Bioscience Research Communications
Vol. 15, No. 6, December 31, 2003
Printed in Nigeria

0795-8072/2003 $126.00 + 0.00

http://www.klobexpublishers.com

BRC 2003042/15615

The growth and yield response of cassava to *Glomus fasciculatum* (an arbuscular mycorrhizal, fungus)

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(Received September 11, 2003)

ABSTRACT: The beneficial effects of arbuscular mycorrhizal (AM) fungus, *Glomus fasciculatum* on the vegetative growth characters and yield of improved cassava (*Manihot esculenta* Crantz) are not well described. Therefore a controlled experiment was carried out to evaluate the response of two improved cassava cultivars TMS 91934 and TMS 30572 to mycorrhizal application. The experiment was arranged in a complete randomized design with three replications. The plants were either inoculated with *G. fasciculatum* (Thax. Sensu Gerd.) or not. Genotypic differences were observed and confirmed between the two cultivars whether inoculated or not. It was evident from the results obtained that the two cultivars responded to the Am fungus; however TMS 30572 showed greater vegetative growth and yield response that TMS 91934. The results also showed that the cassava plants responded to mycorrhizal inoculation as early as two to three weeks after planting. TMS 91934 consistently produced more leaves, leaf area and numbers of stems. Our studies also revealed that TMS 91934 diverted its photoassimilates to the shoot for maintenance of aerial parts rather than to the storage roots, whereas TMS 30572 diverted its photoassimilates more to the tuberous roots instead of maintaining higher leaf area. It was concluded that due to positive growth and yield, use of AM fungus is beneficial for greater productivity of cassava.

Key words: *Glomus fasciculatum;* TMS 30572; TMS 91934; Variation; Photoassimilates; *Manihot esculenta* Crantz.

Introduction

Adequate nutrition is one of the major environmental factors affecting plant growth and productivity (Shuma, 1994). Wide spread of phosphorus deficiency in sub-Saharan Africa (SSA) soils constitute a limiting factor in the production of major food crops in this region (Adepetu, 1986; Kang and Wilson, 1987; Otaga and Omoti, 1978). This deficiency is usually corrected by application of chemical fertilizers. However, the price and inaccessibility to the chemical fertilizers is a major constraint wherein cheaper alternative options for farmers must be made available.

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Several results have shown that ion uptake by both the lower and higher plants are influenced by the genotypic variations among plants species, concentrations of the ions inside the cell sap and soil, and preferential absorption of the ions. Results from several past works show that different host plants respond differently to inoculation of different arbuscular mycorrhiza (AM) species (Smith *et al*., 1992; Carling and brown, 1980; Quitero-Ramis *et al*., 1993) which may result in different host dependency. Efficiency of introduced mycorrhiza in addition to species factor also depends on environmental factors. All AM fungi do not have an equal effect on plants performance. This suggests the need for a choice of suitable species that could be made for exploitation under field conditions (Daft *et al*., 1981; Dodd *et al*., 1990). Different mycorrhizal strains vary in their effectiveness at increasing P uptake and thus growth and the behaviours in different soils.

Cassava was introduced to African continent in 16th century. It has since then become one of the major starch staples, particularly in the humid tropics where it provides over 50% of the local diet (Carter *et al*., 1992). Environmental sensitivity of cassava to prevalent soil nutritional status is unequivocal. This therefore reduces its nutrient uptake and result in yield reductions. Cassava plants therefore need mycorrhizae to survive the harsh conditions it is continually being subjected to both in terms of lack of soil moisture and poor nutrition. Many cassava cultivars made available to the local farmers by the International Institute of Tropical Agriculture (IITA) have not been screened for their mycorrhizal dependence. It is important to identify which commonly grown of the cassava cultivars are responsive to AM inoculation and thereby establish good agronomic practices for its greater productivity in SSA where the price of fertilizer is too high for farmers to afford.

