Asian Journal of Plant Sciences

ISSN 1682-3974

OPEN ACCESS Asian Journal of Plant Sciences

ISSN 1682-3974
DOI: 10.3923/ajps.2019.123.130

Research Article
Growth Response and Production of Purple Sweet Potatoes after Provision of Arbuscular Mycorrhizal Fungi and Organic Fertilizer

Johanis Jullian Pelealu, Lalu Wahyudi and Trina Ekawati Tallei

Department of Biology, Faculty of Mathematics and Natural Sciences, Sam Ratulangi University, Kampus UNSRAT Kleak, Manado 95115, Indonesia

Abstract
Background and Objective: Indonesia is rich in non-rice carbohydrate sources including tubers and seeds, but the achievement of consumption these kind of food has only reached 5%. One of these tubers is purple sweet potato. This study aimed to examine the effect of administration of Arbuscular Mycorrhizal Fungi (AMF) and Organic Fertilizer (OF) on the growth and production of purple sweet potatoes. **Materials and Methods:** Purple sweet potato seeds were sown in the form of plant stems. This study used factorial Randomized Block Design (RBD) consisting of 2 factors with 4 replications. The first factor is the dose of AMF and the second factor is OF. The agronomical parameters observed included stem length, number of leaves, number of branches, number of flowers as well as weight, diameter, number and length of tuber. All variables were analyzed with one-way analysis of variance (ANOVA). **Results:** The results showed that the administration of 20 and 30 g of AMF supplemented with 50 g of OF (m2p1 and m3p1, respectively) significantly increased stem length, number of leaves, number of branches, tuber weight, diameter and length. Statistical analysis showed a highly significant increase in potato yield for inoculated plants compared with non-inoculated controls. **Conclusion:** Hence, it can be concluded that application of Arbuscular Mycorrhizal Fungi in combination with organic fertilizer were able to improve the plant growth and the tuber yield of purple sweet potato.

Key words: Purple sweet potato, mycorrhiza, arbuscular mycorrhizal fungi, organic fertilizer, non-rice carbohydrate

Citation: Johanis Jullian Pelealu, Lalu Wahyudi and Trina Ekawati Tallei, 2019. Growth response and production of purple sweet potatoes after provision of arbuscular mycorrhizal fungi and organic fertilizer. Asian J. Plant Sci., 18: 123-130.

Corresponding Author: Trina Ekawati Tallei, Department of Biology, Faculty of Mathematics and Natural Sciences, Sam Ratulangi University, Kampus UNSRAT Kleak, Manado 95115, Indonesia Tel: +62-817-9255866/00628114314880

Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Sweet potato is an alternative food and used as a substitute for rice. This plant can be grown in various soil conditions and in various heights and climates. One of the popular sweet potato varieties is purple sweet potato (*Ipomoea batatas* var. *Ayamurasaki*) which contains anthocyanin, a source of antioxidants[1]. Purple sweet potato has a high nutrient content, so it can replace the cereals such as rice. In addition, its development, production and utilization are promising, which is in line with the food diversification program in Indonesia. As many as 89% of sweet potato production in Indonesia is used as food with a consumption rate of 7.9 kg/capita/year. The rest is used as industrial raw materials (sauces) and animal feed[2].

The challenges often experienced in the production of horticultural crops including purple sweet potato in organic farming are the slow rate of phosphorus (P) and nitrogen (N) mineralization obtained from organic fertilizers[3], causing slow absorption of nutrients by plants, especially when plants are still small. To overcome this condition, useful microorganisms are used and one useful microorganism that is often used is Arbuscular Mycorrhizal Fungi (AMF) which play an important role in absorbing nutrients[4]. These fungi are considered as biological fertilizer because they provide water, nutrients and protection against pathogens for plants[5]. The extraradical mycelia of these fungi take nutrients from the soil, transfer nutrients to the intraradical mycelia inside the plant roots and cross the plant-fungal interface[6].

The application of compost as an Organic Fertilizer (OF) in agricultural and horticultural practices has provided benefits including increasing soil structure and fertility[7], which consequently stimulated plant growth through various complex mechanisms. It was reported that plant growth due to response to compost substance depends on the host, compost substrate and the presence or absence of AMF propagules[8]. The AMF serve to expand the surface area of roots that absorb nutrients up to 100-1000 times[9]. The role of AMF is to take nutrients from the soil and change them in a form that can immediately be absorbed by plants. Colonization of AMF also suppresses pathogenic microorganisms[10].

