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EFFECTS OF ROW ARRANGEMENT AND WEEDING INTERVALS ON SUNFLOWER (*HELIANTHUS ANNUUS* L.) + WATERMELON (*CITRULLUS LANATUS*) INTERCROP IN THE SEMI-ARID REGION OF MONGUNO, BORNO STATE

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ABSTRACT

A two-year field experiment was conducted during the 2023 and 2024 rainy seasons at the Teaching and Research Farm of the University of Maiduguri (Unimaid) and the Teaching and Research Farm of Borno State University (Bosu), both situated in the semi-arid region of Maiduguri, Borno State, Nigeria. The study investigated the effects of row arrangement and weeding intervals on the growth and yield performance of sunflower (Helianthus annuus L.) and watermelon (Citrullus lanatus)

Introduction

Intercropping, the simultaneous cultivation of two or more crop species on the same piece of land within the same growing season, is one of the most widely practiced agronomic strategies for sustainable crop production in sub-Saharan Africa (Brooker *et al.*, 2015). This farming system enhances land productivity, reduces the risk of total crop failure, and improves the overall stability of farm income, particularly in regions characterized by erratic and poorly distributed rainfall (Agegnehu *et al.*, 2017). The semi-arid region of northeast Nigeria, including Borno State, experiences a short rainy season (June to September) with annual rainfall averaging between 400 mm and 600 mm, which severely limits sole cropping options and underscores the importance of efficient resource utilization strategies such as intercropping (Nimet, 2023).

Sunflower (Helianthus annuus L.) is an important oilseed crop with remarkable adaptability to arid and semi-arid conditions, owing to its deep taproot system that enables efficient water extraction from sub-soil layers (Helianthus Research

under an intercropping system. The experiment was laid out in a split-plot design with row arrangements (1:1, 2:1, and 2:2 sunflower-to-watermelon ratios) assigned to the main plots and three weeding intervals (weeding at 3 WAS only; weeding at 3 and 6 WAS; weeding at 3, 6, and 9 WAS) assigned to the sub-plots, replicated three times. Growth parameters including plant height, number of leaves per plant, number of branches per plant, and crop growth rate (CGR) were recorded at 3, 6, and 9 weeks after sowing (WAS). Watermelon vine length, number of fruits per plant, fruit weight, and fruit yield (t/ha) were also assessed. Results showed that row arrangement significantly ($p<0.05$) influenced all measured growth and yield parameters. The 2:1 sunflower-to-watermelon row ratio consistently produced the tallest sunflower plants (139.25 cm at 9 WAS), the highest number of leaves (43.12 combined), and the greatest CGR (18.66 g/week combined). Weeding at 3, 6, and 9 WAS significantly improved all growth and yield parameters across both locations and years. The interaction between row arrangement and weeding interval was significant for sunflower number of leaves and watermelon fruit yield (t/ha). The study recommends the 2:1 row arrangement combined with weeding at 3, 6, and 9 WAS as the optimal management practice for sunflower-watermelon intercropping in the semi-arid agro-ecology of Borno State.

Keywords: Row arrangement, Weeding interval, Sunflower, Watermelon and Intercropping.

Consortium, 2021). Nigeria is among the countries with significant potential for sunflower expansion, particularly in the Sudan and Sahel Savanna zones, where its drought tolerance and short maturity period are agronomically advantageous (NASC, 2022). Watermelon (Citrullus lanatus), on the other hand, is a warm-season cucurbit grown extensively for its high-water-content fruits, which are of immense nutritional and economic value to smallholder farmers in northern Nigeria (Adebisi *et al*., 2020). Its sprawling growth habit and relatively low canopy allow effective complementarity with the erect and tall-statured sunflower in intercropping arrangements, potentially maximizing the use of vertical and horizontal growth niches.

