



Research Article

Weed Flora Dynamics, Control Strategies and Varietal Response of Soybean (*Glycine max* L.) Productivity in the Sudan Savanna of Nigeria

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ABSTRACT

A field study was conducted during the 2022 rainy season at Bayero University Kano and Bunkure, in Nigeria's Sudan savanna, to evaluate weed flora dynamics, control treatments, and varietal performance on soybean. The experiment employed a split-plot design with seven weed control treatments comprising of pendimethalin at 1.0 and 1.5 kg a.i. ha⁻¹, imazethapyr at 100 g a.i. ha⁻¹, pendimethalin at 1.0 kg a.i. ha⁻¹ + imazethapyr at 100 g a.i. ha⁻¹, pendimethalin at 1.0 kg a.i. ha⁻¹ + hoe weeding at 6 weeks after sowing (WAS), hoe weeding at 3 and 6 WAS, and weedy check as main plots, and three soybean varieties (TGX-1448-2E, TGX-1835-10E, and TGX-1951-3F) as subplots. Results identified nineteen weed species, with broadleaf weeds like *Ipomoea* spp. and *Cirsium vulgare* predominating, while sedges such as *Cyperus rotundus* were more prevalent at Bunkure. Hoe weeding at 3 and 6 WAS and the integrated application of pendimethalin at 1.0 kg a.i. ha⁻¹ + imazethapyr at 100 g a.i. ha⁻¹ achieved the highest weed control indices (>70%) and lowest weed biomass. These treatments significantly enhanced leaf area index, pod weight, and seed yield (>2.6 t ha⁻¹), compared to the weedy check (<1.0 t ha⁻¹). Among varieties, TGX-1951-3F exhibited superior canopy development, weed competitiveness, and yield potential. Integrating herbicide use, specifically pendimethalin at 1.0 kg a.i. ha⁻¹ + imazethapyr at 100 g a.i. ha⁻¹, offers an efficient, less labor-intensive alternative to manual hoeing. Consequently, this integrated approach is recommended for sustainable and economically viable soybean production in the Sudan savanna.

Keywords: Herbicide efficiency; Integrated weed management; Soybean productivity; Varietal competitiveness; Weed control index; Weed flora dynamics

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INTRODUCTION

Soybean (*Glycine max* L.) is a globally important legume valued for its high protein and oil content, contributing to food, feed, and industry. In Nigeria, soybean enhances food security, farmer incomes, and agricultural diversification. The Sudan Savannah, with favorable rainfall and soils, holds potential for soybean expansion, yet yields remain below potential due to two major constraints: severe weed pressure and limited adoption of competitive, high-yielding varieties (Mühlbachová *et al.*, 2023; Usman & Talha Ramzan, 2025). Weeds can cause yield losses of 20-80% depending on severity, competing aggressively for light, water, and nutrients, which delays crop

maturity and lowers grain quality (Stefanic *et al.*, 2022; Caldas *et al.*, 2023).

Manual weeding, though traditional, is labor-intensive, costly, and hampered by rural labor shortages (Islam *et al.*, 2024). Herbicides have emerged as effective alternatives due to their timeliness and efficiency. Pre-emergence herbicides such as Pendimethalin, Butachlor, and S-Metolachlor have proven effective in soybean and other legumes (Shittu *et al.*, 2023; Ayoola & Ilesanmi, 2025). Pendimethalin, in particular, effectively controls annual grasses and broadleaf weeds when applied pre- or early post-emergence (Kanas *et al.*, 2020)

Recent studies emphasize the effectiveness of integrated weed management in grain legumes. In field trials across southern Europe, flumioxazin suppressed >70% of weeds, while benfluralin produced the highest grain yields across legumes (Kousta *et al.*, 2024). Similarly, in southwest Nigeria, hoe weeding combined with pendimethalin and Butachlor + Imazamox reduced weed biomass by over 60% and increased soybean yield by 27–35% compared with the weedy check (Ayoola & Ilesanmi, 2025). Mensah *et al.* (2023) found that integrating TGX 1951-3F with pre-emergence pendimethalin resulted in a 42% yield increase in Ghana's Guinea Savanna, highlighting the synergistic benefits of varietal choice and chemical weed control.

Varietal selection also plays a critical role in productivity. Soybean varieties differ in canopy architecture, plant height, and phenology, which influence their competitiveness with weeds and adaptability to local environments (Fattah *et al.*, 2023; 2024). In recent trials, the variety TGX 1951-3F produced higher leaf area index, lower weed dry weight, and greater pod yield than other varieties, demonstrating superior competitive ability under both weedy and weed-free conditions (Ene *et al.*, 2019). Despite such potential, adoption of improved varieties remains low, partly due to limited testing under diverse local agro-ecologies and weak dissemination systems. While weed management practices and varietal improvement have been studied individually, their combined effect under Sudan Savannah conditions remains poorly understood. This gap limits the development of effective recommendations for farmers.

Therefore, this study evaluates the performance of soybean varieties under different weed control strategies, with specific objectives to: (i) assess the efficacy of manual, chemical, and integrated weed management on weed suppression and yield; (ii) evaluate the growth and yield of soybean varieties under local conditions; and (iii) determine the interaction between weed control strategies and varietal performance. The outcomes are expected to provide practical, evidence-based recommendations that enhance soybean productivity, improve resource use efficiency, and strengthen food security in Nigeria's Sudan Savannah.

MATERIALS AND METHODS

A field experiment was conducted during the 2022 rainy season at two locations in the Sudan Savanna: the CDA Research Farm, Bayero University Kano (11.0983° N, 8.0415° E, 481 m asl) and a community

demonstration farm Bunkure, Kano (11° 41' N and 8° 32' E, 486 m asl). The zone is characterized by monomodal rainfall ranging between 500 and 800 mm annually, a 100-120-day growing season, mean temperatures of 28-32 °C, and soils that are generally low in organic matter, cation exchange capacity, and essential nutrients.

The experiment consisted of seven weed control treatments [Pendimethalin at 1.0 and 1.5 kg a.i. ha⁻¹, Imazethapyr at 100 g a.i. ha⁻¹, Pendimethalin (1.0 kg) + Imazethapyr (100 g), Pendimethalin (1.0 kg) + hoe weeding (HW) at 6 WAS, hoe weeding at 3 and 6 WAS, and an untreated check] evaluated across three soybean varieties (TGX-1448-2E, TGX-1835-10E, and TGX-1951-3F). The varieties differ in maturity, resistance, and yield potential, with TGX-1448-2E being medium maturing, high yielding, and low shattering; TGX-1835-10E early maturing and rust resistant; and TGX-1951-3F medium maturing and tolerant to rust and bacterial pustule. Treatments were arranged in a split-plot design with weed control assigned to the main plots and varieties to the subplots, replicated three times.

Prior to land preparation, composite soil samples were randomly collected at 0–30 cm depth, air-dried, sieved, and analyzed for physical and chemical properties following standard procedures. The experimental fields were then ploughed, harrowed, and ridged at 75 cm spacing. Each gross plot measured 2 × 4.5 m while the net plot measured 2 × 1.5 m, with alley of 0.5 m between plots and 1.5 m between replications. Soybean seeds sourced from IITA were sown at an inter- and intra-row spacing of 75 × 10 cm at three seeds per hole and later thinned to two seedlings per stand at 2 WAS. Fertilizer was applied at the rate of 20 kg N, 40 kg P₂O₅, and 20 kg K₂O ha⁻¹ using NPK (15:15:15) and SSP. Herbicides were applied with a CP3 knapsack sprayer fitted with a flat-fan nozzle calibrated to deliver 250 L ha⁻¹ at 2.1 kg cm⁻². Pre-emergence herbicides were sprayed one day after sowing, and post-emergence imazethapyr was applied at 3 WAS, while hoe weeding was conducted according to treatment combinations. Harvesting was done at physiological maturity when pods turned pale yellow with reduced moisture content.

Data collected covered growth, yield, and weed parameters. Growth parameters included plant height, number of leaves per plant, leaf area index (LAI), and days to 50% flowering. Plant height and number of leaves were measured from five tagged plants per plot at 9 WAS. LAI was recorded at 9 WAS using an AccuPAR LP-80 ceptometer, measured above

and below the canopy, while days to 50% flowering were taken as the number of days from sowing until half of the plants per plot had flowered. Yield parameters included number of pods per plant and pod yield. Pods per plant were counted from five tagged plants at 12 WAS, while pod yield was determined from the net plots, weighed using a Mettler Toledo SB 8001 monobloc balance, and converted to kilograms per hectare. Weed parameters included weed dry weight, weed index, and weed control efficiency, computed following standard procedures.