The AMF association varies in structure and function but most of AMF interaction is between the roots of most higher plants and zygomycetes fungi originating from the genus *Glomales*[11]. It is estimated that more than 80% of terrestrial plants have this type of association, including many important plants in the fields of agriculture and horticulture[11,12]. Until now, little information has been obtained regarding the effect of the introduction of AMF on purple sweet potato plants. Therefore, this study aimed to evaluate the administration of AMF and OF on the growth response and production of purple sweet potatoes.

MATERIALS AND METHODS

The research was conducted on the local farm from April-August, 2018. The beds used to plant purple sweet potatoes had a length of 10 m with a width of 1 m and a height of 30 cm. The distance between beds was 50 cm. Purple sweet potato seeds in the form of plant stems (25 cm each) were planted about two-thirds of the stem in the soil and watered every day. Seedlings were planted horizontally with all shoots pointing in one direction. In one planting groove, one stem was planted with leafy stems protruding above the beds. On each bed, there were 2 rows with a distance of about 30 cm. The methods used here were adopted from previous research with a modification[13].

Provision of mycorrhizal fungi and organic fertilizers: The AMF were administered into planting holes (10 cm deep with a diameter of 2 cm). Organic fertilizers (OF) were given after one week the seedlings were planted. The amount of AMF and OF used were as follows:

m0p0 = Without AMF and OF
m1p0 = AMF 10 g
m2p0 = MF 20 g
m3p0 = AMF 30 g
m0p1 = OF 50 g
m1p1 = AMF 10 g+OF 50 g
m2p1 = AMF 20 g+OF 50 g
m3p1 = AMF 30 g+OF 50 g

Experimental design: The study used a completely randomized design with a 4×2 factorial pattern. One potato seedling was added into a planting hole in a sandy loam soil containing AMF, with each treatment being performed in quadruplicate. Observations were made every month starting from one month old seedlings to harvest and parameters observed were stem length, number of leaves, number of branches, number of flowers, weight, diameter, number and length of tuber. The observations and measurements of stem length, number of leaves, number of branches, number of flowers were conducted every month until harvesting. The weight, diameter, number and length of tuber were measured after harvesting.

Data analysis: Statistical analysis was performed by using Excel. All variables were analyzed with one-way analysis of variance (ANOVA). If the p-value is less than 0.05 then this indicates a significant influence between treatment and groups. The graphs were generated by using Excel and Statistica v13.

RESULTS

This study evaluated 8 agronomical characters of purple sweet potato after inoculation of AMF and provision of OF. The 8 characters were stem length, number of leaves, number of branches number of flowers, weight, diameter, number and length of tuber.

Length of stems: The response of AMF application to the length of purple sweet potato stems can be seen in Fig. 1. Statistical analysis showed that there was a significant influence between treatment and between groups ($p = 0.00$) in length of the stems. The increasing of stems length was observed since the 1st month after administration of AMF and OF and also AMF without OF, compared to control (without AMF and OF).

Number of leaves: The response of AMF application to the number of leaves of purple sweet potato is shown in Fig. 2. There was a significant influence between treatment and groups ($p = 0.00$) in number of leaves. The m3p1 gave best response, although the administration of any given amount of AMF with OF increased the number of the leaves compared to plants without OF. The leaves number was observed to increase significantly from the 3rd month.

Number of branches: The response of AMF application to the number of branches of purple sweet potato is shown in Fig. 3. There was a significant influence between treatment and groups ($p = 0.00$) in number of leaves and m3p1 gave the best response. However, m2p0, m3p0 and m2p1 also increased the number of branches significantly.

Number of flowers: The response of AMF application to the number of flowers of purple sweet potato is shown in Fig. 4. There was a significant influence between treatment and groups ($p = 0.047$) in number of flowers and m1p1, m2p1 and m3p1 increased the ability of plants to flower.

