Original Research Article

Effects of arbuscular mycorrhizal fungal inoculation on growth and yield of two sweet potato varieties

ABSTRACT

Arbuscular mycorrhizal fungi (AMF) represent a functionally important component of soil microbial community, being of particular significance for plant mineral nutrition in tropical agro ecosystems. The effects of AMF inoculation on growth and yield of two sweet potato varieties was studied during the short rains season of 2017/2018 in the Teaching and Research Farm of Agricultural Science and Technology Department, Kenyatta University. The experiment was laid down as 2x2 factorial design in a randomized complete block design (RCBD) with three replications. The experimental factors were two sweet potato varieties (Kemb-10 and Bungoma) and AMF inoculum (With and without inoculation). Data on growth was collected on vine length and number of branches, while data on yield was collected on marketable storage roots and shoot biomass. Data was analyzed using Genstat 15th edition and the results showed that there was significantly difference at $P \leq 0.05$ among the treatments. AMF inoculation increased growth and yield of sweet potatoes by vine length 29.74%, Number of branches 22.36%, marketable storage roots 18.32%, and shoot biomass 28.68% in week 20. Also, variety interacting with AMF inoculation enhanced growth and yield parameters. In conclusion, the study demonstrated that the application of commercial AMF inoculum solely or when interacting with varieties enhanced the growth and yield of sweet potatoes, though there was no significant difference between the two varieties.

Keywords: Arbuscular mycorrhiza fungi; inoculation; interactions; growth; yields.

1. INTRODUCTION

Sweet potato (*Ipomoea batatas* (L) Lam) is a dicotyledonous plant belonging to the family Convolvulaceae. It is one of such important starchy tuber crops in tropical and subtropical countries because of its yield potential and high calorific value. It is an important food security crop in many developing countries [1]. The roots are mainly consumed though the leaves also provide essential minerals, vitamins and protein [2]. It is ranked as the sixth most important food crop worldwide, following rice, wheat, potatoes, maize, and cassava [3]. One reason for this is that sweet potato is a hardy crop and can strive on marginal soils [4]. Notwithstanding its hardy nature, just like other crops it still requires some important nutrients to realize its full production potential. For this reason, over the years, there has been a decline in sweet potato yield due to the inherent poor soils in low- income countries [5].

On the other hand, inorganic fertilizers may enhance good yields [6], but farmers in low- income countries cannot afford the costly inorganic fertilizer. Therefore, the search for cheaper soil amendments such as organic fertilizers to improve the soil fertility has become more important. Organic fertilizers improve the physical, chemical, and biological characteristics of the soil thereby increasing productivity for food, improved income, and nutrition security [7]. As research efforts are directed toward improving soil fertility for increased yields, it is important to consider the effect of microorganisms such arbuscular mycorrhiza on the growth and yield of sweet potatoes.

Arbuscular mycorrhiza fungi (AMF) which belong to phylum Glomeromycota [8]. Amongst the mycorrhizal associations, the AMF association is the most common one [9]. They are ubiquitous obligate mycobionts forming symbiosis with the terrestrial plant communities [10]. The role of mycorrhizae in plant development pertains to mineral nutrition especially the uptake of phosphate [11]. This effect has been attributed to the external hyphae of AMF being able to extend from the root surface to the soil beyond the P depletion zone and so access a greater volume of undepleted soil than the root alone. Therefore AMF is reported to increase the absorptive area [12], because the fine and thinner structure of the fungal hyphae have better access to soil pores and can explore larger soil volumes, which results in more efficient mining for Pi sources [13]. This is because they have a small diameter of hyphae (20–50 µm) which allows access to soil pores that cannot be explored by roots. Mycorrhizal hyphae have a higher affinity (lower Km) for P than roots [14]. AMF also have biochemical and physiological characteristics which differ from those of roots which can enhance P availability. They do acidify the rhizosphere through increased proton efflux or pCO2 enhancement [15], which can mobilize P [16]. Also, according to [17], mycorrhizal plants show enhanced photosynthetic capacity. With these benefits, the AMF are known to be of great importance due to their high capability to increase growth, yield, and quality of crops through the acquisition of nutrients in less fertile soils and consequently lessening the prerequisite for Phosphate-based fertilizers [18]. The present study investigated the effects of AMF inoculation on growth and yield of two sweet potato varieties. The specific objective of this work was to assess the effects of mycorrhizal mixed commercial inoculum on growth and yield of both improved and landrace sweet potato varieties in Kiambu County Kenya.

