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Cassava Performance and Weed Biomass as Affected by Arbuscular Mycorrhizal Inoculation and Weed Control Methods

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Abstract: Cassava is a major crop usually cultivated under low soil fertility by African farmers in an attempt to combat hunger and alleviate poverty. However, its production is limited by inadequacy of funds for the purchase of fertilizer to boost yield. Thus, the introduction of arbuscular mycorrhizal fungi (AMF) inoculation, but information on its effect on cassava under different weed management options is limited. Therefore, the study assessed AMF inoculation (*Glomus clarum*) on cassava under commonly practised weed control methods for two years in South western Nigeria. In a 2 x 4 factorial arrangement, AMF inoculation (no AMF and with AMF) and four weed control methods (hoe, atrazine, melon and atrazine+melon) were evaluated in a randomised complete block design with 3 replicates. Cassava (TMS 30572) was planted at 10,000 plants/ha and each plot size was 5 x 5 m. Data on cassava performance at harvest, nutrient concentration and weed biomass were analysed using analysis of variance ($p<0.05$) and descriptive statistics. Relative to the non-inoculated cassava, AMF inoculation improved the growth parameters in both cropping years. The total weed biomass was significantly reduced by AMF inoculation in the first cropping and by 19.6% compared to the no AMF treatment in the second year. Hoe treatment significantly reduced cassava height and increase total weed biomass compared to atrazine, melon and atrazine+melon in both years. The atrazine+melon treatment had the highest shoot biomass in the first year and significantly higher shoot biomass compared to the other treatments in the second year. The AMF treatment improved cassava fresh root tuber yield by 15.4% in the first year and with significant increase in the second year. The atrazine, melon and atrazine+melon significantly increased fresh root tuber yield in cassava compared to hoe treatment in both years. The yields varied significantly among the treatment interactions with increase in AMF inoculated interactions than the non-inoculated. The highest fresh root tuber yield were observed in AMF x melon, but was similar to AMF x atrazine and AMF x atrazine+melon treatments, while the non-inoculated x hoe treatment had the lowest yield. The AMF inoculation with melon or

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1. Introduction

Cassava (*Manihot esculentus* Crantz) is a major crop cultivated for its acceptance and ease of cultivation among farmers in Sub-Saharan Africa. Population growth and the attempt to adequately provide food for the increasing urban community (from the limited available land resources) coupled with increasing industrial demands and financial constraints faced by farmers to procure fertiliser, have necessitated the continued cultivation of low-fertility soils. According to FAO (2022), the world average cassava yield in 2021 was estimated at 10616.7 kg ha^{-1}, while the average yield of 8545.7 kg ha^{-1} and 6937.4 kg ha^{-1} were reported for Africa and Nigeria, respectively. The yield gap between the average and the potential yields of cassava in Africa and Nigeria indicated that through intensification cassava production can be increased.

Despite the introduction of improved varieties, low soil fertility and poor weed management strategies remain the major constraints to increasing fresh root tuber yield in cassava production in Sub-Saharan Africa (Ekeleme *et al*., 2021). Relative to other crops, cassava does well under poor soil condition (Luar *et al*., 2018). However, research on the potential and importance of the application of soil amendments to improve soil fertility status for improved cassava yield has been adequately exploited (Biratu *et al.,* 2018; Akinrinola and Fagbola, 2019; Omondi and Yermiyahu, 2021; Onasanya *et al*., 2021). Attempt to overcome this problem through inorganic fertilizer application has not been so encouraging. The high cost and negative impact of inorganic fertilizers as well as insufficient availability of organic fertilizers has limited their recommendation for use by farmers in sub-Saharan

Africa including Nigeria (Ricker-Gilbert, 2020). Consequently, the introduction of arbuscular mycorrhizal fungi (AMF) inoculation is gaining recognition to help exploit the inherent soil P that was not readily available for crop use and other essential crop nutrients (Basiru and Hijri, 2022). The contribution of AMF inoculation in enhancing cassava performance has been reported (Cavallari *et al*., 2021). It has become a promising approach to ensuring an increase in crop production for the growing population.

The important contribution of AMF inoculation in improving cassava production has been substantiated, however, the challenge posed by poor weed management strategy poses threat to achieving sustainable crop production (MacLaren *et al*., 2020). The most common approach adopted by farmers in managing weeds has proved not to be efficient in controlling weeds. The approach commonly used in weed management practises by farmers could be 53% less efficient in controlling weeds compared to herbicides application (Ekeleme *et al.*, 2021). Similarly, the continued migration of the local workforce from the rural community has increased the need for an alternative to reduce dependence on labour by sourcing for alternatives approach to weed management in Nigeria. Consequently, the amount of manual labour required through appropriate herbicide use will reduce, thus improving the livelihoods of farmers (Ekeleme *et al.*, 2021). Since cassava is normally intercropped with maize in a maize-based cropping system, most farmers commonly use atrazine as pre-emergence. Reports of AMF interaction with the commonly adopted weed management strategies on the field by farmers to reduce demand for labour are scanty. Therefore, the objective of this study was to evaluate arbuscular mycorrhizal fungi inoculation under different weed management options in cassava cultivation.

2. Materials And Methods

2.1. Experimental Site

The experiment was conducted in 2017 and 2018, at the Ayepe research field of the Department of Agronomy, University of Ibadan, Ibadan, located in the Isokan Local Government Area, of Osun state Nigeria. The coordinate of the location is 7°17'29.83"N and 4°16'31.88"E, at 90.82 m elevation). According to Köppen's climate classification of the region, the location is of the Aw type (Tropical savannah climate) with precipitation of the driest month<100 – mean annual precipitation/25 (Peel *et al*., 2007). The average data on temperature, and precipitation during the growing seasons were obtained from the NASA power data (2022) and presented in Figure 1.

The study was carried out under rainfed conditions with precipitation during the study period in both years.

