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EFFECTS OF ARBUSCULAR MYCORRHIZA FUNGI, ORGANIC FERTILIZER AND DIFFERENT MOISTURE REGIMES ON SOIL PROPERTIES AND YIELD OF *AMARANTHUS CRUENTUS*

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Abstract: A pot experiment was conducted to assess the influence of two arbuscular mycorrhiza (AM) fungi and organic fertilizer (OF) on the growth and yield of *Amaranthus cruentus* under varying soil moisture regimes. This was done with a view to providing information on the crop adaptation to drought conditions and to also sustaining soil nutrient balance for increased crop yields. The experiment consisted of 36 treatments (*Glomus clarum*, *Glomus deserticola* and no AM), organic fertilizer made from market wastes at different rates (0, 5 and 10 t ha^{-1}) and varied water regimes (25, 50, 75 and 100% field capacity [FC]). Each of the treatments was replicated thrice. The treatment combination, 10 t ha^{-1} OF and *G. clarum* produced the highest fresh vegetative yield of 48.82 t ha^{-1} which was not significantly ($p > 0.05$) different from only 45.78 t ha^{-1} fresh yield obtained with 5 t ha^{-1} OF and *G. clarum* when water levels were compared. The repeated experiment with only water addition gave lower and comparable yields of *A. cruentus*. We concluded that the addition of *G. clarum* in combination with 5 t ha^{-1} of organic fertilizer to soil optimally improved the growth and yield of *A. cruentus* in water stress conditions.

Key words: arbuscular mycorrhiza fungi, organic fertilizer, water stress, *Amaranthus cruentus*, market wastes.

Introduction

Crops and soil nutrition are intrinsically linked because the soil houses and provides nutrients for crops, and as a result, soil nutrient decline could lead to low quality and quantity in crop production (Murrell et al., 2015). In addition to this, there are other abiotic stresses like drought and salinity that cause one third of global agricultural losses (Vandenberghe et al., 2017). Some soil nutrient deficiencies have indirectly enhanced human activities to impact negatively on the soil ecosystem through variable cultural farm operations and agricultural

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intensification on crop lands; drought and other abiotic stresses are results of the global climate change issues (Armada et al. 2016; Salehi et al. 2016). Despite the intensified efforts to improve soil nutrient deficiency, drought is not only a problem in itself, but it also inhibits such efforts because nutrient solubility plays a significant role in their absorption by plants (Afshar et al., 2014). Although the application of inorganic fertilizers to soil enhanced soil fertility, they could also lead to loss of soil biodiversity, increased soil acidity and soil degradation, and eventually fail to increase crop yield in the long run (Chemura, 2014; Joshi et al. 2014). Sustainable soil management approaches are, therefore, necessary for a food secured population, and they also involve preserving the natural resources in the air, soil and water environments (Murrell et al., 2015).

Organic inputs are known to be a soil management strategy which plays a pertinent role in climate-smart agriculture. They are able to help soil retain moisture better and thus help alleviate moisture stress (Chemura, 2014). Also, noteworthy is their apparent role in improving soil fertility (Okonji et al., 2018), while carbon sequestration in these inputs has favorable implications for climate change (Aguilera et al., 2013; Lehtinen et al., 2014), and all these culminate in improved agricultural yield. The use of organic inputs to soils is gaining popularity because a lot of organic input sources are from degradable wastes and their use can result in waste management (Aguilera et al., 2013). Another benefit of organic fertilizers in soils is that they provide plants with a good ratio of micro minerals in addition to macro minerals (Murrell et al., 2015).

In crop production, Borie et al. (2010) have suggested that arbuscular mycorrhiza (AM) fungi incorporation into agri-business is an appropriate biotechnology alternative for food security and forest ecosystem sustainability. The AM fungi are symbiotic organisms that help plant nutrient mechanisms by facilitating their nutrient uptake and improving their tolerance to drought and other environmental issues (Eulenstein et al., 2017). The AM fungi are reported to improve plant growth in water stress conditions (Armada et al., 2016), with established controlled and field experiments conducted over a wide range of crops. These AM fungi have also been termed biofertilizers because of their role in facilitating the availability, uptake and absorption of nutrients in plants (Cyril et al., 2014). It is a function of the available nutrients in the soil since the fungi do not provide the nutrients (Medina and Azcon, 2010; Murrell et al. 2015) either to long-duration or short-duration crops such as vegetables.

Vegetables are food crops which are a major repository of vitamins, minerals and antioxidants (Ajiboye et al., 2014). Cultivation of vegetables has been challenging in recent times, in terms of farm input and soil productivity, among others (Agneessens et al., 2014; Widowati and De Neve, 2016), which has resulted in the poor yield and quality of crops. *Amaranthus* is an annual vegetable with several species which are often consumed as food, and as ornamental plants

(Zhigila et al., 2014). In Nigeria, it is commonly called ‘tete’ among the Yorubas, ‘green’ among the Igbos, and ‘aleho’ among the Hausas (Mshelmbula et al., 2017; Towolawi et al., 2017) and it is a good source of vitamins and dietary minerals (Cyril et al., 2014). This study therefore assessed the influence of two arbuscular mycorrhiza fungi (*Glomus clarum*, *Glomus deserticola*) and organic fertilizer (OF) on the growth and yield of *Amaranthus cruentus* under varying soil moisture regimes.

Materials and methods

Experimental location, design used and agronomic practices employed

The experiment was conducted in the greenhouse of the Institute of Ecology and Environmental Studies, Obafemi Awolowo University, Ile-Ife, Nigeria. Viable spores of AM fungi, namely: *Glomus clarum* and *Glomus deserticola*, obtained from the Department of Agronomy, University of Ibadan, Ibadan, Nigeria were propagated using the *Zea mays* plant for a period of three months. During the propagation period, maize plants were watered regularly and chopped leaves of *Gliricidia sepium* were used to nourish the previously sterilized sandy soil used on a weekly basis. At three months, water was withdrawn from maize plants to allow for multiplication of fungi spores for two weeks. The organic fertilizer made from market wastes was procured from a waste recycling firm in a local market in Ibadan, Nigeria. Viable seeds of *Amaranthus cruentus* were obtained from the National Horticultural Research Institute, Jericho, Ibadan, Nigeria.

