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Research Application Summary

The potential role of Abuscular Mycorrhizae and native rhizobia in upscaling maize and cowpea production in semiarid zone of Eastern Kenya

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Abstract

Legumes are an essential component of many cropping systems due to their ability to form symbiotic associations with nitrogen fixing bacteria. Key constraint faced by smallholder farmers in Sub-Sahara Africa is lack of resources so they cannot afford Nitrogen fertilizers. Soil microorganisms especially rhizobia and *Arbuscular mycorrhizae* fungi form tripartite symbiosis and enhance nitrogen fixation, uptake of essential nutrients such as phosphorus and protect plants against biotic and abiotic stress. The study was carried out to determine effect of native rhizobia nodulation in different cowpea genotypes and *Arbuscular mycorrhizae* fungi colonization potential in different maize genotypes. Ten farms were selected from Embu and Kitui Counties in Eastern Kenya (five farms in each county respectively). Four genotypes of cowpea and maize were selected as the trap host. A greenhouse experiment was setup and treatments were set out in randomized complete block design that was replicated four times. After four weeks the plants were harvested and nodule number and dry weight were recorded. The maize was also harvested at the same time and mycorrhizae colonization in the maize roots determined. Cowpea nodulation was significantly ($p<0.0001$) different among genotypes and soil source. The open pollinated cowpea varieties had the highest nodulation ranging from 39.35 to 40.58 and the landrace used had the lowest nodulation (30.35). *Arbuscular mycorrhizae* colonization was significantly ($p<0.05$) different among the test genotypes.

Key words: *Arbuscular mycorrhizae* fungi, cowpea genotypes, maize genotypes, Rhizobia

Resume

Les légumineuses sont une composante essentielle de la plupart des systèmes de culture en raison de leur capacité à former des associations symbiotiques avec des bactéries fixatrices d'azote. La principale contrainte à laquelle sont confrontés les petits producteurs en Afrique au Sud du Sahara est le manque de ressources, de sorte qu'ils ne peuvent pas se permettre d'acheter des engrais azotés. Les microorganismes du sol, en particulier les rhizobiums et les champignons à *Arbuscular mycorrhizae*, forment une symbiose tripartite et améliorent la fixation de l'azote, l'absorption de nutriments essentiels tels que le phosphore et protègent les plantes contre les stress biotiques et abiotiques. L'étude a été réalisée pour déterminer l'effet de la nodulation des rhizobiums indigènes dans différentes variétées de niébé et le potentiel de colonisation des champignons à *Arbuscular mycorrhizae* dans différentes variétées de maïs. Dix exploitations ont été sélectionnées dans les comtés de Embu et de Kitui à l'Est du Kenya (cinq exploitations dans chaque comté). Quatre variétés de niébé et de maïs ont été sélectionnés comme hôte-piège. Un essai en serre a été mis en place, avec des traitements rangés dans un dispositif de blocs aléatoires complets, répété quatre fois. Quatre semaines après l'installation de l'essai, les plants de niébé ont été récoltés et le nombre et poids sec des nodules ont été recensés. Le maïs a également été récolté et la colonisation des mycorhizes dans les racines du maïs a été déterminée. L'intensité de nodulation chez le niébé était significativement différente (p <0,0001) selon les variétés et l'origine de la terre utilisée. Les variétés de niébé à pollinisation libre ont exhibé les meilleures perfomances de nodulation, allant de 39,35 à 40,58 et la variété paysanne utilisée avait la valeur de nodulation la plus faible (30,35). La colonisation par les *Arbuscular mycorrhizae* était significativement différente (p <0,05) d'une variété à une autre.

Mots clés: Champignons à *Arbuscular mycorrhizae*, génotypes de niébé, génotypes de maïs, Rhizobium

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Introduction

Agricultural productivity has declined in Kenya over the last decade. This has been due to several factors such as pests and diseases, and increase in human population which has consequently led to land fragmentation, intensive farming and soil infertility (Mwendwa and Giliba, 2012). Cowpea (*Vigna unguiculata*) is a legume grown in Kenya mainly by smallholder farmers. It is a major source of income and supplements nutrients such as proteins, vitamins and fiber in diets and despite its significantly low yields. Climatic factors, edaphic factors and low nitrogen content account for the low production of legumes in Kenya.