All data generated were subjected to analysis of variance (ANOVA) using GenStat (17th edition). Treatment means showing significant differences were separated using the Student Newman-Keuls (SNK) test at the 5% probability level.

RESULTS AND DISCUSSION

Weed studies

Weed Species Composition

Table 1 presents the weed species composition and their infestation levels in soybean fields at BUK and Bunkure during the 2022 rainy season. The results revealed notable variations in weed flora across the two locations, reflecting differences in soil conditions, cropping history, and management practices as previously highest by Shittu *et al.* (2023) A total of nineteen weed species were identified across both sites, comprising grasses (narrow-leaved), broadleaf weeds, and sedges.

At BUK, narrow-leaved weeds such as *Cynodon dactylon* (Bermuda grass) and *Setaria pumila* (Yellow foxtail) exhibited high infestation levels (51–75%), indicating their strong adaptability and persistence under the local conditions. Conversely, *Echinochloa crus-galli* (L.) *P. beauv.* was absent at BUK but dominated at Bunkure with high infestation, suggesting a site-specific occurrence likely influenced by soil moisture and fertility differences.

Among the broadleaf species, *Ipomoea* species (*I. ericarpa*, *I. mauritiana*, and *I. vagans*) were the most prevalent, exhibiting high infestation (51–75%) at both sites. This dominance implies that *Ipomoea* species thrive under the humid and fertile conditions of the soybean fields, posing a serious management concern due to their rapid vine growth and ability to smother young soybean plants. At Bunkure, *Cirsium vulgare* (Bull thistle) and *Leucas martinicensis* (Whitewort) were highly dominant, whereas *Hyptis spicigera* Lam. and *Laggera aurita* Linn (DC) were more common at BUK. These site-specific differences may be attributed to variations in weed seedbanks and field management practices.

The sedge species, *Cyperus esculentus* (L.) and *C. rotundus* L., occurred at both sites but were more abundant at Bunkure, particularly *C. esculentus*, which showed medium infestation levels (26–50%). Their persistence suggests poor control by pre-emergence herbicides and emphasizes the need for integrated management strategies targeting perennial weeds.

Overall, broadleaf weeds were the most dominant group, followed by grasses and sedges. The high diversity and infestation intensity observed especially of *Ipomoea* spp., *Cirsium vulgare* (Savi) Ten., and *Cynodon dactylon* (Linn), highlight the necessity for early and sustained weed control measures to minimize competition for light, nutrients, and moisture. These findings corroborate those of Shittu and Bassey (2023) and Shittu *et al.* (2024), who reported similar dominance of *Cynodon dactylon* (Linn) and *Cyperus spp* (L.) in legume-based systems of the northern Nigerian savanna. Likewise, Balaji *et al.* (2023) and Barla *et al.* (2020) emphasized that understanding weed species composition and dominance patterns is fundamental for designing site-specific integrated weed management (IWM) strategies that enhance crop competitiveness and yield stability.

Table 1: Weed Species Composition and their Level of Infestation at BUK and Bunkure during the 2022 Rainy Season

Weed species	Common name	BUK	Bunkure
Narrow Leaves (Grasses)			
<i>Cynodon dactylon</i> (Linn)	Bermuda grass	***	*
<i>Echinochloa crus-galli</i> (L.) P.Beauv.	Barnyard grass	-	***
<i>Pennisetum pedicellatum</i> (Trin.) Morrone	Deenanath grass	*	*
<i>Setaria pumila</i> (Poir.) Roem. & Schult.	Yellow Foxtail	***	-
Broad Leaves			
<i>Ageratum conyzoides</i> (L.) Steud	Billy Goat Weed	*	**
<i>Cirsium vulgare</i> (Savi) Ten.	Bull Thistle	*	***
<i>Conyza sumatrensis</i> Retz	Sumatran Fleabane	-	*
<i>Euphorbia hirta</i> L.	Asthma Weed	*	-
<i>Hyptis spicigera</i> Lam.	Black Sesame	**	-
<i>Ipomea ericarpa</i> R.Br.	Tiny Morning Glory	**	***
<i>Ipomea mauritiana</i> Jacq	Morning Glory	**	***
<i>Ipomea vagans</i> Bak.	Wandering Morning Glory	**	***
<i>Laggera aurita</i> Linn (DC)	Sticky Blumea	*	-
<i>Leucas martnicensis</i> (Jacq.) R.Br.	Whitewort	-	***
<i>Pupalia lappacea</i> (L.) Juss	Burweed	***	-
<i>Striga hermontica</i> (Delile) Benth.	Purple witch weed	*	*
<i>Tridax procumbens</i> (L.)	Coat buttons	**	*
<i>Vernonia cinerea</i> (L.) H.Rob.	Little Iron weed	**	-
Sedges			
<i>Cyperus esculentus</i> L.	Yellow Nutsedge	-	**
<i>Cyperus rotundus</i> L.	Purple Nutsedge	**	*

* 1 – 25 % low density ** 26 – 50 % medium density *** 51 – 75 % high density

Weed Biomass and Weed control index (WCI)

At both sites, hoe weeding at 3 and 6 WAS and the integrated application of pendimethalin at 1.0 kg a.i. ha⁻¹ + imazethapyr at 100 g ha⁻¹ proved most effective in suppressing weed biomass while achieving the highest weed control indices. At BUK, hoe weeding reduced weed biomass to 40.9 g m⁻² with a WCI of 70.6%, while the integrated herbicide regime recorded 70.0 g m⁻² and a WCI of 65.8% (Figure 1). A similar pattern emerged at Bunkure, where hoe weeding (31.9 g m⁻²; 84.0%) and pendimethalin + imazethapyr (54.3 g m⁻²; 79.7%) far outperformed all other treatments. By contrast, the weedy check consistently showed the highest biomass (139.7–159.8 g m⁻²) and zero weed control, highlighting the severity of unchecked weed pressure.

Among varieties, TGX 1951-3F and TGX 1835-10E were generally more competitive against weeds,

recording lower biomass levels (86.7–95.0 g m⁻²) and relatively higher WCIs, especially at Bunkure where TGX 1951-3F achieved a WCI of 46.4% compared to 38.9% for TGX 1448-2E. This suggests genotypic differences in weed suppression ability, likely linked to canopy structure and resource use efficiency.

Overall, the results underscore the complementary role of effective weed management and varietal competitiveness in reducing weed pressure. Sustained weed suppression through hoe weeding or integrated herbicides maximizes control efficiency, while varieties like TGX 1951-3F further enhance weed suppression through inherent competitiveness. These findings align with the reports of Kanatas *et al.* (2020), who emphasized that combining cultural and chemical methods with competitive genotypes is key to sustainable weed management in soybean systems.

