



OPTIMIZING SOWING DATE AND BOTANICALS APPLICATION FOR SUSTAINABLE MANAGEMENT OF FALL ARMYWORM [*Spodoptera frugiperda* (J.E Smith)] AND ENHANCED MAIZE PRODUCTIVITY IN THE SUDAN SAVANNA OF NIGERIA

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ABSTRACT

A field experiment was conducted during the 2024 rainy season at Bayero University Kano (BUK) and Minjibir, Nigeria, to assess the effects of sowing window and botanical applications on fall army worm (FAW) infestation and maize performance. Three sowing windows; early (6-8 July), intermediate (16-18 July), and late (26-28 July) as main plot, were tested in combination with eight botanical treatments, three botanical mixtures, a synthetic insecticide (Deltamethrin 25% EC), and an untreated check as sub plot in a split-plot design with three replications. The results revealed that, early sowing significantly ($P < 0.001$) reduced larval populations, leaf damage, and egg mass counts compared to late sowings, with late sowing recording the highest pest pressure. Deltamethrin was the most effective treatment across locations, followed closely by neem seeds, garlic cloves, neem leaves, and chili pepper fruits, which achieved notable reductions in FAW incidence and damage (larval counts reduced by up to 52% compared to control). Yields were highest in early-sown plots treated with either Deltamethrin or neem-based botanicals. No significant ($P > 0.05$) sowing window \times botanical interactions were detected, indicating independent effects. The results highlighted that early sowing between 6-8 July, combined with locally available botanicals particularly neem seeds and garlic cloves can effectively suppress FAW, reduce reliance on synthetic insecticides, and improve maize yields. Adoption of these integrated approaches offers a sustainable, affordable, and environmentally friendly strategy for FAW management in the Sudan Savanna.

Keywords: Botanicals, FAW, Insecticides, Sowing window, Maize, Productivity.

INTRODUCTION

Maize (*Zea mays* L.) is one of Nigeria's most important staple crops, providing food, feed, and income for millions of smallholder farmers (FAO, 2022). In the Sudan Savanna agroecological zone, characterized by erratic rainfall, high temperatures, and short growing seasons, maize production is increasingly threatened by the invasive fall armyworm *Spodoptera frugiperda* (Cudjoe *et al.*, 2021). Since its detection in Nigeria in 2016, this pest has become a major constraint to maize production, with yield losses estimated between 20 and 50 percent across sub-Saharan Africa (Goergen *et al.*, 2016).

Improper sowing dates in the Sudan Savanna often expose maize crops to peak FAW infestation or drought stress, resulting in low yields (Mbaidiro *et al.*, 2023).

Although chemical pesticides remain the predominant control method, their overuse has raised concerns about environmental contamination, resistance development, and high costs for resource-poor farmers (Mukanga *et al.*, 2024), while many farmers also lack training, protective equipment, and proper application techniques (Mergia *et al.*, 2021). Botanical pesticides, derived from sources such as *Azadirachta indica* and *Allium sativum*, offer a promising eco-friendly and affordable alternative (Ngegba *et al.*, 2022). However, their effectiveness depends on application timing, pest pressure, and environmental conditions (Rioba and Stevenson, 2020), and despite their potential, there is limited empirical evidence on the integration of optimized sowing windows with botanical treatments for improving FAW suppression and maize productivity in the Sudan Savanna.



Sustainable FAW control is critical for safeguarding food security in Nigeria, where maize is a dietary staple for over half of the population (IITA, 2023). Heavy reliance on synthetic pesticides is unsustainable due to their economic burden, environmental hazards, and health risks (Siazemo and Simfukwe, 2020). Botanical pesticides are low-cost, biodegradable, and locally available, making them particularly suitable for smallholder farmers, yet their widespread adoption requires scientific validation under local agroecological conditions (Chawanda *et al.*, 2023).

This study is designed to generate evidence on how sowing date adjustments and the use of selected botanicals can interact to reduce FAW damage, enhance crop establishment, and improve maize yield, thereby contributing to integrated pest management strategies, reducing pesticide dependency, and aligning with national climate-smart agriculture initiatives (Odewale *et al.*, 2021). The study aims to evaluate how sowing windows affect fall armyworm infestation, crop establishment, and maize yield, and to assess the effectiveness of selected botanical pesticides in improving maize productivity in the Sudan Savanna.