2. MATERIALS AND METHODS

2.1 Description of the Study Site

An experiment was conducted in the Teaching and Research Farm of Agricultural Science and Technology Department, Kenyatta University at Thika Road, Kiambu, (7.27oN 3.54oE). The farm is within the coordinates 1°10'50.0"S, 36°55'41.0"E (Latitude:-1.180568; Longitude: 36.928042). The area temperature ranges between 12.8^{o}C during the cold month and 24.6^{o}C during the hot seasons. The soils are loamy, acidic, well drained and moderately deep with low level of phosphorus (9.0 mg/kg). The average amount of rainfall received is 989 mm per year

[19] where 1200 mm rains is recorded during the long rains whereas 780 mm is recorded during the short rains.

2.2 Crop Husbandry and Experimental Design

The experiment was carried out for five months during the short rains of 2017/2018 cropping season which occurred between November and March. The experimental factors were two sweet potato varieties (Kemb-10 and Bungoma), and mycorrhizal mixed commercial inoculum. The inoculum consisted of *Rhizophagus irregularis, Funneliformis mosseae, Claroideoglomus claroideum* and *Claroideoglomus etunicatum* AMF species.

The experiment was then laid out as 2x2 factorial experiments in a randomized complete block design (RCBD). The experiment had a total of 8 treatments. Each treatment was replicated three times. Well matured healthy and disease-free cuttings of the two varieties were procured from KARLO Embu. The vines were later covered with a moist cloth under a shade for two days to initiate roots before planting. As per recommendation, 25g of mixed mycorrhizal inoculant was added to the root absorption zone during planting. Sweet potato cuttings measuring 30cm were planted in each replication with 3m × 3m plot size at 60cm × 30 cm spacing. All other recommended cultural practices were applied as needed. Plots were kept free from weeds by regular hand weeding.

2.3 Data Collection

Data on growth (vine length and number of branches) was collected monthly and at the end of the fifth month, final harvesting was done on plants from 1.5 by 1.5 m plots area and the yield parameters (Marketable storage root yield and shoots biomass) were determined**.** Marketable storage roots were judged by tuber size, length, shape, cleanness, free from pests and diseases, and those having the weight of more than 100g. Shoot biomass was judged as those sweet potato vines growing above ground.

a) Bungoma variety   b) Kemb-10 variety

2.4 Data Analysis

Data collected on sweet potato growth and yield components were subjected to analysis of variance using GenStat statistical software version 15.1 edition. The mean separation for treatments was done using Fischer's Protected Least Significance Difference (L.S.D) test at 5% level of significance.

3. RESULTS AND DISCUSSION

3.1 Influence of sweet potato varieties and mycorrhizal inoculation on vine length

The vine lengths differed significantly ($P \leq 0.05$) due to variety and mycorrhiza inoculation as shown in (Table 1). At harvesting week 20, the highest 86.8 cm vine length was recorded in Bungoma variety. Data on mycorrhiza inoculation showed that inoculum influenced higher vine length in studied weeks with the highest 92.9 cm being observed at the end of the fifth month.

