



Research Article

Harnessing Integrated Weed Management to Boost Groundnut (*Arachis hypogaea* L.) Yield and Profitability under Diverse Weed Flora in Nigeria's Sudan Savanna

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ABSTRACT

Weed infestation remains a major constraint to groundnut (*Arachis hypogaea* L.) production in the Sudan Savanna of Nigeria, where diverse annual and perennial species compete for nutrients, light, and water. This study evaluated the efficacy and profitability of integrated weed management strategies at Bayero University Kano and Minjibir during the 2023 rainy season. Sixteen treatments, including various rates of pendimethalin 1.0, 1.5, and 2.0 kg a.i. ha⁻¹; imazethapyr at 100, 125, and 150 g a.i. ha⁻¹ and its combination, hoe weeding and weedy check, were arranged in a randomised complete block design with three replications. Growth parameters, pod yield, and economic indices (net profit and benefit–cost ratio, BCR) were analysed. Results revealed significant ($p < 0.05$) treatment effects on all variables. The combination of pendimethalin at 1.5 kg a.i. ha⁻¹ with either hoe weeding at 6 weeks after sowing (WAS) or imazethapyr at 125 g a.i. ha⁻¹ produced the highest pod yields (1,222–1,398 kg ha⁻¹). These treatments demonstrated superior profitability, generating net returns of ₦290,800–₦315,025 ha⁻¹ and BCR values of 1.91–2.23. Conversely, sole herbicide applications and weedy checks resulted in marginal or negative returns (BCR < 1.0), while two hoe weedings at 3 and 6 WAS achieved comparable yields but incurred higher labour costs. Integrating chemical and mechanical control improves weed suppression and financial sustainability. Integrated weed management using pendimethalin at 1.5 kg a.i. ha⁻¹ plus imazethapyr at 125 g a.i. ha⁻¹ or hoe weeding at 6 WAS maximises groundnut yield and economic returns in the study area.

Keywords: Groundnut; Imazethapyr; Pendimethalin; Return on investment; Weed flora composition

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INTRODUCTION

Groundnut (*Arachis hypogaea* L.) is a major legume crop in sub-Saharan Africa, valued for its high-quality oil and protein content. However, its productivity remains below potential, primarily due to competition from diverse weed species that thrive under the warm and moist conditions of the Sudan Savanna. Weeds such as *Ageratum conyzoides* L., *Commelina benghalensis* L. and *Cynodon dactylon* (L.) Pers. can reduce groundnut yield by 40–80% when left uncontrolled during critical growth stages (Osunleti *et al.*, 2022; Jallow & Manneh, 2025; Kabir *et al.*, 2025). Conventional weed management relies

heavily on manual weeding and single-herbicide use, which are labor-intensive, costly, and environmentally unsustainable (Kaur *et al.*, 2023). Integrated Weed Management (IWM), which combines chemical and cultural control methods, has emerged as a sustainable strategy for enhancing weed suppression while minimizing ecological impacts. Studies have shown that integrating pre-emergence herbicides such as pendimethalin with post-emergence options like imazethapyr, supplemented by timely hoe weeding, effectively reduces weed density and biomass, improves crop vigor, and increases net economic return (Chicham *et*

al., 2020; Shivani *et al.*, 2025). Despite this potential, the field-based performance and profitability of IWM under local weed flora and soil conditions of northern Nigeria remain insufficiently documented.

Weed infestation continues to constrain groundnut production in the Sudan Savanna, where a mixture of annual and perennial species competes aggressively with crops throughout the season. Farmers' dependence on hand weeding remains laborious, inconsistent, and economically inefficient (Shittu *et al.*, 2023; Shittu *et al.*, 2025a, b). The absence of location-specific IWM protocols limits productivity and profitability. Thus, identifying effective herbicide combinations and cultural practices that sustainably suppress weeds without compromising groundnut growth is imperative.

The adoption of integrated weed management is crucial for sustainable groundnut production in this region. Sole chemical control may not ensure season-long weed suppression and can promote herbicide resistance and environmental contamination (Verma & Choudhary, 2020; Reddy *et al.*, 2022), while exclusive manual weeding increases labor costs and reduces profitability. Integrating selective herbicides with strategic hoe weeding can balance efficiency, cost, and sustainability, ensuring broad-spectrum control, minimizing competition during the critical weed interference period, and improving both yield and economic return (Nath *et al.*, 2024; Arshad *et al.*, 2025).

Therefore, this study was conducted to evaluate the efficacy and profitability of integrated weed management strategies in groundnut production under the Sudan Savanna conditions of Nigeria. The specific objectives were to identify the composition of weed species associated with groundnut at different locations; assess the effects of herbicide combinations and manual weeding on weed growth, crop performance, and yield components; determine the most economically viable weed management option based on benefit–cost ratio and net returns of groundnut productivity.

MATERIALS AND METHODS

Experimental Sites

Field experiments were conducted during the 2023 rainy season at two locations within the Sudan Savanna agro-ecological zone of Nigeria. The first site was the Teaching and Research Farm, Faculty of Agriculture, Bayero University Kano (BUK) (11°58.861' N, 8°31.177' E), while the second was the Institute for Agricultural Research (IAR) Farm, Minjibir, Kano State (12°10' N, 8°39' E; 444 m above sea level). Both

locations are characterized by a unimodal rainfall pattern, sandy loam soils, and typical Sudan Savanna vegetation. Meteorological data, including total rainfall, minimum and maximum temperature, relative humidity, and wind speed, were obtained from the Center for Dryland Agriculture (CDA) Meteorological Station for BUK and the IITA weather station for Minjibir. At BUK, the soil was sandy loam (56.9 % sand, 32.6 % silt, 10.6 % clay) with near-neutral pH (6.92), whereas Minjibir had sandy soil (83.2 % sand, 10.1 % silt, 6.7 % clay) with slightly acidic pH (5.87).

