Agr. Foo. Nat. Res. J. Volume 5, Issue 1, Page: 11-20
e-ISSN: 1597-7153 | p-ISSN: 3043-5420

Agriculture, Food and Natural Resources Journal
The Official Journal of the Faculty of Agriculture, Nnamdi Azikiwe University, Awka, Nigeria

Journal homepage: https://journals.unizik.edu.ng/afnrj

Original Article

Effect of weed management methods and plant spacing on the growth and yield of cassava morphotypes

OPEN ACCESS

Ibeabuchi UKO[1]*, Friday EKELEME[2], Anderson Chidi AMADIOHA[2], Lawrence Ikpor CHUKWU[3] & Solomon Chijioke UKO[3]

[1]*Department of Crop Science and Horticulture, Faculty of Agriculture, Nnamdi Azikiwe University, Awka, Nigeria.*
[2]*Department of Plant Health Management, Michael Okpara University of Agriculture, Umudike, Nigeria*
[3]*National Root Crops Research Institute, Umudike, Umuahia, Nigeria*

DOI: https://www.doi.org/10.5281/zenodo.20049591

Editor: *Dr Onyekachi Chukwu, Nnamdi Azikiwe University, NIGERIA*

Received: *November 8, 2025*
Accepted: *February 19, 2026*
Available online: *March 31, 2026*

Peer-review: *Externally peer-reviewed*

Copyright: © 2026 Author(s)
This is an open access article licensed under Creative Commons Attribution 4.0 International License (https://creativecommons.org/licenses/by/4.0/) which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.

Conflict of Interest: *The authors have no conflicts of interest to declare*

Financial Disclosure: *This research was funded by TETFUND under "Academic Staff Training and Development" (June, 2015 to June, 2018). Completed sponsored grant by TETFUND - 2013/2014 (Merged).*

ABSTRACT

An integrated weed management study involving crop spacing, cassava variety, and weed control methods for managing M. invisa in cassava farms was conducted at Umudike, Southeastern Nigeria, over two cropping seasons. The experiment employed a split-split plot arrangement in a randomized complete block design with three replications. Main plot treatments consisted of three plant spacings: 1 m × 0.6 m (S1), 1 m × 0.8 m (S2), and 1 m × 1 m (S3). Two cassava varieties with contrasting morphologies were used as sub-plots: sparse branching TME 419 (V1) and profuse branching NR 8082 (V2). Sub-sub-plot treatments included four weed control methods: hoe weeding at 4, 8, and 12 weeks after planting (WAP) (W1); pre-emergence herbicide (Primextra G. 660 SC at 2.5 kg a.i./ha) applied 1 day after planting (DAP) plus hand weeding at 12 and 16 WAP (W2); pre-emergence herbicide plus post-emergence herbicide (Envoke at 7 g a.i./ha) at 8 WAP (W3); and a weedy control (W0). Data were analyzed using ANOVA, and treatment means were separated using LSD at 5% significance level. Results showed that cassava height was not significantly affected by weed control methods or spacing. TME 419 produced thicker stems than NR 8082. Leaf area of TME 419 decreased with reduced spacing, while NR 8082 increased with reduced spacing. Highest fresh root yields were obtained at 1 m × 0.8 m and 1 m × 0.6 m, indicating these spacings are suitable for relatively fertile soils in Southeastern Nigeria.

KEYWORDS: *Plant spacing, Primextra , Residue management, Weed control*

INTRODUCTION

Cassava (*Manihot esculenta* Crantz) is a perennial root crop belonging to the family Euphorbiaceae and is widely cultivated across tropical and subtropical regions of the world. The crop is characterized by the presence of milky latex typical of members of the Euphorbiaceae and exhibits considerable morphological variability among cultivars and morphotypes (Alves *et al.*, 2020). Cassava is primarily cultivated for its starchy storage roots, which constitute a major source of dietary carbohydrates for millions of people, particularly in developing countries. Globally, cassava ranks among the most important staple crops after rice, maize, and wheat in terms of caloric contribution to human diets (FAO, 2023; Parmar *et al.*, 2021). In addition to

*Corresponding author: i.uko@unizik.edu.ng

human consumption, cassava roots and leaves are used for livestock feed and as raw materials in several agro-industries including starch, ethanol, flour, and biofuel production (Montagnac *et al.*, 2020; Nassar & Ortiz, 2021).

Cassava production has increased considerably over the last decade due to rising demand for food, industrial starch, and climate-resilient crops. The crop is particularly valued for its ability to tolerate drought, low soil fertility, and erratic rainfall conditions, making it an important crop for food security under changing climatic conditions (Jarvis *et al.*, 2022; FAOSTAT, 2024). Nigeria currently remains the largest producer of cassava in the world, contributing a substantial proportion of global production, while countries such as Thailand and Vietnam dominate the export market for cassava-based products (FAO, 2023; Echebiri *et al.*, 2021). Beyond its nutritional importance, cassava has also attracted attention for its medicinal and pharmacological properties, including antimicrobial, anti-inflammatory, and antioxidant activities reported in its leaves and roots (Santos *et al.*, 2022; Uchegbu *et al.*, 2021).

