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Influence of crop rotation and intercropping of cassava with legumes on VA mycorrhizal symbiosis of cassava

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Summary In comparison to cassava grown in monoculture the root infection of cassava with vesicular–arbuscular mycorrhiza was increased by crop rotation with grain legumes in the field. This was also found when cassava was intercropped with legumes and fertilized. A possible specificity of mycorrhizal fungi to increase the yield of one species more than the other when grown in association, is discussed.

Introduction

Cassava (*Manihot esculenta* Crantz) is highly dependent on a vesicular–arbuscular (VA) mycorrhizal fungi association for plant growth[4]. The main effect of VA mycorrhiza is to enhance P uptake of cassava grown on acid soils low in available P[3].

Two strategies to secure benefit from mycorrhizal infection of cassava may be adopted: one is to favor effective indigenous mycorrhizal fungi by adequate cultural practices, the other to field-inoculate cassava with selected fungi. In both cases, the determination of those cultural practices which are beneficial for the mycorrhizal association are of high importance.

Advantages of cassava-grain legume intercropping in terms of total biological productivity of the system are well documented[8]. Furthermore, crop association or rotation with grain legumes may be advantageous to preserve or increase soil fertility[10]. In the present investigation, the influence of cassava sole cropping, association and rotation with cowpea (*Vigna unguiculata* L. Walp), groundnut (*Arachis hypogaea* L.) and mungbean (*Vigna radiata* L.) on mycorrhizal root infection of cassava was evaluated in two field experiments. In addition, the host specificity of various mycorrhizal species was evaluated in a greenhouse trial.

Materials and methods

Field trials were established at two locations in Colombia, at Quilichao, 3°06′ N latitude and 76°31′ W longitude, 1035 m.a.s.l.; and at Media Luna, 10°30′ N latitude and 70°31′ W longitude, 10 m.a.s.l. The two locations have 1800 and 1600 mm total annual precipitation and annual mean temperatures of 23 and 27°C, respectively. The soil at Quilichao has a clay loam texture and has been classified[5] as a typic Dystropept with pH 3.9, organic matter 8%, Bray II extractable P 2 ug/g of soil, the soil at Media Luna is an entisol with sandy texture and pH 6.3, organic matter 0.8%, Bray II extractable P 6 ug/g of soil. Cropping systems at Quilichao were continuous cassava sole cropping, continuous cassava-cowpea intercropping and a cowpea-peanut (one year) cassava (following year) rotation, whereas at Media Luna the systems were continuous cassava sole cropping, continuous cassava-mungbean intercropping, and a fallow – mungbean and peanut – cassava three year rotation. Each cropping system was grown with and without fertilization. Fertilized plots received a total annual application of 60, 44, 62.5, 10 and 1 kg/ha of N, P, K, Zn and B at Quilichao, whereas these elements were applied at rates of 50, 44, 50, 10 and 1 kg/ha at Media Luna, respectively. These fertilizers were applied in side bands to the rows; when intercropped, half of the fertilizer was applied to cassava and half to the legume.

Fine cassava roots were sampled from 12 and 10 months old cassava at Quilichao and Media Luna, respectively. Sampling at Quilichao coincided with the end of the second crop cycle whereas sampling at Media Luna coincided with the end of the third crop cycle.

Roots were stained according to the method of Kruckelmann[6] and percent infected root length was determined according to Giovanetti and Mosse[1].

In the greenhouse trial conducted at CIAT headquarters in Cali, Colombia, the effect of inoculation with *Glomus manihotis* Howeler, Sieverding et Schenk, *Glomus occultum* Walker, and *Entrophospora colombiana* Spain et Schenk on sole growing kudzu (*Pueraria phaseoloides*) and a kudzu–cassava association was evaluated. Five pregerminated kudzu seedlings were planted in small volumes of previously sterilized Quilichao soil and inoculated with 50 spores of each of the above mentioned mycorrhizal species in three different treatments. After six weeks of growth, four of the kudzu plantlets were transplanted to pots containing 5 kg of sterilized Quilichao soil whereas the fifth kudzu plant was transferred to a 5 kg pot and planted together with a 20 cm-stake of cassava cv M Col 113. The experiment was replicated 10 times. Soil in the 5 kg pots was fertilized with 50 kg P and 50 kg K/ha. Kudzu plants were also inoculated with *Rhizobium* sp. for N fixation. Plant tops of kudzu and cassava were harvested 10 weeks after planting and inoculating cassava.