MATERIALS AND METHODS

Experimental Sites

A field experiment was conducted during the 2024 rainy season at both the Centre for Dryland Agriculture (CDA) Training and Research farm at Bayero University (11.0983° N, 8.0415° E, 481 m asl) and the International Institute of Tropical Agriculture (IITA) research field in Minjibir, Kano (12.1458° N, 8.6592° E, 457m asl.). Both sites lie within the Sudan Savanna, a semi-arid zone with monomodal rainfall of 500-800 mm annually, a 100-120-day growing season, and mean temperatures of 28-32°C. The region has a short-wet season followed by a prolonged dry period of six to nine months. Soils are typically low in organic matter, cation exchange capacity, and essential nutrients, particularly nitrogen and phosphorus.

Treatments and Experimental Design

The experiment comprised of three sowing windows (early, intermediate, and late) and eight botanical treatments, including three botanical combinations, a positive control, and an untreated check. The botanicals included: neem seeds (2.5 kg), eucalyptus leaves (3.5 kg), garlic cloves (1.5 kg), neem leaves (2.5 kg), mahogany leaves (2 kg), cassava peels (2.5 kg), bush mint (*Hyptis suaveolens*) leaves (2.5 kg), and chilli pepper fruits (2 kg). The combinations were: garlic cloves (1.5 kg) + eucalyptus leaves (3.5 kg), cassava peels (2.5 kg) + neem seeds (2.5 kg), and mahogany leaves (2 kg) + cassava peels (2.5 kg). Deltamethrin (25 ml) served as the positive control, while the check involved no application. The trial was arranged in a split-plot design, with sowing window as the main plot factor and botanical treatments assigned to subplots. These were replicated three times.

Sowing Windows

Early Sowing: BUK (First Location): 6th July 2024 while Minjibir (Second Location): 8th July 2024, Intermediate Sowing: BUK: 16th July 2024 and Minjibir, 18th July 2024. Planted 10 days after early sowing, coinciding with the emergence of early-sown seedlings. Late Sowing: BUK on the 26th July 2024 while Minjibir on the 28th July 2024. Conducted 10 days after intermediate sowing, when intermediate-sown seedlings had emerged.

Varietal Characteristics and Source

The maize variety used for this experiment was SAMMAZ 51, originally designated as IWD C3 Syn White DT STR Syn, with the national code NGZW 16-132. It was developed through collaboration between the International Institute of Tropical Agriculture (IITA), Ibadan, and the Institute for Agricultural Research (IAR), Samaru. SAMMAZ 51 is characterized by high grain yield potential, tolerance to drought, and resistance to *Striga hermonthica* but susceptible to FAW. Its yield potential ranges from 5 to 8 t ha⁻¹, and it performs best in the Southern and Northern Guinea Savanna ecological zones. The variety was officially released and registered in 2016 by the National Centre for Genetic Resources and Biotechnology (NACGRAB). Seeds for this study were obtained from the Centre for Dryland Agriculture (CDA) Research Farm.



Preparation and Application of the Botanicals at Experimental Sites

Neem seeds, neem leaves, mahogany leaves, *Hyptis suaveolens* leaves, and eucalyptus leaves were harvested from Bayero University Kano (BUK) campus, while garlic cloves, chili pepper fruits, and cassava peels were purchased from Janguza village market. Deltamethrin 25 EC (Green Life Crop Protection Africa) was sourced from a licensed agrochemical dealer in Sabon Gari market, Kano. Botanical preparations followed a modified method by Samaila *et al.* (2017) and Birhanus *et al.* (2019). Washed plant materials were pounded, and 50 g of each paste was mixed with 10 L of water, agitated, and left for 24 h at ambient temperature. Mixtures were filtered through Whatman No. 42 paper (125 mm), concentrated using a rotary evaporator, and percentage extract (% w/v) calculated. For field application, botanical solutions were amended with 40 g detergent as a surfactant. Synthetic insecticides were prepared at 25 ml per 10 L of water per label instructions. Both botanicals and insecticides were applied via full-coverage knapsack spraying to designated plots, excluding controls, with each botanical treatment replicated three times across nine plots per location.