Surface soil sample was collected from an infertile land, sieved and sterilized and three kilograms of the sterilized soil were filled into each of the polythene pots. The experiment consisted of 36 treatments, namely: ([10 g *G. clarum*, 10 g *G. deserticola* and no AM fungi], organic fertilizer at different rates [0, 5 and 10 t ha^{-1}], varied water regimes [25, 50, 75] and 100% field capacity [FC]). Each of the treatments was replicated thrice and factorially arranged in a completely randomized design to give a total of 108 pots. Treatments were applied at sowing and plants in each pot were thinned to two stands at two weeks after sowing (WAS). The pots were maintained weed-free throughout the experimental period and they were watered appropriately.

Collection of data on growth performance commenced at 3 WAS and continued weekly thereafter until 6 WAS. Growth parameters assessed included plant height, number of leaves, stem girth and leaf area. Fresh biomass yield per pot was determined immediately after harvest using a weighing balance. The plants were then oven-dried at 70°C to constant weight using a binder FED 400 model to determine the dry biomass yield. There was a repeated experiment immediately after the harvest of the first set of the vegetable crop to test for residual effects of

AM fungi and organic fertilizer, but with only different water regimes as treatment addition.

Propagation of arbuscular mycorrhiza fungi

Soil inocula containing viable spores of AM fungi, namely *G. clarum* and *G. deserticola* were obtained from the Department of Agronomy, University of Ibadan, Ibadan, Nigeria. Fifty grams of each inoculum were weighed into 10 kg of sterilized coarse sand, and two seeds of maize (*Zea mays*) sown into the pots. The plants were regularly watered and chopped leaves of *Gliricidia sepium* were used to nourish the soil weekly. Three months after sowing, water was withdrawn to allow for multiplication of fungi spores. Two weeks after, maize shoots were cut and soil air-dried.

Extraction and counting of arbuscular mycorrhiza fungi spores

Pre- and post-planting of extraction and counting of AM fungi spores were determined using the wet sieving and decanting method of Habte and Osorio (2001). One hundred grams of air-dried soil were taken from the sterilized bulk soil sample and the AM treatment pots, and each was thoroughly mixed. Each was soaked for 30 minutes with 250 ml of distilled water in a beaker. Each sample was thereafter made with distilled water to 1000 ml suspension and agitated for 30 minutes to dislodge the fungal spores from the soil. The soil suspension was decanted over a stack of sieves (250, 75 and 53 µm) arranged in descending order of their sizes. Thereafter, materials left in the last two sieves (75 and 53 µm) were collected, suspended in 40% sucrose solution and centrifuged at 3000 rpm for 5 minutes. The spores were later examined and counted under a dissecting microscope.

Laboratory analyses

Pre-cropped soil and organic fertilizer (OF) samples were analysed for their properties using standard methods of Page et al. (1982). Soil pH was determined in 1:1 soil/water using a pH meter; total N of the soil and OF were determined using the macro-Kjedahl method, available P of the soil and OF were determined using the Bray P1 method, and organic C of the soil and OF were determined using the Walkley-Black wet oxidation method. Exchangeable bases (Ca^{2+}, Mg^{2+}, K^{+}, and Na^{+}) of the soil and OF were extracted using 1 M ammonium acetate and their concentrations were read using the spectrophotometric method. The summation of the exchangeable bases, $Ca^{2+} + Mg^{2+} + K^{+} + Na^{+}$, gave cation exchange capacity (CEC) of the soil.

Statistical analyses

Data on the yield of *A. cruentus* were subjected to analysis of variance and their means were separated using the Duncan's multiple range test using SAS 9.2 statistical software at $p < 0.05$. Data on the growth parameters were plotted using GraphPad Prism 5.0 software at $p < 0.05$.

Results and Discussion

Mycorrhizal spore count

Total spore counts of AM fungi: *Glomus clarum* and *Glomus deserticola* were 114.17 ± 35.12 and 58.44 ± 17.44 per 100 g of soil, respectively. Okon and Solomon (2014) earlier obtained AM fungi spore count range of 18–112 per 100 g of soil from varieties of crops they worked on.

Soil properties

The physical and chemical properties of the soil and organic fertilizer used in the experiment are presented in Table 1. The soil was of sandy loam texture with sand, silt and clay proportions 692.00, 154.00 and 154.00 g kg^{-1} respectively.

Table 1. Pre-cropped soil and organic fertilizer properties.

Parameter	Value/Soil	Organic fertilizer
pH (1:1 soil/water)	6.70	-
Organic carbon (g kg^{-1})	0.77	76.70
N (g kg^{-1})	0.07	3.01
C:N	-	25.48
Available P (mg kg^{-1})	17.11	12.53
Exchangeable acidity (cmol kg^{-1})	0.10	-
Exchangeable basicity (cmol kg^{-1})	12.16	140.92
Ca^{2+}	9.46	24.40
Mg^{2+}	0.91	3.51
K^{+}	1.11	40.11
Na^{+}	0.68	72.91
Clay (g kg^{-1})	154.0	-
Silt (g kg^{-1})	154.0	-
Sand (g kg^{-1})	692.0	-
Textural class	Sandy loam	

The soil was slightly acidic with soil pH of 6.70. Organic carbon and total N in the soil were 0.77 and 0.07 g kg^{-1} respectively. The organic fertilizer had organic C content of 79.26 g kg^{-1} and total N of 6.97 g kg^{-1}, giving a C:N ratio of 11:1; an attribute that the organic fertilizer used has potential to decompose fast for enhanced soil fertility. The C:N ratio is a critical factor in the decomposition of organic material. The lower the C:N ratio the faster will be its rate of decomposition and nitrogen release in crop husbandry (Ge et al., 2013).

Soil water plays a significant role in organic matter decomposition, mineralization and nutrient availability during crop production. From 75% FC water regime, soil properties, particularly total N, organic C and CEC were significantly increased compared to when soil moisture regimes were much lower (Table 2). However, Rana et al. (2017) observed no significant influence of water regimes on soil organic carbon, a contrary report from our own. Variations from different studies could be attributed to differences in soil properties, chemistry of water used for wetting and water use efficiency by different crop species.

Table 2. Effects of water regimes, organic fertilizer and AMF on properties of soil.