The aim of this study was therefore to evaluate the response of two widely distributed and adopted IITA improved cassava cultivars to arbuscular mycorrhiza (AM) species, *G. fasciculatum* with the objective its use in improving the nutritional status of the plants in order to increase productivity.

Materials and Methods

The experiment was conducted at the International Institute of tropical Agriculture (IITA) Research farm (yam barn area) under controlled container conditions. The site is on Latitude 7°43’N and Longitude 13°9’E. The mean annual rainfall is between 1200-1600mm which is also bimodal in nature. Total A pan evaporation is 1550-1650mm. Mean monthly relative humidity at lowest was 61.5% (February) and above 83.5% in August. The mean annual temperature ranges from 20-30°C (minimum to 24-34°C (maximum).

Soil collection and experimental layout

Top soil (Oxic palenstalf) was sterilized by passing it through a gas propelled furnace. The sterilized soil was allowed to cool down for one week. The soil was then filled into large polyethylene litter bags. Each bag contained 50kg of the soil. The bags were arranged in an open field at yam barn area in a randomized design with three replications. The bags were either inoculated with 10g crude inoculum of *Glomus fasciculatum* or not. The original source of crude inoculum, which was supplied by Dr. Pat Miller of USDA-ARS, Beltsville, consisted of soil, hyphae spores of the AM fungus and root fragment of the trap host. This source was multiplied and used for this experiment under controlled condition. The bags were inoculated by placing the inoculum in a hole dug in soil in each bag. The cassava stake (oof 25cm long) was then placed on it and covered with the soil. The bags were then watered to field capacity. The plants were subsequently watered adequately three times a week.

Destructive samplings were carried out at 3, 6 and 9 months after planting (MAP). The plants were separated into the fibrous roots, tubers, rootstocks, stems, petioles and leaves at harvest. Their fresh weights were taken using a Metler balance. Total leaf area was taken at each harvest with a leaf area meter (model 3000, Licor Inc., USA). Plants heights were measured with a ruler. The samples were dried in an oven at 70°C for 48 hours.

Estimation of AM infection rate

Root samples were collected at each harvest from three replicates for each treatment for AM infections rate. These were stored separately in separate MacCarthney bottles filled with 50% ethanol. The samples were later washed in running water and cleared in 10% KOH. The clean samples were further bleached in H_2O_2 (3 ml of 20% NH_4OH and 30ml of 3% H_2O_2) for 30 minutes under room temperature. The samples were later acidified in 1% HCl for 3 hours. After this, the HCL was poured off and the roots stained in trypan blue solution prepared by mixing 500 ml of glycerol, 450ml of water, 50ml of HCL and 0.05g of trypan blue. The samples were then left overnight after which the stain was poured off. The samples were later stored in glycerol for further investigations.

Percentage root infections were there after estimated on stored samples using grid-line intersect method of Gioveanetti and Mosse (1980).

Results and Discussion

Effect of mycorrhiza at three months after planting

The results obtained at this early vegetative growth stage showed that the number of plant leaves and plant height were significantly higher in plants treated with *G. fasciculatum* than the non-inoculated plants. The leaf area of the inoculated cassava plants was also significantly greater than those of the non-inoculated (Table 1). The number of tillers were also higher in AM treated TMS 30572 than the non-inoculated ones. Genotypic variation between the two cultivars was also observed in their response to mycorrhizal inoculation. TMS 91934 had significantly higher number of leaves, plant height, total leaf area and number of stems. The indication was that the two cassavas showed early positive growth response to mycorhhizal inoculation. TMS 91934 early development was greater than TMS 30572 plants.