Cultural Practices

Land preparation

The experimental field was cleared, ploughed, and harrowed using a tractor to achieve a fine tilth prior to plot layout and sowing. Each gross plot measured 6 rows (0.75 m row spacing) by 5 m length (30 m²), while the net plot size was 1.5 m × 5 m (7.5 m²). A buffer space of 0.5 m was maintained between plots and 1.0 m between replications.

Sowing

Seeds of the maize variety SAMMAZ-51 were sown at a rate of two seeds per hole and later thinned to one plant per stand at 2 WAS, with spacing of 0.75 m between rows and 0.25 m within rows.

Fertilizer application

Fertilization was applied at the recommended rate of 120 kg N, 60 kg P₂O₅, and 60 kg K₂O per hectare. At sowing, NPK 15:15:15 supplied half of the nitrogen and the full phosphorus and potassium requirements, while the remaining 60 kg N ha⁻¹ was applied as urea (46% N) at four weeks after sowing (WAS). Fertilizer was dibbled between two maize stands, buried, and covered with soil.

Weeding

Weeds were managed manually using a hand-held hoe on three occasions, with the first weeding conducted two weeks after sowing for each sowing period.

Data Collection

Entomological observations

Entomological data were collected three weeks after plant emergence, following the application of treatments. A “W”-shaped sampling pattern was used within each plot to ensure representative coverage. Fall armyworm (FAW) infestation was assessed using standardized visual scoring systems: a 0-4 scale for leaf damage and a 1-9 scale for cob damage. Additional measurements included larval population counts and egg mass enumeration.

Larval population (destructive sampling)

Larval counts were conducted at four weeks after sowing (WAS), four days after botanical application (DAP). Five maize plants were randomly selected per plot, carefully split open by hand at the stem and leaf whorls, and examined for FAW larvae. The number of live larvae per plant was counted and recorded.

Foliage (leaf) damage

Leaf damage was assessed at 4 WAS, four days after botanical application. Five randomly selected plants per plot were visually inspected, and the extent of FAW damage was scored using a 0-4 scale:

- 0 = no damage,
- 1 = slight damage (pinholes, small holes, or minor edge feeding),
- 2 = moderate damage (larger holes or greater leaf margin removal),
- 3 = severe damage (numerous large holes and substantial leaf area loss),
- 4 = complete destruction (non-functional leaves).



FAW egg masses

Egg mass counts were taken concurrently with larval and damage assessments. Five randomly selected plants per plot were examined on both sides of the leaves, and the number of FAW egg masses present was counted and recorded.

Agronomic Data

Agronomic data were collected from randomly tagged plants within the net plots, following standard agronomic procedures. Growth parameters measured included stand count per plot, plant height, leaf area, and leaf area index. Yield and yield-related components recorded were ear length per plant, ear weight (m^{-2}), cob weight (m^{-2}), 1000-seed weight, grain weight per cob, shelling percentage, and grain yield (t ha^{-1}).

Statistical Analysis

All collected data were subjected to analysis of variance (ANOVA) following the procedures of Snedecor and Cochran (1967), using GenStat (17th Edition). Treatment means showing significant differences were separated using the Student Newman-Keuls (SNK) test at 5% probability level.

