Increasing cowpea productivity by combining rock phosphate and arbuscular mycorrhizal fungi inoculation in sub-Saharan Africa

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Introduction

- The P deficiency negatively affects the formation of nodule (1, 2) and the symbiotic fixation of N_2 gas by limiting growth and survival of rhizobia (1, 3) in legume crops.
- According to our previous study, P and N uptake by cowpea are significantly correlated ($r = 0.845$, $P < 0.01$) (4).
- Additionally, P uptake has significant and high positive correlation with shoot dry weight (SDW) at 8 weeks after planting (WAP). This is a good indicator of P uptake in cowpea (4).
- Optimum amount of rock P application on cowpea was identified as 57 mg P kg^{-1} (4).
- In sub-Saharan Africa, rock P deposit exists widely (5); thus, it can be used as alternative P source of chemical fertilizer owing to increase of P fertilizer price.
- Arbuscular mycorrhizal fungi (AMF) are known to help promote P and water uptake by crops by elongating their hyphae (6).
- Our study focused on the use of rock P and AMF inoculation to enhance P uptake by cowpea.

Materials and Methods

- **Pot test 1** was conducted to verify the effect of AMF inoculation on cowpea shoot dry weight with 0 and 30 mg P kg^{-1} as KH_2PO_4.
- **Pot test 2** was conducted to verify the effect of co-application of rock P (60 mg P kg^{-1}) and AMF inoculation.
- **Pot test 3** was conducted to identify the optimum amount of rock P application for AMF inoculation using 20, 40, and 60 mg P kg^{-1}.
- **Pot test 4** was conducted to identify the effect of co-application of rock P (40 mg P kg^{-1}) and AMF inoculation on cowpea drought tolerance.

Soil

- Pot tests 1, 2, and 3 were conducted using low P (approx. 1.06 ppm) soil collected from Fashola village (N07º53'718'', E003º45'773'') in Nigeria.
- In pot test 4, low P and N soil that was made mixing sand and clay collected in IITA-Nigeria. The available P was 0.48 ppm and total N was 0.004%. The percentages of sand, silt, and clay were 84, 5, and 11%, respectively.

Nutrients, AMF and irrigation

- Rock P from Togo was along with AMF strain, *Glomus intraradices*.
- In all pot tests, basal application of 50 K (KCl), 50 Mg ($MgSO_4$ $7H_2O$), 5 Zn ($ZnSO_4$ $7H_2O$), 10 Mn ($MnCl_2$ $4H_2O$), 5 Cu ($CuSO_4$ $5H_2O$), 5 Mo ($(NH_4)6MO_7O_{24}$ $4H_2O$)mg kg^{-1} soil (7) was employed.
- De-ionized water was used for irrigation to keep the soil water content at approx. 50% of field capacity in pot tests 1, 2, and 3.
- In pot test 4 (normal irrigation treatment), soil water content was kept at approx. 50% of field capacity. Drought treatment was irrigated 50 ml once per week from 3 WAP to 7 WAP. Water content under drought condition was less than 25% of field capacity.

Results and Discussion

Test 1: Can AMF inoculation help increase SDW in cowpea?

- Infection rate of AMF under zero P application was approx. 30-50% in all cowpea genotypes and maize, but under 30 mg P kg^{-1} was almost 0%.
- Focusing on zero P application, the SDWs of cowpea genotypes with AMF inoculation were higher than without AMF inoculation (Fig. 1).

➢ **AMF inoculation does not work if there is high available P in soil. But under low P condition, AMF can help to increase SDWs of cowpea.**

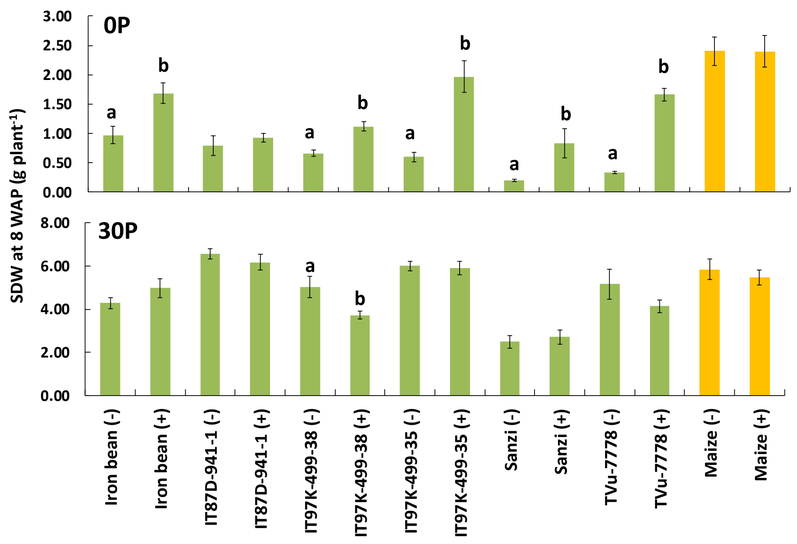

Figure 1: Shoot dry weight (SDW) at 8 weeks after planting (WAP) without (-) or with (+) arbuscular mycorrhizal fungi (AMF) under the treatment of 0 (0P) or 30 mg P kg^{-1} (30P) as KH_2PO_4 in 6 cowpea genotypes and a maize variety
Letters denote the significant differences at $P < 0.05$ by Tukey's method compared to no-inoculated plant in each genotype under each P level. The vertical bar is the standard error. The yellow color represents the value of maize.