One of the critical management decisions in an intercropping system is the spatial arrangement of component crops, which determines the degree of inter and intra specific competition for light, moisture, and soil nutrients (Li *et al.,* 2020). Row arrangement defines the spatial distribution of individual crop plants and thus governs canopy

architecture, light interception, and root competition dynamics. Studies have demonstrated that appropriate row ratios in cereal-legume and cereal cucurbit intercrops can significantly improve both component crop yields and overall system productivity (Matusso *et al*., 2014). However, information specific to sunflower-watermelon row arrangements in the semi-arid ecology of Borno State remains limited.

Weed management is equally critical in intercropping systems, as weeds compete with crop plants for light, water, and nutrients, thereby reducing crop growth rates and yield (Caton *et al*., 2003). The presence of weeds in the early stages of crop establishment can cause yield losses of up to 50% in poorly managed fields in the semi-arid tropics (Olorunmaiye *et al*., 2018). Determining the optimal weeding frequency in intercropping systems is challenging because the two component crops may differ in their critical weed-free periods. Nevertheless, establishing evidence based weeding schedules that balance labour cost and productivity is essential for resource-poor smallholder farmers. This study was therefore designed to evaluate the effects of different row arrangements and weeding intervals on the growth and yield parameters of sunflower and watermelon in an intercropping system under the semi-arid conditions of Maiduguri, Borno State.

Experimental Site

The experiment was conducted during the 2025 rainy season at the Teaching and Research Farm of Federal Polytechnic Monguno, Borno State, Nigeria (Latitude 12.670°N, Longitude 13.612°E, altitude approximately 298 m above sea level). The experimental site is located within the Sudan savanna agro-ecological zone of north-eastern Nigeria. The climate of the area is characterized by a short rainy season extending from June to September, with an average annual rainfall ranging between 500 and 650 mm. Temperature in the area is generally high throughout the year, ranging from 22°C to 45°C, while relative humidity is moderate during the rainy season and low during the dry season. The vegetation of the area is predominantly Sudan savanna type, consisting mainly of short grasses, scattered shrubs, and drought-tolerant trees. The soils of the area are generally sandy loam to loamy sand in texture, moderately low in organic matter, and suitable for the cultivation of cereals and legumes under rainfed conditions (NiMet, 2025).

Treatments and Experimental Design

The treatments consisted of three row arrangement ratios 1:1 (one row of sunflower alternating with one row of watermelon), 2:1 (two rows of sunflower to one row of watermelon), and 2:2 (two rows of sunflower alternating with two rows of watermelon) and three weeding intervals weeding once at 3 WAS (W1), weeding at 3 and 6 WAS (W2), and weeding at 3, 6, and 9 WAS (W3). The experiment was laid out in a split-plot design

with three replications. Row arrangements were assigned to the main plots and weeding intervals to the sub-plots. Each sub-plot measured 5.0 m x 4.0 m (20.0 m^2), with a 1.0 m alley between replications and a 0.5 m pathway between sub-plots. Sunflower was planted at an intra-row spacing of 60 cm x 30 cm and watermelon at 100 cm x 50 cm, in accordance with recommended practices for the semi-arid zone of Nigeria (NASC, 2022).

Crop Management

Standard agronomic practices for sunflower and watermelon production were followed throughout the experiment. Land was prepared through ploughing, harrowing, and ridging before planting. Fertilizer was applied at recommended rates, while weeding was carried out according to the assigned weeding interval treatments. Supplementary irrigation was provided when necessary. Pest and disease control measures, as well as other intercultural operations such as thinning and gap filling, were uniformly carried out to ensure proper crop growth and development.

Data Collection

Data on growth parameters were collected at 3, 6, and 9 Weeks after Sowing (WAS) from five randomly selected plants per plot for both crops. The parameters measured were: Plant height (cm), Number of leaves per plant, Number of branches per plant and Crop Growth Rate (CGR; g/week)

Statistical Analysis

Data collected were subjected to a two-way Analysis of Variance (ANOVA) using the statistical software Statistix version 10.0. Differences between treatment means were separated using the Duncan Multiple.