Table 1. Effects of sweet potato varieties and mycorrhizal inoculation on vine length

VINE LENGTH (cm)			
Variety	**WEEK 4 (WAP)**	**WEEK 12 (WAP)**	**WEEK 20 (WAP)**
Bungoma	20.96b	32.33b	86.8a
Kemb-10	23.56a	35.51a	77.7a
$LSD_{0.05}$	1.95	2.33	11.68
Mycorrhiza			
MN	20.69b	31.28b	71.6b
MP	23.83a	36.56a	92.9a
$LSD_{0.05}$	2.15	2.34	10.88
VXMY			
BN	19.26b	29.59c	74.70b
KN	22.13ab	32.97bc	68.44b
BP	22.67ab	35.08ab	98.81a
KP	25.00a	38.04a	87.00ab
$LSD_{0.05}$	3.04	3.31	16.52

Means followed by the same letter within the same column are not significantly different ($P \leq 0.05$).
WAP=Weeks after planting, MN=Mycorrhiza negative, MP=Mycorrhiza positive, VXMY=Variety interaction with mycorrhiza, BN= Bungoma without mycorrhiza, KN=Kembo-10 without mycorrhiza, BP= Bungoma interaction with mycorrhiza, KP = Kemb-10 interaction with mycorrhiza

Data on interactions between varieties and mycorrhizal revealed that there was significance different at $P \leq 0.05$. In week five the highest 98.81 cm vine length was recorded in Bungoma interacting with mycorrhiza though the positive interactions were not significantly different in all the weeks. Bungoma variety performed better than Kemb-10 variety in terms of vine length even where there was no inoculation. This could have been so because Bungoma variety is land race variety while Kemb 10 variety is an improved variety [20]. This corroborates with [21] who stated that petiole and vine lengths vary widely with genotypes. It is evident from our data that

AMF inoculation improved plant growth expressed as vine length compared with the un-inoculated plants. This results correlates with [22] who studied the effect of AMF inoculation on Temulawak plant and observed that mycorrhizal inoculation improved yield of studied plant. Also the results were in-line with the findings by [23] who stated that treatments had higher values of growth parameters including plant height, and number of seeds per plant. Previous studies show the positive effects of mycorrhiza on plant growth [24].

3.2 Influence of sweet potato varieties and mycorrhizal inoculation on Number of branches

Analysis of variance showed that there was significant difference ($P \leq 0.05$) among the number of branches due to variety in week four only. Inoculated sweet potato produced significantly higher number of branches in all the weeks compared with the un-inoculated plants. The highest number of branches 18.56 was recorded in week 20 (Table 2). Data on interaction showed that there was significance difference ($P \leq 0.05$) in week four. Data revealed that maximum number of branches 19.11 was recorded in week 20 as a result of Bungoma variety interacting with AMF. Meanwhile the lowest number of branches 15.00 was recorded in Kemb-10 without AMF inoculation.

Table 2. Effects of sweet potato varieties and mycorrhizal inoculation on number of branches

	Number of Branches		
Variety	**WEEK 4 (WAP)**	**WEEK 12 (WAP)**	**WEEK 20 (WAP)**
Bungoma	7.5b	10.61a	17.22a
Kemb-10	8.44a	11.23a	16.5a
LSD	0.85	1.09	2.09
Mycorrhiza			
MN	7.72a	10.06b	15.17b
MP	8.22a	11.83a	18.56a
LSD	0.95	1.08	2.07
VXMY			
BN	7.22a	9.78b	15.33ab
BP	7.77a	11.44ab	19.11a
KN	8.22a	10.33ab	15.00b
KP	8.66a	12.22a	18.00ab
LSD	1.2	1.54	2.95

Means followed by the same letter within the same column are not significantly different ($P \leq 0.05$).

WAP=Weeks after planting, MN=Mycorrhiza negative, MP=Mycorrhiza positive, VXMY=Variety interaction with mycorrhiza, BN= Bungoma without mycorrhiza, KN=Kembo-10 without mycorrhiza, BP= Bungoma interaction with mycorrhiza, KP = Kemb-10 interaction with mycorrhiza

Sweet potato varieties performed differently in terms of number of branches due to their genotypic differences. Results on mycorrhiza inoculation indicated that inoculation resulted in the highest number of weeks in all the weeks. Also, varieties interacting with mycorrhiza revealed that the highest number of branches was observed where the varieties were inoculated. These increases may be due to the beneficial effect of AMF in enhancement of phosphorus element uptake, which is achieved through the increase in the absorbing surface and the exploitation of a larger soil volume by the extra radical mycelium of the AMF. On the other hand P is known for the activation of photosynthesis and metabolic processes of organic compounds in plants and hence increasing plant growth [25].