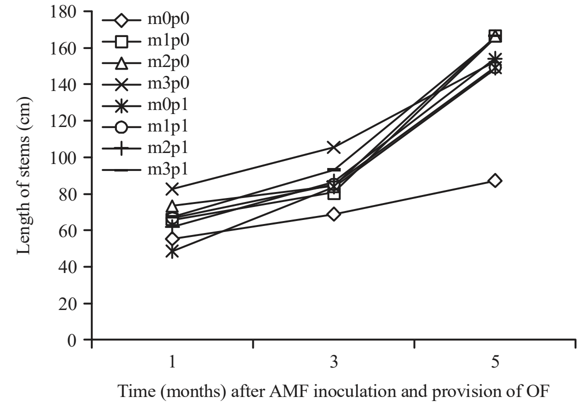

Fig. 1: Response of AMF administration and provision of OF to the length of purple sweet potato stems
m0p0: Without AMF and OF, m1p0: AMF 10 g without OF, m2p0: AMF 20 g without OF, m3p0: AMF 30 g without OF, m0p1: Without AMF+OF 50 g, m1p1: AMF 10 g+OF 50 g, m2p1: AMF 20 g+OF 50 g, m3p1: AMF 30 g+OF 50 g, OF: Organic fertilizer, AMF: Arbuscular mycorrhizal fungi

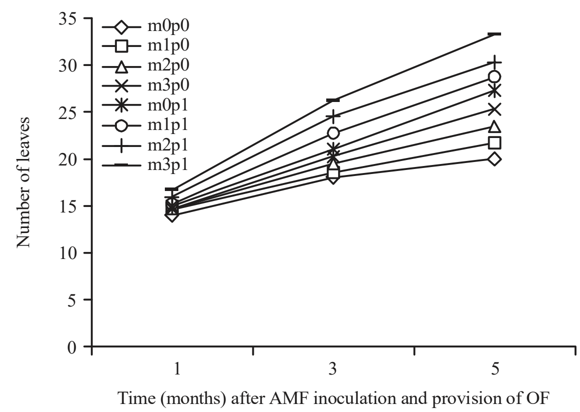

Fig. 2: Response of AMF administration and provision of OF to the number of leaves of purple sweet potato stems
m0p0: Without AMF and OF, m1p0: AMF 10 g without OF, m2p0: AMF 20 g without OF, m3p0: AMF 30 g without OF, m0p1: Without AMF+OF 50 g, m1p1: AMF 10 g+OF 50 g, m2p1: AMF 20 g+OF 50 g, m3p1: AMF 30 g+OF 50 g, OF: Organic fertilizer, AMF: Arbuscular mycorrhizal fungi

Weight of tubers: The response of AMF application to the weight of tubers can be seen in Fig. 5. The ANOVA result provided a p-value 0.030 for treatment. The p-value value (0.500) for the group indicated that there were no significant differences between groups. Administration of m1p1, m2p1 and m3p1 increased the weight of tubers significantly. The best response for the weight of tubers was obtained by m3p1 which produced 4.3 kg tubers per plant compared to the control (m0p0) which produced only 1.7 kg tubers per plant.

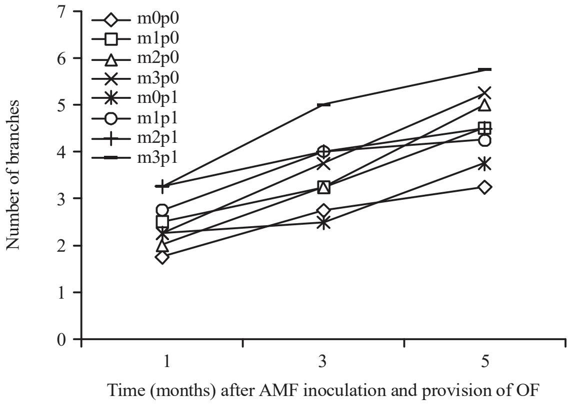

Fig. 3: Response of AMF administration and provision of OF to the number of branches of purple sweet potato stems
m0p0: Without AMF and OF, m1p0: AMF 10 g without OF, m2p0: AMF 20 g without OF, m3p0: AMF 30 g without OF, m0p1: Without AMF+OF 50 g, m1p1: AMF 10 g+OF 50 g, m2p1: AMF 20 g+OF 50 g, m3p1: AMF 30 g+OF 50 g, OF: Organic fertilizer, AMF: Arbuscular mycorrhizal fungi