RESULTS AND DISCUSSION

Effect through Entomological Parameters

Table 1 presented results of the effects of sowing window and botanical applications on FAW larval population, leaf damage, and egg mass per plot. The results clearly showed that, sowing window significantly ($P < 0.001$) influenced FAW infestation levels. Late sowing recorded the highest larval population, leaf damage, and egg masses, while early sowing consistently had the lowest values across both locations. This supports the findings of Chisonga *et al.* (2024), who reported that late planting exposes maize to peak FAW activity, leading to greater pest pressure and yield loss. Similarly, Mbaidiro *et al.* (2023) noted that early planting can help maize escape peak FAW infestations, serving as an effective cultural control strategy within Integrated Pest Management (IPM). Deltamethrin 25% EC proved most effective, producing the lowest larval counts, leaf damage, and egg masses, consistent with its rapid neurotoxic action (FAO & CABI, 2021). Among botanicals, neem seeds, neem leaves, garlic cloves, and chili fruits performed better than other treatments, aligning with reports of neem's strong larvicidal effects (Osei *et al.*, 2022) and the repellency of garlic and chili extracts (Nisar *et al.*, 2023). Control plots recorded the highest pest pressure, reaffirming the destructive impact of FAW without intervention, as also noted in Sub-Saharan Africa (Abrahams *et al.*, 2020). No significant interaction between sowing window and botanicals was observed, suggesting their effects are independent, supporting findings that cultural and botanical practices can reduce FAW damage separately, giving farmers flexible options (Tambo *et al.*, 2021).



Table 1: Influence of Sowing Window and Botanical Applications on Fall Armyworm Control on Establishment Percentage and Plant Height of Maize at BUK and Minjibir during the 2024 Rainy Season

Treatment	Rate (kg)	BUK			Minjibir		
		Larval count	Leaf damage	Egg mass	Larval count	Leaf damage	Egg mass
Sowing Window (SW)							
Early		3.44c	1.82c	3.18c	4.23c	2.10c	4.46c
Inter mediate		4.31b	2.18b	4.08b	5.41b	2.54b	5.33b
Late		4.79a	2.54a	4.80a	6.18a	2.80a	6.28a
P.value		0.033	0.002	0.022	0.020	0.016	<0.001
SE±		0.325	0.0811	0.3379	0.716	0.1324	0.1307
Botanicals (BOT)							
Neem seeds	2.5	1.78i	1.33i	2.45j	3.45j	1.33j	3.89k
Eucalyptus leaves	3.5	5.44c	2.89b	5.11b	5.67d	2.89d	5.90f
Garlic cloves	1.5	2.56h	2.00f	3.22i	4.56i	2.11f	4.67i
Neem leaves	2.5	3.44g	1.67g	3.44h	4.56d	2.44e	5.22g
Mahogany leaves	2.0	3.56f	1.67g	3.89f	4.78h	2.00g	4.33j
Cassava Peels	2.5	5.67b	2.56d	4.89c	6.11c	3.11b	6.11d
Hyptis leaves	2.5	4.78e	2.44e	4.56i	5.89d	3.00c	6.56b
Chilli pepper fruits	2.0	2.56h	1.56h	3.45g	4.56i	1.67h	4.67h
Garlic cloves + Eucalyptus leaves	1.5 + 3.5	5.44c	2.78c	4.33d	6.33b	2.89d	5.90f
Cassava peels + Neem seeds	2.0 + 2.5	5.22d	2.44e	4.11e	5.67f	3.00c	6.00e
Mahogany leaves + Cassava Peels	2.0 + 2.5	4.78e	2.56d	4.89c	5.44g	2.89d	6.12c
Deltametrin (25% EC)	25 mls	1.11j	0.56j	1.44k	3.44k	1.67i	3.67l
Check (Control)		7.67a	3.89a	6.44a	7.44a	3.22a	7.11a
P. value		<.001	<.001	<.001	<.001	<.001	<.001
SE±		0.516	<.001	0.448	0.552	0.1912	0.407
Interaction							
SW x BOT		0.534	0.535	0.876	0.933	0.023	0.266

Mean followed by the same letter within treatment group are not significant different at 5% level of probability using student's New-man Keuls Test.



Effect through Crop Penology

The effects of sowing window and botanical applications on stand count and plant height of maize at BUK and Minjibir during the 2024 rainy season is presented in Table 2. The result indicated that, Sowing window did not significantly ($P > 0.05$) influence establishment percentage or plant height at either location, indicating that initial crop stand and early vegetative growth were relatively stable across planting dates. This contradicts the findings of Midega *et al.* (2021), who observed reduced stand establishment in late-sown maize under high FAW pressure, suggesting that environmental conditions during 2024 may have moderated early damage effects. Differences in stand count and plant height among botanical treatments were not statistically significant ($P > 0.05$). However, Deltamethrin 25% EC, neem-based products, and chili extracts tended to enhance plant vigor, consistent with findings that effective FAW suppression improves vegetative growth (Tambo *et al.*, 2022). Neem treatments support healthier leaf development by reducing feeding damage (Degri *et al.*, 2024), while chili extracts help deter early larval feeding (Ncube *et al.*, 2021). The lack of significant effects may reflect uniform rainfall and low early pest pressure (Zandamela *et al.*, 2024).