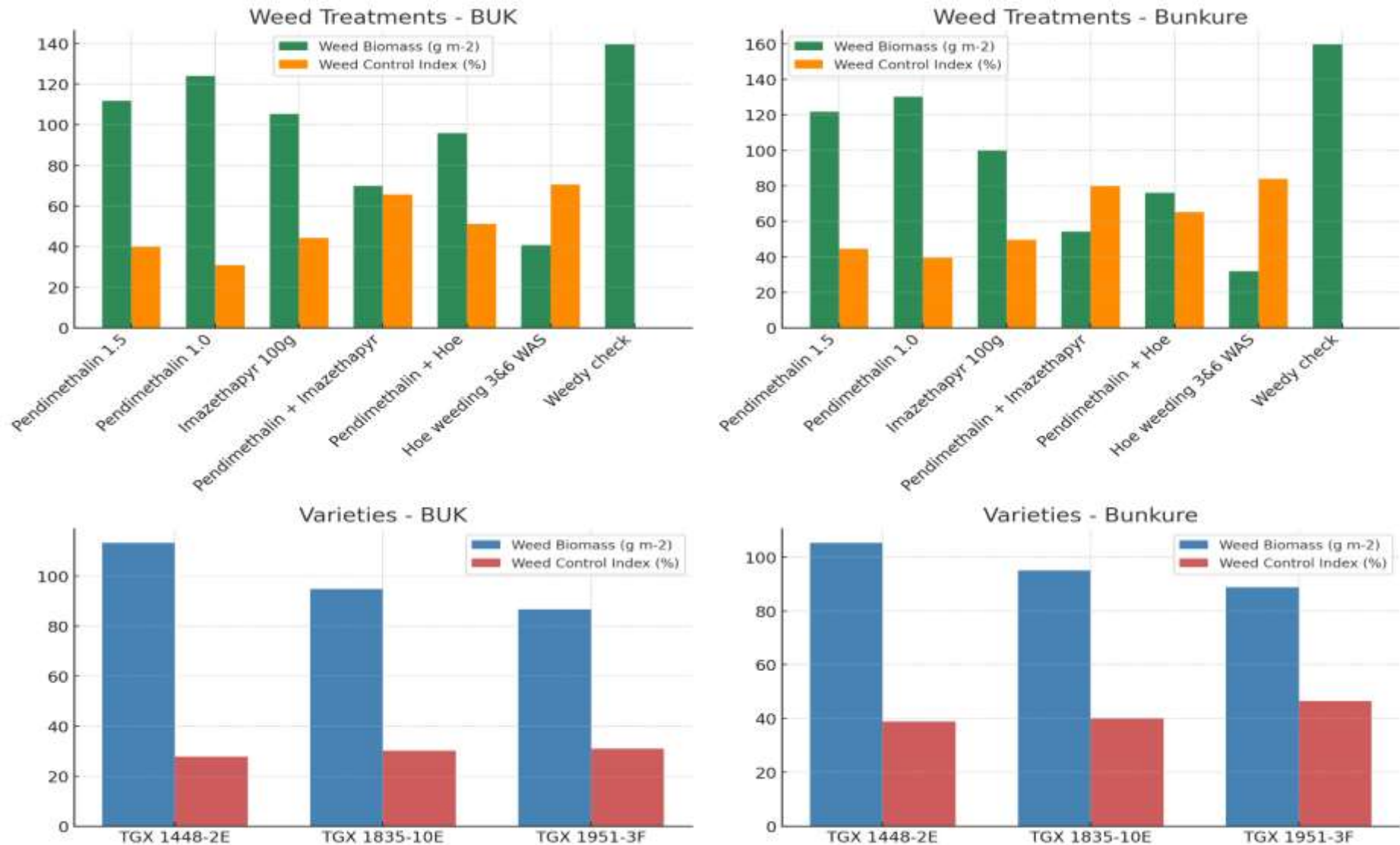


Figure 1: Weed biomass and Weed control index of soybean as influenced by Weed control treatments and Variety at BUK and Bunkure during the 2022 Rainy season

Growth characters of soybean as influenced by Weed control treatment and Variety

Plant height (cm)

Soybean plant height was significantly influenced by weed control treatments at both locations (Table 2). At BUK, hoe weeding at 3 and 6 WAS and the combination of Pendimethalin at 1.0 kg a.i. ha⁻¹ + Imazethapyr at 100 g ha⁻¹ produced the tallest plants at 12 WAS (75.28 cm and 73.53 cm, respectively), while the weedy check recorded the shortest plant (51.81 cm). A similar pattern was observed at Bunkure, where Pendimethalin + Imazethapyr (90.07 cm) and hoe weeding (81.84 cm) significantly ($p < 0.001$) outperformed the weedy check (53.20 cm). These findings confirm that both manual and chemical weed management effectively reduce competition and enhance vegetative growth, consistent with Abdullahi *et al.* (2025), who reported that weed-free conditions significantly improve soybean height compared to unweeded plots. Choudhary *et al.* (2025) reported findings in *Anethum graveolens*.

Varietal effects were also significant, with TGX 1951-3F consistently attaining the greatest height (67.63 cm at BUK and 76.71 cm at Bunkure), followed by TGX 1835-10E, while TGX 1448-2E was shortest. This reflects inherent genotypic differences in competitive ability and stress adaptation. Similar genotype-dependent responses to weed interference were reported by Mamudu and Adeyemi (2022), who observed that certain soybean varieties maintained superior vegetative growth despite weed pressure. Such varieties exhibit strong weed-smothering efficiency, a trait that is critical for effective crop management in the challenging environments of the African Savannas. There was no significant ($p > 0.05$) interaction between weed control treatments and varieties observed, indicating independent effects. Nonetheless, the general trend shows that, at effective weed suppression amplifies the growth advantage of superior varieties. This aligns with Shittu *et al.* (2025), who highlighted that timely weed control enhances crop vigor and resource use efficiency in legumes. Additionally, Ezin *et al.* (2025) reported high heritability for plant height and other yield-related traits of TGX 1951-3F when compared to 30

soybean accessions, with the variety also recording one of the highest grain yields in the northern site (E2). This confirms its genetic stability and superior adaptability across environments. The ability of TGX 1951-3F to combine tall growth habit with high yield potential reinforces its competitive advantage against weeds and its suitability for production in stress-prone environments such as the Sudan Savannah. The consistent superiority of TGX 1951-3F across environments highlights its stability and adaptability under weed competition, making it a promising candidate for both farmer adoption and future breeding programs.

Leaf count per plant

Table 3 presents the leaves count per plant differed significantly among weed control treatments and varieties across both locations. At BUK, hoe weeding at 3 and 6 WAS and the combination of pendimethalin at 1.0 kg a.i. ha⁻¹ with imazethapyr at 100 g ha⁻¹ produced the highest leaf count throughout the growth period, with values ranging from 16.15 at 6 WAS to 32.31 at 12 WAS. A similar trend was observed at Bunkure, where these treatments recorded 68.22 and 66.10 leaves per plant at 12 WAS, respectively. In contrast, the weedy check and pendimethalin at 1.5 kg a.i. ha⁻¹ consistently gave the lowest leaf counts at both sites, indicating the adverse effect of uncontrolled weed competition on vegetative development. These results confirm that integrating herbicides with manual weeding enhances soybean leaf production, which is critical for canopy development and light interception. Recent studies have shown that integrated weed management significantly improves leaf area index and photosynthetic capacity in legumes, ultimately boosting productivity (Kanas *et al.*, 2020; Pamungkas *et al.*, 2025). Additionally, the higher number of leaves under integrated weed control has practical implications, as leaf density directly influences radiation use efficiency and biomass accumulation in soybean (Caldas *et al.*, 2023). By promoting vigorous canopy cover, integrated weed management not only suppresses weed regrowth but also enhances the competitive advantage of soybean plants, thereby contributing to sustainable yield improvements.

Table 2: Plant height of Soybean as influenced by Weed control treatment and Varieties at BUK and Bunkure during the 2022 Rainy Season

Treatment	BUK			Bunkure		
	Weeks after sowing (WAS)					
	6	9	12	6	9	12
Weed Control Treatment (WCT)						
Pendimethalin at 1.5 kg a.i. ha ⁻¹ (PE)	24.78 ^{bc}	51.70 ^b	68.17 ^{bc}	24.33 ^{bc}	50.88 ^{bc}	67.07 ^{cd}
Pendimethalin at 1.0 kg a.i. ha ⁻¹	24.17 ^{bc}	43.56 ^c	60.46 ^d	24.43 ^{bc}	44.16 ^c	61.26 ^d
Imazethapyr at 100 g ha ⁻¹ (PoE)	27.14 ^b	50.15 ^b	66.08 ^c	28.94 ^b	49.02 ^{bc}	65.16 ^{cd}
Pendimethalin at 1.0 kg a.i. + Imazethapyr at 100 g ha ⁻¹	33.33 ^a	57.70 ^a	73.53 ^a	35.44 ^a	67.36 ^a	90.07 ^a
Pendimethalin at 1.0 kg a.i. ha + Hoe weeding at 6 WAS	29.64 ^b	53.78 ^{ab}	69.32 ^b	30.26 ^b	55.83 ^b	73.73 ^c
Hoe weeding at 3 and 6 WAS	36.61 ^a	60.30 ^a	75.28 ^a	33.17 ^{ab}	62.89 ^{ab}	81.84 ^b
Weedy check	23.58 ^c	42.30 ^c	51.81 ^e	22.11 ^c	41.02 ^c	53.20 ^e
P of F	0.004	0.003	0.017	0.007	<.001	<.001
SE±	1.29	2.74	3.70	1.95	3.20	4.00
Variety (V)						
TGX 1448-2E	24.07 ^b	46.76 ^b	61.86 ^b	25.75 ^b	50.02 ^b	65.07 ^b
TGX 1835-10E	26.27 ^a	47.25 ^b	64.07 ^{ab}	28.28 ^{ab}	51.10 ^b	69.23 ^b
TGX 1951-3F	26.05 ^a	50.62 ^a	67.63 ^a	30.26 ^a	57.94 ^a	76.71 ^a
P of F	0.017	0.022	0.007	0.035	0.002	<.001
SE±	1.25	1.41	1.67	1.64	2.10	2.43
Interaction						
WCT × V	0.774	0.358	0.511	0.481	0.333	0.066

Means sharing similar letter(s) within same column are not significantly different at 5% level of probability using SNK. PE= Pre emergence, PoE= Post emergence.