Despite its importance, cassava productivity in many parts of sub-Saharan Africa remains below its potential yield. One of the most critical constraints to cassava production is weed infestation, particularly during the early stages of crop establishment when cassava grows slowly and is less competitive with weeds (Chikoye *et al.*, 2021; Ekeleme *et al.*, 2020). Weeds compete with cassava for nutrients, light, water, and space, thereby reducing crop growth and yield. Studies have reported that uncontrolled weed infestation can result in yield losses ranging from 40% to as high as 90%, depending on weed density, species composition, and duration of weed interference (Chikoye *et al.*, 2021; Ekeleme *et al.*, 2020; Nwosu *et al.*, 2022). In West African cassava fields, troublesome weed species such as *Imperata cylindrica*, *Panicum maximum*, *Mimosa invisa*, and other aggressive grasses and broadleaf weeds have been widely reported (Ekeleme *et al.*, 2020; Udensi *et al.*, 2021). Consequently, effective weed management remains a critical component of cassava production systems.

Weed control in cassava production systems is often labour intensive and constitutes a major proportion of the total production cost. In many tropical farming systems, manual or hoe weeding remains the most commonly used method due to limited access to mechanization and herbicides among smallholder farmers (Chikoye *et al.*, 2021). Reports indicate that weed management can account for more than half of the total labour requirement in cassava cultivation, making it one of the most expensive and time-consuming field operations (Ekeleme *et al.*, 2020). Although chemical and integrated weed management approaches have been introduced to improve weed control efficiency, the adoption of these methods varies widely depending on farm size, availability of inputs, and farmers' knowledge (Udensi *et al.*, 2021).

Plant spacing is another important agronomic factor that significantly influences crop growth, canopy development, and yield. Appropriate plant spacing enhances resource use efficiency and improves crop competitiveness against weeds (Parmar *et al.*, 2021; Nwosu *et al.*, 2022). High crop density resulting from reduced plant spacing can suppress weed growth by reducing light penetration to the soil surface, thereby limiting weed germination and establishment (Korres *et al.*, 2021). The canopy architecture created by different planting densities can modify the crop microclimate, affecting weed emergence, species composition, and the size of the soil seed bank (Korres *et al.*, 2021; Nwosu *et al.*, 2022). Therefore, optimizing plant spacing is a critical cultural practice that can contribute significantly to integrated weed management strategies.

Various weed management methods such as manual weeding, mechanical cultivation, herbicide application, and integrated weed management have been employed in cassava production systems (Ekeleme *et al.*, 2020; Chikoye *et al.*, 2021). However, the effectiveness of these methods varies depending on weed species, environmental conditions, and crop genotype. Cassava's relatively slow initial growth rate allows weeds to establish and dominate the field before the crop canopy closes, thereby reducing crop performance (Parmar *et al.*, 2021). Furthermore, differences in plant architecture and growth patterns among cassava morphotypes may influence their ability to compete with weeds under different management practices.

Understanding the interaction between weed management strategies and plant spacing across different cassava morphotypes is therefore essential for improving cassava productivity. However, limited information exists on how these agronomic practices influence weed dynamics and crop performance under different cassava varieties. Therefore, this study was conducted to evaluate the effects of different weed management methods and plant spacing on the growth and yield of cassava morphotypes, with particular emphasis on the density of *Mimosa invisa* and other associated weeds in cassava fields.

MATERIAL AND METHODS

Study Location: The National Root Crops Research Institute (NRCRI) in Umudike served as the site for this study. The experimental site for the first-season planting was located at 5°29′15″ N and 7°33′12″ E, while the second-season planting was located at 5°29′10″ N and 7°33′18″ E, at an elevation of approximately 122 m above sea level. The geographic coordinates were obtained using Google Maps Global Positioning System (GPS) (Google, 2024).

Umudike lies within the humid rainforest agro-ecological zone of southeastern Nigeria, characterized by a bimodal rainfall pattern lasting from March to November, with peak rainfall between July and September and a short dry spell in August (which is not stable any longer due to climate change). The area receives an average annual rainfall of about 2000–2500 mm and a mean annual temperature of 26–28°C (Ibeawuchi *et al.*, 2020; Nwosu *et al.*, 2021). The soils are predominantly sandy loam

Ultisols derived from coastal plain sands, which are generally low in fertility but suitable for root and tuber crop production (Eshett *et al.*, 2020).

Field Preparation and Treatments: The experimental field was cleared, ploughed, and harrowed before ridges were made 1 meter apart. The stems of the cassava varieties; NR 8082 (a profuse branching variety) and TME 419 (a sparse branching variety) were sourced from the NRCRI, Umudike. Cassava stem cuttings of 23 cm long were planted at different spacing namely: [1m x 0.6m (S1), 1m x 0.8m (S2), and 1m x 1m (S3)] (according to treatments) at about 45^0 angles to the horizontal along the crests of the ridges. Weed control was done according to treatment. The manual hoe weeding was done using locally fabricated small hand hoe while the herbicides were applied using a knapsack sprayer (Cooper Pegler CP-15). The knapsack was fitted with a red flat fan plastic nozzle, and calibrated to spray at a 300 L/ha volume rate. All plots received NPK (15:15:15) fertilizer applied by hand at the rate of 600 kg/ha (Chude *et al.*, 2012), 8 weeks after planting.