Treatment	pH in H_2O	Organic carbon ($g\ kg^{-1}$)	Total nitrogen ($g\ kg^{-1}$)	Available phosphorus ($mg\ kg^{-1}$)	Cation exchange capacity ($cmol\ kg^{-1}$)
FC (%)					
25	7.03a	7.98c	0.77c	55.03a	12.22a
50	7.04a	7.22d	0.78c	55.00a	12.34a
75	6.90b	11.72b	1.80b	50.15b	11.32b
100	6.75c	17.63a	2.22a	49.73b	10.68c
LSD	0.05	0.48	0.27	1.25	0.25
OF ($t\ ha^{-1}$)					
0	6.68b	10.41b	1.02c	24.67c	8.72c
5	7.08a	9.03c	1.78a	59.32b	12.77b
10	7.03a	13.98a	1.39b	73.43a	13.44a
LSD	0.04	0.42	1.08	1.08	0.22
AMF					
Zero	6.96a	10.90b	1.21b	47.46b	11.05c
GC	6.94ab	12.41a	1.72a	55.30a	11.52b
GD	6.90b	10.11c	1.26b	54.67a	12.35a
LSD	0.04	0.42	0.23	1.08	0.22

Mean(s) with the same letter in each column is/are not significantly different at $p < 0.05$.
Legend: GC = *Glomus clarum*, GD = *Glomus deserticola*, FC = Field capacity, OF = Organic fertilizer, AMF = Arbuscular mycorrhiza fungi.

These soil properties sustained the second *A. cruentus* cultivation without further soil amendment additions, but with a reduction in the yield of the test crop. Increased soil organic carbon and slightly acidic soil conditions were observed by Tits et al. (2014), Babajide and Olla (2014), and Okonji et al. (2018) in AMF treated soils.

The symbiotic association of AMF in plants that allows for more P as observed by Cundiff (2012) and Bhardwaj et al. (2014) was equally observed in this study (Table 2). Pots without AMF had significantly ($p < 0.05$) lower available

P of 47.46 mg kg^{-1} when compared with 54.67 and 55.30 mg kg^{-1} of available P for *G. deserticula* and *G. clarum* fungal additions, respectively.

Agronomic growth of *Amaranthus cruentus*

Growth parameters of *A. cruentus* improved with the use of organic fertilizer and the AM fungi. Moyin-Jesu (2015) earlier observed significant improvement in similar growth parameters with organic fertilizer treatments when compared to the control. However, there were reduced growth parameters during the second planting (Figures 1 to 4). Growth parameters increased with increasing rates of water addition, but varied slightly during the repeated experiment, where plants with 75% FC treatments had comparable growth with 100% FC treatment plants. This could be the reasonable soil moisture that allows for availability of nutrients to plants. This agreed with the findings of Khalil and Yousef (2014) where growth parameters of the test plant were significantly lowered with decreasing rates of water availability.

The highest mean plant height of 64.83 ± 6.72 cm obtained with the treatment containing 10 t ha^{-1} OF and *G. clarum* was not significantly different from 61.83 ± 4.91 cm obtained with the treatment containing 5 t ha^{-1} OF and *G. clarum* at 100% FC (Figure 1). Soil inoculation with *G. clarum* gave the best crop physiological growth parameters by Zuccarini and Savé (2016). At 75% FC, the highest mean plant height of 44.67 ± 5.36 cm was obtained with the treatment containing 10 t ha^{-1} OF and *G. deserticola*. The highest mean stem girth of 3.50 ± 0.00 cm was obtained with 10 t ha^{-1} OF and *G. deserticola* at 100% FC; while at 75% FC, the highest mean stem girth of 2.63 ± 0.07 cm was obtained with 10 t ha^{-1} OF (Figure 3). The highest mean leaf area of 98.51 ± 7.61 cm^2 was also obtained with the treatment containing 10 t ha^{-1} OF and *G. deserticola* (Figure 4). Comparable results were obtained during the second planting, though with reduced values. These results agreed with Minaxi et al. (2013) and Cyril et al. (2014) whose work showed the highest plant height of *A. cruentus* with the synergistic use of manure and AM fungi when combined, which was significantly higher than when each of the treatments was singly applied.

Yield of *Amaranthus cruentus*

The yield of *A. cruentus* plants as influenced by AM fungi and OF is shown in Tables 3 and 4. The highest vegetative yield of 73.23 g 3 kg^{-1} soil (48.82 t ha^{-1}) was obtained with the treatment containing 10 t ha^{-1} OF. This was significantly ($F_{72,107} = 67.43$; $p < 0.05$) different from 27.20 g 3 kg^{-1} soil (18.13 t ha^{-1}) at 100% FC in the control pots. The vegetative yield of *A. cruentus* with 10 t ha^{-1} OF, *G. deserticola* and 75% FC water regime was significantly ($p < 0.05$) higher than the control at 100% FC water regime. Other treatments at 75% FC water regime, apart from the control were not significantly different. This revealed that AM fungi and OF aided adaptation of *A. cruentus* plants from 75% FC water regime.