A detailed description of the farming systems in Ayepe had been reported by Mutsaers *et al.* (1987). The soil at the experimental site was classified as Loamy sand with 6.7 pH (H_2O), 806 g kg-1 sand, 111 g kg^{-1} silt, and 63 g kg^{-1} clay.

2.2 Experimental design and treatments

The experiment was a 2 x 4 factorial arrangement involving Arbuscular Mycorrhizal Fungi (AMF) inoculation (no AMF and with AMF) and four weed control methods (hoe, atrazine, melon and atrazine+melon) evaluated in a randomised complete block design with 3 replicates.

2.3 Study materials and field establishment

The mycorrhizal fungus used for this study was *Glomus clarum* obtained from the stock kept and maintained in the Soil Microbiology Laboratory of the Department of Soil Resources Management, University of Ibadan, Nigeria. The cassava variety TMS 30572 used for the study was CMD-resistant and grown by farmers in the locality. Stem cuttings of about 25 - 30 cm were planted at 1 cutting per heap. Two seeds of melon were planted beside the heap at a spacing of 1 m x 1 m. The AMF inoculum was applied beside the planted cuttings at 20 g/plant.

The pre-emergence herbicide (atrazine) was applied at 1.5 kg a.i./ha (ICS-Nigeria, 2011). Herbicides were applied with a knapsack sprayer, using a green deflector polijet nozzle.

2.4 Field management

The field was cleared manually and the refuse was removed before the making of heaps. Heaps were constructed at 1 m x 1 m apart and each plot size was 5 m x 5 m with 1 m between the plot. Weeding operations on the plots were carried out at 4, 8 and 12 weeks after planting (WAP) and subsequently as when necessary until the time of cassava harvest. The cassava was grown for 12 months.

2.5 Data collection

Data on plant height and height at branching (using ruler), stem diameter (using Vernier calliper), number of cassava shoots (by counting), shoot biomass, the total number of cassava stands/plot and cassava fresh root tuber yield was measured at harvest using Salter dial scale model ND. The weed biomass at 4, 8 and 12 WAP was determined using a 1 m x 1 m quadrant. Nutrient concentrations in the 3rd to 5th cassava leaves from the top were determined at 4 months after planting (Howeler, 2012; Adiele *et al*., 2021) as described by IITA (1982) using wet digestion methods.

The repeated experiment (second cropping) was planted 2 weeks after harvesting, at the same spacing and plot layout on an adjacent field.

2.6 Data analysis

The observed parameters were subjected to analysis of variance using SAS version 9.4. Duncan Multiple Range Test at $p<0.05$ level of probability was used in separating the significant means among treatments.

3. Results

3.1.1 The performance of cassava as affected by arbuscular mycorrhizal inoculation

The growth response of cassava to AMF inoculation at harvest was presented in Table 1. Cassava height was significantly increased by AMF inoculation compared to the untreated plants in year 1, while no significant difference was observed in the following year's cultivation. Cassava stem diameter was not significantly affected by AMF inoculation in the two years of cultivation. Also, the height at branching in cassava was not significantly improved by AMF inoculation compared to the untreated plants in both years of cultivation. The number of stems at harvest was higher in the AMF-inoculated plants with no significant variation in the first cropping. However, in the second cropping, the number of stems in the inoculated plants was significantly higher than the stems observed for the non-inoculated. The AMF-inoculated plants had 44.87% more shoot biomass than the treatment without inoculation in the first year, while in the second year, the shoot biomass increase differed significantly compared to the non-inoculated treatment.

3.1. 2 The performance of cassava as affected by weed control methods

The use of atrazine, melon and atrazine+melon significantly improved cassava height compared to the hoe weeding in the first and second cropping (Table 1). Relative to the hoe treatment at the first and second cropping, the stem diameter of cassava at harvest was significantly increased under atrazine+melon and atrazine treatments. The height of cassava at branching was not significantly affected by weed control methods. The atrazine+melon treatment had the lowest value of height at branching in both cropping, while the use of hoe and melon methods of weed control had the highest values in the first and second cropping, respectively. The number of cassava branches was not significantly affected in the first cropping. However, in the second cropping, the atrazine treatment produced significantly fewer number of branches compared to the other weed management options considered. Significantly higher cassava shoot biomass was observed in the atrazine+melon and atrazine treatments compared to hoe and melon treatments in the first year. However, in the second year, the atrazine+melon treatment had significantly higher shoot biomass compared to the other treatments. The lowest cassava shoot biomass in both years was observed under the hoe treatment. In all the growth parameters observed, the atrazine and/or atrazine+melon treatments had higher values compared to the hoe and melon treatments.

3.1.3 The performance of cassava as affected by arbuscular mycorrhizal inoculation x weed control method interactions

Cassava heights at harvest were not significantly different from one another, except between the treatment involving no AMF inoculation and hoe in the first cropping (Table 1). Also, in the second cropping, the treatments were similar for cassava height. However, the no AMF inoculation x atrazine, no AMF x melon and AMF x atrazine+melon interactions had significantly higher cassava height at harvest than the no AMF x hoe treatment. The trends in stem diameter in cassava were similar in the first and second cropping, except between no AMF x atrazine+melon and no AMF x hoe in the first cropping, and with AMF x atrazine in the second year that had significant variations. For cassava main stem height at first branching, the treatment with AMF x hoe had significantly higher height than the no AMF x atrazine+melon treatment, while the other treatments did not differ significantly in the first cropping. In the second cropping, the interactions between arbuscular mycorrhizal inoculation and weed control method on cassava height at first branching were not significant. Although the plants under AMF inoculation x melon had the highest number of cassava stems at harvest in the first cropping, the difference was not significant. In the second cropping, all weed control methods with AMF inoculation had a significantly higher number of stems than the no AMF interactions, except AMF inoculation x atrazine interaction. Cassava shoot biomass was significantly higher in the interactions involving no AMF x atrazine, no AMF x melon and with AMF x atrazine+melon compared to no AMF x hoe treatment in the first cropping. For the second cropping, the treatment with AMF inoculation x atrazine+melon had significantly higher shoot biomass at harvest compared to the other treatments. Also, the other interactions had significantly higher shoot biomass than the no AMF x hoe interaction.