Soil Sampling and Analysis

Before sowing, composite soil samples were collected at a depth of 15–30 cm using a soil auger to determine pre-planting soil fertility status. Samples were air-dried, sieved, and analyzed for physical and chemical properties. Soil particle size distribution was determined using the hydrometer method; pH was measured in water using a pH meter; organic carbon by the Walkley–Black method (Black, 1968); and total nitrogen by the Macro-Kjeldahl method (Bremner, 1996). Available phosphorus was analyzed using Bray and Kurtz I method (Bray & Kurtz, 1984), while exchangeable bases were determined using the ammonium saturation method (Chapman, 1965). Organic matter was computed by multiplying the percentage organic carbon by 1.724 (Olmedo *et al.*, 2017).

Treatments and Experimental Design

The experiment consisted of sixteen (16) weed control treatments combining herbicide rates and manual weeding, arranged in a Randomized Complete Block Design (RCBD) with three replications. The treatments comprised of pendimethalin applied at 1.0, 1.5, and 2.0 kg a.i. ha⁻¹; imazethapyr applied at 100, 125, and 150 g a.i. ha⁻¹; combinations of pendimethalin at 1.0, 1.5, and 2.0 kg a.i. ha⁻¹ with imazethapyr at 100, 125, and 150 g a.i. ha⁻¹, respectively; pendimethalin at 1.0, 1.5, and 2.0 kg a.i. ha⁻¹ each combined with one hoe weeding at 6 weeks after sowing (WAS); two hoe weeding at 3 and 6 WAS; a weedy check; and single hoe weeding at either 3 or 6 WAS.

Crop Variety

The groundnut variety SAMNUT 24 was used in this study. Seeds were obtained from the International Institute of Tropical Agriculture (IITA). The variety is early-maturing, resistant to rosette disease, and high-yielding, with pod yield ranging between 2–3 t ha⁻¹ and haulm yield between 2–3 t ha⁻¹ (Vabi *et al.*, 2019).

Cultural Practices

Land Preparation and Plot Layout

Fields at both locations were ploughed, harrowed, and ridged manually at 0.75 m spacing. The total field size measured 28 m × 46 m. Each gross plot measured 3 m × 4 m (12 m²), with a net plot size of 2 m × 1.5 m. A 0.5 m alley separated plots, while 1.5 m separated replicates.

Sowing and Crop Establishment

Three seeds of groundnut were sown per hole at 75 cm × 10 cm spacing and thinned to two plants per stand after emergence. Sowing was conducted manually at the onset of steady rainfall.

Fertilizer Application

Fertilizer was applied at a rate of 20 kg N, 54 kg P₂O₅, and 20 kg K₂O ha⁻¹, supplied as NPK (15:15:15) and SSP (18% P₂O₅). Application was done by band placement two weeks after sowing.

Herbicide Application

Pre-emergence herbicides were applied one day after planting according to treatment specification, while post-emergence herbicides were applied three weeks after sowing using a CP3 knapsack sprayer (15 L capacity) fitted with a flat-fan nozzle. Applications were carried out in the morning under low wind conditions to avoid drift.

Weeding

Manual hoe weeding was conducted as specified in the treatments either once (3 or 6 WAS) or twice (3 and 6 WAS) and as a supplementary operation where required to maintain weed-free conditions.

Harvesting

Harvesting was carried out manually at physiological maturity when pods turned from green to pale yellow. Plants were carefully uprooted, pods detached, and sun-dried to a safe moisture level before shelling and weighing.

Data Collection

Weed Data

Weed data were collected from a 0.5 × 0.5 m quadrat placed randomly within the net plot area at harvest to ascertain the Weed species composition: identified, counted, and classified to determine relative abundance.

The assessment of weed flora composition involved determining species frequency and density through random sampling with a 0.5 × 0.5 m quadrat. Identification was performed following the taxonomic guidelines and conventional procedures established by Akobundu et al. (2016) and Rana and Rana (2018). To ensure botanical accuracy, unidentified specimens were carefully packaged and submitted to the Herbarium of the Department of Plant Science, Bayero University, Kano, for verification against standard herbarium specimens

and botanical catalogs. All identified specimens were subsequently archived for reference.

Crop Growth and Yield Parameters

Data were collected on plant height (cm), number of leaves per plant and number of branches per plant, following standard agronomic procedures for data collection.

Economic Analysis

An economic evaluation of all weed control treatments was conducted to determine profitability the crop production venture. The total cost of production (TC) was computed by summing input and labor costs, including land preparation, herbicide materials, seed, fertilizer, and weeding. The total revenue (TR) was obtained by multiplying the kernel yield (kg ha⁻¹) by the prevailing market price (₦500 per kg).

Profit was calculated as:

$$\text{Profit (₦)} = \text{TR} - \text{TC}$$

and the Benefit–Cost Ratio (BCR) was computed as:

$$\text{BCR} = \frac{\text{TR}}{\text{TC}}$$

to identify the most economically viable treatment.

RESULTS AND DISCUSSION

Weed Flora Composition and Distribution

The result of weed flora associated with groundnut (*Arachis hypogaea* L.) cultivation at Bayero University Kano (BUK) and Minjibir during the 2023 rainy season revealed considerable variation in species composition and relative abundance between the two locations (Table 1). A total of 37 weed species were identified across both sites, comprising 26 broadleaf species, 9 grasses, and 2 sedges. This diversity reflects the influence of soil type, cropping history, and microclimatic variation typical of the Sudan Savanna zone.