3.3 Influence of sweet potato varieties and mycorrhizal inoculation on yield

The results of mean sweet potato marketable storage roots and shoot biomass yield recorded at 20 WAP are as shown in (Table 3). There was significant difference ($P \leq 0.05$) between the means in all the parameters. Kemb-10 recorded the highest 41.2 tha^{-1} marketable storage root yield. Data on shoot biomass yield revealed that Bungoma variety had the highest 67.86tha^{-1} shoot biomass yield.

Table 3. Effects of sweet potato varieties and mycorrhizal inoculation on marketable storage root and shoot biomass yield

Variety	Marketable storage root yield (t/ha)	Shoot biomass (t/ha)
Bungoma	35.03b	67.79a
Kemb-10	41.20a	57.85b
$LSD_{0.05}$	5.32	8.48
Mycorrhiza		
MN	34.89b	54.96b
MP	41.33a	70.72a
$LSD_{0.05}$	4.88	12.87
VXMY		
BN	31.39b	61.31ab
KN	38.36ab	48.57b
BP	38.62ab	74.28a
KP	43.95a	67.13a
$LSD_{0.05}$	7.54	11.98

Means followed by the same letter within the same column are not significantly different ($P \leq 0.05$).
WAP=Weeks after planting, MN=Mycorrhiza negative, MP=Mycorrhiza positive, VXMY=Variety interaction with mycorrhiza, BN= Bungoma without mycorrhiza, KN=Kembo-10 without mycorrhiza, BP= Bungoma interaction with mycorrhiza, KP = Kemb-10 interaction with mycorrhiza

Data on mycorrhiza inoculation showed that there was significance difference in all the variables. Inoculation resulted in the highest marketable storage root and shoot biomass yield 41.33tha^{-1} and 70.8tha^{-1} respectively. Interactions between variety and mycorrhiza inoculation were revealed. The highest 43.95tha^{-1} storage root yield was observed in Kemb-10 interacting with mycorrhiza while the lowest 31.39tha^{-1} was recorded in Bungoma without mycorrhiza inoculation. Results on shoot biomass indicated that Bungoma variety interacting with mycorrhiza had the maximum 74.28t/ha biomass.

The yield variation may be due to genetic potential of different varieties [26]. Also [27] reported enormous existent variation among varieties. Among mycorrhiza inoculation, inoculation had positive effects on the marketable and above biomass yields. This pronounced positive effect agrees with most previous studies [28][29]. Inoculation of microplants of potato cv. Golden Wonder with a commercially available AM fungus inoculum containing three species increased the tuber yield when grown in the greenhouse in sand containing slow release fertilizer [30]. These results are also in agreement with Fitriatin et al. [31] reported that applications of phosphorus solubilizing microbe significantly improved yield of maize on Ultisol. The results are also in comparison with those of Mukhongo at al. [32] who observed that combined application of biofertilizers and inorganic nutrients improves sweet potato yield.

4. CONCLUSION

The study demonstrated that the application of AMF solely increased the growth and yield of sweet potatoes, though there was no significant difference between the two varieties. This is an indicator that AMF had no preference between the two varieties. Furthermore, it is conclusive that appropriate interactions between sweet potato varieties and mycorrhiza can significantly enhance plant growth and yield.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Crissman C., Anderson P., Fuglie K., Kapinga R., Lemaga B., Devaux A., Bussink C. Trends in the potato and sweet potato sectors in sub-Saharan Africa and their contribution to the Millennium Development Goals In Kapinga R. E., editor; , Kingamkono R., editor; , Msabaha M., editor; , Ndunguru J., editor; , Lemaga B., editor; and Tusiime G., editor. (Eds.), Tropical root and tuber crops: Opportunities for poverty alleviation and sustainable livelihoods in developing countries: Proceedings of the thirteenth triennial symposium of the international society for tropical root crops (iSTRC). 2007; (pp. 9–19). Arusha, Tanzania: International Society for Tropical Root Crops.