3.2.1 Weed biomass as affected by arbuscular mycorrhizal inoculation

The cassava plot inoculated with AMF had significantly lower weed biomass compared to the non-inoculated treatment at 4 WAP (Table 2). At 8 and 12 WAP the weed biomass did not differ significantly between the inoculated and the non-inoculated, however, AMF inoculated treatment had 33.3 and 15.0% lower weed biomass than the non-inoculated in the first and second years, respectively.Relative to the no AMF treatment, the total weed biomass was significantly reduced by mycorrhizal inoculation in the first year and 19.6%

Table 1: Cassava performance as influenced by mycorrhizal inoculation, weed control methods and their interactions at harvest

Mean	Year 1					Year 2				
	Plant height (cm)	Stem diameter (cm)	Height at branching (cm)	No. of stems	Shoot biomass	Plant height (cm)	Stem diameter (cm)	Height at branching (cm)	No. of stems	Shoot biomass
Mycorrhizal inoculation (M)										
No AMF	239.71b	2.03	129.39	1.25	1.56	237.73	1.98	125.14	1.10b	0.88b
With AMF	280.06a	2.05	155.56	1.67	2.26	234.98	2.10	120.35	2.08a	1.89a
LSD	26.80	ns	ns	ns	ns	ns	ns	ns	0.27	0.35
Weed control methods (W)										
Hoe	226.99b	1.77b	162.42	1.42	1.08b	204.76b	1.70b	124.32	1.67a	0.93b
Atrazine	273.30a	2.05ab	142.73	1.42	2.23a	246.52a	2.23a	129.17	1.25b	1.31b
Melon	269.22a	2.07ab	148.60	1.58	2.04ab	247.82a	2.10ab	129.45	1.67a	1.30b
Atrazine+Melon	270.01a	2.27a	116.15	1.42	2.29a	246.32a	2.12ab	108.05	1.78a	2.00a
LSD	37.91	0.44	ns	ns	1.04	40.38	0.46	ns	0.38	0.50
M x W interactions										
No AMF x Hoe	160.16b	1.72b	143.70ab	1.33	0.66b	186.93b	1.61b	131.97	1.00b	0.32c
Atrazine	272.05a	2.06ab	127.67ab	1.33	1.55ab	269.93a	2.11ab	117.67	1.17b	1.10b
Melon	257.01a	1.91ab	164.03ab	1.17	1.98ab	252.43a	2.18ab	132.30	1.00b	1.13b
Atrazine+Melon	269.61a	2.43a	82.17b	1.17	2.05ab	241.64ab	2.01ab	118.63	1.22b	0.97bc
With AMF x Hoe	293.83a	1.82ab	181.13a	1.50	1.50ab	222.60ab	1.79ab	116.67	2.33a	1.55b
Atrazine	274.56a	2.03ab	157.80ab	1.50	2.91a	223.10ab	2.34a	140.67	1.33b	1.51b
Melon	281.44a	2.22ab	133.17ab	2.00	2.11ab	243.20ab	2.02ab	126.60	2.33a	1.46b
Atrazine+Melon	270.40a	2.11ab	150.13ab	1.67	2.53a	251.00a	2.22ab	97.47	2.33a	3.02a
LSD	53.61	0.62	95.16	ns	1.48	57.10	0.65	ns	0.54	0.71

AMF = arbuscular mycorrhizal fungi

Table 2: Weed biomass (t/ha) as affected by arbuscular mycorrhizal inoculation, weed control methods and their interactions

Mean	Year 1 (WAP)				Year 2 (WAP)			
	4	8	12	Total weed	4	8	12	Total weed
Mycorrhizal inoculation (M)								
No AMF	1.67a	1.50	1.23	4.40	1.42	2.13	1.40	4.95
With AMF	0.87b	1.01	0.83	2.70	0.97	1.82	1.19	3.98
LSD	0.54	ns	ns	1.14	ns	ns	ns	ns
Weed control methods (W)								
Hoe	2.08a	2.00	1.64	5.71a	2.04a	2.76	1.83	6.63a
Atrazine	0.14b	0.80	0.66	1.60b	0.35b	1.84	1.21	3.39bc
Melon	2.38a	1.40	1.14	4.92a	1.96a	2.04	1.35	5.35ab
Atrazine+Melon	0.48b	0.83	0.68	1.98b	0.42b	1.25	0.81	2.48c
LSD	0.77	ns	ns	2.53	0.75	ns	ns	2.79
M x W interactions								
No AMF x Hoe	2.75ab	2.62a	2.14a	7.50a	2.42ab	2.62	1.73	6.76a
Atrazine	0.10d	0.69b	0.56b	1.35c	0.25d	1.86	1.22	3.33ab
Melon	3.00a	1.61ab	1.31ab	5.92ab	2.50a	2.38	1.57	6.44a
Atrazine+Melon	0.83cd	1.10ab	0.90ab	2.83bc	0.50cd	1.66	1.09	3.25ab
With AMF x Hoe	1.42c	1.38ab	1.13ab	3.92a-c	1.67ab	2.91	1.92	6.50a
Atrazine	0.18d	0.92ab	0.75ab	1.85c	0.45cd	1.81	1.19	3.45ab
Melon	1.75bc	1.19ab	0.97ab	3.92a-c	1.42bc	1.71	1.12	4.25ab
Atrazine+Melon	0.12d	0.55b	0.45b	1.12c	0.33d	0.83	0.54	1.70b
LSD	1.09	1.73	1.42	3.58	1.07	ns	ns	3.94

AMF = arbuscular mycorrhizal fungi

weed biomass reduction in the second year. Generally, the application of soil amendments for crop improvement has been reported to also increase weed growth.