Table 3 shows the influence of sowing window and botanical applications on leaf area and leaf area index (LAI) of maize at both locations. Sowing window had a significant ($P < 0.001$) effect on all parameters. Early sowing consistently produced the largest leaf areas and highest LAI values, followed by intermediate, with late sowing recording the lowest. This supports the findings of Prasanna *et al.* (2022), who reported that early planting allows maize to achieve greater canopy development before peak FAW infestation, thus maximizing light interception and photosynthetic capacity. Conversely, late sowing often coincides with higher pest activity and suboptimal growth conditions (Chen *et al.*, 2023). Although botanical treatments did not significantly ($P > 0.05$) influence leaf area or LAI, some patterns were evident. At both locations, Deltamethrin 25% EC and neem-based treatments generally recorded higher leaf area and LAI compared to the control. Neem-derived formulations have been widely documented to reduce leaf damage and preserve functional leaf area in maize under FAW attack (Mensah *et al.*, 2024). Similarly, garlic and chili extracts may deter feeding, indirectly supporting greater canopy retention (Golubkina *et al.*, 2022). The lack of statistical significance may relate to the compensatory growth capacity of maize under moderate damage levels (Jiang *et al.*, 2024). No significant interaction between sowing window and botanical treatments was observed on leaf area and LAI at both locations.

Effect through Yield and Yield Components

The influence of sowing window and botanical applications on ear length, ear weight, and cob weight of maize at BUK and Minjibir during the 2024 rainy season is shown in Table 4. The result showed that, sowing window significantly ($P < 0.001$) influenced yield components, with early planting producing heavier ears and cobs than intermediate or late sowing, reflecting reports that delayed planting increases maize losses under FAW pressure (Makgoba *et al.*, 2021). Although ear length differences were not significant ($P > 0.05$), early sowing still showed slight advantages, likely due to reduced pest injury during early ear development. Botanical applications had no significant ($P > 0.05$) effect, yet Deltamethrin and mixtures such as cassava peels plus neem leaves tended to enhance ear and cob weights compared to the control, in line with findings that botanicals can mitigate FAW damage and improve yield (Chawanda *et al.*, 2023). The sowing window \times botanical interaction on yield traits was not significant in both locations, indicating largely independent effects.

Table 5 examines sowing window and botanicals' effects on 1000-seed weight, grain weight per cob, shelling percentage, and grain yield. The sowing window had significant ($P < 0.05$) influence on grain weight per cob, shelling percentage, and grain yield at BUK, with early sowing delivering better performance; intermediate sowing matched early yield at BUK but was lower at Minjibir.



Table 2: Influence of Sowing Window and Botanical Applications on Fall Armyworm Control on Establishment Percentage, and Plant Height of Maize at BUK and Minjibir during the 2024 Rainy Season