Experimental Design: This was a split-split plot within a randomized complete block design replicated three times. The main plot treatments were three crop spacings [1m x 0.6m (S1), 1m x 0.8m (S2), and 1m x 1m (S3)]. The sub-plot treatments involved two cassava varieties with different morphologies (TME 419 and NR 8082), while the sub-sub-plot treatments included four weed control methods: hoe weeding at 4, 8 &12 WAP [weeks after planting (W1)]; application of pre-emergence herbicide (Primextra G. 660 sc at rate 2.5 kg a.i./ha) 1 DAP (day after planting) + hand weeding at 12 and 16 WAP (W2); Application of pre-emergence herbicide (Primextra G. 660 sc at rate 2.5 kg a.i./ha) 1 DAP + post-emergence herbicide (Envoke at rate 7 g a.i./ha) at 8 WAP (W3); and Control – [weedy plot (W0)].

Data Collection: The following parameters were collected from the experiment;

Cassava plant height: The height of five tagged cassava plants in the inner ridges were measured at 4, 8, 12 and 16WAP, with a measuring tape from the tip of the plant to the base of each stem.

Cassava leaf area: A non-destructive technique, as described by Lutaladio (1986), was used to measure the leaf area. This method involves taking the average length of three middle leaves per plant and multiplying by 6.11 at 4, 8, 12, 14, and 16 WAP.

Cassava stem girth: The stem girth from five tagged cassava plants in the inner ridges were measured at 4, 8, 12 and 16WAP, and at harvest using a semi-digital Vernier caliper (RAIDER).

Cassava number of stems: This was taken from each five tagged cassava plants in the inner ridges were countered during harvesting of the root tubers.

Cassava fresh root yield: Cassava stands plants in the inner ridges were carefully pulled by hand from the soil and the root tuber weight from each experimental plot was measured using a weighing scale.

Statistical Model and Analysis: Data collected were analyzed using analysis of variance (ANOVA) with GenStat statistical software (Discovery Edition Version 4, GenStat Release 10.3DE). Significant differences between treatment means were seperated using the least significant difference (LSD) at a 5% probability level.

RESULTS

Effect of Spacing and Weed Control Methods on the Height of Cassava

1st-season2nd-season1st-season2nd-season2nd-season
Cassava plant height did not vary significantly among the different plant spacings during the first and second cropping seasons (Table 1). Similarly, weed control methods did not significantly influence cassava height at 8 WAP in both cropping seasons and at 12 WAP in first season.

However, at 12 WAP in the second cropping season, weed management significantly influenced cassava height. The treatment involving pre-emergence herbicide (Primextra G. 660 SC at 2.5 kg a.i. ha^{-1} applied 1 DAP) followed by post-emergence herbicide (Envoke at 7 g a.i. ha^{-1} applied at 8 WAP) (W3) recorded the highest cassava height (1.047 m). This value was comparable to pre-emergence herbicide followed by hand weeding at 12 and 16 WAP (W2) which recorded 0.980 m, but both treatments were significantly higher than other weed control methods and the weedy control (W0).

Effect of Spacing and Weed Control Methods on Stem Girth of Cassava

1st-season2nd-season2nd-season Plant spacing did not significantly affect cassava stem girth at 8 and 12 WAP in both cropping seasons (Table 1). However, cassava variety significantly influenced stem girth except at 12 WAP in 1st-season. The TME 419 variety consistently recorded larger stem girth than NR 8082 in both cropping seasons.

Weed management methods significantly influenced cassava stem girth at 8 and 12 WAP in both years. The W3 treatment (pre-emergence Primextra followed by post-emergence Envoke) produced the largest stem girth, particularly in the second cropping season, whereas the weedy control (W0) consistently recorded the lowest stem girth values in both cropping seasons.

Table 1. Effect of plant spacing, cassava variety and weed control methods on cassava plant height and stem girth in 2015 and 2016 cropping seasons at Umudike

Treatment	Cassava height (m)				Cassava Stem girth (mm)			
	8 WAP		12 WAP		8 WAP		12 WAP	
	1st-season	2nd-season	1st-season	2nd-season	1st-season	2nd-season	1st-season	2nd-season
Plant Spacing								
1m x 0.6m	0.462	0.658	1.071	0.953	7.97	10.85	84.0	14.53
1m x 0.8m	0.438	0.635	1.028	0.959	7.97	10.69	84.1	14.97
1m x 1m	0.470	0.723	1.075	0.948	8.45	10.85	84.5	14.59
LSD $_{(0.05)}$	NS	NS	NS	NS	NS	NS	NS	NS
Cassava Variety								
TME 419	-	-	-	-	8.97	12.05	84.9	16.19
NR 8082	-	-	-	-	7.29	9.54	83.5	13.20
LSD $_{(0.05)}$	-	-	-	-	0.737	0.81	NS	1.37
Weed Control methods								
W0	0.432	0.569	1.123	0.825	7.16	9.37	54.8	11.99
W1	0.449	0.646	1.082	0.961	8.09	10.94	101.6	15.31
W2	0.464	0.760	0.986	0.980	8.45	10.81	86.8	15.36
W3	0.482	0.713	1.042	1.047	8.83	12.08	93.7	16.14
LSD $_{(0.05)}$	NS	NS	NS	0.094	1.055	0.965	7.10	1.166
Interactions	NS	NS	NS	NS	NS	NS	NS	NS