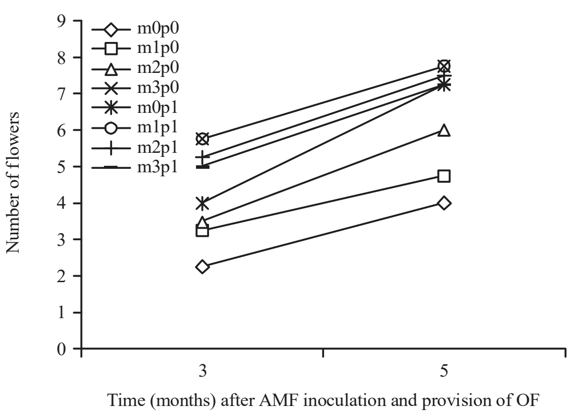

Fig. 4: Response of AMF administration and provision of OF to the number of flowers of purple sweet potato stems
m0p0: Without AMF and OF, m1p0: AMF 10 g without OF, m2p0: AMF 20 g without OF, m3p0: AMF 30 g without OF, m0p1: Without AMF+OF 50 g, m1p1: AMF 10 g+OF 50 g, m2p1: AMF 20 g+OF 50 g, m3p1: AMF 30 g+OF 50 g, OF: Organic fertilizer, AMF: Arbuscular mycorrhizal fungi

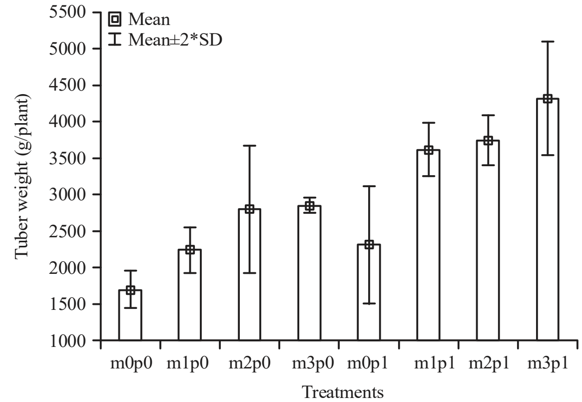

Fig. 5: Response of AMF administration and provision of OF to tubers weight
m0p0: Without AMF and OF, m1p0: AMF 10 g without OF, m2p0: AMF 20 g without OF, m3p0: AMF 30 g without OF, m0p1: Without AMF+OF 50 g, m1p1: AMF 10 g+OF 50 g, m2p1: AMF 20 g+OF 50 g, m3p1: AMF 30 g+OF 50 g, OF: Organic fertilizer, AMF: Arbuscular mycorrhizal fungi

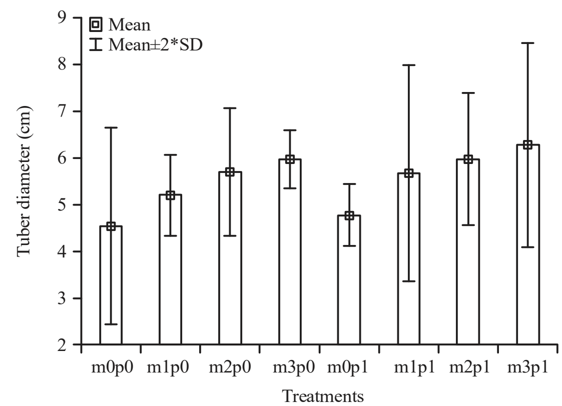

Fig. 6: Response of AMF administration and provision of OF to the diameter of tubers
m0p0: Without AMF and OF, m1p0: AMF 10 g without OF, m2p0: AMF 20 g without OF, m3p0: AMF 30 g without OF, m0p1: Without AMF+OF 50 g, m1p1: AMF 10 g+OF 50 g, m2p1: AMF 20 g+OF 50 g, m3p1: AMF 30 g+OF 50 g, OF: Organic fertilizer, AMF: Arbuscular mycorrhizal fungi

Diameter of tubers: The response of AMF application to the diameter of tubers is shown in Fig. 6. The ANOVA result provided a p-value 0.001 for treatments indicating that there was a significant difference between treatments. The p-value for the group of 0.002 showed significant differences between groups. Administration of m3p1 and m3p0 gave the best response.

Number of tubers: The response of AMF application to the number of tubers can be seen in Fig. 7. The ANOVA result provided a p-value 0.000 for treatment. This indicated a significant difference between treatments. The p-value for the group of 0.009 showed significant differences between groups. The number of tuber significantly reduced due to the addition of AMF. The higher the AMF concentration, the lower the number of tuber.

Length of tubers: The response of AMF application to the length of tubers can be seen in Fig. 8. The ANOVA result provided a p-value 0.000 for treatment. The p-value value for the group of 0.248 showed no significant differences between groups. Administration of m2p1 and m3p1 gave the best response.