Treatment	Rate (kg)	BUK			Minjibir		
		Stand count per plot	Plant height (cm)		Stand count per plot	Plant height (cm)	
			8 WAS	10 WAS		8 WAS	10 WAS
Sowing Window (SW)							
Early		77.33	114.51	124.70	96.28	105.11	115.16
Intermediate		73.44	100.70	121.68	77.05	101.13	110.12
Late		77.78	100.00	119.40	75.64	99.88	105.28
P.value		0.915	0.910	0.400	0.096	0.075	0.261
SE±		10.324	2.443	4.407	7.738	6.179	5.720
Botanicals (BOT)							
Neem seeds	2.5	77.33	108.9	125.09	86.33	108.89	112.18
Eucalyptus leaves	3.5	73.44	108.4	122.94	82.33	105.19	116.88
Garlic cloves	1.5	77.38	107.9	120.31	84.33	103.54	116.97
Neem leaves	2.5	69.78	105.7	123.98	87.78	107.71	119.76
Mahogany leaves	2.0	66.78	107.3	120.53	81.44	110.68	121.52
Cassava peels	2.5	74.11	103.7	118.79	81.67	108.41	120.04
Hyptis leaves	2.5	74.33	107.8	121.00	83.56	108.96	122.17
Chilli Pepper Fruits	2.0	67.44	107.8	124.06	82.78	107.38	120.59
Garlic cloves + Eucalyptus leaves	1.5 + 3.5	70.67	108.1	120.14	76.78	106.86	122.26
Cassava peels + Neem seeds	2.0 + 2.5	72.89	108.0	122.77	82.56	105.90	120.17
Mahogany leaves + Cassava peels	2.0 + 2.5	72.56	107.7	121.50	81.22	107.83	121.16
Delthrametrin (25% EC)	25 mls	69.11	109.6	125.47	82.44	108.92	124.16
Check (Control)		73.89	105.0	120.18	85.87	105.95	120.55
P. Value		0.915	0.723	0.400	0.803	0.075	0.976
SE±		4.029	2.972	4.580	4.853	4.188	4.578
Interaction							
SW x BOT		12.309	0.242	0.441	11.185	0.237	0.976



Table 3: Influence of Sowing Window and Application of Botanicals on Fall Armyworm Control on Leaf area and Leaf area index of Maize at BUK and Minjibir during 2024 Rainy Season

Treatment	Rate (kg)	BUK					Minjibir				
		Leaf area (cm ²)			Leaf area index (LAI)		Leaf area (cm ²)			Leaf area index (LAI)	
		6	8	10	8	10	6	8	10	8	10
Sowing Window (SW)											
Early		318.6a	429.2a	469.9a	0.16a	0.23a	305.8a	305.8a	431.5a	0.24a	0.23a
Intermediate		295.9b	379.9b	441.2b	0.15b	0.20b	271.3b	261.2b	371.9b	0.20b	0.23b
Late		232.3c	277.0c	307.6c	0.11c	0.15c	244.3c	263.8c	299.7c	0.13c	0.15c
P. value		<0.001	<0.001	<0.001	<0.001	<0.01	<0.001	<0.001	<0.001	<0.001	<0.001
SE±		4.57	6.08	8.56	0.00	0.00	7.88	9.92	9.23	0.00	0.00
Botanical (BOT)											
Neem leaves	2.5	200.1	232.9	232.9	2.692	1.662	237.4	255.5	268.3	3.11	3.33
Eucalyptus leaves	3.5	195.3	224.9	224.9	2.731	1.657	244.1	292.3	303.5	2.45	2.84
Garlic cloves	1.5	186.6	200.4	200.4	2.694	1.649	257.5	285.3	297.1	2.75	2.66
Neem leaves	2.5	194.4	228.9	228.9	2.684	1.634	240.4	265.1	277.4	2.83	2.98
Mahogany leaves	2.0	184.3	216.2	216.2	2.606	1.647	259.3	268.4	280.0	3.47	2.71
Cassava peels	2.5	189.9	216.2	216.2	2.674	1.580	199.8	214.7	235.1	2.81	2.63
Hyptis leaves	2.5	184.3	227.1	227.1	2.572	1.681	263.5	277.8	288.3	2.82	2.71
Chilli pepper fruits	2.0	192.3	225.6	225.6	2.616	1.681	188.4	227.5	256.0	2.76	3.00
Garlic Clove + Eucalyptus leaves	1.5 + 3.5	193.9	217.9	217.9	2.736	1.653	251.1	281.3	302.0	2.67	2.86
Cassava peels + Neem leaves	2.5 + 2.5	187.0	205.4	205.4	2.604	1.655	261.5	270.5	291.3	2.61	2.94
Mahogany leaves + Cassava Peels	2.0 + 2.5	181.0	205.0	205.0	2.686	1.637	247.5	261.3	278.2	2.71	2.36
Delthrametrin (25 % EC)	25 mls	188.7	191.1	191.1	2.597	1.623	297.2	315	335.2	3.44	3.12
Check (control)		180.7	225.8	225.8	2.707	16.37	281.4	304	316.0	2.22	2.35
P. value		0.977	0.404	0.404	0.765	0.374	0.486	0.441	0.448	0.457	0.571
SE±		13.89	17.35	17.35	0.0944	0.032	88.9	86.4	87.9	0.92.1c	98.6
Interaction											
SW x BOT		0.797	0.523	0.523	0.899	0.369	0.571	0.563	0.572	0.478	0.626