At BUK, the most dominant weeds were *Corchorus aestuans* L. (wild jute) and *Cynodon dactylon* (L.) Pers. (Bermuda grass), each recording a very high relative abundance of 76–100%, followed by *Cyperus rotundus* L. (purple nutsedge) with a similar abundance level. These species are known for their aggressive growth, extensive root systems, and adaptability to sandy loam soils. Moderately abundant species (26–50%) included *Boerhavia erecta* L., *Euphorbia heterophylla* L., *Ageratum conyzoides* L., and *Tridax procumbens* L., all common in disturbed arable fields (Adigun & Babalola, 2023; Wahua & Abass, 2024; Hayat et al., 2025). Species exhibiting intermediate dominance (51–75%) were *Ipomoea triloba* L. and *Sigesbeckia orientalis* L., while sparse species (1–25%) included *Amaranthus*

spinosus L., *Commelina benghalensis* L., and *Synedrella nodiflora* (L.) Gaertn. The dominance of perennial grasses and sedges in this location suggests persistent weed pressure and reduced soil disturbance, favoring species capable of vegetative regeneration (Lv *et al.*, 2023).

In contrast, Minjibir had a higher density of annual broadleaf weeds. The most prevalent species were *Alysicarpus rugosus* (Willd.) DC. (one-leaf clove) and *Oldenlandia corymbosa* L. (diamond flower), both showing very high abundance (76–100%), followed by *Mitracarpus villosus* (Sw.) DC. (51–75%) and *Nicotiana rustica* L. (26–50%). Among grasses, *Sorghum halepense* (L.) Pers. (Johnson grass) and *Sporobolus indicus* (L.) R. Br. (smut grass) were moderately abundant (26–50%), while *Eragrostis tremula* (Lam.) Steud. also occurred frequently (26–50%). Volunteer *Vigna unguiculata* (L.) Walp. (cowpea) appeared at low abundance (1–25%), indicating previous legume cropping and seed carry-over. These observations suggest that Minjibir's higher soil moisture and moderate fertility favor the proliferation of annual and short-lived perennial weeds.

Comparatively, BUK was dominated by persistent perennial species (*C. dactylon* (L.) Pers. and *C. rotundus* L. at 76–100% abundance), whereas Minjibir was characterized by annual broadleaves (*A. rugosus* (Willd.) DC. and *O. corymbosa* L. at 76–100%). This contrast highlights the need for site-specific weed management strategies. At BUK, long-term control measures such as crop rotation, deep tillage, and systemic herbicide use are required to manage perennial grasses and sedges. At Minjibir, frequent emergence of annual broadleaf species can be effectively managed using pre-emergence herbicides like pendimethalin or cultural methods such as timely hoe weeding (Baidhawi, 2023; Dash *et al.*, 2025).

Overall, the dominance of *C. dactylon* (L.) Pers, *C. rotundus* L., *C. aestuans* L., *A. rugosus* (Willd.) DC, and *O. corymbosa* L. across both locations underscores their competitive and adaptive nature in groundnut fields. Their persistent occurrence suggests that single-method control is inadequate. Therefore, integrating pre- and post-emergence herbicides (pendimethalin and imazethapyr) with strategic hoe weeding offers the most sustainable solution for season-long weed suppression, aligning with earlier findings by Nath *et al.* (2024) and Arshad *et al.* (2025).

Growth and Yield Response of Groundnut to Weed Management Treatments

The results presented in Table 2 show significant differences ($p < 0.05$) among weed-control

treatments for all growth and yield parameters at both experimental sites. At BUK, plant height ranged from 39.33 cm in the weedy check to 80.63 cm under two hoe weeding's at 3 and 6 WAS. Similarly, at Minjibir, the tallest plants (31.73 cm) were also recorded in plots weeded twice, while the shortest (21.00 cm) occurred in the weedy check. Plots treated with integrated combinations of Pendimethalin at 1.5 kg ha⁻¹ + hoe weeding at 6 WAS and Pendimethalin at 1.5 kg ha⁻¹ + Imazethapyr at 125 g ha⁻¹ produced intermediate plant heights (61.47–63.87 cm at BUK; 30.4–31.3 cm at Minjibir). These results indicate that effective weed suppression minimized early-season competition for light, nutrients, and water, leading to greater vegetative growth. Similar trends were reported by Rastogi *et al.* (2024) and Hirani *et al.* (2025), who observed improved canopy expansion and photosynthetic activity of legumes under integrated weed management systems.

Leaf production followed a comparable pattern. At BUK, the highest leaf count (135.50 leaves plant⁻¹) was recorded under two hoe weeding's, closely followed by Pendimethalin (1.5 kg ha⁻¹) + hoe weeding (131.30 leaves plant⁻¹), whereas the weedy check had the lowest value (79.17 leaves plant⁻¹). At Minjibir, the same treatments produced 96.70 and 94.00 leaves plant⁻¹, respectively, compared with 73.33 leaves plant⁻¹ in the weedy check. The increased leaf area and number of leaves under integrated treatments reflect higher photosynthetic capacity and assimilate production due to reduced weed interference. The combination of herbicides with manual weeding maintained prolonged weed-free periods, supporting vigorous foliage growth an essential factor for pod development and yield in groundnut.

The number of branches per plant, which contributes directly to pod-bearing sites, was significantly affected by treatments ($p < 0.05$) at both locations. The highest branching was recorded in two hoe weeding's (17.27 and 15.97 branches plant⁻¹) and Pendimethalin at 1.5 kg ha⁻¹ + hoe weeding (16.23 and 15.93 branches plant⁻¹), whereas the weedy check had only 11.53 and 12.30 branches plant⁻¹ at BUK and Minjibir, respectively. The combination of Pendimethalin at 1.5 kg ha⁻¹ + Imazethapyr also promoted robust branching (14–16 branches plant⁻¹). This indicates that integrated weed control not only suppresses weed density but also enhances groundnut morphogenesis, likely due to improved root development and nodulation under low competition (Shittu *et al.*, 2023; 2025).