Table 3: Leaves Count per plant of Soybean as Influenced by Weed control treatment and Varieties at BUK and Bunkure during the 2022 Rainy Season

Treatment	BUK			Bunkure		
	Weeks after sowing (WAS)					
	6	9	12	9	12	6
Weed Control Treatment (WCT)						
Pendimethalin at 1.5 kg a.i. ha ⁻¹ (PE)	13.58 ^{cd}	22.24 ^{cd}	26.86 ^c	14.00 ^c	23.11 ^c	44.36 ^c
Pendimethalin at 1.0 kg a.i. ha ⁻¹	12.98 ^d	21.05 ^d	24.01 ^d	12.96 ^d	21.00 ^d	37.92 ^d
Imazethapyr at 100 g ha ⁻¹ (PoE)	13.89 ^{bc}	22.89 ^{bc}	28.56 ^b	14.33 ^c	23.77 ^c	46.69 ^c
Pendimethalin at 1.0 kg a.i. + Imazethapyr at 100 g ha ⁻¹	15.87 ^a	26.87 ^a	30.23 ^a	17.67 ^a	30.53 ^a	66.10 ^a
Pendimethalin at 1.0 kg a.i. ha + Hoe weeding at 6 WAS	14.35 ^b	23.80 ^b	28.34 ^b	15.51 ^b	26.17 ^b	53.64 ^b
Hoe weeding at 3 and 6 WAS	16.15 ^a	27.46 ^a	32.31 ^a	17.76 ^a	30.69 ^a	68.22 ^a
Pendimethalin at 1.5 kg a.i. ha ⁻¹ (PE)	12.35 ^e	19.75 ^e	24.45 ^d	12.06 ^e	19.18 ^e	32.73 ^e
P of F	<.001	<.001	<.001	<.001	<.001	<.001
SE±	0.27	0.55	0.64	0.23	0.66	1.41
Variety (V)						
TGX 1448-2E	14.27 ^a	23.80 ^a	26.85 ^a	14.98	25.27	55.56 ^a
TGX 1835-10E	14.41 ^a	23.78 ^a	26.43 ^a	15.09	25.14	49.38 ^b
TGX 1951-3F	13.83 ^b	22.73 ^b	24.40 ^b	14.63	24.35	44.91 ^c
P of F	<.001	<.001	<.001	0.096	0.090	<.001
SE±	0.14	0.28	0.31	0.15	0.43	0.89
Interaction						
WCT × V	0.024	0.028	0.053	0.007	0.009	0.002

Means sharing similar letter(s) within same column are not significantly different at 5% level of probability using SNK. PE= Pre emergence, PoE= Post emergence

Significant variations in growth parameters were observed among soybean varieties across locations. At BUK, TGX 1448-2E and TGX 1835-10E recorded significantly higher leaf numbers compared to TGX 1951-3F, particularly at 9 and 12 WAS. For instance, TGX 1448-2E produced 23.80 and 26.85 leaves at 9 and 12 WAS, respectively, while TGX 1951-3F had only 22.73 and 24.40 leaves. At BUK, TGX 1448-2E and TGX 1835-10E recorded significantly higher leaf numbers compared to TGX 1951-3F, particularly at 9 and 12 WAS. For instance, TGX 1448-2E produced 23.80 and 26.85 leaves at 9 and 12 WAS, respectively, while TGX 1951-3F had only 22.73 and 24.40 leaves. At Bunkure, the varietal effect was less pronounced at 9 and 12 WAS, but TGX 1448-2E maintained an advantage in leaf production, especially at 6 WAS (55.56 leaves), compared to TGX 1951-3F (44.91 leaves). This suggests that although TGX 1951-3F exhibited superior plant height, it may allocate fewer resources to leaf proliferation compared to TGX

1448-2E, reflecting contrasting growth strategies among varieties. Similar varietal differences in leaf production and partitioning of assimilates have been documented in soybean, with genetic background influencing canopy development and yield potential (Mensah *et al.*, 2023; Abdullahi *et al.*, 2025).

The interaction of weed control treatments and varieties was significant across BUK and Bunkure and is shown in Table 4. At both locations, the interaction between weed control treatments and soybean varieties significantly ($p < 0.001$) influenced the number of leaves per plant at 6 and 9 WAS, demonstrating the combined role of genetic potential and weed management in canopy development. At 6 WAS, hoe weeding at 3 and 6 WAS, and the combination of pendimethalin at 1.0 kg a.i. ha⁻¹ with imazethapyr at 100 g ha⁻¹, produced the highest number of leaves across varieties. TGX 1835-10E (16.65) and TGX 1448-2E (16.39) at BUK,

and TGX 1835-10E (18.85) at Bunkure, recorded superior leaf counts under hoe weeding at 3 and 6 WAS compared to the weedy check (12.26 at BUK; 11.95 at Bunkure). This suggests that maintaining a weed-free environment during early growth stages enhanced photosynthetic leaf expansion, a critical factor for assimilate accumulation. Similar findings were reported by Singh *et al.* (2022) and Choudhary *et al.* (2025), who highlighted that integrated weed management improves canopy traits and resource use efficiency in legumes.

At 9 WAS, hoe weeding at 3 and 6 WAS and the combination of pendimethalin at 1.0 kg a.i. ha⁻¹ + imazethapyr at 100 g ha⁻¹ produced the highest leaf counts, particularly in TGX 1951-3F (35.25 at BUK; 31.11 at Bunkure). A similar trend was observed at 12 WAS in Bunkure (Figure 2), indicating the prolonged benefit of sustained weed suppression and the ability of TGX 1951-3F to maintain vigorous vegetative growth. In contrast, the weedy check consistently recorded the lowest leaf counts, reaffirming the detrimental effect of weed interference on canopy development. These results are consistent with Caldas *et al.* (2023), who reported that weed competition reduces leaf area index and light interception, ultimately constraining yield potential. The varietal differences observed across treatments further highlight genetic variability. TGX 1951-3F exhibited the greatest responsiveness to effective weed management, especially under hoe weeding and herbicide combinations, whereas TGX 1448-2E and TGX 1835-10E performed moderately. This corroborates the findings of Mensah *et al.* (2022), who emphasized that soybean varieties with superior canopy development possess greater competitive ability against weeds. Similarly, Rüdél *et al.* (2021) noted that varieties capable of producing robust leaf biomass under stress conditions demonstrate higher adaptability and yield resilience in tropical environments.

Table 4: Interaction of Weed Control Treatment and Variety on Leaves Count at 6 and 9 WAS at BUK and Bunkure during the 2022 Rainy Season

Treatment	BUK			Bunkure		
	Variety					
	TGX 1448-2E	TGX 1835-10E	TGX 1951-3F	TGX 1448-2E	TGX 1835-10E	TGX 1951-3F
Weed Control Treatment (WCT)	6 WAS					
Pendimethalin at 1.5 kg a.i. ha ⁻¹ (PE)	13.57 ^{gh}	13.82 ^{fg}	13.34 ^{ghi}	14.19 ^{d-h}	14.17 ^{d-h}	13.65 ^{e-h}
Pendimethalin at 1.0 kg a.i. ha ⁻¹	13.46 ^{gh}	12.85 ^{hij}	12.64 ^{ij}	13.48 ^{e-h}	12.65 ^{fgh}	12.75 ^{fgh}
Imazethapyr at 100 g ha ⁻¹ (PoE)	14.47 ^{ef}	13.72 ^{fg}	13.49 ^{gh}	14.37 ^{d-g}	14.20 ^{d-h}	14.42 ^{def}
Pendimethalin at 1.0 kg a.i. + Imazethapyr at 100 g ha ⁻¹	15.23 ^{cde}	16.56 ^{ab}	15.82 ^{bc}	18.43 ^{ab}	18.28 ^{ab}	16.29 ^{bcd}
Pendimethalin at 1.0 kg a.i. ha + Hoe weeding at 6 WAS	14.48 ^{ef}	14.83 ^{de}	13.73 ^{fg}	15.97 ^{cd}	15.33 ^{de}	15.25 ^{de}
Hoe weeding at 3 and 6 WAS	16.39 ^{ab}	16.65 ^a	15.41 ^{cd}	16.46 ^{bcd}	18.85 ^a	17.97 ^{abc}
Weedy check	12.26 ^j	12.42 ^j	12.35 ^j	11.95 ^h	12.17 ^{fgh}	12.07 ^{gh}
SE±	0.41			0.07		
	9 WAS					
Pendimethalin at 1.5 kg a.i. ha ⁻¹ (PE)	15.97 ^{e-i}	19.07 ^{e-h}	20.04 ^{d-g}	23.64 ^{d-h}	23.31 ^{d-h}	22.37 ^{e-h}
Pendimethalin at 1.0 kg a.i. ha ⁻¹	17.39 ^{f-i}	20.27 ^{ghi}	16.10 ^{e-i}	22.17 ^{e-h}	20.27 ^{fgh}	20.55 ^{fgh}
Imazethapyr at 100 g ha ⁻¹ (PoE)	18.88 ^{e-i}	19.24 ^{e-h}	23.95 ^{cde}	24.01 ^{c-f}	23.37 ^{d-h}	23.93 ^{c-g}
Pendimethalin at 1.0 kg a.i. + Imazethapyr at 100 g ha ⁻¹	27.17 ^{bc}	32.77 ^{ab}	33.35 ^{ab}	32.37 ^a	31.50 ^{ab}	27.71 ^{bcd}
Pendimethalin at 1.0 kg a.i. ha + Hoe weeding at 6 WAS	19.86 ^{c-f}	21.73 ^{c-f}	26.32 ^{bcd}	27.30 ^{bcd}	25.61 ^{cde}	25.60 ^{cde}
Hoe weeding at 3 and 6 WAS	22.34 ^{cde}	31.06 ^{ab}	35.25 ^a	28.34 ^{abc}	32.63 ^a	31.11 ^{ab}
Pendimethalin at 1.5 kg a.i. ha ⁻¹ (PE)	14.78 ⁱ	15.50 ^{hi}	16.90 ^{ghi}	19.03 ^h	19.32 ^{gh}	19.18 ^h
SE±	2.40			1.15		