Cowpea has the ability to establish symbiosis with rhizobia which enhance nodulation and the uptake of nitrogen though biological nitrogen fixation (BNF) hence promoting plant growth and productivity (Mwendwa and Giliba, 2012). Maize (*Zea mays* L.) on the other hand is one of the most important staple foods relied upon by over 90% of the Kenyan population. However, maize production has been declining in Kenya over the years, largely due to declining soil fertility (mainly phosphorus, nitrogen, potassium) and the skyrocketing world fertilizer prices (Onono *et al.,* 2013), making fertilizers too expensive for maize farmers. A change in soil management practice can help reduce the excessive use of mineral Phosphate fertilizers, through for example by adoption of *Arbuscular mycorrhizae* fungi which forms synergistic associations with vascular flowering plants that are found in the terrestrial environment. Presence of *Arbuscular mycorrhizae* fungi in the soil reduces the need for P fertilizer application due to their ability to enhance P uptake by the plants. This reduces loss of nutrients through seepage to the immediate environment (Onono *et al.,* 2013). *Arbuscular mycorrhizae* fungi form belowground hyphal networks that enhance plant growth and nutrient acquisition. *Arbuscular mycorrhizae* fungi presence in subsistence agricultural farms experiencing low rainfall and mineral stress has been reported to improve maize yield in Nepal (Shrestha *et al.,* 2009). This study examined the effect of mycorrhizae colonization of maize and nodulation of cowpea by rhizobia.

Materials and methods

This study involved greenhouse experiments and laboratory analyses. Soil samples (20 kg) were obtained from ten farms (5 farms in Embu County and 5 farms in Kitui county). The samples from each farm were dried and separated into two portions. One portion was used for examination of physico-chemical properties of the soil and the other portion used for rhizobia trapping with cowpea as host plant and AMF trapping with maize as host plant in the greenhouse. Pot cultures were established. Four maize (*Zea mays* L.) cultivars (two open pollinated varieties: OPV 1, OPV 2, hybrid maize and a landrace), and four cowpeas cultivars (three open pollinated varieties: OPV 1, OPV 2, OPV 3 and a landrace) were grown in a split-plot experimental design. Each genotype was replicated four times. At V4 stage, the plants were harvested. The maize was examined for AMF root colonization, while for cowpea plants the nodule dry weight and nodule number were determined.

Percentage data on maize colonization potential of AMF on various maize genotypes were log transformed before analysis to normalize the data. The results were then analyzed using two-way analysis of variance. The source of soil and the genotypes were considered as independent factors. The analysis was done using SAS software version 9.2. Post hoc test where means were significantly different was performed using Tukey's HSD.

For the various cowpea genotypes, data on the number of nodules, and nodule dry weight were analyzed using two-way analysis of variance (ANOVA). Means were separated by Tukey's Honest Significance Difference (HSD) at 5% probability level using SAS software (version 9.2).

Results and discussion

There was significant ($p<0.0001$) variation in nodule number between farms. The highest cowpea nodulation (46.625) was observed in crops planted in soils from Farm 8 (Machang'a, Embu County). Farm 2 from Kitui west had the lowest cowpea nodulation as compared to the other farms (Table 1). The variation in nodulation among the farms could be due to soil characteristics such as available phosphorus and calcium, pH, salinity and soil nitrogen (Agoyi *et al.,* 2017). According to Mothapo *et al.* (2013), nodulation can also be influenced by cropping history in the farm.

Cowpea nodulation. Open pollinated genotypes C1, C3 and C4 had the highest nodulation of above 39.150 nodules per plant for genotype C1 to 43.700 nodules per plant for genotype C3. The landrace C2 commonly grown in Kitui and Embu county had the lowest nodulation (30.350) (Table 1) This is in agreement with Yusuf *et al.* (2008) that cowpea and soybean nodulation is greatly dependent on the crop genotype. Working on common bean Argaw and Muleta (2018) reported that genotypes significantly influence common bean nodulation and variation in nodulation among varieties could be attributed to differences in genetic makeup of the various genotypes.