Pod yield was the most responsive indicator of treatment effects. At BUK, yield ranged from 605 kg ha⁻¹ in the weedy check to 1,862 kg ha⁻¹ in the double-hoeing treatment, representing a 208% increase. Integrated methods also produced high yields in the order of Pendimethalin at 1.5 kg ha⁻¹ + hoe weeding (1,529 kg ha⁻¹) and Pendimethalin at 1.5 kg ha⁻¹ + Imazethapyr at 125 g ha⁻¹ (1,404 kg ha⁻¹). A similar trend was recorded at Minjibir, where the highest yield (1,517 kg ha⁻¹) occurred under two hoe weeding, followed by Pendimethalin at 1.5 kg ha⁻¹ + hoe weeding (1,398 kg ha⁻¹), compared with 671 kg ha⁻¹ in the weedy check. The yield advantage of integrated approaches reflects enhanced weed control efficiency, prolonged weed-free periods, and improved resource utilization. Conversely, sole herbicide treatments such as Imazethapyr alone (100–150 g ha⁻¹) produced lower yields (665–710 kg ha⁻¹ at BUK; 692–783 kg ha⁻¹ at Minjibir), likely due to partial weed suppression and late-season interference. These outcomes agree with findings by Shivani *et al.* (2023), Kaur *et al.* (2024), and Arshad *et al.* (2025), who reported that combining pre-emergence and post-emergence herbicides with mechanical weeding optimizes weed control and yield performance in legumes.

Growth and yield were generally higher at BUK than Minjibir, except under two hoe weeding where yields were comparable. This is attributable to soil differences: BUK's sandy loam (56.9 % sand, 32.6 % silt, 10.6 % clay) with near-neutral pH (6.92) and higher fertility supported stronger vegetative growth, whereas Minjibir's sandy, slightly acidic soil (83.2 % sand, 10.1 % silt, 6.7 % clay; pH 5.87) limited plant size despite effective weed control. Treatments combining pendimethalin at 1.5 kg ha⁻¹ with imazethapyr at 125 g ha⁻¹ or hoe weeding at 6 WAS consistently achieved superior performance, confirming that IWM optimizes productivity across variable soil conditions.

Economic Analysis

The benefit–cost analysis presented in Tables 3 and 4 revealed notable differences among weed-control treatments across locations, reflecting the economic efficiency of integrating herbicide and manual control strategies. At BUK, integrated weed management treatments significantly outperformed the weedy check (₦ 5,750; BCR = 0.97), which recorded a negative return due to severe yield loss (443 kg ha⁻¹) under uncontrolled weed growth. Among all treatments, the combination of Pendimethalin at 1.5 kg a.i. ha⁻¹ + Imazethapyr at 125 g ha⁻¹ produced the

highest net profit (₦315,025 ha⁻¹) and BCR (2.23). This implies that for every ₦1.00 invested, the farmer realized an average return of ₦2.23, representing a net gain of ₦1.23 after recovering all production costs. The next most profitable treatments were Pendimethalin at 1.5 kg ha⁻¹ + hoe weeding at 6 WAS (₦290,800; BCR = 1.91) and two hoe weeding at 3 and 6 WAS (₦288,000; BCR = 1.74), meaning each ₦1 spent generated ₦1.91 and ₦1.74, respectively. Moderate profitability was also recorded under Pendimethalin at 1.0 kg ha⁻¹ + Imazethapyr at 100 g ha⁻¹, which returned ₦1.95 per ₦1 invested, equivalent to a ₦0.95 profit margin.

In contrast, sole applications of Imazethapyr at 100–150 g ha⁻¹ resulted in very low profits (₦20,075–₦43,825 ha⁻¹) and marginal BCR values (1.09–1.19), indicating minimal returns of just ₦0.09–₦0.19 for every ₦1 invested. This clearly demonstrates the inefficiency of relying on a single herbicide without mechanical support for prolonged weed control.

At Minjibir, the same treatment combinations maintained their superior performance. Pendimethalin at 1.5 kg ha⁻¹ + Imazethapyr at 125 g ha⁻¹ achieved the highest net profit (₦251,050 ha⁻¹) and BCR (1.98), meaning each ₦1 spent returned almost ₦2.00, with a net gain of ₦0.98 after cost recovery. Other integrated treatments, such as Pendimethalin at 1.5 kg ha⁻¹ + hoe weeding at 6 WAS (₦227,900; BCR = 1.71) and two hoe weeding (₦236,025; BCR = 1.61), also yielded high financial returns. In practical terms, this indicates that for every ₦1 invested, farmers earned between ₦1.59 and ₦1.89, confirming that integrated weed management provides stronger economic leverage compared to single-method weed control. Conversely, the weedy check (₦–55,100; BCR = 0.76) and sole Imazethapyr treatments (₦–28,250 to ₦–43,650; BCR = 0.81–0.88) were uneconomical, as returns failed to offset input costs due to poor weed suppression and reduced pod yields (379–413 kg ha⁻¹).

Overall, profitability was higher at BUK than at Minjibir, likely due to better soil fertility and moisture conditions that improved groundnut response to weed management. Nevertheless, the consistency in treatment ranking across sites confirms the reliability of Pendimethalin-based integrated weed management as a robust, cost-effective strategy for the Sudan Savanna environment. These results align with the findings of Verma and Choudhary (2020), Kaur *et al.* (2024), and Shittu and Lamarana (2024), who reported that integrating chemical and cultural weed control improves cost recovery, resource-use

efficiency, and long-term profitability. The high BCR values (>1.5) obtained in this study demonstrate that integrated approaches are not only agronomically

superior but also financially sustainable, providing tangible economic benefits to groundnut farmers in northern Nigeria.