Results and discussion

Effect of crop rotation

Table 1 shows that at both field sites, cassava fresh root yields in continuous sole cropping were similar to those obtained from the cassava sole crop in rotation. However, rotation increased mycorrhizal root infection significantly, the increase being considerably greater at Quilichao where the infection level was generally much lower than at Media Luna. Adding fertilizer did not affect the mycorrhizal root infection of cassava at Quilichao, but resulted in a 25% yield increase in both the continuous sole crop and the rotation system. At Media Luna fertilization decreased the root infection of cassava in both the continuous sole crop and the rotation system, the decrease being less severe in the rotation systems, but no influence on cassava fresh root yield was observed. These data suggest that on low P soils cassava yield is only increased by fertilization if mycorrhizal root infection is not decreased. Furthermore, the results confirm earlier findings[9] indicating that in soils very low in P small amounts of fertilizer do not affect root infection negatively whereas at slightly higher soil P levels, fertilization may decrease infection[2]. Rotation with other mycotrophic plants such as cowpea, groundnut or mungbean appear to be favourable for root infection of cassava, although further studies need to confirm these preliminary findings. On the other hand, several years of continuous sole cropping other field crops were not found to decrease mycorrhizal root infections[7,11].

Effect of intercropping cassava with legumes

Without fertilization, intercropped cassava showed a mycorrhizal root infection level similar to that observed in continuous sole cropping at both sites, the general infection level being low at Quilichao while reaching very high values at Media Luna (Table 1). On the other hand, with fertilization, root infection of intercropped cassava approached more the levels observed in the rotation systems at both locations. However, fresh root yields of intercropped cassava were not significantly increased at either location and intercropped grain legume yields responded to fertilization only at Quilichao. Fertilizer applications are known to change the relative competitiveness of crops when grown in association which may lead to different types of fertilizer responses in the component crops of an association[8]. While in general the presence of grain legumes appeared to favor root infection of cassava, it is not clear which of the intercropped species profited more from mycorrhizal infestation. An underlying reason for the

Table 1. Influence of cropping system on mycorrhizal infection and root fresh yields of cassava and dry seed yields of legumes (means with SE) at two locations

Cassava cropping system	Fertilization	CIAT-Quilichao* Infected root length %	CIAT-Quilichao* Root or seed yields t/ha	Media Luna** Infected root length %	Media Luna** Root or seed yields t/ha
Monoculture:					
Cassava	No	11.7 ± 0.2	26.0 ± 1.7	94.6 ± 1.1	18.3 ± 0.6
	Yes	12.2 ± 2.1	32.5 ± 1.7	86.4 ± 3.1	18.4 ± 0.6
Rotation:					
Cassava	No	20.4 ± 3.7	26.4 ± 1.1	95.5 ± 2.7	18.5 ± 0.9
	Yes	20.8 ± 0.2	33.6 ± 2.4	92.8 ± 0.9	17.6 ± 0.5
Intercropping:					
Cassava	No	11.3 ± 1.1	18.0 ± 0.7	94.3 ± 1.9	14.3 ± 0.2
	Yes	18.1 ± 2.2	18.4 ± 2.9	92.9 ± 0.2	15.7 ± 1.9
Legumes	No	– ***	0.57 ± 0.07	–	0.69 ± 0.05
	Yes	–	1.20 ± 0.01	–	0.61 ± 0.06

* Cassava cv. 'CMC-84'; cowpea cv. 'TVX-1193-059 D'; yields from second year growth cycle.
** Cassava cv. 'M Col-22'; mungbean cv. '200-M-304'; yields from third year growth cycle.
*** Not defined.

Table 2. Influence of different mycorrhizal species on shoot dry matter production of cassava/kudzu association in pot culture (means of 10 replications with S.E.)

Mycorrhizal species*	Shoot production (g/pot) Kudzu sole	Total ass.**	Cassava from ass.	Kudzu from ass.	Relation cassava: kudzu in ass.
Glomus manihotis	24.4 (± 1.5)	25.1 (± 0.9)	15.1 (± 1.1)	10.0 (± 1.5)	1.51
Glomus occultum	20.2 (± 1.7)	21.7 (± 0.9)	14.0 (± 0.7)	7.7 (± 1.5)	1.82
Entrophospora colombiana	23.0 (± 1.0)	23.6 (± 0.7)	10.2 (± 1.4)	13.4 (± 1.3)	0.76

* Non-inoculated plants produced: Kudzu sole: 6.1 ± 0.5 g; Cassava sole: 8.2 ± 1.0 g dry matter.
** Assocation of one cassava plant with one kudzu plant.

differences in yield response of cassava and legumes may therefore exist in the form of a specificity of one of the several mycorrhizal species present at the two locations to favor growth and yield of one plant species involved in the association more than the other one(s). This hypothesis was supported by results from the greenhouse trial in which the mycorrhizal fungus *Entrophospora colombiana* enhanced the growth of the legume more than that of cassava when cassava and the legume grew in the same pot (Table 2). *E. colombiana* is the dominant mycorrhizal species at Quilichao[4] whereas at Media Luna, other species such as *Glomus manihotis*, *Sclerocystis* spp. and *Gigaspora* spp. were present. Further studies should verify the specific influence of mycorrhizal species on yield interactions between cassava and legumes when planted in association. In addition, long term observations should determine whether different cassava cropping systems produce changes in the mycorrhizal species composition in the field and whether these changes can affect yield.

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