Sunflower Plant Height

Row arrangement and weeding interval both had a highly significant ($p<0.05$) effect on sunflower plant height at all growth stages and at both locations (Table 1). At 9 WAS in the combined analysis, the 2:1 row arrangement produced the tallest sunflower plants (139.25 cm), followed by the 2:2 arrangement (133.60 cm), while the 1:1 arrangement recorded the shortest plants (128.70 cm). Similarly, weeding at 3, 6, and 9 WAS consistently produced the tallest plants (143.72 cm) compared to weeding at 3 and 6 WAS (135.43 cm) and weeding at 3 WAS only (122.15 cm). The interaction between row arrangement and weeding interval was non-significant for plant height at all growth stages.

Sunflower Number of Leaves

The number of leaves per sunflower plant was significantly ($p<0.05$) influenced by both row arrangement and weeding interval at all growth stages (Table 2). At 9 WAS in the combined analysis, the 2:1 row arrangement recorded the highest number of leaves (43.12), followed by the 2:2 arrangement (38.65), and the 1:1 arrangement recorded the fewest leaves (33.74). Weeding at 3, 6, and 9 WAS produced the highest number of leaves (44.85) across all growth stages. A significant interaction was observed between row arrangement and weeding interval for the number of leaves at 9 WAS in the Funtua environment and in the combined analysis (Table 3). The combination of the 2:1 row arrangement with three weeding operations (at 3, 6, and 9 WAS) produced the highest number of leaves (49.06 and 48.14 at Funtua and combined, respectively), while the 1:1 row arrangement weeded only at 3 WAS produced the fewest leaves (29.10 and 28.28, respectively).

Sunflower Crop Growth Rate (CGR)

Sunflower CGR was significantly ($p<0.05$) affected by both row arrangement and weeding interval at 6 and 9 WAS across all environments (Table 4). At 9 WAS, the combined mean CGR was highest under the 2:1 row arrangement (18.66 g/week), followed by the 2:2 arrangement (16.66 g/week), while the 1:1 arrangement recorded the lowest (14.85 g/week). More frequent weeding progressively increased sunflower CGR: weeding at 3, 6, and 9 WAS produced 20.91 g/week, compared to 17.10 g/week (weeding at 3 and 6 WAS) and 13.18 g/week (weeding at 3 WAS only). A significant interaction was observed at 9 WAS at Funtua, suggesting that the superior CGR achieved by the 2:1 row arrangement was further enhanced by three weeding operations at that location.

Watermelon Growth and Yield Parameters

Row arrangement and weeding interval significantly ($p<0.05$) affected all measured watermelon parameters (Table 5). The 2:1 row arrangement produced the longest vines (104.62 cm), the highest number of fruits per plant (2.88), the heaviest fruit weight per plant (4.87 kg), and the greatest fruit yield (13.22 t/ha). In contrast, the 1:1 arrangement recorded the lowest performance across all parameters, including the smallest fruit yield (9.43 t/ha). Weeding at 3, 6, and 9 WAS resulted in the highest fruit yield (14.29 t/ha), significantly superior to weeding at 3 and 6 WAS (11.68 t/ha) and weeding at 3 WAS only (8.77 t/ha). A significant interaction was observed for fruit yield (t/ha), indicating that the combination of the 2:1 row arrangement and three weeding operations provided the most favourable environment for maximum watermelon productivity.

Discussion

The consistently superior performance of the 2:1 sunflower-to-watermelon row arrangement for both component crops across all measured parameters underscores the critical role of spatial organisation in determining the outcome of intercropping systems. A wider effective inter-row spacing in the 2:1 arrangement likely reduced inter-specific competition for light and below-ground resources, allowing both sunflower and watermelon to exploit their respective ecological niches more fully (Li *et al*., 2020). This is consistent with findings by Matusso *et al*. (2014), who reported that wider row ratios in maize-soybean intercrops improved the light use efficiency of the component crops by reducing mutual shading. The 2:1 arrangement may also have created a more favourable microclimate for watermelon vine expansion due to reduced canopy competition from sunflower, thereby enhancing photosynthate partitioning toward fruit development.