Means follow by the same letters within groups are not significantly different at 5% level of probability using Students New-Man Keuls Test (SNK)



Table 4: Influence of Sowing Window and Application of Botanicals on the Control of Fall Armyworm on Ear Length, Ear Weight and Cob Weight of Maize at BUK and Minjibir during 2024 Rainy Season

Treatment	Rate (kg)	BUK			Minjibir		
		Ear length (cm)	Ear weight m ⁻² (g)	Cob weight m ⁻² (g)	Ear length (cm)	Ear weight m ⁻² (g)	Cob weight m ⁻² (g)
Sowing Window (SW)							
Early		409.8	409.8	572.4a	26.51a	593.5a	503.4a
Intermediate		381.3	381.3	343.4b	19.44b	417.7b	342.7b
Late		437.1	437.1	313.7c	19.35c	417.7c	309.7c
P. value		0.393	0.393	<0.01	0.004	0.003	0.011
SE±		343.3	343.3	70.86	0.374	27.33	34.86
Botanicals (BOT)							
Neem seeds	2.5	21.09	503.8	409.8	21.09	467.4	381.3
Eucalyptus leaves	3.5	20.52	451.1	381.3	20.52	442.4	356.8
Garlic cloves	1.5	20.67	497.2	437.1	20.67	499.7	433
Neem leaves	2.5	21.29	471.7	393.6	21.29	449.6	373.6
Mahogany leaves	2.0	19.94	422.6	343.3	19.94	447.4	359.2
Cassava peels	2.5	20.33	517.4	414.6	20.33	469.3	383.9
Hyptis leaves	2.5	20.33	513.1	427.3	20.33	479.1	406.4
Chilli pepper fruits	2.0	21.39	476.9	427.3	21.39	466.6	397.2
Garlic cloves + Eucalyptus leaves	1.5 + 3.5	20.12	457.6	355.8	20.12	453.8	383.4
Cassava Peels + Neem leaves	2.5 + 2.5	20.19	468.8	403.8	20.19	461.7	377.3
Mahogany leaves + Cassava Peels	2.0 + 2.5	20.32	529.3	445.9	20.32	453.7	378.1
Delthrametrin (25% EC)	25 mls	20.83	532.2	455.7	20.83	484.7	406.3
Check (Control)		20.07	508.6	433.9	20.07	437.9	371.7
P. value		0.206	0.193	0.202	0.206	0.975	0.92
SE±		0.575	39.91	41.09	0.621	42.53	42.71
Interaction							
SW x B		0.621	0.644	0.202	0.575	0.934	0.924

Means followed by the same letter within treatment group are not significant different at 5% level of probability using Student's New-man Keuls Test.



Table 5: Influence of Sowing Window and Application of Botanicals on the Control of Fall Armyworm on 1000 Seed Weight, Grain Weight per Cob, Shelling Percentage and Grain yield of Maize at BUK and Mijibir during 2024 Rainy Season