Means followed by the same letter(s) are not significantly different at 5% level of probability using SNK. PE= Pre emergence, PoE= Post emergence.

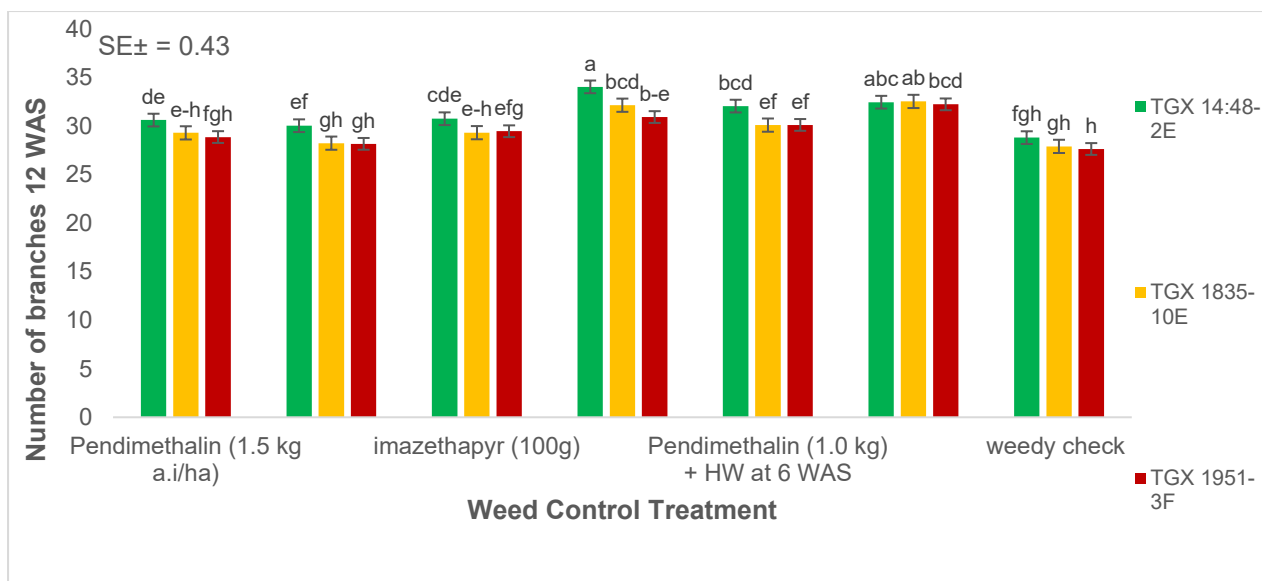


Figure 2: Interaction of weed control and variety on Leaves Count per plant of soybean at 12 WAS at Bunkure during the 2022 Rainy season

Number of branches per plant

Weed control treatments significantly ($p < 0.001$) influenced the number of branches per plant at both BUK and Bunkure across all sampling periods (Table 5). At BUK, hoe weeding at 3 and 6 WAS and the combination of pendimethalin at 1.0 kg a.i. ha⁻¹ + imazethapyr at 100 g ha⁻¹ consistently produced the highest number of branches (9.22 and 8.99, respectively at 12 WAS). These were significantly greater than the weedy check, which recorded the lowest (6.33). A similar trend was observed at Bunkure, where hoe weeding at 3 and 6 WAS (12.41 branches) and pendimethalin + imazethapyr (12.37 branches) markedly outperformed other treatments, while the weedy check remained lowest (8.12 branches). This clearly demonstrates that both timely manual hoe weeding and integrated herbicide use effectively reduce weed-crop competition, thereby allowing soybeans to develop more lateral branches.

The varietal effect was also significant, with TGX 1448-2E producing the highest branch number at both locations and all growth stages (10.68 and 11.26 branches at 12 WAS in BUK and Bunkure, respectively). TGX 1835-10E followed, while TGX 1951-3F consistently produced fewer branches. The superior branching of TGX 1448-2E suggests higher potential for canopy coverage and photosynthetic efficiency, traits often linked with improved

biomass and yield potential (Ene *et al.*, 2019; Khan *et al.*, 2023).

The WCT × V interaction on the number of branches per plant at both BUK and Bunkure was significant and is presented in Table 6. Across both sites, TGX 1448-2E consistently produced the highest number of branches under hoe weeding and integrated herbicide regimes. At Bunkure, 9 WAS, TGX 1448-2E recorded 7.58 branches under hoe weeding and 8.23 under pendimethalin + imazethapyr, compared to only 4.95 branches in TGX 1951-3F under the weedy check. A similar trend was observed at 12 WAS in Bunkure (Figure 3), confirming that effective weed management not only enhances overall branching but also allows genotypes to fully express their yield potential. These results align with the findings of Absy and Yacoub (2020) and Rüdél *et al.* (2021), who noted that weed-free conditions promote greater branching and pod initiation in legumes by minimizing early-season competition. Furthermore, Asaduzzaman *et al.* (2024) highlighted that genotypes with superior branching ability, such as TGX 1448-2E, are better able to tolerate weed pressure because their wider canopies suppress weed regrowth through shading. Therefore, integrating effective weed control strategies with appropriate varietal selection is essential for maximizing soybean productivity.

Table 5: Number of Branches per plant of Soybean as Influenced by Weed control treatment and Varieties at BUK and Bunkure during the 2022 Rainy Season

Treatment	BUK			Bunkure		
	Weeks after sowing (WAS)			9	12	6
	6	9	12			
Weed Control Treatment (WCT)						
Pendimethalin at 1.5 kg a.i. ha ⁻¹ (PE)	3.67 ^d	5.71 ^d	6.83 ^d	3.66 ^d	5.70 ^d	8.82 ^d
Pendimethalin at 1.0 kg a.i. ha ⁻¹	3.74 ^{cd}	5.85 ^{cd}	7.27 ^{cd}	3.79 ^c	5.96 ^c	9.60 ^c
Imazethapyr at 100 g ha ⁻¹ (PoE)	3.79 ^{bc}	5.95 ^{bc}	7.53 ^{bc}	3.83 ^c	6.04 ^c	9.85 ^c
Pendimethalin at 1.0 kg a.i. + Imazethapyr at 100 g ha ⁻¹	4.02 ^a	6.42 ^a	8.99 ^a	4.28 ^a	6.94 ^a	12.37 ^a
Pendimethalin at 1.0 kg a.i. ha + Hoe weeding at 6 WAS	3.84 ^b	6.05 ^b	7.85 ^b	3.99 ^b	6.36 ^b	10.76 ^b
Hoe weeding at 3 and 6 WAS	4.07 ^a	6.53 ^a	9.22 ^a	4.25 ^a	6.89 ^a	12.41 ^a
Weedy check	3.58 ^e	5.52 ^e	6.33 ^e	3.54 ^e	5.45 ^e	8.12 ^e
P of F	<.001	<.001	<.001	<.001	<.001	<.001
SE±	0.02	0.07	0.20	0.04	0.08	0.25
Variety (V)						
TGX 1448-2E	4.30 ^a	6.84 ^a	10.68 ^a	4.42 ^a	7.08 ^a	11.26 ^a
TGX 1835-10E	3.73 ^b	5.86 ^b	9.46 ^b	3.81 ^b	6.02 ^b	9.93 ^b
TGX 1951-3F	3.40 ^c	5.31 ^c	9.01 ^c	3.48 ^c	5.47 ^c	9.63 ^b
P of F	<.001	<.001	<.001	<.001	<.001	<.001
SE±	0.01	0.04	0.10	0.02	0.05	0.16
Interaction						
WCT × V	0.005	0.005	0.051	<.001	<.001	0.013

Means sharing similar letter(s) within same column are not significantly different at 5% level of probability using SNK. PE= Pre emergence, PoE= Post emergence.