The significant positive effect of increasing weeding frequency on all growth and yield parameters highlights the severity of weed pressure in the semi-arid intercropping environments of northeastern Nigeria. The progressive improvement in plant height, CGR, and fruit yield from one to three weeding operations demonstrates that a single weeding event is insufficient to maintain a weed-free environment throughout the critical growth period. Early weed removal at 3 WAS is evidently important for seedling establishment, but subsequent weeding at 6 and 9 WAS is necessary to sustain growth momentum, particularly as canopy closure is incomplete in many intercropping configurations (Olorunmaiye *et al*., 2018). These results corroborate the findings of Caton *et al*. (2003), who demonstrated that the critical weed-free period for cucurbit-based intercrops in tropical semi-arid zones frequently extends beyond 6 WAS.

The significant interaction between row arrangement and weeding interval for sunflower leaf number and watermelon fruit yield suggests that the benefits of improved spatial arrangement are amplified by more rigorous weed control. The synergy observed for the 2:1 arrangement coupled with three weeding operations indicates that when spatial competition is already minimised, the additional removal of weed competitors further liberates resources for enhanced crop productivity. This principle of compound resource liberation has been described theoretically by Brooker *et al*. (2015) and is confirmed empirically by the present study. The non-significance of the interaction for most other parameters simplifies management recommendations, as the best-performing treatments can be prescribed independently without requiring complex combined assessments.

Table 1: Plant height (cm) of sunflower as affected by row arrangement and weeding interval at 3, 6 and 9 WAS across both seasons (2024 and 2025) rainy seasons

Treatment	3 WAS		6 WAS		9 WAS		Combined 9WAS	
2024	2025	2024	2025	2024	2025	2024	2025	
Row Arrangement (RA)								
1:1 (Sunflower:Watermelon)	38.42[b]	36.18[b]	95.31[b]	91.14[b]	112.45[b]	109.22[b]	128.70[b]	125.33[b]
2:1 (Sunflower:Watermelon)	42.85[a]	40.61[a]	103.72[a]	99.50[a]	122.16[a]	118.43[a]	139.25[a]	135.88[a]
2:2 (Sunflower:Watermelon)	40.17[a b]	38.93[a b]	99.88[a b]	96.41[a b]	117.34[a b]	113.72[a b]	133.60[a b]	130.15[a b]
SE(±)	1.724	1.698	2.851	2.744	3.412	3.287	3.891	3.756
Weeding Interval (WI)								
Weeding at 3 WAS only	37.14[c]	34.92[c]	91.23[c]	88.05[c]	107.44[c]	103.88[c]	122.15[c]	118.62[c]
Weeding at 3 & 6 WAS	41.88[b]	39.63[b]	101.67[b]	97.44[b]	119.22[b]	115.66[b]	135.43[b]	131.07[b]
Weeding at 3, 6 & 9 WAS	44.30[a]	42.11[a]	106.85[a]	102.73[a]	125.33[a]	121.54[a]	143.72[a]	139.46[a]
SE(±)	1.724	1.698	2.851	2.744	3.412	3.287	3.891	3.756
Interaction RA x WI	NS	NS	NS	NS	NS	NS	NS	NS

Mean values followed by the same letter(s) in a column are not significantly different according to Duncan's Multiple Range Test (DMRT) at 5% level of probability. NS = Not Significant; * = Significant ($p < 0.05$); WAS = Weeks after Sowing.
Source: Sani M.M. and Mohammed, A.K. (2026).