Overall response of growth and production of purple sweet potato to the administration of AMF and OF: The results in Table 1 show that administration of m1p1 gave a

Table 1: Response of growth and production of purple sweet potato to the administration of AMF and OF

Parameters	m0p0	m1p0	m2p0	m3p0	m0p1	m1p1	m2p1	m3p1
Length of stem		+	+	+	+	+	+	+
Leave number						+	+	+
Branch number			+	+		+	+	+
Flower number					+	+	+	+
Tuber weight						+	+	+
Tuber diameter				+	+	+	+	+
Tuber number	+	+			+	+		
Tuber length						+	+	+

m0p0: Without AMF and OF, m1p0: AMF 10 g without OF, m2p0: AMF 20 g without OF, m3p0: AMF 30 g without OF, m0p1: Without AMF+OF 50 g, m1p1: AMF 10 g+OF 50 g, m2p1: AMF 20 g+OF 50 g, m3p1: AMF 30 g+OF 50 g, +: The increase in parameters

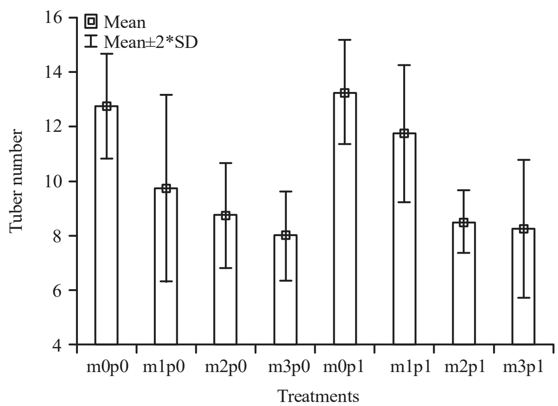

Fig. 7: Response of AMF administration and provision of OF to the number of tubers

m0p0: Without AMF and OF, m1p0: AMF 10 g without OF, m2p0: AMF 20 g without OF, m3p0: AMF 30 g without OF, m0p1: Without AMF+OF 50 g, m1p1: AMF 10 g+OF 50 g, m2p1: AMF 20 g+OF 50 g, m3p1: AMF 30 g+OF 50 g, OF: Organic fertilizer, AMF: Arbuscular mycorrhizal fungi

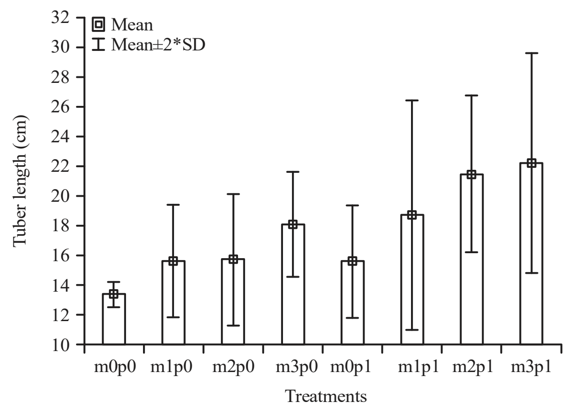

Fig. 8: Response of AMF administration and provision of OF to the length of tubers

m0p0: Without AMF and OF, m1p0: AMF 10 g without OF, m2p0: AMF 20 g without OF, m3p0: AMF 30 g without OF, m0p1: Without AMF+OF 50 g, m1p1: AMF 10 g+OF 50 g, m2p1: AMF 20 g+OF 50 g, m3p1: AMF 30 g+OF 50 g, OF: Organic fertilizer, AMF: Arbuscular mycorrhizal fungi

very good response in increasing stem length, number of leaves, number of branches, number of flowers, tuber weight, tuber diameter, number and tuber length. The weight, diameter and length of tuber increased significantly when administered with m1p1, m2p1 and m3p1.

DISCUSSION

Current agricultural practices and intensification can decrease the abundance and diversity of AMF as well as soil fertility[13-15]. Therefore, inoculation of AMF may form a new mycorrhizal symbiosis which caused a beneficial effect on overall plant growth and development[16]. Organic matter in the form of organic fertilizer given to the soil serves as a carbon source for soil microbes[17]. Organic matter also increases soil porosity and reduced the mechanical barriers to AMF hyphal growth, so that hyphae can continue to grow near the roots of plants and infect them.