3.2.2 Weed biomass as affected by weed control methods

The atrazine and atrazine+melon treatments had significantly lower weed biomass compared to the hoe and melon treatments at 4 WAP in the first and second cropping (Table 2). The weed biomass among the treatments was not significantly affected by weed control methods at 8 and 12 WAP. However, at 8 and 12 WAP, the atrazine treatment had the lowest weed biomass in the first cropping and atrazine+melon in the second cropping. The total weed biomass differed significantly among treatments in the two years of cropping. In the first year, atrazine and atrazine+melon treatments had significantly lowered total weed biomass compared to hoe and melon treatments. For the second year cropping, the hoe treatment had significantly higher total weed, while the least was observed in the atrazine+melon treatment.

3.2.3 Arbuscular mycorrhizal inoculation x weed control method interactions on weed biomass

The treatments involving atrazine with or without Inoculation resulted in significantly lower weed biomass compared to the treatments without atrazine at 4 WAP in both cropping (Table 2). At 8 and 12 WAP in the first cropping, the interactions of AMF inoculation with atrazine and atrazine+melon treatments had significantly lower weed biomass compared to no AMF x hoe treatment, while others were similar. The trend in the second cropping was similar to the observed at the first cropping for weed biomass at 8 and 12 WAP. However, the variations were not significant, but the lowest values at 8 and 12 WAP were observed in the AMF inoculation x atrazine+melon treatment. The total weed biomass ranged from 1.12 to 7.5 and 1.7 to 6.76 t/ha in the first and second cropping, respectively, and varied significantly among the treatments. The lowest and highest weed biomass were observed in the interactions involving AMF x atrazine+melon and no AMF x hoe, respectively.

3.3.1 Nutrient concentration in cassava as affected by arbuscular mycorrhizal inoculation

The AMF-inoculated treatment improved N concentration in cassava by 11.26% in the first year, and in the second year, the increase was significantly higher compared to the non-inoculated treatment (Table 3). The total P observed in cassava was significantly increased by AMF inoculation compared to the no AMF treatment in the first year, while the difference was not significant in the second year. For K concentration in cassava, the AMF inoculation significantly enhanced its concentration than the observed value in the non-inoculated plants in both years. Calcium concentration in cassava treated with AMF inoculation was higher by 20.79% compared to the no AMF treatment in the first year, while in the second year, the increase was significant. The concentration of Mg in cassava was higher by concentration compared to the observed value in the treatment without AMF inoculation.

3.3.2 Nutrient concentration in cassava as affected by weed control methods

The atrazine, melon and atrazine+melon approach of weed control significantly increased N

Table 3: Nutrient concentrations in cassava as affected by the interactions of arbuscular mycorrhizal inoculation and weed control methods

Mean	Year 1 (%)					Year 2 (%)				
Mycho	N	TP	K	Ca	Mg	N	TP	K	Ca	Mg
Mycorrhizal inoculation (M)										
No AMF	4.44	1.08b	5.72b	1.75	1.65	3.86b	1.21	6.48b	1.57b	1.76b
With AMF	4.94	1.41a	7.04a	1.90	1.57	4.68a	1.22	7.05a	2.55a	2.21a
LSD	ns	0.01	1.24	ns	ns	0.33	ns	0.27	0.44	0.30
Weed control methods (W)										
Hoe	3.97b	1.33b	5.76	1.11c	1.33b	3.89b	1.36a	6.43c	1.72b	1.68b
Atrazine	4.96a	0.98d	5.55	1.84b	1.80a	4.26ab	1.20b	6.93b	1.89ab	2.02ab
Melon	4.85a	1.46a	6.92	2.20a	1.40ab	4.28ab	1.06c	6.30c	2.23ab	2.06ab
Atrazine+Melon	4.97a	1.20c	7.28	2.15a	1.92a	4.67a	1.25ab	7.40a	2.38a	2.17a
LSD	0.72	0.01	ns	0.31	0.54	0.47	0.13	0.38	0.62	0.42
M x W interactions										
No AMF x Hoe	3.66c	1.18d	4.96c	1.07c	1.24bc	3.41c	1.34ab	6.13de	1.07cd	1.17c
Atrazine	4.50a-c	0.85g	5.67bc	1.93b	1.58a-c	4.01bc	1.24a-c	7.27b	1.9bc4	1.71bc
Melon	4.81ab	1.08f	5.67bc	1.85b	1.86ab	4.13b	0.91d	6.50c-e	0.90d	1.98ab
Atrazine+Melon	4.78ab	1.21c	6.57a-c	2.14ab	1.92ab	3.90bc	1.34ab	6.03e	2.37b	2.18ab
With AMF x Hoe	4.27bc	1.49b	6.57a-c	1.14c	1.41a-c	4.36b	1.37a	6.73bc	2.38b	2.19ab
Atrazine	5.41a	1.12e	5.43c	1.74b	2.02a	4.50b	1.15c	6.60cd	1.84bc	2.33a
Melon	4.90ab	1.84a	8.17a	2.54a	0.94c	4.43b	1.21a-c	6.10de	3.56a	2.14ab
Atrazine+Melon	5.16ab	1.18d	8.00ab	2.16ab	1.92ab	5.44a	1.16bc	8.77a	2.40b	2.16ab
LSD	1.02	0.02	2.48	0.44	0.76	0.67	0.18	0.54	0.88	0.60

AMF = arbuscular mycorrhizal fungi

concentration in cassava compared to the hoe method in the first year of cropping (Table 3). In the second year, atrazine+melon treated plants had significantly higher N concentrations than the hoe method of controlling weeds, while the other treatments were similar. The total P in cassava varied significantly among treatments with the highest in the first and second years observed in melon and hoe treatments, respectively. The lowest total P in the first year of cropping was observed in the atrazine-treated plant, while in the second year, the melon treatment had the lowest total P value. The concentration of K did not vary significantly among the treatments in the first year, however, atrazine+melon treated plant had the highest value. In the second year, plants treated with atrazine+melon had a significantly higher concentration of K compared to the other treatments. Similarly, atrazine treatment improved K concentration more than hoe and melon treatments. The concentration of Ca was significantly increased in the melon and atrazine+melon treated plants compared to the atrazine treated plants, which also had a significantly higher value than the hoe treatment in the first cropping. In the second cropping, the atrazine+melon treatment improved Ca concentration compared to the hoe method of controlling weeds, while the other treatments were similar. The atrazine+melon treated plants in both years of cropping had a significantly higher concentration of Mg than the hoe method. The other weed control methods were similar in both years, except for atrazine treated plants in the first cropping with significantly higher Mg concentration than the hoe treated plants.