Effect of mycorrhizaat six months after planting

Tables 2 and 3 show the growth results obtained at 6 month after planting. The number of leaves produced was significantly higher in *G. fascilatum* inoculated TMS 91934. The influence of this AM fungus on the number of leaves produced at 6 months was not significant in TMS 30572. The plant height, total leaf area and number of stems were all promoted by the treatment except in TMS 91934, where both the inoculated and non-inoculated produced the same number of stems. At this stage, the genotype difference between the cultivars had disappeared, except in the number of stems produced. This implied that genotypic variation was more at an early growth stage. The tuberous roots, leaf, and stem weights were all enhanced by the fungus as shown in the previous work with different cassava clones (Osonubi, 1994; Osonubi *et al*., 1998; Oyetunji, *et al*. 2003; Ekanayake *et al*., 1996; Ekanayake *et al*., 2000). This enhanced performance is attributed to the higher number of leaves produced by mycorhhizal treated cassava which consequently resulted in higher total leaf area. It also means a greater photosynthetic capacity over the non-inoculated cassava plants. It therefore can result in production of more carbohydrates and consequently more biomass. This could be the reason in production of more carbohydrates and consequently more biomass. This could be the reason why TMS 30572 produced more tuberous root weight than TMS 91934, whether inoculated or not, suggesting that genotypic variation exist between the two improved cultivars.

Effect of mycorhhizal at nine month after planting

The numbers of fibrous roots produced by the non-inoculated cassava plants were significantly higher than those inoculated with the AM fungus at nine months after planting. The numbers of leaves produced were also improved by AM inoculation in the two cultivars (Tables 4 and 5). The leaf area, leaf weights and tuberous root weights were also positively enhanced by mycorrhizal treatment. This corroborated the findings of Osonubi, 1994, Atayese *et al*., 1993; Ekanayake *et al*., 1996; Fagbola, *et al*., 1998; 2001). The fibrous root weight of non-inoculated TMS 4(2)1425 was significantly lower than the inoculated plants. The inoculated TMS 91934 produced more leaves, leaf areas and tuberous roots than the non-inoculated counterparts (Tables 4 and 5). The stem weight of the inoculated TMS 30572 was significantly lower than that of non-inoculated plants. Contrary to this, the stem weight of inoculated TMS 91934 was significantly higher than that of the non-inoculated (Table 5). The results also revealed more diversion of assimilates to the stem in TMS 91934 instead of been diverted to the storage roots. This resulted in less tuberousroot production in TMS 91934.

Table 1: The effect of *G. fasciculatum* on vegetative growth performance of TMS 30572 and TMS 91934 at 3 months after planting (MAP) in sterilized soil.

Treatment	**No. of leaves/plant**	**Plant heaight (cm)**	**Total leaf area (cm^2/plant)**	**No. of stems/plant**
TMS 30572				
AM inoculated	57.00	84.50a	8129.50a	3.0a
AM non-inoculated	21.00b	27.00b	1778.60b	1.33b
TMS 91934				
AM inoculated	87.33a	114.67a	10900.40a	4.67a
AM non-inoculated	54.33b	80.00b	2671.67b	5.33a
Mean clone effect				
TMS 91934	70.83a	97.33a	6786.10a	5.0a
TMS 30572	35.40b	50.00b	4319.00b	2.0b
Mean mycorrhizal effect				
AM inoculated	75.20a	102.6a	9792.32a	4.00a
AM non-inoculated	37.67b	53.60b	2252.2b	3.33a
Treatment effect				
Mycorrhized	***	***	***	NS
Clone	***	*	***	*
Mycor*clone	**	*	***	NS

[A]Means followed by the same letter in the same column and under each treatment are not significantly different at P<0.05.

[B]*, **, ***, NS denote significance at 5%, 1%, 0.1%, and non significance respectively.

Table 2: The effect of *G. fasciculatum* on vegetative growth performance of TMS 30572 and TMS 91934 at 6 MAP in sterilized soil.

