kg N, 54 kg P2O5 and 20 kg K2O/ha using NPK 15:15:15 while the remaining balance of the P2O5 was supplied through SSP 18% by basal application.

Harvesting was carried out when the crop reached physiological maturity stage (leaves turned yellowish brown and pods tureen brownish in color). The net plots were harvested by digging the whole plant using hoe and picking up the remaining pods from the soil.

Data Collection

Data were collected on weed characters including weed species composition, weed covers score, weed dry weight and weed control index. Similarly, data was also collected on crop growth and yield characters such as number of leaves, leaf area, leaf area index, crop vigor score, stand count at harvest, total dry matter, number of pods per plant, kernel yield per plot and kernel yield per hectare using standard agronomic procedures.

Data collected were subjected to analysis of variance as described by Snedecor and Cochran (1994) using GenStat (17th ed.). Significant treatment means were separated using Student -Newman

Keuls Test at 5% probability level.

RESULTS AND DISCUSSION

Table 1 presents the result of the soil analysis of the two experimental sites. The soil at both BUK and Guringawa fall into the “Sandy Loam” textural class with sand (700; 800 g kg-1), silt (100; 54 g kg-1) and clay (200; 146 g kg-1) for BUK and Guringawa, respectively, indicating a relatively balanced composition of sand, silt, and clay. The pH values in both water (H2O) and potassium chloride (KCl) are slightly acidic (6.4 and 4.9) for BUK soil and slightly alkaline (6.8 and 5.4) for Guringawa soil. This difference in pH can affect nutrient availability and plant growth. BUK soil has a slightly higher (3.6) organic carbon content compared to Guringawa soil (3.4). Organic matter is crucial for soil health, nutrient retention, and microbial activity. BUK soil also has a higher total nitrogen content (1.1 g kg-1), which is essential for plant growth than Guringawa (0.7 g kg-1). Guringawa soil has a significantly higher (16.9 mg kg-1) available phosphorus content, which is a vital nutrient for plant development than BUK (7.8 mg kg-1). Both soils have similar levels of calcium (Ca++) and magnesium (Mg++) but Guringawa soil has higher levels of potassium (K+) and sodium (Na+).

The differences in soil properties between BUK and Guringawa could have significant implications for agricultural productivity and plant growth. For example, the higher organic carbon and total nitrogen content in BUK soil may support better plant health and nutrient availability. On the other hand, the higher available phosphorus content in Guringawa soil could be beneficial for certain crops that have a high phosphorus requirement. The slightly acidic pH of BUK soil might require careful management to ensure optimal nutrient availability for plants. Lime application could be considered to raise the pH and improve nutrient uptake. In contrast, the slightly alkaline pH of Guringawa soil may favor the availability of certain micronutrients. The higher cation exchange capacity (CEC) of Guringawa soil indicates its ability to retain and exchange cations, which can influence nutrient availability and soil fertility. However, a high CEC can also lead to greater competition for nutrients between plants and other soil components.

Weed specie distribution associated with bambaranut at BUK and Guringawa during 2020 wet season

The weed specie composition associated with Bambaranut at BUK and Guringawa is shown in Table 2. Results indicated that the total number of weeds across both locations were twenty-two (22). There were seven (7) and five (5) narrow weeds species and thirteen (13) and ten (10) broad leaved weeds, respectively at both BUK and Guringawa. Several broadleaf weed species, such as Amaranthus spinosus, Acanthospermum hispidum, Alternanthera sessilis, and Euphorbia hirta, were highly prevalent at both locations. Eleusine indica and Digitaria horizontalis were common narrow leaf weeds at both sites. Cyperus rotundus was a significant sedge weed at BUK while it was absent at Guringawa. Similarly, a number of weed species exhibited high infestation levels (≥ 60%) at one or both locations. This indicates a serious weed problem that could negatively impact crop yield and quality while several weed species were moderately infested (31-60%), suggesting a need for timely weed control measures. The spatial distribution of weed species corroborates the findings of Shittu and Bassey (2023) and Shittu (2023), who identified Cynodon dactylon and Cyperus spp. as prevalent noxious weeds in the savanna region of Nigeria. Their high density necessitates effective control measures to mitigate their impact on crop yield. In a more recent development, Shittu et al. (2024) reported Cyperus rotundus, Eluesine indica, and Euphorbia hirta to be significant weeds that threaten groundnut production in the dry region of Nigeria. Therefore, a high weed infestation can result in lower crop yields, deteriorated quality from pests and disease, and increased production costs due to weed control measures. Understanding weed biology is crucial for crop competitiveness as affirm by Ramesh et al. (2017). Hence, early weed control, crop rotation, cover crops, herbicide application, and manual weeding are essential for effective weed control, minimizing crop yield and quality, and improving soil health.