Table 1: Composition of weed flora associated with groundnut cultivation at BUK and Minjibir locations during 2023 Rainy Season

Weeds	Common Name	BUK	Minjibir
Broadleaf			
<i>Adenostemma lavenia</i> (L.) Kuntze	Sticky adenostemma	*	-
<i>Ageratum conyzoides</i> L.	Goatweed	**	*
<i>Alysicarpus rugosus</i> (Willd.) DC	One-leaf clove	-	****
<i>Amaranthus spinosus</i> L.	Spiny amaranth	*	*
<i>Boerhavia erecta</i> L.	Erect spiderling	**	-
<i>Clitoria ternatea</i> L.	Butterfly pea	**	-
<i>Commelina benghalensis</i> L.	Bengal dayflower	*	**
<i>Commelina diffusa</i> Burm. f.	Spreading dayflower	*	**
<i>Convolvulus arvensis</i> L.	Field bindweed	*	-
<i>Corchorus aestuans</i> L.	Wild jute	****	*
<i>Cyanthillium cinereum</i> (L.) H. Rob.	Little ironweed	**	-
<i>Eclipta prostrata</i> (L.) L.	False daisy	*	**
<i>Euphorbia heterophylla</i> L.	Mexican fireplant	**	-
<i>Gomphrena serrata</i> L.	Globe amaranth	**	-
<i>Ipomoea triloba</i> L.	Littlebell morning glory	***	*
<i>Mitracarpus villosus</i> (Sw.) DC.	Hairy girdlepod	-	***
<i>Nicotiana rustica</i> L.	Wild tobacco	-	**
<i>Oldenlandia corymbosa</i> L.	Diamond flower	-	****
<i>Senna obtusifolia</i> (L.) H.S. Irwin & Barneby	Sicklepod	*	-
<i>Sida acuta</i> Burm. f.	Common wireweed	*	-
<i>Sigesbeckia orientalis</i> L.	St. Paul's wort	*	**
<i>Silene latifolia</i> Poir.	White campion	*	-
<i>Synedrella nodiflora</i> (L.) Gaertn.	Cinderella weed	*	**
<i>Tridax procumbens</i> L.	Coat buttons	**	-
<i>Trifolium angustifolium</i> L.	Narrowleaf clove	-	**
<i>Vigna unguiculata</i> (L.) Walp.	Cowpea (volunteer)	*	*
<i>Zinnia elegans</i> Jacq.	Garden zinnia	*	-
Grasses			
<i>Cenchrus echinatus</i> L.	Spiny burr grass	*	-
<i>Cynodon dactylon</i> (L.) Pers.	Bermuda grass	****	**
<i>Dactyloctenium aegyptium</i> (L.) Willd.	Crowfoot grass	**	-
<i>Digitaria sanguinalis</i> (L.) Scop.	Large crabgrass	*	-
<i>Eragrostis tremula</i> (Lam.) Steud	Trembling lovegrass	-	**
<i>Hemarthria altissima</i> (Poir.) Stapf & C.E. Hubb.	Limpo grass	*	-
<i>Setaria viridis</i> (L.) P. Beauv.	Green foxtail	*	-
<i>Sorghum halepense</i> (L.) Pers.	Johnson grass	*	**
<i>Sporobolus indicus</i> (L.) R. Br.	Smut grass	*	**
<i>Tragus berteronianus</i> Schult.	Small carrot-seed grass	*	**
Sedges			
<i>Cyperus compressus</i> L.	Flat sedge	*	-
<i>Cyperus rotundus</i> L.	Purple nutsedge	****	**

1 – 25 % = *, 26 – 50 % = **, 51 – 75 % = *** and 76 – 100 % = ****

Table 2: Effect of Weed control treatments on plant height, Number of leaves per plant, Number of branches and Pod yield of Groundnut at BUK and Minjibir in 2023 Rainy Season