There was significant interaction (p = 0.0191) between variety and farm in determining cowpea nodulation (Table 1). This has been observed in other legumes. Agoyi *et al.* (2017) explained that nodulation was significantly dependent on promiscuous soybean genotypes and the environment where they were growing.

There was significant (p < 0001) difference in nodule dry weight between the various farms. The highest nodule dry weight was recorded in farm 7 (0.195 g) from Embu county. Lowest nodules dry weight was observed in farm 9 (0.099g) from Embu county. The nodule dry weight ranged from 0.101 to 0.181g in Kitui County farms and 0.099 to 0.195 g in Embu county farms (Table 1). There was no significant (p=0.5649) variation in nodule dry weight between the various genotypes (Table 1). The highest nodule dry weight was observed in genotype C4 (0.1576 g), while the lowest was observed for variety C2 (0.14183 g) (Table 1). Further, there was no significant (p = 0.2885) interaction between farm and cowpea genotype in determining the nodule dry weight.

Table 1 Rhizobia nodulation in different cowpea genotypes

Treatment farm	Region	Nodule number	Nodule dry weight (grams)
Farm 1	Kitui west	$38.44 \pm 2.62^{abc*}$.	0.18 ± 0.01^{a}
Farm 2	Kitui west	30.94 ± 3.10^{c}	0.10 ± 0.01^{b}
Farm 3	Kitui west	41.81 ± 2.99^{abc}	0.16 ± 0.02^{ab}
Farm 4	Kitui west	33.81 ± 1.88^{bc}	0.16 ± 0.02^{ab}
Farm 5	Kitui west	44.63 ± 3.66^{ab}	0.15 ± 0.01^{ab}
Farm 6	Machang’a	34.44 ± 3.02^{bc}	0.15 ± 0.02^{ab}
Farm 7	Machang’a	44.56 ± 4.43^{ab}	0.20 ± 0.02^{a}
Farm 8	Machang’a	46.63 ± 3.56^{a}	$0.16 \pm 0.01a^{b}$
Farm 9	Machang’a	32.44 ± 2.60^{c}	0.10 ± 0.01^{b}
Farm 10	Machang’a	36.75 ± 1.75^{abc}	0.11 ± 0.01^{b}
Variety			
C1		39.15 ± 1.92^{a}	0.14 ± 0.01^{a}
C2		30.35 ± 1.51^{b}	0.14 ± 0.01^{a}
C3		43.70 ± 2.42^{a}	0.14 ± 0.01^{a}
C4		40.58 ± 1.73^{a}	0.16 ± 0.01^{a}
P values			
Farm		<0.0001	<0.0001
Variety		<0.0001	0.5649
Farm*Variety		0.0191	0.2885

*Values with dissimilar letters along the columns are significantly different at (P<0.05) according to Tukeys’ HSD. C1, OPV-1; C2, landrace-Kikamba; C3, OPV-2, C4, OPV 3.

However, there was significant difference ($p < 0.05$) in arbuscular mycorrhizae fungi colonization between genotypes. The landrace (Kikamba) had the highest colonization (62 %), and it was followed by open pollinated varieties (OPV 1) and (OPV 2) obtained from KALRO –Katumani. The hybrid commonly grown in the regions under study had a low colonization of 50 %. These results are in agreement with studies by Chu *et al.* (2013) who reported significant variation in percentage mycorrhizae colonization among different maize genotypes. There was also significant difference in mycorrhizae colonization between the 10 farms. This could be attributed to possibility the differences in soil characteristics as reported by Kim *et al.* (2017).

Conclusion

This study established that cowpea nodulation is dependent on the cowpea genotype and source of soil. The landrace cowpea variety performed poorly in nodule colonization as compared to the OPVs. It was also established that percentage AMF colonization is dependent on the soil type and the maize genotype under study. The landrace maize crop performed well in AMF colonization as compared to the OPVs and hybrid.

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