*WAP = Weeks after planting, W0 = Control – [weedy plot (W0)], W1 = Hoe weeding at 4, 8 & 12 WAP (weeded control), W2 = Application of pre-emergence herbicide (Primextra G. 660 sc at rate 2.5 kg a.i./ha) 1 DAP + hand weeding at 12 and 16 WAP, W3 = Application of pre-emergence herbicide (Primextra G. 660 sc at rate 2.5 kg a.i./ha) 1 DAP + post-emergence herbicide (Envoke at rate 7 g a.i./ha) at 8 WAP, * = Significant at 0.05% and NS = Not significant.*

Effect of Spacing and Weed Control Methods on Leaf Area of Cassava

1st-season Cassava leaf area was not significantly influenced by plant spacing but varied significantly among cassava varieties and weed control methods (Table 2). The TME 419 variety exhibited significantly greater leaf area expansion than NR 8082 in both cropping seasons.

Plots treated with pre-emergence Primextra followed by post-emergence Envoke (W3) produced the largest leaf area at 8 and 12 WAP in both cropping seasons, except at 8 WAP in first season.

The interaction between plant spacing and cassava variety (Table 3) indicated that leaf area of TME 419 decreased with reduced spacing, whereas NR 8082 showed increased leaf area under closer spacing. Furthermore, the interaction effect revealed that at 8 WAP in the second cropping season, TME 419 produced larger leaf area across all plant spacings compared with NR 8082.

Table 2. Effect of plant spacing, cassava variety, and weed control methods on cassava leaf area in 2015 and 2016 cropping season at Umudike at 8 & 12 weeks after planting.

Treatment	Leaf area (m^2)			
	8 WAP		12 WAP	
	1st-season	2nd-season	1st-season	2nd-season
Plant Spacing (PS)				
1m x 0.6m	0.821	0.931	0.872	1.013
1m x 0.8m	0.780	0.948	0.883	0.978
1m x 1m	0.832	0.968	0.905	0.992
LSD $_{(0.05)}$	NS	NS	NS	NS
Cassava Variety (CV)				
TME 419	0.890	1.023	0.926	1.070
NR 8082	0.733	0.875	0.847	0.918
LSD $_{(0.05)}$	0.061	0.048	0.037	0.058
Weed Control methods (WC)				
W0	0.704	0.864	0.770	0.903
W1	0.908	0.955	0.926	1.019
W2	0.804	0.962	0.912	1.017
W3	0.828	1.015	0.938	1.036
LSD $_{(0.05)}$	0.066	0.062	0.037	0.046
Interaction				
PS x CV	NS	*	NS	NS
PS x WC	NS	NS	NS	NS
CV x WC	NS	NS	NS	NS
PS x CV x WC	NS	NS	NS	NS

*WAP = Weeks after planting, W0 = Control – [weedy plot (W0)], W1 = Hand weeding at 4, 8 &12 WAP (weeded control), W2 = Application of pre-emergence herbicide (Primextra G. 660 sc at rate 2.5 kg a.i./ha) 1 DAP + hand weeding at 12 and 16 WAP , W3 = Application of pre-emergence herbicide (Primextra G. 660 sc at rate 2.5 kg a.i./ha) 1 DAP + post-emergence herbicide (Envoke at rate 7 g a.i./ha) at 8 WAP, * = Significant at 0.05% and NS = Not significant.*

Table 3. Effect of plant spacing and cassava variety interaction on cassava leaf area in 2015 and 2016 cropping seasons at Umudike at 8 & 12 weeks after planting (WAP).

Plant spacing	Cassava variety	WAP, cropping seasons and Cassava leaf area (m^2)			
		8 WAP		12 WAP	
		1st-season	2nd-season	1st-season	2nd-season
1m x 0.6m	TME 419	0.858	0.960	0.899	1.072
	NR 8082	0.784	0.901	0.845	0.953
1m x 0.8m	TME 419	0.864	1.023	0.920	1.066
	NR 8082	0.697	0.874	0.846	0.889
1m x 1m	TME 419	0.947	1.084	0.960	1.072
	NR 8082	0.717	0.852	0.849	0.911
LSD $_{(0.05)}$		NS	0.071	NS	NS

WAP = Weeks after planting, NS = Not significant,

Effect of Spacing and Weed Control Methods on Cassava Number of Stems

Weed control methods significantly influenced the number of stems per cassava stand in both cropping seasons (Table 4). In first season, the highest number of stems (3) was recorded in hoe-weeded plots (W1). In the second season, the W3 treatment recorded the highest number of stems (3).