Treatment	Rate (kg)	BUK				Minjibir			
		1000 seed weight (g)	Grain weight cob ⁻¹ (g)	Shelling Percentage (%)	Grain Yield (t ha ⁻¹)	1000 seed weight (g)	Grain weight cob ⁻¹ (g)	Shelling percentage (%)	Grain yield (t/ha ⁻¹)
Sowing Window (SW)									
Early		211.1	0.064a	88.04a	6.2a	175	0.054a	77.78a	4.5
Intermediate		204.9	0.060b	62.53b	5.6a	242	0.048b	57.38b	4.4
Late		198.3	0.049c	54.55c	2.8b	199	0.041b	51.49c	4.2
P. value		0.219	0.010	0.019	0.048	0.34	0.050	<.001	0.489
SE±		60.32	0.86	6.973	0.99	40.2	0.211	0.930	0.21
Botanical (BOT)									
Neem seeds	2.5	208.9	0.053	73.4a	5.7	191	0.044	58.5	4.6
Eucalyptus leaves	3. 5	202.4	0.046	67.9i	5.4	186	0.043	62.1	4.2
Garlic cloves	1.5	210.3	0.055	70.0b	6.4	188	0.040	62.6	4.6
Neem leaves	2.5	201.2	0.051	68.7g	5.7	193	0.042	63.4	4.9
Mahogany leaves	2.0	204.8	0.053	69.5d	5.7	192	0.040	63.1	4.5
Cassava peels	2. 5	205.3	0.047	66.9k	5.6	396	0.037	62.2	4.0
Hyptis leaves	2. 5	204.4	0.044	68.7f	5.8	185	0.039	65.0	4.1
Chilli pepper fruits	2.0	207.9	0.051	68.6h	5.6	196	0.042	60.8	4.6
Garlic cloves + Eucalyptus leaves	1.5 + 3.5	205.1	0.048	69.7c	5.6	181	0.039	62.2	4.0
Chilli pepper fruits + Neem leaves	2.5 + 2.5	205.8	0.050	67.6j	5.6	193	0.040	62.6	4.4
Mahogany leaves + Cassava peels	2.0 + 2.5	204.6	0.046	66.5l	5.5	191	0.039	64.5	4.1
Deltamethrin (25% EC)	25 mls	199.9	0.055	68.9e	5.6	190	0.049	62.6	4.9
Check (Control)		201.9	0.040	62.9m	5.3	190	0.035	59.9	3.7
P. value		0.804	0.920	0.019	0.467	0.511	0.304	0.771	0.401
SE±		5.44	42.71	2.942	23.20	83.6	0.021	2.856	0.1651
Interaction									
SW x BOT		0.66	0.924	8.522	0.494	0.439	0.399	4.845	0.203

Means followed by the same letter within treatment group are not significant different at 5% level of probability using Student's New-man Keuls Test



This underscores the importance of optimal sowing timing for maximizing reproductive efficiency under FAW pressure, consistent with findings by Durocher-Granger *et al.* (2024) in Zambia where early planting aligned with reduced pest damage and better yields. Botanical treatments impacted shelling percentage significantly ($P < 0.05$), while 1000-seed weight and grain yield were not markedly affected. Notably, garlic cloves improved shelling percentage and yield nearly to levels obtained with Deltamethrin. This aligns with newer reports, such as Chawanda *et al.* (2023), indicating that botanicals like neem, garlic, and cassava derivatives can enhance yield and grain quality, especially where synthetic inputs are limited.

CONCLUSION AND RECOMMENDATION

This study confirms that fall armyworm (*Spodoptera frugiperda*) is a persistent and serious threat to maize production in the Sudan Savanna, with infestation severity strongly influenced by sowing time. Early sowing (6-8 July) significantly reduced larval populations, leaf and cob damage, and egg mass counts, resulting in higher grain yields compared to intermediate (16-18 July) and late sowing (26-28 July) windows. Among botanical treatments, neem seeds, garlic cloves, neem leaves, and chili pepper fruits provided effective FAW suppression, with yields approaching those achieved with the synthetic insecticide Deltamethrin. The absence of significant sowing window \times botanical interactions suggests that timely planting and effective botanical applications offer independent, additive benefits. Therefore, to minimize FAW damage and maximize yield, farmers in the Sudan Savanna should prioritize early sowing between 6-8 July to escape peak pest pressure. For pest management, neem-based products and garlic extracts are recommended as cost-effective, locally available, and environmentally friendly alternatives to synthetic insecticides. Botanical applications should begin early in crop establishment, preferably before tasseling, to ensure maximum efficacy. Adoption of these practices will contribute to sustainable FAW management, reduced chemical reliance, and improved food security in the region.

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