Table 2: Number of leaves per sunflower plant as affected by row arrangement and weeding interval at 3, 6 and 9 WAS at both seasons and the combined analysis in 2024 and 2025 rainy seasons

Treatment	3 WAS		6 WAS		9 WAS		Combined 9WAS
2024	2025	2024	2025	2024	2025	2024/2025	
Row Arrangement (RA)							
1:1	10.21[b]	9.88[b]	22.44[b]	21.02[b]	34.85[c]	32.63[c]	33.74[c]
2:1	13.72[a]	12.55[a]	28.95[a]	27.34[a]	44.18[a]	42.06[a]	43.12[a]
2:2	12.03[ab]	11.12[ab]	25.71[ab]	24.13[ab]	39.42[b]	37.88[b]	38.65[b]
SE(±)	0.921	0.887	1.632	1.574	2.143	2.067	1.987
Weeding Interval (WI)							
Weeding at 3 WAS	10.08[c]	9.51[c]	21.13[c]	19.88[c]	32.46[c]	30.94[c]	31.70[c]
Weeding at 3 & 6 WAS	12.34[b]	11.25[b]	26.22[b]	24.55[b]	39.93[b]	37.87[b]	38.90[b]
Weeding at 3, 6 & 9 WAS	13.54[a]	12.79[a]	29.87[a]	28.06[a]	46.06[a]	43.74[a]	44.85[a]
SE(±)	0.921	0.887	1.632	1.574	2.143	2.067	1.987
Interaction RA x WI	NS	NS	NS	NS	*	NS	*

Mean values followed by the same letter(s) in a column are not significantly different according to Duncan's Multiple Range Test (DMRT) at 5% level of probability. NS = Not Significant; * = Significant ($p < 0.05$); WAS = Weeks after Sowing.
Source: Sani M.M. and Mohammed, A.K. (2026).

Table 3: Interaction of row arrangement and weeding interval on sunflower number of leaves at 9 WAS for the 2024, 2025 and combined mean rainy seasons

Row Arrangement × Weeding Interval	2024 (9 WAS)	2025 (9 WAS)	Combined 9 WAS
1:1 × Weeding at 3 WAS	29.10^{g}	27.45^{g}	28.28^{g}
1:1 × Weeding at 3 & 6 WAS	36.22^{e}	33.88^{ef}	35.05^{ef}
1:1 × Weeding at 3, 6 & 9 WAS	39.23^{d}	36.55^{de}	37.89^{de}
2:1 × Weeding at 3 WAS	38.15^{de}	35.80^{de}	36.97^{e}
2:1 × Weeding at 3 & 6 WAS	45.32^{b}	43.10^{bc}	44.21^{bc}
2:1 × Weeding at 3, 6 & 9 WAS	49.06^{a}	47.22^{a}	48.14^{a}
2:2 × Weeding at 3 WAS	32.12^{f}	30.07^{f}	31.10^{f}
2:2 × Weeding at 3 & 6 WAS	38.25^{de}	36.65^{de}	37.45^{de}
2:2 × Weeding at 3, 6 & 9 WAS	47.89^{a}	46.04^{ab}	46.96^{ab}
SE(±)	2.014	1.988	1.967

Mean values followed by the same letter(s) in a column are not significantly different according to Duncan's Multiple Range Test (DMRT) at 5% level of probability. NS = Not Significant; * = Significant ($p < 0.05$); WAS = Weeks after Sowing.
Source: Sani M.M. and Mohammed, A.K. (2026).

Table 4: Crop growth rate (g/week) of sunflower as affected by row arrangement and weeding interval at 6 and 9 WAS at both seasons and the combined analysis in 2024 and 2025 rainy seasons

Treatment	6 WAS		9 WAS		Combined 6WAS		Combined 9WAS	
2024	2025	2024	2025	2024	2025	2024	2025	
Row Arrangement (RA)								
1:1	8.43^{b}	7.78^{b}	15.62^{b}	14.08^{b}	8.11^{b}	7.44^{b}	14.85^{b}	13.47^{b}
2:1	11.25^{a}	10.53^{a}	19.48^{a}	17.85^{a}	10.89^{a}	10.21^{a}	18.66^{a}	17.03^{a}
2:2	9.87^{ab}	9.14^{ab}	17.33^{ab}	16.00^{ab}	9.50^{ab}	8.87^{ab}	16.66^{ab}	15.12^{ab}
SE(±)	0.985	0.962	1.234	1.187	0.843	0.821	1.098	1.056
Weeding Interval (WI)								
Weeding at 3 WAS	7.68^{c}	6.92^{c}	13.92^{c}	12.44^{c}	7.30^{c}	6.68^{c}	13.18^{c}	11.94^{c}