The weedy control (W0) consistently produced the lowest number of stems in both cropping seasons. Cassava variety significantly affected stem number in second season, where TME 419 produced more stems (3) than NR 8082 (2). Plant spacing had no significant effect on the number of cassava stems.

Effect of different Spacing and Weed Control Strategies on Cassava Root Yield

Plant spacing and weed control methods significantly affected cassava fresh root yield in both cropping seasons (Table 4). In the first season, cassava planted at 1 m × 0.6 m spacing produced the highest root yield (24.13 t ha^{-1}) followed by 1 m × 0.8 m (18.7 t ha^{-1}). However, in the second cropping season, the 1 m × 0.8 m spacing produced the highest yield (27.24 t ha^{-1}) followed closely by 1 m × 0.6 m (26.81 t ha^{-1}).

Among weed management treatments, hoe weeding (W1) produced the highest root yield (26.52 t ha^{-1}) in the first cropping season, whereas in second season, the treatment involving pre-emergence Primextra followed by two hoe weedings (W2) produced the highest yield (34.71 t ha^{-1}).

The interaction among plant spacing, cassava variety, and weed control methods was significant in both cropping seasons (Table 5). In the first season, TME 419 planted at 1 m × 0.6 m spacing under W1 treatment produced the highest root yield (36.6 t ha^{-1}). In the second season, the highest yield (52.32 t ha^{-1}) was recorded by TME 419 under W2 treatment at 1 m × 0.8 m spacing. The weedy control plots consistently recorded the lowest yields in both cropping seasons.

Table 4. Effect of plant spacing, cassava variety, and weed control methods on number of cassava stems per stand and cassava fresh root yield (t/ha) at 10 months after planting in 2015 and 2016 cropping seasons.

	Number of stems, root weight (t/ha) and cropping season			
	Number of stems		Fresh root weight (t/ha)	
Treatment	1st-season	2nd-season	1st-season	2nd-season
Plant Spacing (PS)				
1m x 0.6 m (S1)	2	2	24.13	26.81
1m x 0.8 m (S2)	2	2	18.70	27.24
1m x 1m (S3)	2	2	15.66	19.75
LSD (0.05)	NS	NS	5.375	3.125
Cassava Variety (CV)				
TME 419 (V1)	2	3	18.62	26.06
NR 8082 (V2)	2	2	20.38	23.14
LSD (0.05)	NS	0.36	NS	NS
Weed Control methods (WC)				
W0	1	1	5.85	8.66
W1	3	3	26.52	25.74
W2	2	3	23.83	34.71
W3	3	3	21.79	29.30
LSD (0.05)	0.39	0.34	2.991	5.317
Interaction				
PS x CV	NS	NS	NS	NS
PS x WC	NS	NS	NS	NS
CV x WC	NS	NS	NS	NS
PS x CV x WC	NS	NS	*	NS

*W0 = Control – [weedy plot (W0)], W1 = Hoe weeding (HW) at 4, 8 and 12 WAP (weeded control), W2 = Application of pre-emergence herbicide (Primextra G. 660 sc at rate 2.5 kg a.i./ha) 1 DAP + hand weeding at 12 and 16 WAP , W3 = Application of pre-emergence herbicide (Primextra G. 660 sc at rate 2.5 kg a.i./ha) 1 DAP + post-emergence herbicide (Envoke at rate 7 g a.i./ha) at 8 WAP, * = significant at 0.05% probability level, NS = Not significant.*

Plots hoe weeded (W1) gave the highest root fresh yield (26.52 t/ha) in 2015 cropping season. Whereas in 2016 cropping season, the plots treated with the application of pre-emergence herbicide (Primextra G. 660 sc at rate 2.5 kg a.i./ha) 1 DAP followed by two hoe weedings (W2) produced the highest fresh root yield (34.71 t/ha).

The interaction effects of plant spacing, cassava variety, and weed control methods was significant in both cropping seasons (Table 5). The result obtained in 2015 cropping season showed that TME419 in the plots hoe weeded (W1) with the plant spacing of 1 m x 0.6 m had the highest root yield (36.6 t/ha) followed by NR8082 at same spacing in W1 (29.92 t/ha) and at 1 m x 0.8 m spacing in W2 (29.63 t/ha) control method. On the average, cassava plants at 1 m x 0.6 m spacing produced higher root yield than those spaced at 1 m x 0.8 m, and at 1 m x 1 m in both cropping seasons, irrespective of the cassava variety and weed control methods except at 1 m x 0.8 m in W3 weed control method where NR8082 recorded the highest yield (29.63 t/ha) under W2 control method. In 2016, TME419 yielded the highest root production (52.32 t/ha) in plots with 'W2' treatment at 1 m x 0.8 m spacing, while NR8082 followed with 37.66 t/ha in the same 'W2' treatment at 1 m x 0.6 m spacing. The cassava varieties in the Control – [weedy plot (W0)] (W0) had the lowest cassava fresh root yields in both cropping seasons

Table 5. Effect of plant spacing, cassava variety and weed control methods interaction on cassava fresh root yield at 10 months after planting (MAP) in 2015 and 2016 cropping seasons.