Table 6: Interaction of Weed Control Treatment and Variety on Number of branches per plant at 6 and 9 WAS at BUK and Bunkure during the 2022 Rainy Season.

Treatment	BUK			Bunkure		
	Variety					
	TGX 1448-2E	TGX 1835-10E	TGX 1951-3F	TGX 1448-2E	TGX 1835-10E	TGX 1951-3F
Weed Control Treatment (WCT)	6 WAS					
Pendimethalin at 1.5 kg a.i. ha ⁻¹ (PE)	4.19 ^d	3.66 ^g	3.35 ^{klm}	4.29 ^{cd}	3.70 ^{f-i}	3.38 ^{kl}
Pendimethalin at 1.0 kg a.i. ha ⁻¹	4.17 ^d	3.55 ^{hi}	3.28 ^{lm}	4.18 ^{de}	3.52 ^{h-l}	3.29 ^{kl}
Imazethapyr at 100 g ha ⁻¹ (PoE)	4.34 ^c	3.65 ^{gh}	3.37 ^{kl}	4.32 ^{cd}	3.71 ^{f-i}	3.46 ^{i-l}
Pendimethalin at 1.0 kg a.i. + Imazethapyr at 100 g ha ⁻¹	4.46 ^b	3.99 ^e	3.60 ^{gh}	4.98 ^a	4.20 ^{de}	3.65 ^{f-j}
Pendimethalin at 1.0 kg a.i. ha + Hoe weeding at 6 WAS	4.34 ^c	3.78 ^f	3.39 ^{jk}	4.58 ^{bc}	3.84 ^{fg}	3.55 ^{g-k}
Hoe weeding at 3 and 6 WAS	4.65 ^a	4.00 ^e	3.56 ^{hi}	4.66 ^b	4.27 ^d	3.82 ^{fgh}
Weedy check	3.98 ^e	3.49 ^{ij}	3.25 ^m	3.93 ^{ef}	3.46 ^{i-l}	3.22 ^l
SE±	0.03			0.07		
	9 WAS					
Pendimethalin at 1.5 kg a.i. ha ⁻¹ (PE)	6.61 ^d	5.72 ^h	5.21 ^{klm}	6.82 ^{cd}	5.80 ^{fg}	5.27 ^{ghi}
Pendimethalin at 1.0 kg a.i. ha ⁻¹	6.57 ^{de}	5.49 ^{ij}	5.06 ^{lm}	6.58 ^{de}	5.44 ^{ghi}	5.08 ^{hi}
Imazethapyr at 100 g ha ⁻¹ (PoE)	6.91 ^c	5.69 ^{hi}	5.24 ^{kl}	6.88 ^{cd}	5.81 ^{fg}	5.43 ^{ghi}
Pendimethalin at 1.0 kg a.i. + Imazethapyr at 100 g ha ⁻¹	7.16 ^b	6.37 ^{ef}	5.71 ^h	8.23 ^a	6.79 ^d	5.81 ^{fg}
Pendimethalin at 1.0 kg a.i. ha + Hoe weeding at 6 WAS	6.92 ^c	5.96 ^g	5.29 ^{kl}	7.41 ^{bc}	6.08 ^{ef}	5.60 ^{fgh}
Hoe weeding at 3 and 6 WAS	7.55 ^a	6.40 ^{def}	5.63 ^{hi}	7.58 ^b	6.92 ^{cd}	6.15 ^{ef}
Weedy check	6.18 ^{fg}	5.38 ^{jk}	5.00 ^m	6.07 ^{ef}	5.32 ^{ghi}	4.95 ⁱ
SE±	0.11			0.15		

Means followed by the same letter(s) are not significantly different at 5% level of probability using SNK. PE= Pre emergence, PoE= Post emergence.

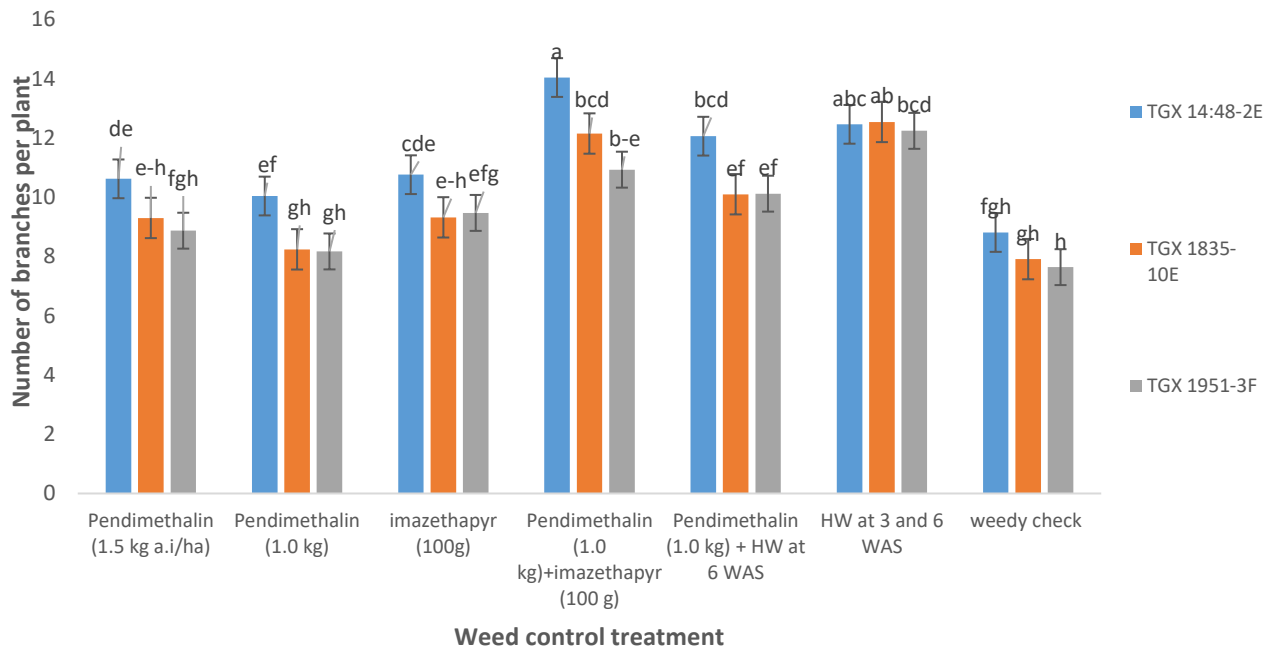


Figure 3: Interaction of weed control and variety on Number of branches per plant of soybean at 12 WAS at Bunkure during the 2022 Rainy Season

Leaf Area Index

The results in Table 7 indicate that both weed control treatments and soybean varieties significantly influenced leaf area index (LAI) at BUK and Bunkure. Across all sampling periods, hoe weeding at 3 and 6 WAS and the combination of pendimethalin at 1.0 kg a.i. ha⁻¹ + imazethapyr at 100 g ha⁻¹ produced the highest LAI values. At BUK, LAI under hoe weeding reached 4.32, 5.71, and 7.13 at 6, 9, and 12 WAS respectively, while at Bunkure it was slightly higher (4.81, 6.65, and 7.51). The pendimethalin + imazethapyr combination showed a comparable effect (4.18-6.80 at BUK; 4.34-7.39 at Bunkure), suggesting that integrated herbicide use offers similar canopy development benefits as timely hoe weeding. In contrast, the weedy check consistently recorded the lowest LAI, with values as low as 1.67 at 6 WAS in BUK and 1.47 at Bunkure, confirming the severe suppressive effect of uncontrolled weed growth on canopy expansion. The observed superiority of hoe weeding and integrated herbicide regimes for canopy development highlights the importance of effective early-season weed control in promoting light interception and photosynthetic efficiency. Similar findings were reported by Makale *et al.* (2023) Bin Lukangila *et al.* (2024), who separately observed that integrated weed management strategies significantly improved LAI and biomass accumulation in cashew and maize, respectively. Likewise, Ekeleme *et al.* (2021) demonstrated that