2. Bovell-Benjamin, A.C. Sweet potato utilization in human health, industry and animal feed systems In: Ray, R.C. and Tomlins, K.L. (eds) Sweet potato: Post Harvest Aspects in Food, Feed, and Industry. Nova Science Publishers, New York, 2010; pp. 193–224

3. International Potato Center. Sweet potato Facts and Figures. Available at: https://cipotato.org/crops/sweetpotato/sweetpotato-facts-and-figures/ [accessed March 27, 2018].

4. Nedunchezhiyan, M., and Ray, R. C. Sweet potato growth, development, production and utilization: Overview. In R. C. Ray, and K. I. Tomlins (Eds.), Sweet potato: Post harvest aspects in food (pp. 2–26). New York: Nova Science Publishers Inc.2010;

5. Sowley, E., Neindow, M., and Abubakari, A. Effect of poultry manure and NPK on yield and storability of orange-and white- fleshed sweet potato [Ipomoea batatas (L.) Lam]. ISABB Journal of Food and Agricultural Sciences, 2015; 5(1), 1–6

6. Ali, M., Costa, D., Abedin, M., Sayed, M., and Basak, N. Effect of fertilizer and variety on the yield of sweet potato. Bangladesh Journal of Agricultural Research, 2009; 34(3), 473–480

7. Gibberson, D. I., Joshua, O.-S., Ato, B.-P., Justice, O., and Paul, A. A. The effect of deficit irrigation and manure on soil properties, growth and yield of orange fleshed sweet potato [Ipomea batatas Lam]. Scholars Journal of Agriculture and Veterinary Sciences, 2016; 3(7), 463–473. https://doi.org/10.21276/sjavs.2016.3.7.4

8. Schu¨bler A, Schwarzott D, Walker C. A new fungal phylum, the Glomeromycota: phylogeny and evolution. Mycol Res 2001; (105):1413–1421.

9. Tahat, M.M. and K. Sijam. 2012. Mycorrhizal fungi and abiotic environmental conditions relationship. *Res. J. Environ. Sci*., 2012; 6: 125-133.

10. Barea JM, Jeffries P. Arbuscular mycorrhizas in sustainable soil plant systems. In: B. Hock and A. Varma (eds) Mycorrhiza, structure, Function, Molecular Biology and biotechnology. Springer-Verlag, Heidelberg. 1995; 521-559.

11. Moose B. The influence of soil type and endogone strain on the growth of mycorrhizal plants in phosphate deficient soil. Rev. Ecol. Sol.1972; (9):529.

12. Smith, S. E., and Read, D. J. *Mycorrhizal Symbiosis*, 2nd Edn. London: Academic Press. 2007

13 Schnepf, A., Leitner, D., Klepsch, S., Pellerin, S., and Mollier, A. "Modelling phosphorus dynamics in the soil-plant system," in *Phosphorus in Action: Biological Processes in Soil Phosphorus Cycling*, eds E. K. Bünemann, A. Obserson, and E. Frossard (Heidelberg: Springer), 2011; 113–133.

14. Howlever, R. H., Asher, C. J. and Edwards, D. G. Establishment of an effective mycorrhizal association on cassava in flowing solution culture and its effects on phosphorus nutrition. New Phytol. 1981; 90: 279–283.

15. Rigou, L. and Mignard, E. Factors of acidification of the rhizosphere of mycorrhizal plants. Measurement of pCO2 in the rhizosphere. Acta Bot. Gall. 1994; 141: 533–539.

16. Bago, B. and Azcon-Aguilar, C. Changes in the rhizospheric pH induced by arbuscular mycorrhiza formation in onion (*Allium cepa* L). Z. Pflanz. Bodenkunde. 1997; 160: 333–339.