			Cropping season and root weight (t/ha)	
Plant spacing	**Cassava variety**	**Weed control methods**	**1st-season**	**2nd-season**
1m x 0.6m	TME 419	W0.	6.64	13.17
		W1.	36.69	22.08
		W2.	28.17	35.61
		W3.	25.56	31.02
	NR 8082	W0.	12.00	10.24
		W1.	29.92	30.30
		W2.	28.45	37.66
		W3.	25.59	34.37
1m x 0.8m	TME 419	W0.	3.16	8.94
		W1.	24.40	30.75
		W2.	19.54	52.32
		W3.	19.15	36.79
	NR 8082	W0.	1.71	3.38
		W1.	27.86	27.45
		W2.	29.63	28.88
		W3.	24.17	29.44
1m x 1m	TME 419	W0.	6.16	9.99
		W1.	16.11	23.76
		W2.	19.98	28.21
		W3.	17.81	20.05
	NR 8082	W0.	5.44	6.20
		W1.	24.14	20.08
		W2.	17.19	25.60
		W3.	18.47	24.10
LSD $_{(0.05)}$			8.86	12.23

W0 = Control – [weedy plot (W0)], W1 = Hand weeding at 4, 8 &12 WAP (weeded control), W2 = Application of pre-emergence herbicide (Primextra G. 660 sc at rate 2.5 kg a.i./ha) 1 DAP + hand weeding at 12 and 16 WAP , W3 = Application of pre-emergence herbicide (Primextra G. 660 sc at rate 2.5 kg a.i./ha) 1 DAP + post-emergence herbicide (Envoke at rate 7 g a.i./ha) at 8 WAP.

DISCUSSION

The absence of significant differences in cassava height among the tested plant spacings suggests that the range of spacing evaluated in this study did not substantially influence early vegetative growth. Cassava plants typically allocate assimilates to canopy establishment during the early stages of growth, and plant height may therefore remain relatively stable across moderate variations in plant density. Previous studies have reported that cassava growth parameters such as height and stem elongation are less sensitive to spacing than yield components, particularly within commonly recommended agronomic densities (Parmar *et al.*, 2021). Furthermore, cassava's relatively slow initial growth allows plants to adjust their architecture to available space without major differences in vertical growth. The significant increase in plant height observed under effective weed control treatments indicates that reduced weed competition likely improved resource availability, especially nutrients and soil moisture. Effective weed management during the first three months after planting has been widely recognized as critical for cassava growth because this period coincides with the crop's slow canopy development and vulnerability to weed interference (Phaphenit & Poonpaiboonpipat, 2023).

The larger stem girth observed in the TME 419 variety compared with NR 8082 highlights the influence of varietal morphology and genetic differences on cassava growth performance. Cassava varieties differ significantly in their branching pattern, canopy architecture, and biomass allocation, which can influence stem development and mechanical support requirements. Vigorous and tall cassava genotypes often develop thicker stems to support greater canopy biomass and leaf area expansion. Similar observations have been reported in cassava agronomic studies where erect and vigorous cultivars exhibited greater stem girth and vegetative biomass than highly branching types (Kreye *et al.*, 2020). In addition, the reduced stem girth observed in the weedy control plots demonstrates the negative effects of weed competition on cassava vegetative growth. Weeds compete aggressively with cassava for essential growth resources including light, nutrients, water, and space, thereby reducing crop growth and biomass accumulation. Studies on cassava agronomy have shown that poor weed management can substantially suppress vegetative growth and reduce plant vigour, particularly during the early stages of crop establishment (Soares *et al.*, 2022).

The larger leaf area recorded in herbicide-treated plots suggests that effective weed suppression improved canopy development and photosynthetic capacity. Leaf area is an important physiological parameter that determines the plant's ability to intercept solar radiation and conduct photosynthesis. When weeds are effectively controlled, cassava plants experience reduced competition for light and nutrients, allowing them to develop a more expansive canopy. This observation is consistent with findings from previous studies which reported that improved weed management enhances leaf area development and biomass accumulation in cassava and other root crops (Amoako *et al.*, 2022). Furthermore, varietal differences in leaf area observed between TME 419 and NR 8082 may be attributed to genetic variations in canopy architecture and branching pattern. Genotypic differences in cassava growth habit are known to influence canopy structure, light interception efficiency, and ultimately crop productivity.

The higher number of stems produced by the TME 419 variety indicates its greater vegetative vigor and branching potential compared with NR 8082. Stem production is an important agronomic trait in cassava because stems serve as planting materials for subsequent cultivation cycles. Varieties that produce more stems can provide farmers with additional planting materials, thereby enhancing the economic value of the crop. Previous studies have reported that cassava genotypes differ widely in their ability to produce stem cuttings due to differences in branching characteristics and vegetative growth patterns (Kreye *et al.*, 2020). The reduction in stem number observed in the weedy control plots further emphasizes the detrimental effects of weed competition on cassava growth. When weeds are not adequately controlled, they compete strongly with cassava during the early growth stages, resulting in reduced vegetative development and lower stem production.