The data showed that administration of AMF and OF and also AMF alone increased the length of stem significantly as compared to the control plant without AMF or OF. A research showed that plant grew higher significantly if inoculated with mycorrhizae[18]. This is because AMF produced auxins and gibberellins-like substances[19]. Inoculation of AMF increased the potato plant height[20]. The leaves number were observed to increase significantly in 3rd month after administration of m3p1. Provision of AMF and OF improved the absorption of N, P and K, which in turn increase the number of leaves of *Arachis pintoi*[13,21]. A previous investigation showed that AMF can maintain and improve the P and N intake[22]. The increasing of the area absorption surface and N mineralization of organic matter will in turn increase the N uptake by AMF[23]. Some AMF can increase P uptake in media from organic materials[24], indicated that AMF is not only infective but also effective.

Treatment m3p1 gave the best response in increasing the number of branches. As reported previously, inoculation of AMF increases the number of potato branches[20]. The number of branches per plant was significantly higher in AMF inoculated plantlets as compared to the plants without

AMF[25]. Such increase was caused by the widening of the surface area absorption of P from the soil by extended fungal hyphae as it was directly proportional to the higher level of mycorrhizal colonization[26]. Provision of AMF and OF has been shown to increase the flower formation, compared to treatment with AMF alone[13,21]. In this study, treatments m1p1, m2p1 and m3p1 gave best response in increasing the number of flowers. A study showed that inoculation with AMF significantly enhanced the number of flowers per plant and per cluster of *Pelargonium zonale*[27]. Flower bud emergence was accelerated and number of flowers per plant increased when the rose plant was treated with AMF[28].

It was observed that the m3p1 increased the weight of tubers by 2.5 times compared to the control (without AMF or OF) and m3p1 produced 4.3 kg tuber per plant and the control plants only produce 1.7 kg tuber per plant. The AMF promoting effect on potato tuber initiation was observed previously[29,30]. Inoculation of AMF *Glomus etunicatum* increased the tube weights of the five species of yam (*Dioscorea* spp.)[31]. *Glomus dussii* inoculation yielded significantly higher tuber weights[32]. Inoculation of AMF *Acaulospora scrobiculata* yielded higher tuber weight of *Flemingia vestita*[33]. Treatments m3p1 and m3p0 increased the diameter of the tubers. This showed that OF did not contribute significantly to tuber diameter. Commercial AMF inoculation increased the production of potato tubers[34]. Inoculation of AMF produced larger sized potatoes (10-20%) compared to controls[34]. There was an increase of 30-35% in the diameter of *Libidibia ferrea* inoculated with AMF related to non-inoculated control[35].

The amount of tuber is inversely proportional to all other parameters of tuber (weight, diameter and length) after provision with AMF and OF. The tuber size at harvest is inversely proportional to the number of tubers[36]. The treatment m3p1 increased tuber length 1.7 times compared to control. A study showed that inoculation of AMF on yam increased the length of the tubers[31]. Inoculation of AMF *Acaulospora laevis* increased tuber length of *Gloriosa superba*[25]. Administration of AMF and OF gave a very good response in increasing stem length, number of leaves, number of branches, number of flowers, weight, diameter and tuber length, except tuber numbers.

Overall agronomic character of the purple sweet potato increased significantly when administered with m2p1 and m3p1. A study showed that after inoculation of AMF and all fertilization regimes, the plant biomass, height, leaves area and stems diameter increased significantly[37]. The AMF make plants more efficiently to acquire nutrients which in turn leading to the improvement of plant growth[38]. A research on *Arachis pintoi* showed that provision of AMF increased plant length, number of leaves and flowers[13]. Overall this study showed that AMF administration without the OF addition can be applied without a significant decrease in yield, thus further increasing profitability.

CONCLUSION

From this study it can be concluded that the administration of m2p1 and m3p1 gave the best response in increasing the weight, diameter and length of the tuber of purple sweet potato. In an overall assessment, provision of AMF and OF increased the growth and development parameters of the plants, therefore increased the production of purple sweet potato.

SIGNIFICANCE STATEMENT

This study discovers that Arbuscular Mycorrhizal Fungi (AMF) and Organic Fertilizer (OF) can be applied to improve the yields of purple sweet potato tubers. This study will help the farmers to use AMF and OF doses optimally so as to increase profit in the cultivation of purple sweet potatoes.

ACKNOWLEDGMENT

This research was funded by the Directorate of Research and Community Service, Ministry of Research and Higher Education of the Republic of Indonesia, Decree No. 3/E/KPT/2018, contract number 132/UN12.13/LT/2018.