Weed cover score, weed dry weight and weed control index of bambaranut genotypes

The influence of bambaranut genotypes and period of weed interference on weed cover scores (WCS), weed dry weight (WDW), and weed control index (WCI) at BUK and Guringawa is presented in Table 3. Genotype did not significantly influence WCS, WDW, and WCI at both locations. However, WCS, WDW, and WCI were significantly influenced by the period of weed interference, where plots kept weed infested for 12 WAS significantly resulted in higher WCS while plots kept weed-free for 12 WAS resulted in lower WCS at both locations. Similarly, plots kept weed infested at 12 and 9 WAS significantly had higher WDW in comparison to plots kept weed free at 9 and 12 WAS, respectively, at BUK, while at Guringawa, plots kept weed infested and weed free up to 12 WAS significantly resulted in higher and lower WDW, respectively. On the other hand, plots kept weed infested and weed-free up to 12 WAS significantly recorded lower (0.00%) and higher WCI (52.0%; 74.1%), respectively, at BUK and Guringawa. The interaction between bambaranut genotypes and period of weed interference on WCS, WDW, and WCI was not significant at both locations. The genotype of the bambaranut did not significantly influence weed infestation levels. This suggests that weed control strategies should be applied uniformly to different genotypes. This agreed with the findings of Khan et al. (2021b), who discovered the variation in yield trait of diverse bambaranut genotypes as influenced by spacing and phosphate fertilization. Prolonged weed infestation, particularly up to 12 weeks after sowing (WAS), led to higher weed cover, weed dry weight, and a lower weed control index. Weeds compete with the crop for essential resources like water, nutrients, and sunlight, leading to reduced crop growth and yield. Kaur et al. (2018) and Korres (2018) affirm that crops and weeds share resources like sunlight, space, and atmospheric gases. Therefore, competition for these resources alters their utilization and affects interactions between plants and environmental factors. According to Shittu et al. (2023), it is important to note that weeds are more aggressive and persistent than crops and can reduce crop yields by extracting more water and nutrients from soil; therefore, they need to be properly managed below economic threshold levels to avert losses (Shittu and Lamarana, 2024; Shittu et al., 2024; Shittu, 2025). Early weed control is crucial to minimize weed competition and maximize crop productivity. Keeping the crop weed-free for at least 12 WAS is essential. Effective weed control enhances bambaranut crop yield, reduces production costs, and promotes sustainable agriculture by reducing overreliance on chemical herbicides, as earlier reported by Shittu and Bassey (2023) and Shittu and Lamarana (2024), respectively, in cowpea.

Number of leaves per plant, leaf area and leaf area index

Table 4 presents the number of leaves, leaf area, and leaf area index per plant of Bambaranut as Influenced by Period of Weed Interference and Genotype during the 2020 Wet Season of the two experimental sites. The result revealed that genotype had a significant influence on the number of leaves per plant (NLP) at BUK only, while leaf area (LA) and leaf area index (LAI) were not significantly influenced by genotype at BUK, while at Guringawa, leaf area was significantly influenced by genotype only. On the other hand, NLP, LA, and LAI were significantly influenced by periods of weed interference at both locations. Plants kept weed free up to 6 WAS significantly produced more number of leaves per plant at BUK compared to plants that were infested for 9 WAS and 12 WAS, which resulted in producing lower number of leaves per plant, respectively, at BUK. Plots kept weed-free up to 12 WAS significantly produced larger leaves, although at par with periods of weed interference compared to plots kept weed-infested up to 12 WAS, which had the smaller leaves at BUK. Plots kept weed-free for 6, 9, and 12 and weed-infested for only 3 WAS were highly significant and resulted in higher LAI, followed by plots kept weed-free for 3 WAS, while plots kept weed-infested for 6-12 WAS significantly resulted in lower LAI at BUK.