3.3.3 Nutrient concentration in cassava as affected by the interaction of arbuscular mycorrhizal inoculation and weed control methods

The nutrient concentrations in cassava differed significantly among treatment interactions in the first and second cropping (Table 3). The N concentration ranges from 3.66% (no AMF x hoe) to 5.41% (with AMF x atrazine) in the first cropping and 3.41% (no AMF x hoe) to (with AMF x atrazine+melon) in the second cropping. The inoculated cassava plants under melon and hoe methods of weed control had significantly higher total P than the other treatments in first and second cropping, respectively. The concentration of P was relatively lower under atrazine application, with or without AMF inoculation. The K concentration in cassava differed significantly among treatments and ranged from 4.96 in the no AMF x hoe interaction to 8.71 in the with AMF inoculation x melon interaction in the first cropping. In the second cropping, however, the lowest and highest K concentrations were observed under the no AMF x atrazine+melon interaction and with AMF x atrazine+melon. Calcium concentrations in both cropping were significantly higher in the inoculated plants with melon compared to the other treatment interactions, except with and without AMF inoculation x atrazine+melon in the first cropping. The AMF inoculated x atrazine interaction significantly improved Mg concentration in cassava compared to no AMF x hoe and with AMF x melon in the first cropping. Also, in the second cropping, AMF x atrazine interaction significantly increased Mg concentration compared to the no AMF x hoe and no AMF x atrazine interactions.

3.4.1 The total number of cassava stands as affected by arbuscular mycorrhizal inoculation

The effect of mycorrhizal inoculation compared to the non-inoculated treatments on the total number of stands/ha is shown in Figure 1. The inoculated treatment had 6.11% higher total number of stands/ha compared to the non-inoculated treatment in the first cropping. However, in the second cropping, the inoculated plants had a significantly higher total number of stands/ha than the no AMF treatment.

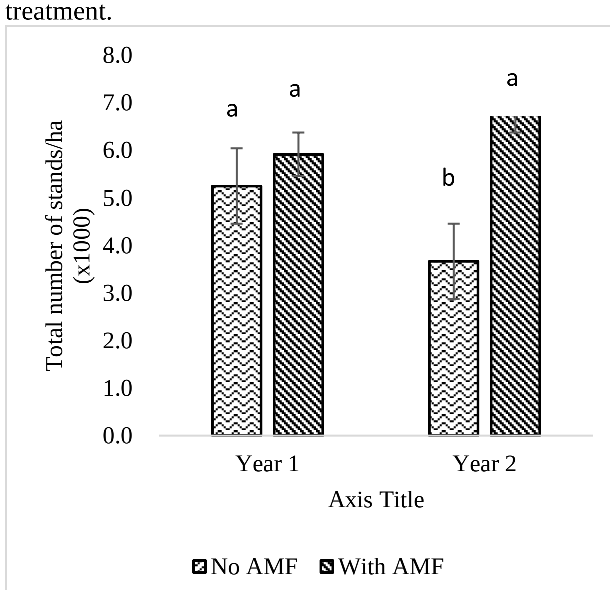

Figure 1: Fresh root cassava tuber yield as affected by weed control methods. Bars sharing the same letters are not significantly different (p = 0.05, LSD test).

3.4.2 The total number of cassava stands as affected weed control methods

The two years average total number of cassava stands/ha is shown in Figure 2. The methods of weed control varied significantly among the treatments for the average total number of cassava stands/ha during the two years of cropping. The hoe treatment had significantly higher total number of stands than the atrazine and atrazine+melon treatments, but was similar to the melon treatment. The plot treated with atrazine+melon had the lowest total number of stands/ha, but the difference was not significant from the atrazine treatment.

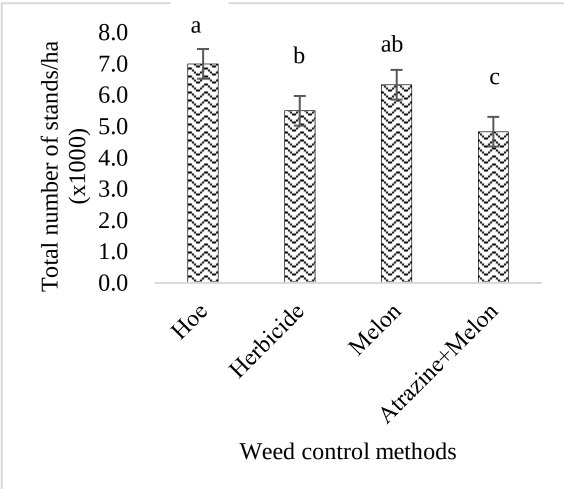

Figure 2: Total number of cassava stands at harvest as affected by weed control methods. Bars sharing the same letters are not significantly different (p = 0.05, LSD test).

3.4.3 The total number of cassava stands count as affected AMF inoculation x weed control methods interactions

The total number of cassava stands/ha was significantly affected by treatment interactions as indicated in Figure 3. Significantly higher number of stands was observed under no AMF x hoe interaction compared to the other treatment interactions. Relatively, with or without AMF inoculation, atrazine treated plots had lower number of stands than the untreated plots. This could be the consequential effect of the herbicide on stand survival.