effective canopy expansion under weed-free conditions enhances radiation use efficiency and contributes directly to higher yield potential. Varietal differences were also evident, particularly at BUK where TGX 1835-10E produced the highest LAI (3.26, 4.03, and 5.11 at 6, 9, and 12 WAS), followed closely by TGX 1951-3F, while TGX 1448-2E consistently recorded lower values. At Bunkure, varietal differences were less pronounced, though TGX 1835-10E and TGX 1951-3F generally outperformed TGX 1448-2E. These results suggest that genotypic capacity for leaf area expansion plays an important role in soybean adaptation to weed pressure, with TGX 1835-10E and TGX 1951-3F showing stronger competitive growth. The varietal performance observed in this study is consistent with the reports of Esegbeet *al.* (2024), who noted that soybean varieties such as TGX 1951-3F exhibit strong vegetative vigor and high heritability for canopy-related traits, making them more resilient under varying production environments. Furthermore, Chiemek *et al.* (2024) emphasized that soybean genotypes with larger LAI are more competitive against weeds due to enhanced shading and reduced weed regrowth. Thus, integrating effective weed control with the selection of vigorous varieties like TGX 1835-10E and TGX 1951-3F can sustain canopy development, improve resource use efficiency, and optimize soybean productivity in the Sudan Savannah. There

was no significant ($p > 0.05$) interaction of WCT \times V on LAI at both locations.

Yield Components and Stand Count at harvest

Table 8 shows that weed control treatments (WCT) and varietal differences had strong effects on soybean reproductive performance and final yield at both BUK and Bunkure. At both sites, hoe weeding at 3 and 6 WAS and the integrated application of pendimethalin at 1.0 kg a.i. ha⁻¹ + imazethapyr at 100 g ha⁻¹ produced the highest pod weight per plant and seed yields. At BUK, hoe weeding achieved a pod weight of 217.8 g plant⁻¹ and yield of 2.07 t ha⁻¹, while pendimethalin + imazethapyr recorded 200.6 g plant⁻¹ and 1.97 t ha⁻¹. A similar pattern was evident at Bunkure, where these treatments resulted in yields above 2.6 t ha⁻¹, significantly ($p < 0.001$) higher than the weedy check (0.89 t ha⁻¹). These findings highlight the critical role of sustained weed suppression in ensuring resource availability for pod formation and seed filling. By contrast, the weedy check consistently produced the lowest yields, reflecting the intense competition from weeds for nutrients, moisture, and light. Interestingly, while differences in the number of seeds per pod were statistically significant at BUK, they were less pronounced at Bunkure. This suggests that pod weight and seed yield were more sensitive indicators of treatment effects than seed number per pod. Similar observations were reported by Singh *et al.* (2022), who found that weed competition affects assimilate partitioning and pod weight more severely than seed set.

Across sites, TGX 1951-3F produced the highest pod weight and seed yield (1.60 t ha⁻¹ at BUK; 1.95 t ha⁻¹ at Bunkure), outperforming TGX 1448-2E, which had the lowest values. TGX 1835-10E was intermediate but showed strong consistency in yield stability across environments. The superior performance of TGX 1951-3F can be attributed to its higher branching and larger leaf area index, which together enhance assimilate supply for

reproductive development. This agrees with Fattah *et al.* (2024), who noted that soybean varieties with vigorous canopy traits translate vegetative vigor into yield gains under favorable management.

The significant WCT \times Variety interactions for seed yield at both sites (Figure 4 & 5) indicate that genotypic potential is maximized only under effective weed management. TGX 1951-3F, in particular, expressed its yield advantage under hoe weeding and integrated herbicide regimes, while all varieties performed poorly under the weedy check. These results support the conclusions of Caldas *et al.* (2023) and Araújo *et al.* (2025), who emphasized that weed management and genotype selection must be jointly optimized to achieve sustainable soybean productivity.

Stand count at harvest

Weed control treatments also influenced stand count at harvest, with hoe weeding and integrated herbicide treatments maintaining higher plant stands compared to the weedy check. At Bunkure, pendimethalin + imazethapyr maintained the highest stand (21.06 plants), while uncontrolled weeds reduced stand counts below 14 plants. This reduction likely reflects competitive stress and mortality from prolonged weed interference, consistent with reports by Singh *et al.* (2022), who observed that weed infestation can cause early plant attrition and reduced stand density in legumes.

The significant WCT \times Variety interactions for pod weight and seed yield at both sites indicate that genotypic potential is maximized only under effective weed management. TGX 1951-3F, in particular, expressed its yield advantage under hoe weeding and integrated herbicide regimes, while all varieties performed poorly under the weedy check. These results support the conclusions of Mensah *et al.* (2022) and Caldas *et al.* (2023), who emphasized that weed management and genotype selection must be jointly optimized to achieve sustainable soybean productivity.

Table 7: Leaf Area Index of Soybean as Influenced by Weed control treatment Varieties at BUK and Bunkure during the 2022 Rainy Season

Treatment	BUK			Bunkure		
	Weeks after sowing (WAS)					
	6	9	12	6	9	12
Weed Control Treatment (WCT)						
Pendimethalin at 1.5 kg a.i. ha ⁻¹ (PE)	2.52 ^c	3.33 ^c	4.15 ^{cd}	2.82 ^c	3.72 ^c	4.15 ^c
Pendimethalin at 1.0 kg a.i. ha ⁻¹	2.08 ^d	2.77 ^d	3.47 ^d	2.07 ^d	2.74 ^d	3.05 ^d
Imazethapyr at 100 g ha ⁻¹ (PoE)	2.72 ^{bc}	3.61 ^{bc}	4.53 ^b	3.07 ^c	4.05 ^c	5.04 ^c
Pendimethalin at 1.0 kg a.i. + Imazethapyr at 100 g ha ⁻¹	4.18 ^a	5.49 ^a	6.80 ^a	4.34 ^a	6.10 ^a	7.39 ^a
Pendimethalin at 1.0 kg a.i. ha + Hoe weeding at 6 WAS	3.05 ^b	4.04 ^b	5.04 ^{bc}	3.88 ^b	5.13 ^b	5.92 ^b
Hoe weeding at 3 and 6 WAS	4.32 ^a	5.71 ^a	7.13 ^a	4.81 ^a	6.65 ^a	7.51 ^a
Weedy check	1.67 ^d	2.19 ^e	2.72 ^e	1.47 ^d	1.93 ^d	2.40 ^d
P of F	<.001	<.001	<.001	<.001	<.001	<.001
SE±	0.19	0.25	0.31	0.64	0.40	0.51
Variety (V)						
TGX 1448-2E	2.52 ^b	3.70 ^b	4.59 ^b	3.06 ^b	4.47 ^b	5.18 ^b
TGX 1835-10E	3.26 ^a	4.03 ^a	5.11 ^a	3.84 ^a	4.65 ^a	5.55 ^a
TGX 1951-3F	3.22 ^a	3.90 ^{ab}	4.81 ^{ab}	3.89 ^a	4.72 ^a	5.56 ^a
P of F	<.001	0.047	0.013	<.001	0.504	0.051
SE±	0.09	0.12	0.16	0.13	0.11	0.13
Interaction						
WCT × V	0.051	0.200	0.440	0.119	0.290	0.373

Means sharing similar letter(s) within same column are not significantly different at 5% level of probability using SNK. PE= Pre emergence, PoE= Post emergence

Table 8: Number of Seeds per pod, Pod weight per plant, Seed yield and Stand count at harvest of Soybean as influenced by Weed control treatment Varieties at BUK and Bunkure during the 2022 Rainy Season