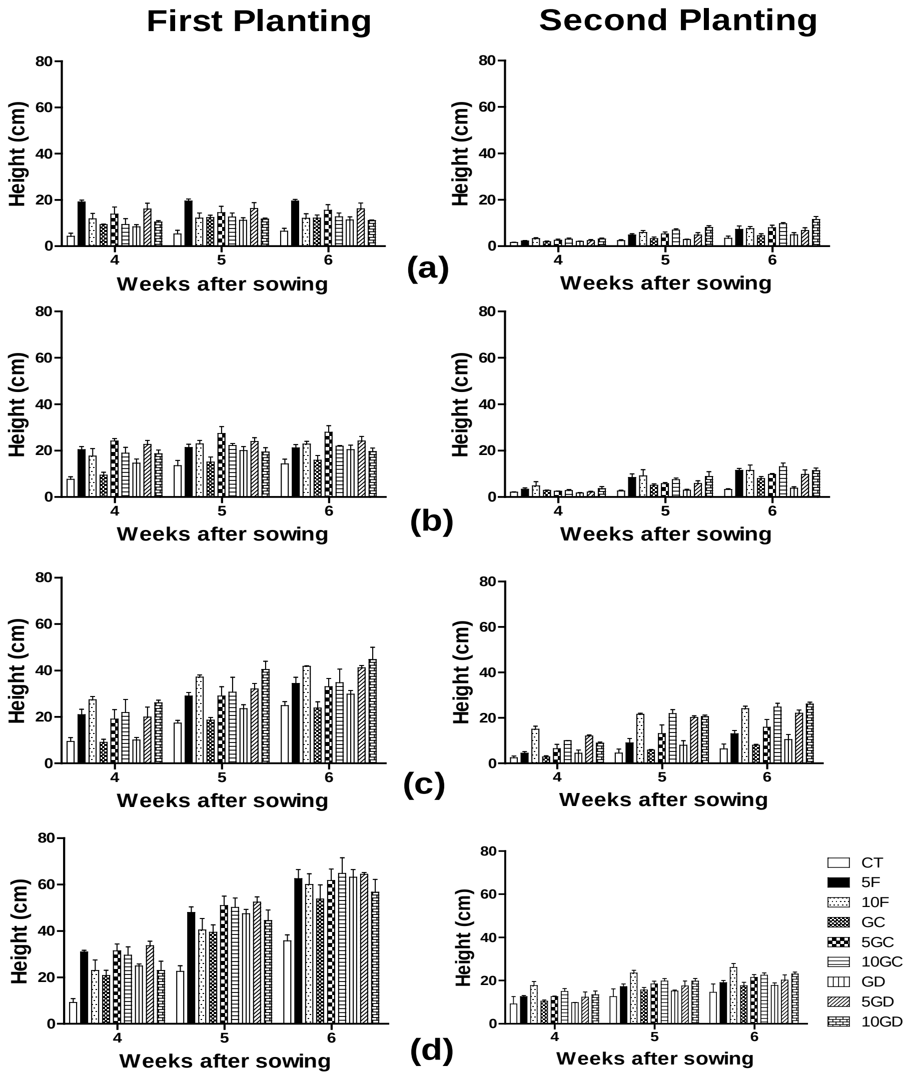

Figure 1. Mean plant height of *A. cruentus* with AMF and OF applications under varying moisture regimes of (a) 25%, (b) 50%, (c) 75% and (d) 100% FC. Vertical bars represent standard errors.
Legend: CT = Control; 5F = 5 t ha^{-1} OF, 10F = 10 t ha^{-1} OF; GC = *Glomus clarum*; 5GC = *Glomus clarum* + 5 t ha^{-1} OF; 10GC = *Glomus clarum* + 10 t ha^{-1} OF; GD = *Glomus deserticola*; 5GD = *Glomus deserticola* + 5 t ha^{-1} OF; 10GD = *Glomus deserticola* + 10 t ha^{-1} OF.

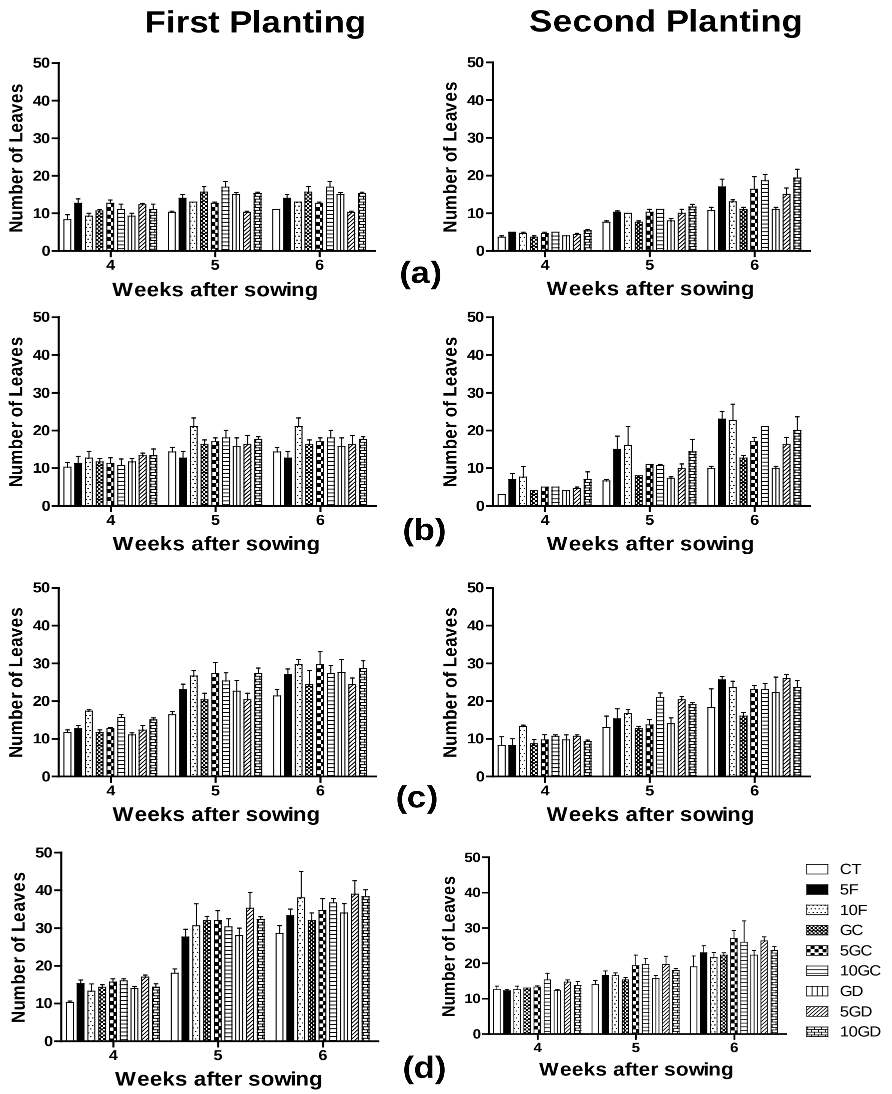

Figure 2. Mean number of leaves of *A. cruentus* with AMF and OF applications under varying moisture regimes of (a) 25%, (b) 50%, (c) 75% and (d) 100% FC. Vertical bars represent standard errors.

Legend: CT = Control; 5F = 5 t ha^{-1} OF, 10F = 10 t ha^{-1} OF; GC = *Glomus clarum*; 5GC = *Glomus clarum* + 5 t ha^{-1} OF; 10GC = *Glomus clarum* + 10 t ha^{-1} OF; GD = *Glomus deserticola*; 5GD = *Glomus deserticola* + 5 t ha^{-1} OF; 10GD = *Glomus deserticola* + 10 t ha^{-1} OF.