3.5.1.Fresh root yield of cassava as affected by arbuscular mycorrhizal inoculation

The response of cassava fresh root tuber yield to AMF inoculation was not significantly affected in the first cropping, however, a yield increase of 15.42% fresh root tuber was observed from the inoculated plants compared to the non-inoculated (Figure 4). For the second cropping, the fresh root tuber yield in cassava was significantly improved by AMF inoculation compared to the no AMF treatment.

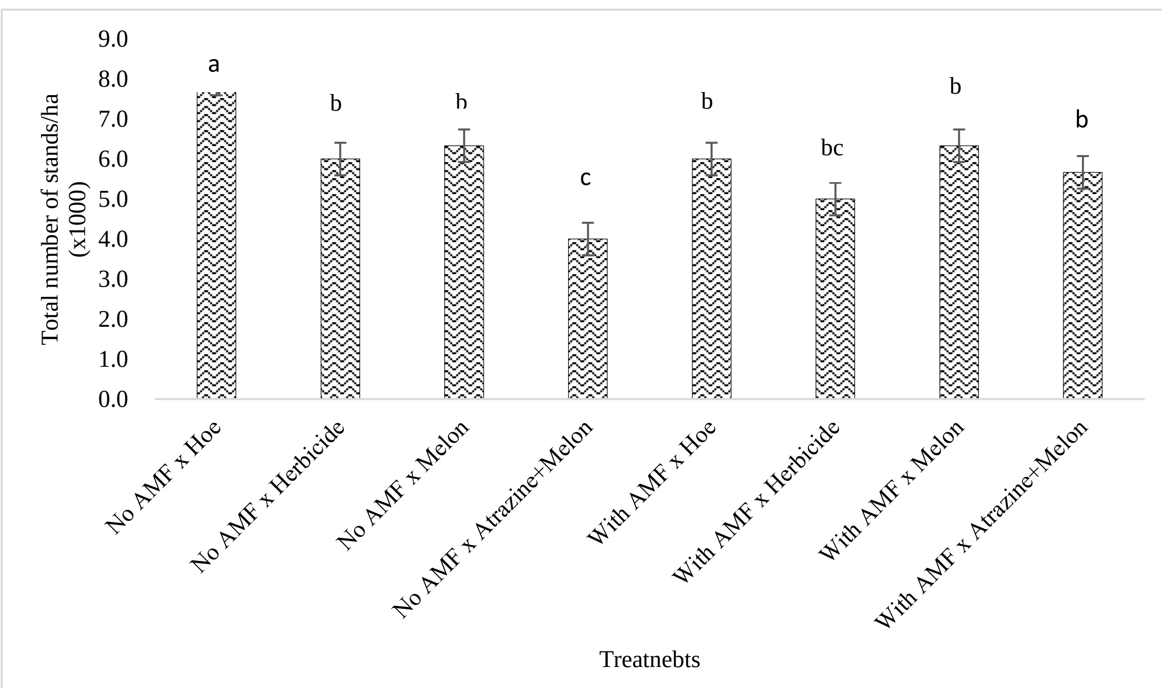

Figure 3: Total number of cassava stands stands at harvest as affected by the interactions of arbuscular mycorrhizal inoculation and weed control methods. Bars sharing the same letters are not significantly different (p = 0.05, LSD test).

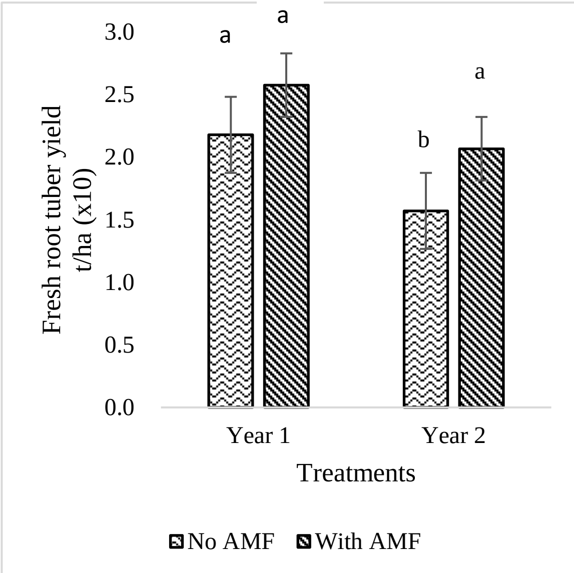

Figure 4: Fresh root yield of cassava as affected by weed control methods. Bars sharing the same letters are not significantly different (p = 0.05, LSD test).

3.5.2 Fresh root yield of cassava as affected by weed control methods

The trend in fresh root tuber yield in cassava was similar in the two cropping (Figure 5). The atrazine, melon and atrazine+melon methods of weed control significantly increased cassava fresh root tuber yield compared to the hoe method in the first and second years of cropping.

3.5.3 Fresh root yield of cassava as affected by arbuscular mycorrhizal inoculation x weed control methods

The fresh root tuber yield of cassava as affected by the interactions of arbuscular mycorrhizal inoculation and weed control methods was shown in Figure 6.

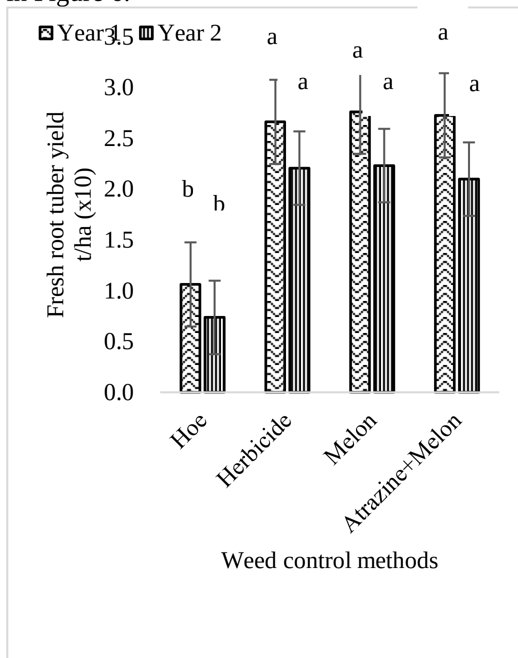

Figure 5: Cassava fresh root tuber yield as affected by weed control methods. Bars sharing the same letters are not significantly different (p = 0.05, LSD test).