17. Boldt, K., Pors, Y., Haupt, B., Bitterlich, M., Kuhn, C., Grimm, B., et al. Photochemical processes, carbon assimilation and RNA accumulation of sucrose transporter genes in tomato arbuscular mycorrhiza. J. Plant Physiol. 2011; (168), 1256–1263. doi: 10.1016/j.jplph.2011.01.026

18. Roy-Bolduc, A., and M. Hijri. The use of mycorrhizae to enhance phosphorus uptake*:* A way out the phosphorus crisis. J. Biofertil. Biopestici. 2011(2)*:*104.

19. FAO/UNESCO. FAO-UNESCO Soil map of the world. Vol. IV. Africa, UNESCO, Paris. 1974;4: 307-308

20. Mwololo J.K., Mburu M. W. K., and Muturi P.W. Performance of sweet potato varieties across environments in Kenya. International Journal of Agronomy and Agricultural Research. 2012; Vol. 2, No. 10, p. 1-11,

21. Yen, D.E. The sweet potato and Oceania; An essay in Ethno botany. Honolulu, Hawaii; Bishop Museum press.1974

22. Samanhudi, A., Yunus, B. Pujiasmanto and M. Rahayu. Application of organic manure and mycorrhizal for improving plant growth and yield of Temulawak (Curcuma xanthorrhiza Roxb.). Sci. Res. J. 2014; 2(5): 2201-2796.

23. Jarande, N.N., P.S. Mankar, V.S. Khawale, A.A. Kanase and J.T. Mendhe. Response of chickpea (Cicer arietinum L.) to different levels of phosphorus through inorganic and organic sources. J. Soils and Crops. 2006; 16(1): 240-243.

24. Cekic, F.O., Unyayar, S., Ortas, I. Effects of arbuscular mycorrhizal inoculation on biochemical parameters in Capsicum annuum grown under long term salt stress. Turk J .Bot.2012 (36), 63-72

25. Purekar PN, Singh RR, Deshmukh RD. Plant Physiology and Ecology. 2 nd Ed. Chand, S. and Company, New Delhi, India.1992;

26. Mcharo M, Carey EE, Gichuki ST. Performance of selected sweet potato varieties in Kenya. Afr. Crop Sci. 2001; (9): 4 9-59

27. Vorasoot, N., P. Songsri, C. Akkasaeng, S. Jogloy and A. Patanothais. Effect of water stress on yield and agronomic characters of peanut. Journal of Science Technology, 2003; (25): 283-288.

28. Novak, Bruno, Ivanka Žutić, Nina Toth, and Nadica Dobričević. "Sweet potato [Ipomoea batatas (L.) Lam] yield influenced by seedlings and mulching." *Agriculturae Conspectus Scientificus* 72, no. 4 (2007): 357-359

29. Douds Jr, D. D., Joseph Lee, J. E. Shenk, and S. Ganser. "Inoculation of sweet potatoes with AM fungi produced on-farm increases yield in high P soil." *Journal of Applied Horticulture* 17, no. 3 (2015): 171-175.

30. Ryan, NA., Deliopoulos, T.. Jones, P. and Haydock, P.P.J. Effects of mixed-isolate illycoiThizal inoculum on potato-potato cyst nematode interaction. Annals of Applied Botwti, 2003; (143). 111-119.

31. Fitriatin, B.N., Yuniarti, A., Turmuktini, T., Ruswandi, T.K. The effect of phosphate solubilizing microbe producing growth regulators on soil phosphate, growth and yield of maize and fertilizer efficiency on Ultisol. Eurasian Journal of Soil Science.2014; 3(2): 101–107.

32. Mukhongo, Ruth W., John B. Tumuhairwe, Peter Ebanyat, AbdelAziz H. AbdelGadir, Moses Thuita, and Cargele Masso. "Combined application of biofertilizers and inorganic nutrients improves sweet potato yields." *Frontiers in plant science* 8 (2017): 219.