Test 2: Can co-application of rock P and AMF application increase SDW of cowpea ?

- Cowpea genotype, Sanzi, only showed significantly ($P < 0.05$) higher SDW under co-application of rock P and AMF inoculation than under rock P only (Fig. 2).
- The SDWs of other 14 cowpea genotypes (except Sanzi) under co-application of rock P and AMF inoculation were slightly higher than under rock P only (Fig. 2).

➢ **These results indicated that rock P application at 60 mg P kg^{-1} is too high for AMF inoculation to work.**

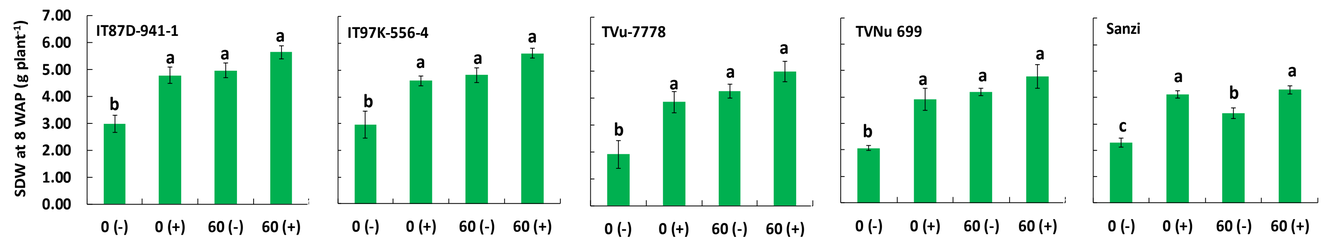

Figure 2: Shoot dry weight (SDW) at 8 weeks after planting (WAP) without (-) or with (+) arbuscular mycorrhizal fungi (AMF) inoculation under the treatment of 0 and 60 mg P kg^{-1} as RP in 15 cowpea genotypes
The vertical bar represents the standard error. Letters denote the significant differences at $P < 0.05$ by Tukey's method compared to 0 mg P kg^{-1} without AMF inoculation.

Test 3: How much of rock P is optimum for AMF inoculation to work?

- Mean of SDWs from the data of 6 cowpea genotypes was significantly higher under the treatment of 20 mg P kg^{-1} compared to zero application.
- Significant differences among 20, 40, and 60 mg P kg^{-1} were not identified.

➢ **The result explains that 20 mg P kg^{-1} was optimum amount of rock P application for cowpea with AMF inoculation.**

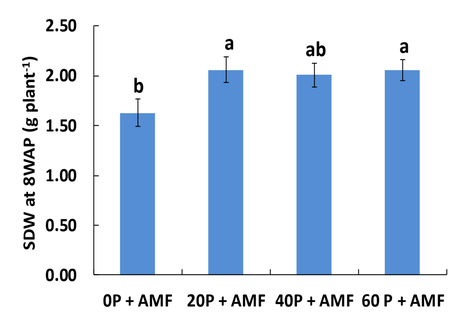

Figure 3: Means of SDWs at 8 weeks after planting (WAP) under the different RP application amounts; 0, 20, 40, and 60 mg kg^{-1} with arbuscular mycorrhizal fungi (AMF) inoculation in 6 cowpea genotypes
The vertical bar represents the standard error. Letters denote the significant differences at $P < 0.05$ by Tukey's method compared to 0 mg P kg^{-1}.

Test 4: Can co-application of rock P and AMF inoculation increase drought tolerance?

- TVu-7778 is a susceptible genotype to drought stress (8). However, young plant survived with co-application of rock P and AMF inoculation.
- Flowering of survived plants started from co-application of rock P and AMF inoculation and sole AMF inoculation at 10 WAP.

➢ **Co-application of rock P and AMF inoculation has high possibility of inducing drought tolerance of cowpea.**

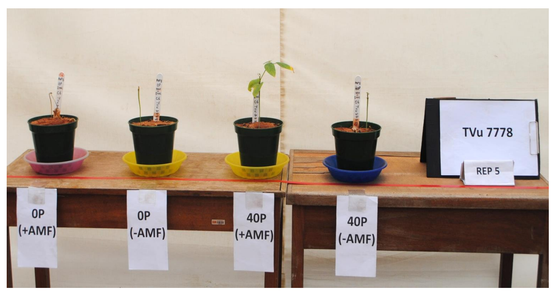

Photo 1: Responses of cowpea genotypes, TVu-7778 to drought stress under the different treatments (7WAP)
0P: zero P application, 40P: rock P application as 40 mg P kg^{-1}, +AMF: with AMF inoculation, -AMF: without AMF inoculation.

Conclusion

1. Inoculation of AMF such as *Glomus intraradices* can increase SDW at 8 WAP of cowpea under low P condition. Therefore, it can contribute to increase P uptake by young cowpea plant.
2. For AMF inoculation to work, we need to apply at least 20 mg P kg^{-1} as rock P.
3. Co-application of rock P and AMF inoculation has high possibility of inducing drought tolerance in cowpea.

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