Significantly higher fresh root tuber yields of cassava were observed in the interactions that involved atrazine, melon and atrazine+melon compared to the interactions involving hoe. However, the highest cassava fresh root tuber yield was observed under AMF inoculation x melon interaction.

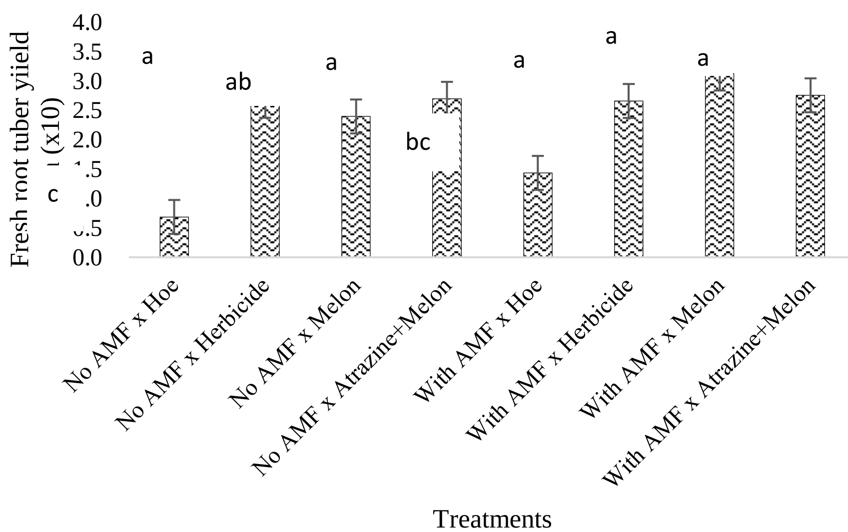

Figure 6: Fresh root tuber yield of cassava as affected by the interactions of arbuscular mycorrhizal inoculation and weed control methods. Bars sharing the same letters are not significantly different (p = 0.05, LSD test).

4. Discussion

The influence of AMF inoculation on cassava for height and stem diameter was higher than observed in the non-inoculated plants for the two years of cropping. These confirmed the significant contribution of AMF inoculation on the observed parameters of cassava. Similar results of AMF inoculation improvement in cassava height and stem diameter over the non-inoculated had been reported by Séry *et al.* (2016) and Cavallari *et al.* (2021). The increase in cassava height in favour of AMF inoculation could be attributed to the enhancement of nutrient uptake that encourages the multiplication of meristematic cells and the enlargement of cells through improved water intake (Adiele *et al.*, 2021). Thus, there is an increase in horizontal and vertical growth in the plant. The plant's main stem height at first branching is an important aid for the ability of the crop to smoother weeds at an earlier stage of growth. However, this parameter did not differ between the inoculated and the non-inoculated plants. The AMF inoculation improved the number of branches at harvest over the non-inoculated implied that the canopy structure in the inoculated plot could intercept a larger percentage of photosynthetically active radiation was more than in the non-inoculated plots. This attribute is likely to be an advantage in helping to suppress weed by reducing the amount of photosynthetically active radiation that reaches the ground for inception by the weed for proper growth (Da Silva *et al*., 2022). A similar result was reported by Di Bella *et al.* (2021) that the increase in biomass production suppresses weed incidence in sugarcane. This claim can be substantiated by the lower total weed biomass in the inoculated treatment. The consequential effect of growth increase resulted in the increment in shoot biomass as indicated in the inoculated cassava compared to the non-inoculated for the two cropping years. The consequential influences of the increase in cassava growth in the treatment with AMF inoculation over the non-inoculated plants corroborated the higher shoot biomass in the inoculated plots.

The effect of an appropriate weed management approach that helps to suppress weed growth and enhance crop yield is a major factor in ensuring food security in the raising population increase. The approach that ensures effective suppression of weed growth and development at a minimal cost and reduces the demand for labour that is becoming limited in the rural area where most of the food required by the urban communities is produced is paramount to sustaining production. According to Akobundu (1987), the labour requirement for weeding as a percentage of total labour needed for crop production (harvesting inclusive) is 25% for cassava. The use of hoe had the least cassava height, and stem diameter indicating that the effect of the competition of above and below-ground resources was higher compared to the other treatments. The intensity of weed competition for resources limits crop growth (Korav et al., 2018). This result conforms with Ekeleme et al. (2021) report, that crop growth is limited under hoe weeding (commonly practised by farmers) by as much as 53% relative to the use of herbicides. The limitation to growth in the hoe treatment is attributable to the growth of weeds before the first weeding. The short time of weed interference before weeding could reduce nutrients available to the young-growing cassava plant and distort the rate of growth. Furthermore, the competition experienced by the plants under hoe treatment suffered more competition for resources with weed before the subsequent weeding operation was carried out. The intermittent level of competition limits available nutrients, moisture and photosynthetically active radiation for proper crop growth. The use of melon in suppressing weed growth and development serves as a cover crop in cassava (Di Bella et al., 2021). The contribution of melon in weed suppression was most effective after the first weeding operation. This was due to the period required for the crop to achieve good ground cover for the effective suppression of weed growth. Hence, the treatment also suffers some degree of competition for resources before proper ground cover. The atrazine and atrazine+melon treatments on the other hand were able to suppress weed competition at the early part of crop growth relative to hoe and the melon treatments. The limited or relatively no early crop growth competition enhanced the cassava planted under these treatments to develop better than the other treatments. However, since the application of atrazine has a definite span for effective weed control, the melon as a cover crop assisted in prolonging the effectiveness of weed growth suppression by the atrazine+melon treatment. implying a better competitive advantage from the treatments than hoe or melon treatments (Carvalho et al., 2022). The limited above-ground competition experienced by the treatments could be responsible for the better growth observed. According to Da Silva et al. (2022) limited competition for space and nutrients between crops improved growth than when crops are subjected to competition.