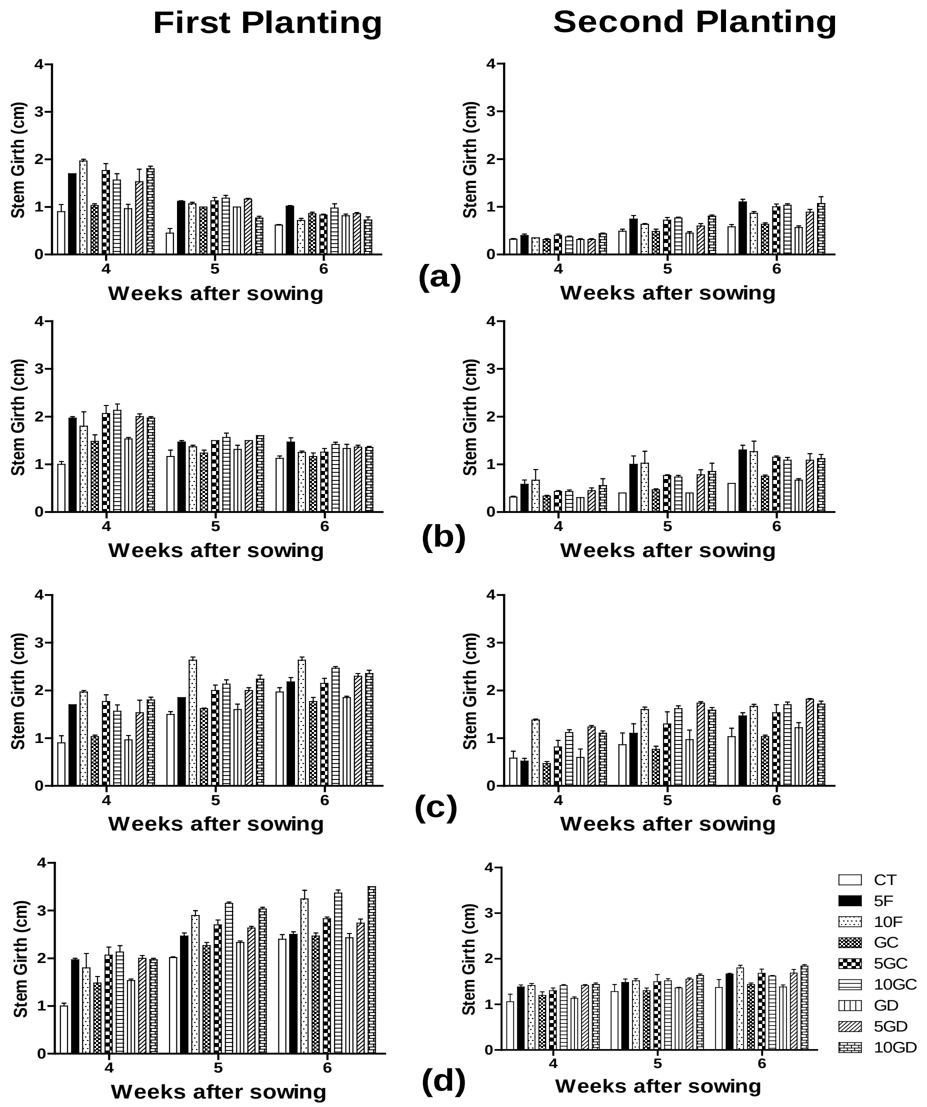

Figure 3. Mean stem girth of *A. cruentus* with AMF and OF applications under varying moisture regimes of (a) 25%, (b) 50%, (c) 75% and (d) 100% FC. Vertical bars represent standard errors.

Legend: CT = Control; 5F = 5 t ha^{-1} OF, 10F = 10 t ha^{-1} OF; GC = *Glomus clarum*; 5GC = *Glomus clarum* + 5 t ha^{-1} OF; 10GC = *Glomus clarum* + 10 t ha^{-1} OF; GD = *Glomus deserticola*; 5GD = *Glomus deserticola* + 5 t ha^{-1} OF; 10GD = *Glomus deserticola* + 10 t ha^{-1} OF.