REFERENCES

1. Lim, S., J. Xu, J. Kim, T.Y. Chen and X. Su *et al*., 2013. Role of anthocyanin-enriched purple-fleshed sweet potato p40 in colorectal cancer prevention. Mol. Nutr. Food Res., 57: 1908-1917.
2. Suryani, R., 2016. Outlook komoditas pertanian tanaman pangan ubi jalar. Pusat Data dan Sistem Informasi Pertanian Kementerian Pertanian, Indonesia.
3. Kelderer, M., M. Thalheimer, O. Andreaus, A. Topp, R. Burger and P. Schiatti, 2008. The mineralization of commercial organic fertilizers at 8° C temperature. Proceedings of the 13th International Conference on Cultivation Technique and Phytopathological Problems in Organic Fruit-Growing, February 18-20, 2008, Weinsberg, Germany, pp: 160-166.
4. Jarstfer, A.G. and D.M. Sylvia, 1992. Inoculum Production and Inoculation Strategies for Vesicular-Arbuscular Mycorrhizal Fungi. In: Soil Microbial Tecnologies: Applications in Agriculture, Forestry and Environmental Management, Dekker, M.B.M. (Ed.), Marcel Dekker, New York, pp: 349-377.

5. Berruti, A., E. Lumini, R. Balestrini and V. Bianciotti, 2015. Arbuscular mycorrhizal fungi as natural biofertilizers: Let's benefit from past successes. Front. Microbiol., Vol. 6. 10.3389/fmicb.2015.01559.
6. Bücking, H. and A. Kafle, 2015. Role of arbuscular mycorrhizal fungi in the nitrogen uptake of plants: Current knowledge and research gaps. Agronomy, 5: 587-612.
7. Vaughan, D. and R.E. Malcolm, 1985. Soil Organic Matter and Biological Activity. Martinus Nijhoff, Dr. W. Junk Publishers, Dordercht, The Netherlands.
8. Guttay, A.J.R., 1983. The interaction of fertilizers and vesicular-arbuscular mycorrhizae in composted plant residues. J. Amer. Soc. Hort. Sci., 108: 222-224.
9. Larcher, W., 1995. Physiological Plant Ecology. Springer-Verlag, Berlin, pp: 506.
10. Werner, G.D.A. and E.T. Kiers, 2015. Order of arrival structures arbuscular mycorrhizal colonization of plants. New Phytol., 205: 1515-1524.
11. Harrier, L.A., 2001. The arbuscular mycorrhizal symbiosis: A molecular review of the fungal dimension. J. Exp. Bot., 52: 469-478.
12. Smith, S.E. and D.J. Read, 1997. Mycorrhizal Symbiosis. Academic Press, San Diego, CA., USA.
13. Tallei, T.E., J.J. Pelealu and F.E. Kandou, 2016. Effects of arbuscular mycorrhiza inoculation on length, leaf number and flowering of *Arachis pintoi*. Asian J. Microbiol. Biotechnol. Environ. Sci., 18: 803-806.
14. Fortin, J.A., C. Plenchette and Y. Piché, 2009. Mycorrhizas: The New Green Revolution. MultiMondes, Que´bec, ISBN-13: 978-2895441540, Pages: 140.
15. Di Falco, S. and E. Zoupanidou, 2016. Soil fertility, crop biodiversity and farmers' revenues: Evidence from Italy. Ambio, 46: 162-172.
16. Mohammadi, K., S. Khalesro, Y. Sohrabi and G.R. Heidari, 2011. Beneficial effects of the mycorrhizal fungi for plant growth: A review. J. Applied Environ. Biol. Sci., 1: 310-319.
17. Cooperband, L., 2002. Building soil organic matter with organic amendments. Centre for Integrated Agricultural System. University of Wisconsin-Madison. USA. https://www.cias.wisc.edu/wp-content/uploads/2008/07/soilorgmtr.pdf
18. Zolfaghari, M., V. Nazeri, F. Sefidkon and F. Rejali, 2013. Effect of arbuscular mycorrhizal fungi on plant growth and essential oil content and composition of *Ocimum basilicum* L. Iran. J. Plant Physiol., 3: 643-650.
19. Strzelczyk, E. and A.P. Burdziej, 1984. Production of auxins and gibberellin-like substances by mycorrhizal fungi, bacteria and actinomycetes isolated from soil and the mycorrhizosphere of pine (*Pinus silvestris* L.). Plant Soil, 81: 185-194.