Treatments	BUK					Minjibir				
	Plant height (cm)	Number of Leaves per plant	Number of branches per plant	Pod yield (kg ha ⁻¹)		Plant height (cm)	Number of Leaves per plant	Number of branches per plant	Pod yield (kg ha ⁻¹)	
Imazethapyr at 100 g ha ⁻¹	40.00 ^{de}	100.53 ^{cd}	11.87 ^b	665 ^f		22.20 ^{de}	76.00 ^{de}	12.60 ^b	692 ^e	
Imazethapyr at 125 g ha ⁻¹	40.83 ^{de}	107.87 ^c	13.10 ^{ab}	686 ^f		24.73 ^{cde}	76.03 ^{de}	12.73 ^{ab}	713 ^e	
Imazethapyr at 150 g ha ⁻¹	41.57 ^{de}	108.87 ^c	13.43 ^{ab}	710 ^f		25.10 ^{cde}	77.00 ^{cde}	12.97 ^{ab}	783 ^{de}	
Pendimethalin at 1.0 kg a.i. ha ⁻¹	49.63 ^{b-e}	113.73 ^{bc}	13.77 ^{ab}	768 ^{def}		26.27 ^{cd}	84.20 ^{bcd}	13.50 ^{ab}	1,015 ^{cde}	
Pendimethalin at 1.5 kg a.i. ha ⁻¹	51.73 ^{b-e}	115.10 ^{bc}	13.87 ^{ab}	863 ^{def}		27.00 ^{bcd}	89.10 ^{ab}	13.97 ^{ab}	1,158 ^{cde}	
Pendimethalin at 2.0 kg a.i. ha ⁻¹	50.67 ^{b-e}	115.07 ^{bc}	13.77 ^{ab}	845 ^{def}		27.00 ^{bcd}	86.20 ^{abc}	13.87 ^{ab}	1,017 ^{cde}	
Pendimethalin at 1.0 kg a.i. ha ⁻¹ + HW at 6 WAS	60.53 ^{bc}	120.63 ^b	15.10 ^{ab}	1,262 ^{a-d}		29.5 ^{abc}	92.67 ^{ab}	14.87 ^{ab}	1279 ^{bcd}	
Pendimethalin at 1.0 kg a.i. ha ⁻¹ + Imazethapyr 100 g ha ⁻¹	55.20 ^{bcd}	118.20 ^{bc}	14.30 ^{ab}	1,194 ^{bcd}		27.63 ^b	92.23 ^{ab}	14.73 ^{ab}	1,256 ^{bcd}	
Pendimethalin at 1.5 kg a.i. ha ⁻¹ + HW at 6 WAS	63.87 ^b	131.30 ^{ab}	16.23 ^{ab}	1,529 ^{ab}		31.33 ^{ab}	94.00 ^{ab}	15.93 ^a	1,398 ^{ab}	
Pendimethalin at 1.5 kg a.i. ha ⁻¹ + Imazethapyr 12 5g ha ⁻¹	61.47 ^{bc}	129.73 ^{ab}	16.10 ^{ab}	1,404 ^{abc}		30.40 ^{abc}	92.90 ^{ab}	14.97 ^{ab}	1,333 ^{bc}	
Pendimethalin at 2.0 kg a.i. ha ⁻¹ + HW at 6 WAS	53.43 ^{b-e}	116.87 ^{bc}	14.10 ^{ab}	1,034 ^{bcd}		27.30 ^b	92.23 ^{ab}	14.30 ^{ab}	1,244 ^{bcd}	
Pendimethalin at 2.0 kg a.i. ha ⁻¹ + Imazethapyr 150 g ha ⁻¹	52.97 ^{b-e}	116.40 ^{bc}	13.87 ^{ab}	950 ^{cde}		27.20 ^{bcd}	89.57 ^{ab}	14.30 ^{ab}	1,167 ^{cde}	
HW at 3 WAS only	49.23 ^{cde}	112.07 ^{bc}	13.67 ^{ab}	888 ^{def}		25.40 ^{cde}	84.00 ^{bcd}	13.20 ^{ab}	800 ^{de}	
HW at 6 WAS only	48.10 ^{cde}	108.87 ^c	13.53 ^{ab}	792 ^{def}		25.40 ^{bcd}	82.90 ^{bcd}	13.10 ^{ab}	785 ^{de}	
HW at 3 and 6 WAS	80.63 ^a	135.50 ^a	17.27 ^a	1,862 ^a		31.73 ^a	96.70 ^a	15.97 ^a	1,517 ^a	
Weedy Check	39.33 ^e	79.17 ^d	11.53 ^b	605 ^f		21.00 ^e	73.33 ^e	12.30 ^b	671 ^e	
p-value	<.001	0.035	0.045	<.001		<.001	<.001	0.004	<.001	
SE±	3.30	3.85	0.76	122.5		1.21	2.26	0.64	65.50	

Means followed by the same letter(s) within the same column are not significantly different at 5 % level of probability using SNK

Table 3: Economic Performance and Benefit–Cost Analysis of Weed Control Treatments in Groundnut at Bayero University Kano (BUK) during the 2023 Rainy Season

Treatments	Yield (kg ha ⁻¹)	Total Cost (₦)	Total Revenue (₦)	Net Profit (₦)	BCR
Imazethapyr at 100 g ha ⁻¹	504	232,000	252,075	20,075	1.09
Imazethapyr at 125 g ha ⁻¹	517	233,250	258,300	25,050	1.11
Imazethapyr at 150 g ha ⁻¹	557	234,500	278,325	43,825	1.19
Pendimethalin at 1.0 kg a.i. ha ⁻¹	762	242,300	381,225	138,925	1.57
Pendimethalin at 1.5 kg a.i. ha ⁻¹	821	250,000	410,400	160,400	1.64
Pendimethalin at 2.0 kg a.i. ha ⁻¹	791	257,600	395,400	137,800	1.53
Pendimethalin at 1.0 kg a.i. ha ⁻¹ + HW at 6 WAS	1,062	312,300	530,850	218,550	1.70
Pendimethalin at 1.0 kg a.i. ha ⁻¹ + Imazethapyr 100 g ha ⁻¹	966	247,300	482,925	235,625	1.95
Pendimethalin at 1.5 kg a.i. ha ⁻¹ + HW at 6 WAS	1,222	320,000	610,800	290,800	1.91
Pendimethalin at 1.5 kg a.i. ha ⁻¹ + Imazethapyr 12.5 g ha ⁻¹	1,143	256,250	571,275	315,025	2.23
Pendimethalin at 2.0 kg a.i. ha ⁻¹ + HW at 6 WAS	1,026	327,600	512,925	185,325	1.57
Pendimethalin at 2.0 kg a.i. ha ⁻¹ + Imazethapyr 150 g ha ⁻¹	983	265,100	491,700	226,600	1.85
HW at 3 WAS only	631	287,000	315,450	28,450	1.10
HW at 6 WAS only	612	297,000	306,225	9,225	1.03
HW at 3 and 6 WAS	1,350	387,000	675,000	288,000	1.74
Weedy Check	443	227,000	221,250	- 5,750	0.97

HW =Hoe Weeding. WAS = Weeks after sowing

Table 4: Economic Performance and Benefit–Cost Analysis of Weed Control Treatments in Groundnut at Minjibir during the 2023 Rainy Season