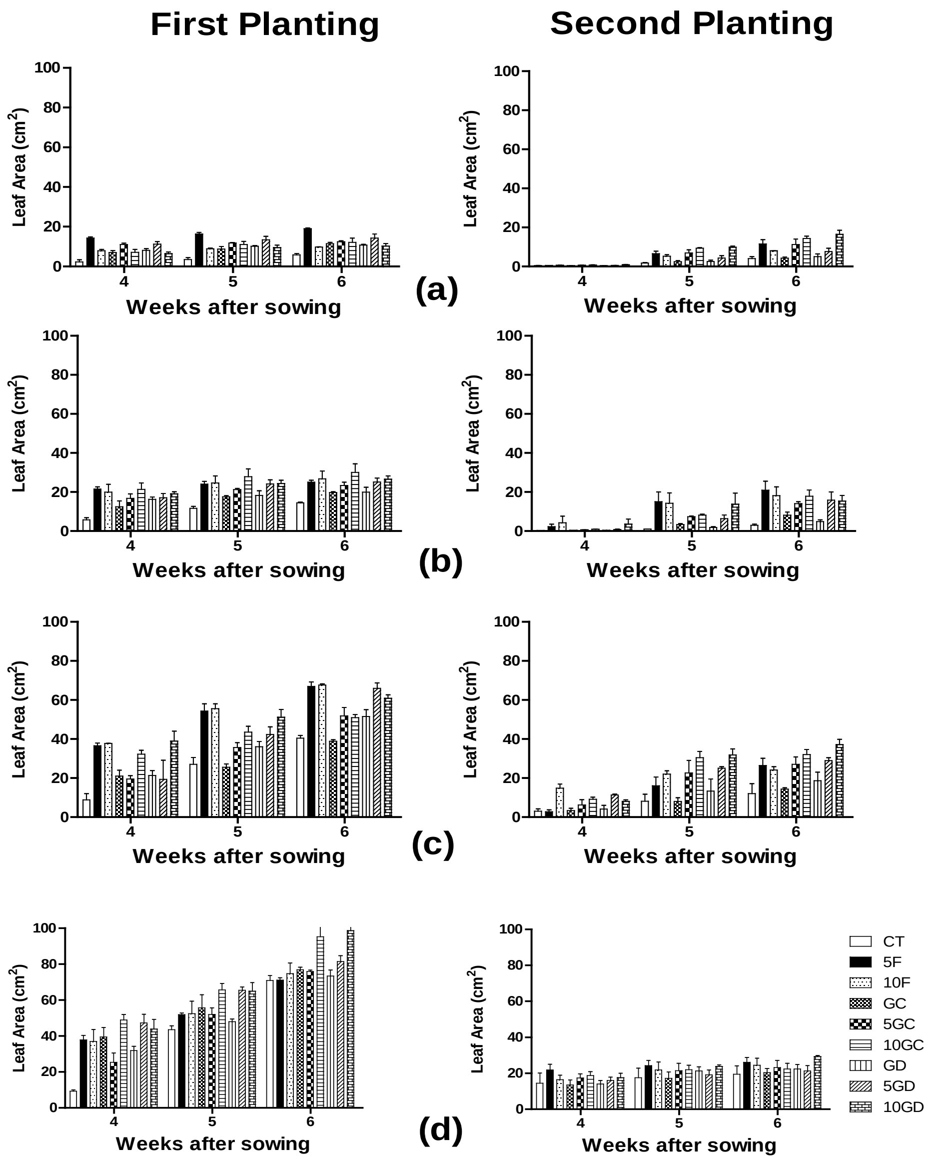

Figure 4. Mean leaf area of *A. cruentus* with AMF and OF applications under varying moisture regimes of (a) 25%, (b) 50%, (c) 75% and (d) 100% FC. Vertical bars represent standard errors.

Legend: CT = Control; 5F = 5 t ha^{-1} OF, 10F = 10 t ha^{-1} OF; GC = *Glomus clarum*; 5GC = *Glomus clarum* + 5 t ha^{-1} OF; 10GC = *Glomus clarum* + 10 t ha^{-1} OF; GD = *Glomus deserticola*; 5GD = *Glomus deserticola* + 5 t ha^{-1} OF; 10GD = *Glomus deserticola* + 10 t ha^{-1} OF.

Table 3. Mean vegetative yield (g/3 kg soil) of *A. cruentus* at the first harvest.

Water regime	Treatment arbuscular mycorrhiza fungi	Organic fertilizer rate (t ha^{-1})	Fresh weight	Dry weight
A (25%)	Control	0	0.73j	0.28u
		5	2.37j	0.67stu
		10	1.50j	0.53tu
	Glomus clarum	0	1.87j	0.50tu
		5	1.80j	0.48tu
		10	2.17j	0.69stu
	Glomus deserticola	0	1.40j	0.41tu
		5	1.53j	0.40tu
		10	1.30j	0.43tu
B (50%)	Control	0	2.93j	0.85rstu
		5	5.10j	1.39opqr
		10	5.23j	1.40opqr
	Glomus clarum	0	3.23j	0.95qrst
		5	5.27j	1.51nopq
		10	4.97j	1.43opqr
	Glomus deserticola	0	5.80j	1.17qrs
		5	5.03j	1.42opqr
		10	4.37j	1.28pqr
C (75%)	Control	0	17.00i	2.05lmn
		5	27.47gh	2.80ijk
		10	26.37gh	2.47jkl
	Glomus clarum	0	16.23i	1.81mnop
		5	27.67gh	2.97ij
		10	31.43g	2.45jkl
	Glomus deserticola	0	18.93hi	1.94lmno
		5	29.57g	2.26klm
		10	39.80f	3.76h
D (100%)	Control	0	27.20gh	3.27hi
		5	68.67ab	8.47b
		10	57.60cd	4.86fg
	Glomus clarum	0	43.53ef	5.20ef
		5	58.67cd	7.21c
		10	73.23a	8.99a
	Glomus deserticola	0	50.43de	4.43g

Means followed by the same letter(s) within a column are not significantly different at $p < 0.05$ according to the Duncan's multiple range test.

Table 4. Mean vegetative yield (g/3 kg soil) of *A. cruentus* at the second harvest.

Water regime	Treatment arbuscular mycorrhiza fungi	Organic fertilizer rate (t ha^{-1})	Fresh weight	Dry weight
A (25%)	Control	0	0.85no	0.15mno
		5	2.54jklmno	0.59jklmno
		10	1.83klmno	0.44klmno
	Glomus clarum	0	0.78no	0.16mno
		5	2.97ijklmno	0.65jklmno
		10	3.60ijklmn	0.79jklmno
	Glomus deserticola	0	0.84no	0.16mno
		5	1.48mno	0.38lmno
		10	4.72hijkl	0.97ijklm
B (50%)	Control	0	0.35o	0.08o
		5	4.69hijkl	1.01ijkl
		10	5.83fghi	1.25ghijk
	Glomus clarum	0	1.76lmno	0.39lmno
		5	4.27ijklm	0.79jklmno
		10	5.52hij	0.94jklmn
	Glomus deserticola	0	0.70no	0.13no
		5	5.24hij	0.75jklmno
		10	3.52ijklmn	0.88jklmno
C (75%)	Control	0	3.13ijklmno	0.77jklmno
		5	6.04fghi	1.37fghij
		10	11.07bc	2.68abc
	Glomus clarum	0	4.29ijklm	0.74jklmno
		5	7.59efgh	1.94cdefgh
		10	11.24abcd	2.65abc
	Glomus deserticola	0	5.69ghi	1.18hijkl
		5	8.58defg	2.59abcd
		10	13.96a	2.38bcde
D (100%)	Control	0	4.88hijk	1.73efghi
		5	11.44abcd	3.18a
		10	12.53abc	2.69abc
	Glomus clarum	0	7.49efgh	1.83defgh
		5	9.71cde	2.00bcdefg
		10	12.78ab	2.78ab
	Glomus deserticola	0	8.70def	2.10bcdef
		5	10.09bcde	2.13bcdef
		10	12.90ab	2.79ab

Means followed by the same letter(s) within a column are not significantly different at $p < 0.05$ according to the Duncan's multiple range test.

The findings of Khalil and Yousef (2014) supported the findings that higher soil moisture could lead to higher yield of crops, and also Okonji et al. (2018) observed the enhanced yield of rice when soil was inoculated with AMF.