On the other hand, plots kept weed-free for 12 WAS significantly had more number of leaves per plant, which was at par plant, although statistically comparable with other periods of weed interference except plots that were kept weed-infested between 9 and 12 WAS, which resulted in a lower number of leaves per plant at Guringawa. Similarly, plots kept weed-free for 12 WAS significantly resulted in producing wider leaves than plots infested by weeds up to 12 WAS, which resulted in producing narrow leaves. Furthermore, plots kept weed-free for up to 6 WAS significantly resulted in producing plants with a higher LAI than plots kept weed-infested up to 12 WAS, which resulted in a small LAI. The interaction between genotype and period of weed interference on number of leaves per plant, LA and LAI, was not significant at both locations.

Findings revealed that genotype significantly influences leaf development at BUK and Guringawa, while genotype does not affect leaf area or LAI. Weed interference affects all leaf parameters, with longer weed-free periods leading to higher leaf numbers and larger areas. The initial 6 weeks after sowing are critical for weed control. Weed competition reduces leaf area, number, and LAI, affects photosynthetic capacity, water use efficiency, and nutrient uptake, affecting plant growth. Regardless of the availability of resources, weeds lower crop productivity. According to Horvath et al. (2023), weeds change the developmental paths of crops early in the growth season by releasing volatile chemicals, soil-borne compounds, and changes in light quality. Growth is suppressed by weed signals. According to Latif et al. (2021), weed interference significantly reduced groundnut yield in both seasons, affecting the source-to-sink relationship and crop productivity. Therefore, early weed control is crucial for leaf growth and yield, and selecting varieties with good competitive ability and tolerance to weed stress can help to mitigate the negative impacts of weed interference. Thus, varietal selection and precision agriculture techniques optimize weed control and resource use. Iddrisu et al. (2024) claim that weeds mostly affect the groundnuts’ source-sink size, causing plants to grow shorter, have smaller leaves, and produce less dry matter.

Stand count and crop vigor scores

Stand Count and Crop Vigor Score of Bambaranut as influenced by genotype and period of weed interference during the 2020 wet season at BUK and Guringawa are shown in Table 5. Results indicated that stand count at harvest and crop vigor score were not significantly influenced by genotype at both locations. However, they were significantly influenced by periods of weed interferences. Plots kept weed-free for 12 WAS, although statistically similar with other periods of weed interference, significantly resulted in a higher stand count compared to plots that were kept weed-infested up to 12 WAS at BUK and Guringawa, respectively. Plots kept weed-free for 3, 6, 9, and 12 WAS and those kept weed-infested for only 3 WAS resulted in a statistically comparable higher vigor score compared to plots that were kept weed-infested for 9 and 12 WAS, which resulted in lower vigor at both locations, respectively.

Maintaining a critical weed-free period for 12 WAS leads to high stand count and vigor. Early weed control, especially within the first 3 WAS, is crucial for maintaining high plant vigor and stand establishment. Prolonged weed infestation can lead to reduced plant establishment, stunted growth by releasing allelopathic substances, increased disease and pest incidence, restricted air circulation, and delayed crop maturity, resulting in reduced yield and quality, thereby resulting in increased production costs. This finding corroborated those of Kubiak et al. (2022) and Minhass et al. (2023), who reported independently the deleterious effects of weeds in plantation establishment and wheat, respectively. This result also supported the preceding study by Iddrisu et al. (2024) on decreased crop vigor and leaf area, which always have a detrimental effect on production.

The interaction between genotype and period of weed interference on crop vigor score was significant at both locations (Table 6), where brown color genotype kept under weed free for 6 WAS significantly resulted in higher vigor although at par with other interaction combinations compared to plots kept weed infested for 6-12 WAS in both cream and brown genotype which resulted in lower vigor at BUK. On the other hand, plots kept weed infested for 3 WAS and subsequently weed free in cream color genotype significantly resulted in higher vigor which was similar with other interaction combinations compared to plots kept weed infested for 9-12 WAS in cream genotype which resulted in lower vigor at Guringawa.