Treatments	Yield (kg ha ⁻¹)	Total Cost (₦)	Total Revenue (₦)	Net Profit (₦)	BCR
Imazethapyr at 100 g ha ⁻¹	379	232,000	189,600	- 42,400	0.82
Imazethapyr at 125 g ha ⁻¹	379	233,250	189,600	- 43,650	0.81
Imazethapyr at 150 g ha ⁻¹	413	234,500	206,250	- 28,250	0.88
Pendimethalin at 1.0 kg a.i. ha ⁻¹	754	242,300	377,100	134,800	1.56
Pendimethalin at 1.5 kg a.i. ha ⁻¹	794	250,000	396,900	146,900	1.59
Pendimethalin at 2.0 kg a.i. ha ⁻¹	771	257,600	385,425	127,825	1.50
Pendimethalin at 1.0 kg a.i. ha ⁻¹ + HW at 6 WAS	1004	312,300	502,050	189,750	1.61
Pendimethalin at 1.0 kg a.i. ha ⁻¹ + Imazethapyr 100 g ha ⁻¹	835	247,300	417,675	170,375	1.69
Pendimethalin at 1.5 kg a.i. ha ⁻¹ + HW at 6 WAS	1096	320,000	547,900	227,900	1.71
Pendimethalin at 1.5 kg a.i. ha ⁻¹ + Imazethapyr 12.5 g ha ⁻¹	1015	256,250	507,300	251,050	1.98
Pendimethalin at 2.0 kg a.i. ha ⁻¹ + HW at 6 WAS	810	327,600	405,225	77,625	1.24
Pendimethalin at 2.0 kg a.i. ha ⁻¹ + Imazethapyr 150 g ha ⁻¹	802	265,100	401,025	135,925	1.51
HW at 3 WAS only	588	287,000	293,775	6,775	1.02
HW at 6 WAS only	571	297,000	285,450	- 11,550	0.96
HW at 3 and 6 WAS	1246	387,000	623,025	236,025	1.61
Weedy Check	344	227,000	171,900	-55,100	0.76

HW = Hoe Weeding WAS = Weeks after sowing

CONCLUSION

The study demonstrated that integrated weed management combining selective herbicides with

timely hoe weeding significantly improved groundnut growth, pod yield, and profitability in the Sudan Savanna of Nigeria. Treatments integrating

pendimethalin at 1.5 kg a.i. ha⁻¹ with either imazethapyr at 125 g a.i. ha⁻¹ or hoe weeding at 6 WAS consistently outperformed single-herbicide or manual methods, providing the highest net returns and benefit–cost ratios. Sole herbicide use or unmanaged plots were uneconomical. These results confirm that combining chemical and mechanical weed control effectively suppresses both broadleaf and grass weeds, prolongs weed-free periods, and maximizes economic returns. Adoption of pendimethalin at 1.5 kg a.i. ha⁻¹ integrated with either imazethapyr at 125 g a.i. ha⁻¹ or a single hoe weeding at 6 WAS is therefore recommended as an optimal strategy for sustainable and profitable groundnut production in the Sudan Savanna.

Author Contributions

IMM and EAS conducted the research, collected the data, and performed the first draft of the manuscript. TTB designed and supervised the research, performed the formal analysis, and oversaw data visualization. IMM and EAS contributed to the research design, performed data validation. EAS revised the draft manuscript. All authors proofread and approved the final manuscript.

Competing interests

The authors declare that there was no competing interest.

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REFERENCES

Adigun M. O., & Babalola O. A. (2023). Effects of Weed Management on Soil Microbiological Properties in Groundnut Production. *Microbiology Research Journal International* 33 (12), 1-13. <https://doi.org/10.9734/mrji/2023/v33i11-121416>.
Akobundu, O., I. Ekeleme, F., Agyakwa, C. W., & Ogazie, C. A. (2016). A handbook of West African Weeds (3rd Edition). International Institute of Tropical Agriculture.
Arshad, M. A., Abbas, R. N., Baloch, R., Ahmad, A., Zulfiqar, U., El-Beltagi, H. S., Alomran, M.M., & Vara Prasad, P. V. (2025). Assessing herbicide efficacy and selectivity for weed management and enhancing the production of non-GMO soybean cultivation. *Archives of Agronomy and Soil Science*, 71(1), 1–23. <https://doi.org/10.1080/03650340.2025.2554157>

Baidhawi. (2023). The Effectiveness of Mixing Herbicides and Manual Weed Control on Corn (*Zea mays* L). *Jurnal Agrium*, 20 (2), 185-193

Bray, R.H. & Kurtz, L.T. (1984). Determination of total, organic and available forms of phosphorus in soils. *Soil Science*, 59, 39-45, 1945.

[Chapman](#), H.D. (1965). Cation-Exchange Capacity. Chapter 57. Book Series: [Agronomy Monographs](#). Book Editor(s): [A. G. Norman](#). <https://doi.org/10.2134/agronmonogr9.2.c6>.

Chicham, S., Bhadauria, S.S., Sakya, N., Gaur, D., Dang, R.S., Mahor, S., Kirar, N.S., Rawat, G.S., Sharma, J. & Roi, A., (2020). Effect of chemical weed management practices on black gram under sandy clay loam soils of Madhya Pradesh, India. *International Journal of Chemical Studies*, 8(3), 1923-1928. <https://doi.org/10.22271/chemi.2020.v8.i3aa.9486>

Dash, R., Das, K., Tripathy, S., Panda, N., & Kar, I. (2025). Effect of Herbicidal Weed Management on Productivity and Profitability of Summer Cowpea. *Indian Journal of Agricultural Research*. 59(5), 748-751. <https://doi.org/10.18805/IJARE.A-6089>.