The repeated experiment without further application of AM fungi and OF treatments gave lower and comparable values. These results agreed with the findings of Cyril et al. (2014) where the application of manure in combination with AM fungi showed a significantly higher vegetative yield of *A. cruentus* than the control or the use of inorganic fertilizer. Salami and Osonubi (2003) similarly recorded the improved cassava yield with AM fungi inoculation, and Bona et al. (2016) equally showed that AM fungi were useful for sustainable agriculture.

Conclusion

The synergistic use of AM fungi and organic fertilizer improved the availability of total N, organic C and CEC of the soil. The growth and yield of *A. cruentus* cultivated under different soil moisture regimes when AM fungi and organic fertilizer were applied also varied. The addition of *G. clarum* fungi with 5 t ha^{-1} of organic fertilizer to soil optimally improved the growth and yield of *A. cruentus* in water stress conditions.

References

Afshar, R.K., Chaichi, M.R., Rezaei, K., Asareh, M.H., Karimi, M., & Hashemi, M. (2014). Irrigation regime and organic fertilizers influence on oil content and fatty acid composition of milk thistle seeds. *Agronomy, Soils and Environmental Quality*, *107* (1), 187-194.

Agneessens, L., De Waele, J., & De Neve, S. (2014). Review of alternative management options of vegetable crop residues to reduce nitrate leaching in intensive vegetable rotations. *Agronomy*, *4* (4), 529-555.

Aguilera, E., Lassaletta, L., Sanz-Cobena, A., Garnier, J., & Vallejo, A. (2013). The potential of organic fertilizers and water management to reduce N_2O emissions in mediterranean climate cropping systems - A review. *Agriculture, Ecosystems and Environment*, *164*, 32-52.

Ajiboye, A.A., Fadimu, O.Y., Ajiboye, M.D., Agboola, D.A., Adelaja, A.B., & Bem, A.A. (2014). Phytochemical and nutritional constituents of some common vegetables in Southwest, Nigeria. *Global Journal of Science Frontier Research*, *14* (3), 49-53.

Armada, E., López-Castillo, O., Roldán, A., & Azcón, R. (2016). Potential of mycorrhizal inocula to improve growth, nutrition and enzymatic activities in *Retama sphaerocarpa* compared with chemical fertilization under drought conditions. *Journal of Soil Science and Plant Nutrition*, *16* (2), 380-399.

Babajide, P.A., & Olla, N.O. (2014). Performance of indigenous *Celosia argentea* variety and soil physico-chemical properties as affected by dual application of compost and single N-mineral fertilizer in southern guinea savanna vegetation zone of Nigeria. *Journal of Biology, Agriculture and Healthcare*, *4* (19), 69-75.

Bhardwaj, D., Ansari, M.W., Sahoo, R.K., & Tuteja, N. (2014). Biofertilizers function as key player in sustainable agriculture by improving soil fertility, plant tolerance and crop productivity. *Microbial Cell Factories*, *13* (66), 1-10.

Bona, E., Cantamessa, S., Massa, N., Manassero, P., Marsano, F., Copetta, A., Lingua, G., D'Agostino, G. Gamalero, E., & Berta, G. (2016). Arbuscular mycorrhizal fungi and plant growth-promoting Pseudomonads improve yield, quality and nutritional value of tomato: A field study. *Mycorrhiza*, *27*, 1-11.

Borie, F., Rubio, R., Morales, A., Curaqueo, G., & Cornejo, P. (2010). Arbuscular mycorrhizae in agricultural and forest ecosystems in Chile. *Journal of Soil Science and Plant Nutrition*, *10* (3), 185-206.

Chemura, A. (2014). The growth response of coffee (*Coffea arabica* L.) plants to organic manure, inorganic fertilizers and integrated soil fertility management under different irrigation water supply levels. *International Journal of Recycling of Organic Waste in Agriculture*, *3*, 1-59.

Cundiff, G.T. (2012). *Using arbuscular mycorrhizae to influence yield, available soil nutrients and soil quality in conventional vs. organic vegetable production.* Western Kentucky University, Bowling Green, Kentucky, USA.

Cyril, C.N., Kehinde, O.O., Olanrewaju, A.D., David, S.D., & Aderemi-Williams, O. (2014). Vegetative growth and yield response of *Amaranthus cruenthus* to arbuscular mycorrhizal fungi (AMF), poultry manure (PM), combination of AMF-PM and inorganic fertilizer. *American Journal of Experimental Agriculture*, *4* (6), 665-673.

Eulenstein, F., Tauschke, M., Behrendt, A., Monk, J., Schindler, U., Lana, M.A., & Monk, S. (2017). The application of mycorrhizal fungi and organic fertilisers in horticultural potting soils to improve water use efficiency of crops. *Horticulturae*, *3* (1), 1-8.

Ge, S., Xu, H., Ji, M., & Jiang, Y. (2013). Characteristics of soil organic carbon, total nitrogen, and C/N ratio in Chinese apple orchards. *Open Journal of Soil Science*, *3*, 213-217.

Habte, H., & Osorio, N.W. (2001). Arbuscular mycorrhizas: Producing and applying arbuscular mycorrhizal inoculums. College of Tropical Agriculture and Human Resources, University of Hawaii, Hawaii, USA.

Joshi, R., Singh, J., & Vig, A.P. (2014). Vermicompost as an effective organic fertilizer and biocontrol agent: effect on growth, yield and quality of plants. *Reviews in Environmental Science and BioTechnology*, *13* (3), 1-23.

Khalil, S.E., & Yousef, R.M. (2014). Interaction effects of different soil moisture levels, arbuscular mycorrhizal fungi and three phosphate levels on: growth, yield and photosynthetic activity of garden cress (*Lepidium sativum* L.) plant. *International Journal of Advanced Research*, *2* (6), 723-737.

Lehtinen, T., Schlatter, N., Baumgarten, A., Bechini, L., Krüger, J., Grignani, C., Zavattaro, L., Costamagna, C., & Spiegel, H. (2014). Effect of crop residue incorporation on soil organic carbon and greenhouse gas emissions in European agricultural soils. *Soil Use and Management*, *30* (4), 524-538.

Medina, A., & Azcon, R. (2010). Effectiveness of the application of arbuscular mycorrhiza fungi and organic amendments to improve soil quality and plant performance under stress conditions. *Journal of Soil Science and Plant Nutrition*, *10* (3), 354-372.