Treatment	BUK				Bunkure			
	Number of Seeds pod ⁻¹	Pod weight plant ⁻¹	Seed yield (t ha ⁻¹)	Stant count at harvest	Number of Seeds pod ⁻¹	Pod weight plant ⁻¹	Seed yield (t ha ⁻¹)	Stant count at harvest
Weed Control Treatment (WCT)								
Pendimethalin at 1.5 kg a.i. ha ⁻¹ (PE)	2.44 ^{abc}	149.0 ^d	1.11 ^c	15.39 ^{bc}	2.89	161.4 ^d	1.64 ^d	15.58 ^c
Pendimethalin at 1.0 kg a.i. ha ⁻¹	2.56 ^{abc}	137.2 ^e	0.94 ^d	14.00 ^{bc}	2.56	144.8 ^d	1.20 ^e	13.70 ^c
Imazethapyr at 100 g ha ⁻¹ (PoE)	2.44 ^{abc}	158.4 ^d	1.22 ^c	15.67 ^{bc}	2.67	189.8 ^c	1.89 ^c	17.04 ^b
Pendimethalin at 1.0 kg a.i. + Imazethapyr at 100 g ha ⁻¹	2.89 ^a	200.6 ^b	1.97 ^a	18.61 ^{ab}	2.67	266.8 ^a	2.69 ^a	21.06 ^a
Pendimethalin at 1.0 kg a.i. ha + Hoe weeding at 6 WAS	2.33 ^{bc}	173.2 ^c	1.38 ^b	16.75 ^b	2.22	225.6 ^b	2.29 ^b	17.08 ^b
Hoe weeding at 3 and 6 WAS	2.78 ^{ab}	217.8 ^a	2.07 ^a	19.83 ^a	2.89	278.0 ^a	2.73 ^a	20.99 ^{ab}
Weedy check	2.22 ^c	105.2 ^f	0.78 ^e	13.00 ^c	2.56	102.2 ^e	0.89 ^g	13.43 ^c
P of F	0.009	<.001	<.001	0.023	0.062	<.001	<.001	0.001
SE±	0.20	4.62	0.051	1.00	0.19	10.92	0.061	1.15
Variety (V)								
TGX 1448-2E	2.29 ^b	139.2 ^c	1.03 ^c	16.42	2.38 ^b	155.6 ^c	1.28 ^c	16.76
TGX 1835-10E	2.48 ^b	166.0 ^b	1.42 ^b	17.31	2.76 ^a	183.6 ^b	1.67 ^b	18.61
TGX 1951-3F	2.81 ^a	184.2 ^a	1.60 ^a	15.24	2.76 ^a	217.4 ^a	1.95 ^a	15.58
P of F	0.002	<.001	<.001	0.100	0.008	<.001	<.001	0.117
SE±	0.10	2.60	0.023	1.90	0.12	5.12	0.041.	1.41
Interaction								
WCT × V	0.255	0.201	<.001	0.842	0.362	0.101	<.001	0.963

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

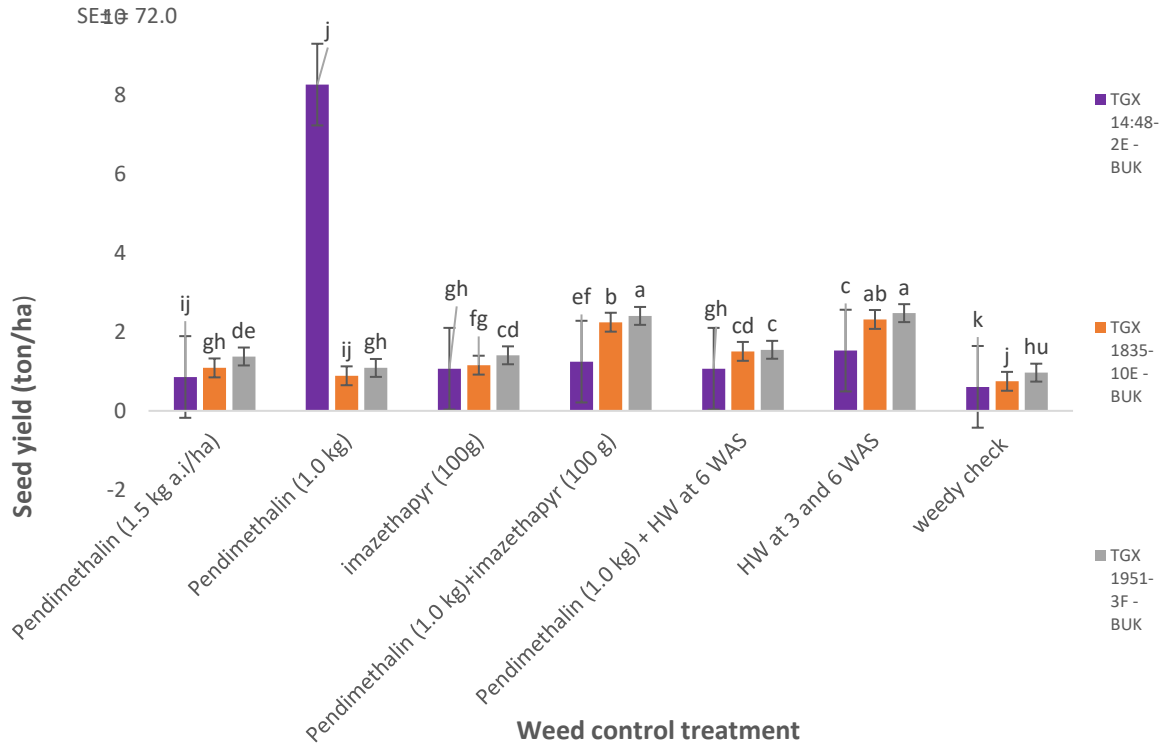


Figure 4: Interaction of weed control and variety on Seed yield of soybean (t/ha) at BUK during the 2022 Rainy season

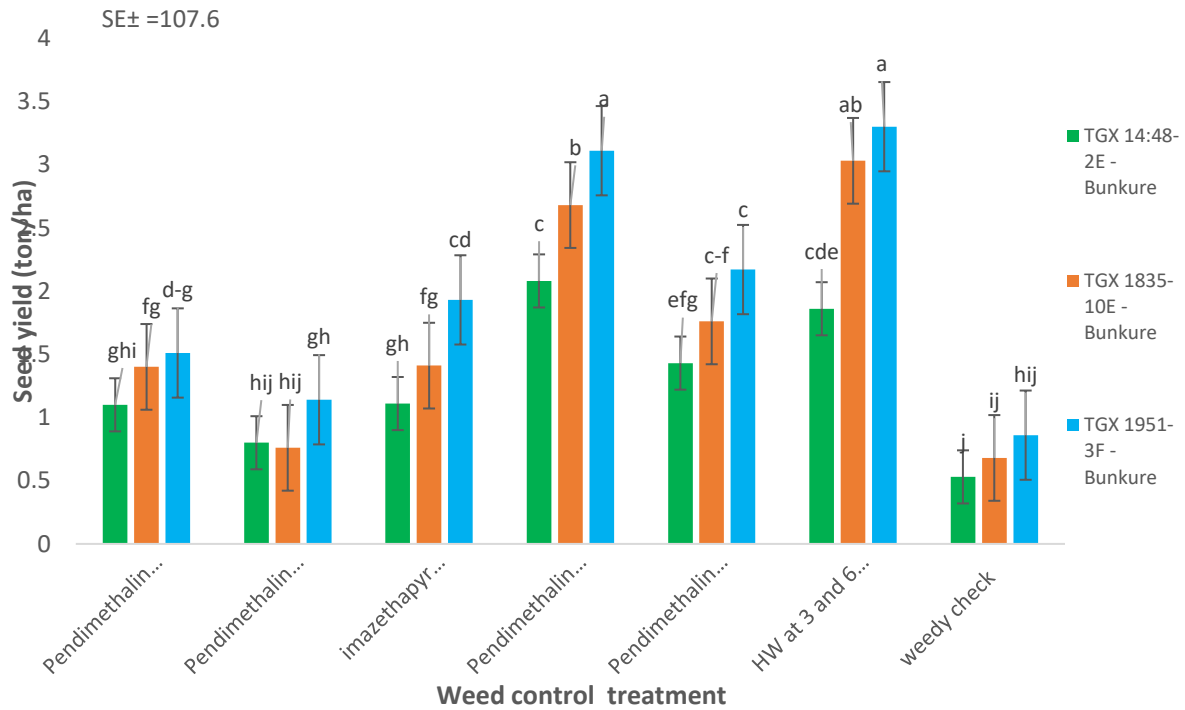


Figure 5: Interaction of weed control and variety on Seed yield of soybean (t/ha) at Bunkure during the 2022 Rainy season

CONCLUSION

This study confirmed that weed control strategies and varietal differences significantly influenced weed suppression and soybean productivity across both BUK and Bunkure during the 2022 rainy season. Weed flora in the Sudan Savanna was diverse and dominated by broadleaf species, indicating the need for effective and adaptable management approaches. Among the treatments, hoe weeding at 3 and 6 WAS and the integrated application of pendimethalin at 1.0 kg a.i. ha⁻¹ plus imazethapyr at 100 g ha⁻¹ consistently provided superior weed control and enhanced crop growth and yield. Soybean varieties TGX 1835-10E and TGX 1951-3F exhibited better competitive ability and yield stability across locations. Overall, integrating effective weed control measures with competitive soybean varieties is essential for improving yield and ensuring sustainable soybean production in the Sudan Savanna ecology.

Authors Contribution

KAB 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. KAB 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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