The study found that genotype and weed interference significantly influenced crop vigor, with brown color genotypes benefiting more from early weed control, indicating a genotype-specific response. The interaction between genotype and environment can influence plant growth and development. In this case, the brown color genotype may be more sensitive to weed competition than the cream color genotype. This could be attributed to the genetic variation coupled with environmental interactions that favor some varieties to perform better than others. A similar finding was reported by Vaidya and Stinchcombe (2020) and Mahmood et al. (2022), who reported the role of genotype, environment, and management as the factors determining crop productivity. Thus, weed competition reduces plant growth and vigor, necessitating early weed control to establish a strong crop canopy and reduce weed competition.

Yield and yield related characters

Table 7 presents the dry matter content, number of pods per plant, and kernel yield of bambaranut as influenced by genotype and period of weed interference during the 2017 wet season. Results show that all the mentioned parameters were not significantly influenced by genotype at both locations. However, they were significantly influenced by a period of weed interference across both locations. Plots kept weed-free for 12 WAS and plots kept weed-infested for 3 WAS only and subsequently weed-free significantly resulted in higher dry matter compared with plots kept weed-infested for 9 and 12 WAS, respectively, at BUK that resulted in lower dry matter. A similar pattern was also obtained at Guringawa, with little variation where plots kept free for 12 WAS, although at par with other treatments, significantly resulted in higher dry matter content. The number of pods per plant was significantly higher in plots kept weed-free for 12 WAS, which is comparable with other treatments except plots kept weed-free for only 3 WAS and plots kept weed-infested for up to 12 WAS that produced a lower number of pods per plant at BUK, while at Guringawa, plots kept weed-free for 12 WAS and weed-infested for only 3 WAS significantly produced a higher number of pod plants than plots kept weed-infested for 12 WAS, which resulted in lower pods per plant. Kernel yield per plant was significantly higher in plots kept weed-free for 12 WAS, although at par with other treatments, plots kept weed-infested for 12 WAS resulted in lower kernel yield per plant at BUK, while at Guringawa, plots kept weed-free for 12 WAS and weed-infested for 3 WAS significantly produced higher kernel yield per plant compared with other treatments, while plots kept weed-infested for 12 WAS resulted in lower kernel yield per plant. Plots kept weed-free for 12 WAS and those kept weed-infested for 3 WAS significantly produced higher kernel yield compared with plots kept weed-free for only 3 WAS and weed-infested up to 12 WAS, which resulted in lower kernel yield at both locations, respectively.

Although the impact of variety was not explicitly examined in the study, it is plausible that distinct cultivars would display differing levels of resistance to weed competition. The study clearly demonstrates that weed interference negatively impacts the dry matter content, number of pods per plant, and kernel yield of bambaranut. To avert this drawback, keeping the crop weed-free for at least 12 weeks after sowing is crucial for maximizing yield. This period allows the crop to establish itself and compete effectively with weeds, while early weed control, especially within the first 3 weeks after sowing, is essential to minimize weed competition and ensure optimal crop growth. This result supports the findings of Oyewole and Obaweda (2020) and Akogu et al. (2021), who separately reported higher growth and yield components of okra and bambara groundnut as a result of a weed-free environment that was maintained after the critical period for weed infestation, which was accomplished by administering three hoe weeding’s or weed-free conditions.

CONCLUSION

This study clearly demonstrates that weed interference beyond six weeks after sowing significantly suppresses bambaranut growth, stand establishment, vigor, and yield. The most critical period for weed control was identified as the first 12 weeks after sowing (WAS), during which maintaining weed-free conditions led to substantial improvements in leaf development, dry matter accumulation, pod formation, and kernel yield. For instance, kernel yield increased from 12.7 g plant^{-1} under season-long infestation to 25.7 g plant^{-1} when kept weed-free for 12 WAS. Although genotypic differences were generally non-significant, some interactions suggested that early weed control could benefit certain varieties more than others. Based on these findings, it is recommended that bambaranut fields be kept weed-free for at least 12 WAS to ensure optimal productivity. Integrated weed management practices combining early hoe weeding, pre-emergence herbicides, and cultural controls should be prioritized. Moreover, breeding and selection of genotypes with strong competitive ability under weed pressure could further support sustainable production. Agricultural extension programs should emphasize this critical weed-free period to guide farmers toward cost-effective and environmentally sound weed control strategies for bambaranut cultivation in savanna ecologies.

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