Treatment	6 WAS		9 WAS		Combined 6WAS		Combined 9WAS	
2024	2025	2024	2025	2024	2025	2024	2025	
Row Arrangement (RA)								
Weeding at 3 & 6 WAS	10.22^{b}	9.48^{b}	17.85^{b}	16.36^{b}	9.85^{b}	9.22^{b}	17.10^{b}	15.56^{b}
Weeding at 3, 6 & 9 WAS	12.43^{a}	11.72^{a}	21.67^{a}	20.15^{a}	12.07^{a}	11.44^{a}	20.91^{a}	19.38^{a}
SE(±)	0.985	0.962	1.234	1.187	0.843	0.821	1.098	1.056
Interaction RA x WI	NS	NS	NS	NS	NS	NS	*	NS

Mean values followed by the same letter(s) in a column are not significantly different according to Duncan's Multiple Range Test (DMRT) at 5% level of probability. NS = Not Significant; * = Significant ($p < 0.05$); WAS = Weeks after Sowing.

Source: Sani M.M. and Mohammed, A.K. (2026).

Table 5: Watermelon growth and yield parameters as affected by row arrangement and weeding interval in the combined analysis across both seasons (2024 and 2025)

Treatment	Fruit Weight (kg/plant)	No. of Fruits/plant	Vine Length (cm)	CGR (g/week)	Fruit Yield (t/ha)
Row Arrangement (RA)					
1:1	3.42^{b}	2.15^{b}	88.32^{b}	4.85^{b}	9.43^{b}
2:1	4.87^{a}	2.88^{a}	104.62^{a}	6.72^{a}	13.22^{a}
2:2	4.14^{ab}	2.54^{ab}	96.43^{ab}	5.83^{ab}	11.35^{ab}
SE(±)	0.437	0.253	4.762	0.564	1.143
Weeding Interval (WI)					
Weeding at 3 WAS	3.18^{c}	1.92^{c}	82.15^{c}	4.33^{c}	8.77^{c}
Weeding at 3 & 6 WAS	4.25^{b}	2.62^{b}	98.74^{b}	5.91^{b}	11.68^{b}
Weeding at 3, 6 & 9 WAS	5.12^{a}	3.07^{a}	110.46^{a}	7.13^{a}	14.29^{a}
SE(±)	0.437	0.253	4.762	0.564	1.143
Interaction RA x WI	NS	NS	NS	NS	*

Mean values followed by the same letter(s) in a column are not significantly different according to Duncan's Multiple Range Test (DMRT) at 5% level of probability. NS = Not Significant; * = Significant ($p < 0.05$); WAS = Weeks after Sowing.

Source: Sani M.M. and Mohammed, A.K. (2026).

Conclusion

This study demonstrates that both row arrangement and weeding interval are critical determinants of growth and yield performance in sunflower-watermelon intercropping in the semi-arid zone of Borno State. Based on the results of this study, the following conclusions and recommendations are made:

i. The 2:1 sunflower-to-watermelon row arrangement is recommended for its consistent superiority in sunflower plant height, leaf number, CGR, and watermelon fruit yield across both locations and growing seasons.
ii. Weeding at three intervals (3, 6, and 9 WAS) is recommended as the optimal weed management strategy for the sunflower-watermelon intercrop in the semi-arid ecology of northeastern Nigeria.
iii. The significant interaction for sunflower leaf production and watermelon fruit yield indicates that maximum system productivity is achieved by combining the 2:1 row arrangement with three weeding operations, and this combination is specifically recommended for farmers seeking to optimise land productivity.

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