Hayat, Q., Ali, Z., Awais, M., Shaheen, M.F. (2025). Multivariate analysis for morphological traits of *Cyperus rotundus*. *Journal of Life Social Science*, 4, 43
Hirani, A. K., Korav, S., Rajanna, G. A., Elansary, H. O., & Mahmoud, E. A. (2024). Determination of critical crop-weed competition period: Impact on growth, nutrient dynamics and productivity of green gram (*Vigna radiata*). *Heliyon*, 10(17), e36855. <https://doi.org/10.1016/j.heliyon.2024.e36855>

<https://doi.org/10.3389/fsufs.2023.1271340>
Jallow S.A.F. & Manneh F.J. (2025). Response of Groundnut (*Arachis hypogaea* L.) Varieties to Critical Period of Crop-Weed Interference in West Coast Region of The Gambia. *European Scientific Journal*, 21 (12), 73. <https://doi.org/10.19044/esj.2025.v21n12p73>

Kabir, M. M., Bello, T. T., & Shittu, E. A. (2025). Weed Species Composition and Profitability of Groundnut (*Arachis hypogaea* L.) Production as Affected by Variety and Intra-Row Spacing in Kano, Sudan Savannah, Nigeria. *African Journal of Agricultural Science and Food Research*, 18(1), 47-58. <https://doi.org/10.62154/ajasfr.2025.018.010615>

Kaur S, Schwartz-Lazaro LM, Werle R and Cordeau S (2023) Editorial: Integrated weed management for reduced weed infestations in sustainable cropping systems. *Frontiers in Agronomy*, 5, 1301564. <https://doi.org/10.3389/fagro.2023.1301564>

- Kaur, R., Bana, R.S., Singh, T., Meena, S.L, Raj, R., Dass, A., Govindasamy, P., Gill, J.S., Kumar, S., Sen, S., Kumar, S., Choudhary, A.K. & Das, T.K. (2024) Sequential herbicide application coupled with mulch enhances the productivity and quality of winter onion (*Allium cepa* L.) while effectively controlling the mixed weed flora. *Frontiers in Sustainable Food System*, 7, 1271340.
- Lv, G., He, M., Wang, C., & Wang, Z. (2023). The stability of perennial grasses mediates the negative impacts of long-term warming and increasing precipitation on community stability in a desert steppe. *Frontiers in Plant Science*, 14, 1235510. <https://doi.org/10.3389/fpls.2023.1235510>
- Nath, C. P., Singh, R. G., Choudhary, V. K., Datta, D., Nandan, R., & Singh, S. S. (2024). Challenges and Alternatives of Herbicide-Based Weed Management. *Agronomy*, 14(1), 126. <https://doi.org/10.3390/agronomy14010126>
- Osunleti, S. O., Ajani, O. A., Olaogun, O., Osunleti, T. O., & Olatunde, E. O. (2022). Assessing the critical period of weed interference in groundnut (*Arachis hypogaea* L.) in Ogun State, South western Nigeria. 25(3), 219–225. <https://doi.org/10.15414/afz.2022.25.03.219-225>
- Rana, S. S. & Rana, M. C. (2018). Principles and Practices of Weed Management. Department of Agronomy, College of Agriculture, CSK Himachal Pradesh Krishi Vishwavidyalaya, Palampur. 29-138. <http://doi.org/10.13140/RG.2.2.27494.01603>
- Rastogi, M., Vivek, Dhyani, B., Kumar, M., Singh, A., & Verma, S. (2024). The Impact of Integrated Weed Management Practices on Nutrient Uptake in Rice (*Oryza sativa* L.). *Journal of Scientific Research and Reports*, 30(10), 169–176. <https://doi.org/10.9734/jsrr/2024/v30i102443>
- Reddy, K.S., Tyagi, D.B., Sharma, J.D., Kumar, S.P., & Teja, M.S. (2022). Effect of Pre and Post-Emergence Herbicide Applications on Growth, Yield and Economics of Black Gram (*Vigna mungo* L.) and Reduction in Weed Growth. *Environment and Ecology*, 40 (4A), 2183-2187.
- Shittu, E. A. & Lamarana, L. B. (2024). Analysis of effectiveness and profitability of selected weed control methods for cowpea [*Vigna unguiculata* (L.) Walp] production in the Sudan savanna ecology of Nigeria. *Journal of Agricultural Economics, Environment and Social Science*, 10 (2):1-12.
- Shittu, E.A., Basse, M.S., & Babayola, M. (2023). Physiological Growth Indices and Yield Attributes of Groundnut (*Arachis hypogaea* L.) Varieties as Affected by Weed Control Methods and Season in Northern Guinea Savanna Ecology, Nigeria. *International Academy Journal of Agribusiness and Agricultural Science Annals*, 6 (2), 29-48.
- Shittu, E.A., Bello, T.T., & Atta, A.D. (2025b). Weed dynamics and yield of groundnut (*Arachis hypogaea* L.) as influenced by variety and plant population. *FNAS Journal of Basic and Environmental Research*, 2(3), 86-94. <https://doi.org/10.63561/jber.v2i3.829>
- Shittu, E.A., Bello, T.T., & Basse, M.S. (2025a). Impact of weed management strategies on soil chemical properties, fertility dynamics, and sesame (*Sesamum indicum* L.) productivity in a semi-arid environment. *FNAS Journal of Applied Chemical Science Research*, 2(3), 45-54. <https://doi.org/10.63561/jacsr.v2i3.804>
- Shivani, Grewal, S. K., Gill, R. K., Kaur Virk, H., & Bhardwaj, R. D. (2022). Impact of post-emergent imazethapyr on morpho-physiological and biochemical responses in lentil (*Lens culinaris* Medik.). *Physiology and molecular biology of plants: an international journal of functional plant biology*, 28(9), 1681–1693. <https://doi.org/10.1007/s12298-022-01244-x>
- Vabi, B. M., Mohammed, S. G., Echekwu, C. A., Mukhtar, A. A., Ahmed, B., Ajeigbe, H. A. & Eche, C. O. (2019). *Best choices for enhancing groundnut productivity in Nigeria*. Patancheru, India: ICRISAT.
- Verma, A., & Choudhary, R. (2020) Effect of weed management practices on weed growth and yield of green gram (*Vigna radiata* (L.) Wilczek) in Southern Rajasthan. *International Research Journal of Pure and Applied Chemistry*, 21 (20), 12-19.
- Wahua, C., and Abass, M. (2024). Comparative morpho-anatomy of two sedges (*Cyperus cyperoides* (L.) Kuntze and *Cyperus rotundus*. *Scientia Africana*, 23, 104-111.