The interactions of AMF inoculation and weed control methods were aimed at sustaining or increasing the growth of crops to enhance yield. Relative to the interactions with the non-inoculated plants, the interactions involving AMF inoculation had increased growth, Thus indicating the positive contribution of AMF inoculation in enhancing the efficiency of the different weed control methods considered in the study. The result was in support of Akinrinola and Fagbola (2021) report that AMF inoculation improved crop growth and aided in suppressing weed development. The contribution of AMF inoculation on crop growth resulted in better effectiveness of the various weed control methods in producing crops with improved height, stem diameter, number of stems and shoot biomass with lower branch height relative to the non-inoculated plots. These improved growths could also be a consequence of reduced competition for available resources with weeds.

The reduction in weed biomass at 4 weeks after plant by AMF inoculation signifies an important role in the overall performance of cassava. According to Filho et al. (2018), Valadatilde et al. (2013) and Korav et al. (2018), weed interference at the early stage of crop development would determine the final performance of the crop. In this study, the AMF inoculation aided in considerably reducing weed interference. As a consequence, the growth of cassava had minimal interference, thus reducing competition for resources. The subsequent reduction in weed biomass during the period of observation and total weed biomass further indicated the impact of AMF inoculation over the non-inoculated. The reduction in weed biomass could be linked to the improvement in cassava growth that increased its competitive ability over the weeds. This observation is supported by Da Silva et al., 2022), that improved crop nutrition enhances crop ability to compete with weeds for the limited available resources.

The higher stand count observed for the AMF inoculated compared to the non-inoculated implies that the AMF inoculated cuttings were relatively able to provide protection from the vagaries of environmental conditions that could be unfavourable to the establishment of the stem cutting. This claim was also reported by Abdel-Rahman et al. (2019) that AMF inoculation enhanced the rooting of *Ficus benjamina*. Furthermore, the cuttings under atrazine and atrazine+melon had more missing stands than the hoe and melon treatments. The higher loss of stands observed in the atrazine treated plants suggested that the cutting after planting suffered some level of injury through herbicide toxicity. This indicated that the herbicide had a detrimental effect on the cassava stems planted. This finding in the injuries caused by the herbicides could be attributed to the irreversible oxidative damage caused to the plants (Qi et al., 2015). The plant was unable to metabolise the herbicide to its advantage. However, the improvement in the cassava stands count when AMF inoculation was in combination with the weed control methods that the inoculated plants were able to withstand the detrimental effect of atrazine. The application of atrazine may have inhibited the activity of antioxidant enzymes that is essential in eliminating reactive oxygen species. Thus, lowering the inhibition of these enzymes improves the metabolism and recovery of plants from the oxidative stress caused by atrazine. This was possible because the AMF mycelial network that extends beyond the cassava root were able to help in metabolising the herbicide to improve growth and yield. The injuries caused by the herbicide were limited by the inclusion of AMF inoculation. This claim was confirmed by the good yield observed for the interactions of weed control methods with AMF inoculation.

The differences in the yield of the crop are generally associated with the variation in the improvement of growth, nutrient concentration and the management strategy that helped in reducing weed interference on the crop. In the two years of cultivation, the higher yield in the AMF inoculated plants relative to the non-inoculated could be attributed to the improvement in the growth, nutrient concentration and the reduction in weed biomass. Cavallari et al. (2021) also reported the contribution of AMF in increasing cassava yield. These results suggest that AMF inoculation can enhance cassava production through the aid of the symbiotic association that exist between cassava and the fungi (Sery et al., 2016). Similarly, the effectiveness of the different weed control measures mostly adopted by farmers (hoe) was ineffective relative to melon and the application of atrazine and atrazine+melon. The greater yields from the melon, atrazine and atrazine+melon over the hoe supported that the treatments were more effective in weed control, thus improving growth and nutrient concentration in cassava. The relation of weed biomass to cassava yield was reported to be 0.81 (Khanthavong et al., 2016). The report was substantiated by the results of this study as the treatments that reduced total weed biomass, the most had higher cassava fresh root yields. Similarly, these results corroborated Ekeleme et al. (2021) that the weed control method practised by farmers is less effective compared to the application of herbicides. However, the yield from the melon treatment was at par with the atrazine and atrazine+melon implies that, aside from the reduction of weeds through ground cover by the melon (cover crop), it also conserves soil moisture content, improves soil temperature and soil structure, and enhance soil organic matter content (Lal, 2020). Thus the growth of cassava is improved, thereby leading to better yield. The study on the interaction between AMF inoculation and weed control methods revealed that AMF inoculation enhanced the root tuber yields of cassava observed for the different weed control methods. This was particularly true for the AMF x melon interaction, where the yield surpasses the other treatment interactions. This suggest that the AMF inoculation x melon interaction did not just improve the crop nutrition, but was able to further improve the soil physical condition better than the other treatment interactions. This was achievable through the improvement of cassava plant growth under water stress condition (Ijoyah et al., 2012).

5. Conclusion

The improvement in cassava growth, yield and the reduction in weed interference is a major approach to increasing production to meet the increasing population and increase farmers' income. The inoculation of cassava with AMF improved the growth and yield of cassava, through the reduction in weed biomass and increase in the number of surviving stand count, and nutrient concentration of N, P, K, Mg and Ca relative to the non-inoculated plants. Also, weed growth suppression under the hoe method was not comparable to atrazine, melon and atrazine+melon in improving cassava performance and nutrient concentrations. However, the application of atrazine resulted in the reduction in surviving stand count. The interaction of AMF inoculation x weed control methods further increased cassava performances through improved nutrient concentration and enhanced weed suppression. The interaction of AMF inoculation with atrazine or atrazine+melon improved cassava stand count. Consequently, AMF inoculation with atrazine+melon was suggested for sustainable cassava production.

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