The higher fresh root yields obtained at closer spacings (1 m × 0.6 m and 1 m × 0.8 m) indicate that increased plant population per unit area enhanced overall cassava productivity. Increased planting density often results in more efficient utilization of available resources such as light, nutrients, and soil moisture, which can lead to higher yield per hectare. Studies evaluating cassava agronomic practices have shown that optimizing plant density can significantly increase root yield by improving canopy closure and reducing weed pressure within the field (Onasanya *et al.*, 2021). Higher plant density also facilitates faster canopy formation, which suppresses weed growth through shading and reduces competition for resources. Similarly, research on cassava intensification has demonstrated that integrating improved agronomic practices such as appropriate plant spacing, fertilizer management, and effective weed control can substantially increase cassava root yield beyond traditional farmer practices (Ekeleme *et al.*, 2021).

The superior root yield observed under integrated weed management treatments further underscores the importance of maintaining a weed-free environment during the critical growth period of cassava. Herbicide-based treatments combined with supplementary manual weeding provided more effective weed suppression than the untreated control plots. Effective weed management allows cassava plants to utilize available growth resources more efficiently, resulting in improved biomass accumulation and root development. Previous research has demonstrated that appropriate herbicide use combined with other agronomic practices can significantly increase cassava yields and reduce labour requirements associated with manual weeding (Ekeleme *et al.*, 2021). Conversely, the significantly lower yields recorded in the weedy control plots highlight the severe yield penalties associated with uncontrolled weed infestation. Weed interference has been identified as one of the major constraints to cassava productivity in tropical farming systems, often causing substantial yield reductions when weeds are not adequately managed (Soares *et al.*, 2022).

Overall, the results of this study demonstrated that optimizing plant spacing and implementing effective weed management strategies are essential for improving cassava growth and yield. The findings also highlight the importance of considering varietal characteristics when developing agronomic recommendations for cassava production systems.

CONCLUSION AND RECOMMENDATIONS

In the study area, adopting plant spacings of 1 m x 0.6 m and 1 m x 0.8 m is recommended for optimal canopy coverage, weed suppression, and enhanced root yield in cassava production. Integrating good land preparation / tillage, planting cassava at 1m x 0.6 and 1m x 0.8m for sparse branching and profuse branching varieties, respectively. The application of pre-emergence herbicide (Primextra G. 660 sc at rate 2.5 kg a.i./ha) 1 DAP at a recommended safe level followed by hoe weeding at 12 and/or 16 WAP seems a promising option for cassava cropping system in *M. invisa* infested fields.

Acknowledgement

Authors are grateful to Chikodi Okoh, Abraham, Onyemuche, Onyinyechi Amuta, Oluchi Azuoke, Magnus, Mrs. Okafor and her children, Chizaram and her friends, Kelechi Njoku, Sunday, Joshua, and my siblings for their assistance from land preparation, mapping, planting, weeding, fertilizer application to data collection. Special thanks to N.R.C.R.I. Umudike and Paul Ekeledo for providing land and tractors. Our heartfelt gratitude to Prof. Carol Arinze-Umeobi, Director of TETFUND 2015, for sponsoring this programme, and to Prof. J.E. Ahaneku, former Vice Chancellor of Nnamdi Azikiwe University, Awka, for his support. Your contributions were crucial to this research work.

Authors' Contributions

Conceptualization: L.I and I..; Methodology: F..; Validation: F., I. and L.I.; Formal Analysis: I.; Investigation: I. and S.C.; Resources: I.; S.C.; Data Curation: F. and L.I..; Writing – Original Draft Preparation: I..; Writing – Review & Editing: A.C.; Visualization: I.. and A.C.; Supervision: A.C. and F.; Project Administration: F. and L.I..; Funding Acquisition: I."

Ethical Statement

Not applicable.

REFERENCES

Alves, A. A. C., Setter, T. L., & Fregene, M. (2020). Cassava botany and physiology. In: Hershey, C. (Ed.), *Achieving sustainable cassava production*. CABI Publishing. https://doi.org/10.1079/9781786393050.0011

Chikoye, D., Ekeleme, F., & Udensi, E. U. (2021). Integrated weed management in cassava production systems in sub-Saharan Africa. *Crop Protection*, 146, 105661. https://doi.org/10.1016/j.cropro.2021.105661

Echebiri, R. N., Nwosu, C., & Onwumere, J. (2021). Nigeria's cassava production and export potential in the global market. *African Journal of Agricultural Research*, 17(5), 756-765. https://doi.org/10.5897/AJAR2021.15432

Ekeleme, F., Chikoye, D., & Udensi, E. U. (2020). Weed management in cassava production in Nigeria. *Nigerian Journal of Weed Science*, 33(1), 1–12.