Treatment	**No. of leaves/plant**	**Plant height (cm)**	**Total leaf area (cm^2/plant)**	**No. of stems/plant**
TMS 30572				
AM inoculated	79.00a	157.67a	11267.00a	3.33a
AM non-inoculated	69.00a	98.33b	5844.00b	2.0b
TMS 91934				
AM inoculated	105.33a	159.00a	13147.00a	4.67a
AM non-inoculated	57.67b	100.67b	2836.00b	4.33a
Mean clone effect				
TMS 91934	81.50a	129.83a	7991.57a	4.50a
TMS 30572	74.00a	128.00a	8555.50a	2.67b
Treatment effect				
Mycorrhized	**	***	***	*
Clone	*	NS	***	NS
Mycor*clone	NS	NS	NS	NS

[A]Means followed by the same letter in the same column and under each treatment is not significantly different at P<0.05.

[B]**, **, ***, NS denote significance at 5%, 1%, 0.1% and non-significance respectively.

Conclusion

Our study showed that the two cassava cultivars responded positively to *G. fasciculatum* inoculation as reflected in a number of growth parameters and root yield. The response was found to manifest as early as three weeks after planting. Positive growth response was maintained up to nine months after planting when the plants were harvested. Genotypic variation was also observed between the cultivars. TMS 91934 diverted most of its photoassimilates to the shoot development whereas TMS 30572 diverted more of the photoassimilates to the storage organ.

ACKNOWLEDGEMENTS: This study was funded by the core budget of the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria. The first author is grateful for the Visiting research Fellowship awarded for doctoral dissertation research received from IITA.

Table 3: Effect of *G. fasciculatum* on yield components performance of TMS 30572 and TMS 91934 in sterilized soil at 6 MAP.

Treatment	Dry tuber weight (g/plant)	Dry fibrous root weight (g/plant)	Dry stem weight (g/plant)	Dry leaf weight (g/plant)	Shoot/root weight ratio
TMS 30572					
AM inoculated	94.53a	55.05a	43.30a	42.80a	1.06a
AM non-inoculated	32.77b	46.57a	19.43b	26.76b	0.93a
TMS 91934					
AM inoculated	33.30a	53.43a	29.87a	45.9a	1.16a
AM non-inoculated	1.63b	63.40a	24.55a	36.07a	1.13a
Mean clone effect					
TMS 91934	63.65a	50.81a	31.30a	40.98a	0.99a
TMS 30572	17.47b	58.43a	27.22a	34.78a	1.14a
Treatment effect					
Mycorrhized	***	NS	NS	*	NS
Clone	***	NS	NS	NS	NS
Mycor*clone	***	NS	NS	NS	NS

[A]Means followed by the same letter in the same column and under each treatment is not significantly different at P<0.05.
[B]*, **, ***, NS denote significance at 5%, 1%, 0.1% and non-significance respectively.

Table 4: The effect of *G. fasciculatum* on vegetative growth performance of TMS 30572 and TMS 91934 at 9 MAP in a sterilized soil.

Treatment	No. of leaves/plant	No. of fibrous root/plant	No. of tuberous roots/plant	Specific leaf area	Root weight ratio	Shoot weight ratio	Plant height (cm)
TMS 30572							
AM	925.30a	27.00a	21.33a	376.3a	0.095b	14.91a	220.00a
NAM	762.20b	31.67a	13.67b	348.9a	0.15a	7.46b	219.33a
TMS 91934							
AM	836.7a	38.00b	16.00a	612.20a	0.27a	7.17a	213.67a
NAM	185.00b	77.50a	7.00b	232.90b	0.19b	7.40a	120.00b
Treatment effect							
Mycorrhized	***	NS	**	*	**	NS	*
Clone	**	*	***	**	NS	NS	NS
Mycor*clone	**	NS	*	*	NS	NS	NS

[A]Means followed by the same letter in the same column and under each treatment is not significantly different at P<0.05.
[B]*, **, ***, NS denote significance at 5%, 1%, 0.1% and non-significance respectively.
[C]AM = with and NAM = without *G. fasciculatum* treatment, and mycor = mycorrhized.

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