Minaxi, S.J., Chandra, S., & Nain, L. (2013). Synergistic effect of phosphate solubilizing rhizobacteria and arbuscular mycorrhiza on growth and yield of wheat plants. *Journal of Soil Science and Plant Nutrition*, *13* (2), 511-525.

Moyin-Jesu, E.I. (2015). Use of different organic fertilizers on soil fertility improvement, growth and head yield parameters of cabbage (*Brassica oleraceae* L). *International Journal of Recycling of Organic Waste in Agriculture*, *4* (4), 291-298.

Mshelmbula, B.P., Florence, L., Midawa, S.M., & Yusuf, C.S. (2017). Genetic responds of two varieties of *Amaranthus* on diffrerent salinity concentrations grown in Mubi, Nigeria. *Applied Science Reports*, *17* (3), 63-71.

Murrell, E.G., Hanson, C.R., & Cullen, E.M. (2015). European corn borer oviposition response to soil fertilization practices and arbuscular mycorrhizal colonization of corn. *Ecosphere*, *6* (6), 1-12.

Okon, I.E., & Solomon, M.G. (2014). Arbuscular mycorrhiza fungi status of some crops in the Cross River Basin of Nigeria. *Global Journal of Pure and Applied Sciences*, *20*, 5-9.

Okonji, C.J., Sakariyawo, O.S., Okeleye, K.A., Osunbiyi, A.G., & Ajayi, E.O. (2018). Effects of arbuscular mycorrhizal fungi inoculation on soil properties and yield of elected rice varieties. *Journal of Agricultural Sciences*, *63* (2), 153-170.

Page, A.L., Miller, R.H., & Keeney, D.R. (1982). *Methods of soil analysis, part 2, chemical and microbiological properties.* American Society of Agronomy, Inc., Madison, WI, USA.

Rana, K.N., Patel, G.J., Desai, C.K., & Akbari, M.P. (2017). Quality of Amaranthus (*Amaranthus hypochondriacus* L.) and soil properties influenced by irrigation scheduling based on critical growth stages and levels of iron. *Journal of Pharmacognosy and Phytochemistry, 6* (5), 101-103.

Salami, A.O., & Osonubi, O. (2003). Influence of mycorrhizal inoculation and different pruning regimes on fresh root yield of alley and sole cropped cassava (*Manihot esculenta Crantz*) in Nigeria. *Archives of Agronomy and Soil Science, 49* (3), 317-323.

Salehi, A., Tasdighi, H., & Gholamhoseini, M. (2016). Evaluation of proline, chlorophyll, soluble sugar content and uptake of nutrients in the German chamomile (*Matricaria chamomilla* L.) under drought stress and organic fertilizer treatments. *Asian Pacific Journal of Tropical Biomedicine, 6* (10), 886-891.

Tits, A.M., Elsen, A., Bries, J., & Vandendriessche, H. (2014). Short-term and long-trem effects of vegetable, fruit and garden waste compost applications in an arable crop rotation in Flanders. *Plant and Soil*, *376* (1/2), 43-59.

Towolawi, A.T., Arowolo, T.A., Bada, B.S.,Badejo, A.A., & Taiwo, A.M. (2017). Phytoextraction assessment of green Amaranth (*Amaranthus viridis* Linn.) grown on soil amended with sewage sludge. *Ife Journal of Science, 19* (1), 133-140.

Vandenberghe, L.P., Garcia, L.M., Rodrigues, C., Camara, M.C., Pereira, G.V., de Oliveira, J., & Soccol, C.R. (2017). Potential applications of plant probiotic microorganisms in agriculture and forestry. *AIMS Microbiology, 3* (3), 629-648.

Widowati, L.R., & De Neve, S. (2016). Nitrogen dynamics and nitrate leaching in intensive vegetable rotations in highlands of central Java, Indonesia. *Journal of Tropical Soils, 21* (2), 67-78.

Zhigila, D.A., Yuguda, U.A., Akawu, J.J., & Oladele, F.A. (2014). Palynomorphs and floral bloom as taxonomic characters in some species of the genus *Amaranthus* L. (*Amaranthaceae*). *Bayero Journal of Pure and Applied Sciences, 7* (2), 164-168.

Zuccarini, P., & Savé, R. (2016). Three species of arbuscular mycorrhizal fungi confer different levels of resistance to water stress in *Spinacia oleracea* L. *Plant Biosystems, 150* (5), 851-854.

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UTICAJI ARBUSKULARNIH MIKORIZNIH GLJIVA, ORGANSKOG ĐUBRIVA I RAZLIČITIH REŽIMA VLAGE NA OSOBINE ZEMLJIŠTA I PRINOS BILJKE *AMARANTHUS CRUENTUS*

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R e z i m e

Ogled je sproveden u sudovima kako bi se procenio uticaj dve arbuskularne mikorizne (AM) gljive i organskog đubriva (engl. *organic fertilizer* – OF) na rast i prinos biljke *Amaranthus cruentus* pri različitim režimima vlage zemljišta. Ovo je urađeno u cilju pružanja informacija o adaptaciji useva na uslove suše i kako bi se održala ravnoteža hranljivih materija u zemljištu u cilju povećanja prinosa useva. Ogled se sastojao od 36 tretmana (*Glomus clarum, Glomus deserticola* i bez AM), organskog đubriva proizvedenog od pijačnog otpada u različitim količinama (0, 5 i 10 t ha^{-1}) i različitih vodnih režima (25, 50, 75 i 100% poljskog kapaciteta [engl. *field capacity* – FC]). Svaki tretman ogleda je postavljen u tri ponavljanja. Kombinacijom tretmana, 10 t ha^{-1} OF i *G. clarum* dobijen je najveći sveži vegetativni prinos – 48,82 t ha^{-1}, koji nije statistički značajno ($p>0,05$) odstupao samo od tretmana sa 5 t ha^{-1} OF i *G. clarum* (45,78 t ha^{-1}) pri poređenju vodnih režima. Ponovljenim ogledom samo sa dodavanjem vode, dobijeni su niži i uporedivi prinosi biljke *A. cruentus*. Može se zaključiti da je dodavanje *G. clarum* zemljištu u kombinaciji sa 5 t ha^{-1} organskog đubriva optimalno poboljšalo rast i prinos biljke *A. cruentus* u uslovima vodnog stresa.

Ključne reči: arbuskularne mikorizne gljive, organsko đubrivo, vodni stres, *Amaranthus cruentus*, pijačni otpad.

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