FAO. (2023). *FAOSTAT statistical database on cassava production*. Food and Agriculture Organization of the United Nations. https://www.fao.org/faostat

FAOSTAT. (2024). *Global cassava production statistics*. Food and Agriculture Organization of the United Nations. https://www.fao.org/faostat

Jarvis, A., Ramirez-Villegas, J., Herrera Campo, B., & Navarro-Racines, C. (2022). Climate change impacts on cassava production systems. *Agricultural Systems*, 195, 103297. https://doi.org/10.1016/j.agsy.2021.103297

Korres, N. E., Norsworthy, J. K., & Burgos, N. R. (2021). Crop density and canopy architecture as tools for weed suppression. *Agronomy*, 11(6), 1108. https://doi.org/10.3390/agronomy11061108

Montagnac, J. A., Davis, C. R., & Tanumihardjo, S. A. (2020). Nutritional value of cassava for human health and food security. *Comprehensive Reviews in Food Science and Food Safety*, 19(6), 3014–3034. https://doi.org/10.1111/1541-4337.12585

Nassar, N. M. A., & Ortiz, R. (2021). Cassava improvement: Challenges and prospects. *Plant Cell, Tissue and Organ Culture*, 146, 189–203. https://doi.org/10.1007/s11240-021-02013-7

Nwosu, F. O., Udensi, E. U., & Chikoye, D. (2022). Influence of plant spacing on weed suppression and yield of cassava in southeastern Nigeria. *Nigerian Agricultural Journal*, 53(2), 112–120.

Parmar, A., Sturm, B., & Hensel, O. (2021). Crops that feed the world: Cassava (Manihot esculenta Crantz). *Food Security*, 13, 907–927. https://doi.org/10.1007/s12571-021-01170-4

Santos, A. F., Silva, L. M., & Oliveira, R. (2022). Phytochemical and pharmacological properties of cassava leaves. *Journal of Ethnopharmacology*, 289, 114984. https://doi.org/10.1016/j.jep.2022.114984

Uchegbu, R. I., Okoli, B. E., & Nwankwo, C. S. (2021). Bioactive compounds and medicinal potentials of cassava (*Manihot esculenta*). *Heliyon*, 7(6), e07225. https://doi.org/10.1016/j.heliyon.2021.e07225

Udensi, E. U., Ekeleme, F., & Chikoye, D. (2021). Weed flora dynamics and management strategies in cassava-based systems in West Africa. *Weed Biology and Management*, 21(4), 182–195. https://doi.org/10.1111/wbm.12258

Eshett, E. T., Omueti, J. A. I., & Ezeaku, P. I. (2020). Characterization and management of ultisols in southeastern Nigeria for sustainable crop production. *Nigerian Journal of Soil Science*, 30(1), 1–10.

Google. (2024). *Google Maps*. https://maps.google.com

Ibeawuchi, I. I., Onweremadu, E. U., & Nwite, J. C. (2020). Agro-ecological characteristics and cropping systems of southeastern Nigeria. *African Journal of Agricultural Research*, 15(5), 730–738. https://doi.org/10.5897/AJAR2019.14467

Nwosu, F. O., Chikoye, D., & Udensi, E. U. (2021). Agro-ecological conditions and crop productivity in the humid rainforest zone of southeastern Nigeria. *Journal of Agriculture and Environment*, 17(2), 45–53.

Amoako, O. A., Tetteh, J. P., & Adiku, S. (2022). Growth and yield performance of cassava under different crop management practices. *International Journal of Agricultural Technology*, 18(5), 1871–1886.

Ekeleme, F., Chikoye, D., Udensi, E., & Lum, A. (2021). Increasing cassava root yield on farmers' fields in Nigeria through improved agronomic practices. *Agricultural Systems*, 191, 103159. https://doi.org/10.1016/j.agsy.2021.103159

Kreye, C., Bouman, B., & van Ittersum, M. (2020). Intensification options of smallholder cassava production systems. *Agronomy Journal*, 112(5), 3493–3504. https://doi.org/10.1002/agj2.20419

Onasanya, O. O., Hauser, S., Necpálová, M., Salako, F. K., Kreye, C., Tariku, M., Six, J., Pypers, P. (2021 On-farm assessment of cassava root yield response to tillage, plant density, weed control and fertilizer application in southwestern Nigeria. *Field Crops Research,* 262: 10803. https://doi.org/10.1016/j.fcr.2020.108038

Parmar, A., Sturm, B., & Hensel, O. (2021). Crops that feed the world: Cassava (*Manihot esculenta Crantz*). *Food Security*, 13, 907–927. https://doi.org/10.1007/s12571-021-01170-4

Phaphenit, K. & Poonpaiboonpipat, T. (2023). Critical period of weed control in cassava planted during the rainy season of Thailand. *International Journal of Agricultural Technology*, 19(3), 1179-1190.

Soares, D. O., Pinto, K. G., Bhowmik, P. C., & Albertino, S. M. (2022). Chemical properties of soil and cassava yield as a function of weed management by cover crops in the Amazon ecosystem. *Sustainability*, 14(3), 1886. https://doi.org/10.3390/su14031886