20. Lone, R., R. Shuab, V. Sharma, V. Kumar, R. Mir and K.K. Koul, 2015. Effect of arbuscular mycorrhizal fungi on growth and development of potato (*Solanum tuberosum*) plant. Asian J. Crop Sci., 7: 233-243.
21. Oehl, F., E. Sieverding, P. Mader, D. Dubois, K. Ineichen, T. Boller and A. Wiemken, 2004. Impact of long-term conventional and organic farming on the diversity of arbuscular mycorrhizal fungi. Oecologia, 138: 574-583.
22. Liu, G., J. Pfeifer, R.D.B. Francisco, A. Emonet and M. Stirnemann *et al*., 2018. Changes in the allocation of endogenous strigolactone improve plant biomass production on phosphate-poor soils. New Phytol., 217: 784-798.
23. Reynolds, H.L., A.E. Hartley, K.M. Vogelsang, J.D. Bever and P.A. Schultz, 2005. Arbuscular mycorrhizal fungi do not enhance nitrogen acquisition and growth of old-field perennials under low nitrogen supply in glasshouse culture. New Phytol., 167: 869-880.
24. Andrade, S.A.L., C.A. Abreu, M.F. de Abreu and A.P.D. Silveira, 2004. Influence of lead additions on arbuscular mycorrhiza and *Rhizobium* symbioses under soybean plants. Applied Soil Ecol., 26: 123-131.
25. Yadav, K., A. Aggarwal and N. Singh, 2013. Arbuscular Mycorrhizal Fungi (AMF) induced acclimatization, growth enhancement and colchicine content of micropropagated *Gloriosa superba* L. plantlets. Ind. Crops Prod., 45: 88-93.
26. Al-Amri, S.M., K.M. Elhindi and A.F. Sharaf El-Din, 2016. Effects of arbuscular mycorrhizal fungus *Glomus mosseae* and phosphorus application on plant growth rate, essential oil content and composition of coriander (*Coriander sativum* L.). Prog. Nutr., 18: 443-454.
27. Conversa, G., A. Bonasia, C. Lazzizera and A. Elia, 2015. Influence of biochar, mycorrhizal inoculation, and fertilizer rate on growth and flowering of Pelargonium (*Pelargonium zonale* L.) plants. Front. Plant Sci., Vol. 6. 10.3389/fpls.2015.00429.
28. Garmendia, I. and V.J. Mangas, 2012. Application of arbuscular mycorrhizal fungi on the production of cut flower roses under commercial-like conditions. Spanish J. Agric. Res., 10: 166-174.
29. Graham, S.O., N.E. Green and J.W. Hendrix, 1976. The influence of vesicular-arbuscular mycorrhizal fungi on growth and tuberization of potatoes. Mycologia, 68: 925-929.
30. Niemira, B., G.R. Safir, R. Hammerschmidt and G.W. Bird, 1995. Production of prenuclear minitubers of potato with peat-based *Arbuscular mycorrhizal* fungal inoculum. Agron. J., 87: 942-946.
31. Lu, F.C., C.Y. Lee and C.L. Wang, 2015. The influence of arbuscular mycorrhizal fungi inoculation on yam (*Dioscorea* spp.) tuber weights and secondary metabolite content. Peer J., Vol. 3. 10.7717/peerj.1266
32. Tchabi, A., F.C.C. Hountondji, B. Ogunsola, L. Lawouin, D. Coyne, A. Wiemken and F. Oehl, 2016. Effect of two species of arbuscular mycorrhizal fungi inoculation on development of micro-propagated yam plantlets and suppression of *Scutellonema bradys* (Tylenchideae). J. Entomol. Nematol., 8: 1-10.

33. Songachan, L.S. and H. Kayang, 2018. Effects of arbuscular mycorrhizal fungal inoculation on growth and yield of *Flemingia vestita* Benth. ex Baker. Int. J. Agric. Technol., 14: 377-388.
34. Duffy, E.M. and A.C. Cassells, 2000. The effect of inoculation of potato (*Solanum tuberosum* L.) microplants with arbuscular mycorrhizal fungi on tuber yield and tuber size distribution Applied Soil Ecol., 15: 137-144.
35. Dos Santos, E.L., F.A. da Silva and F.S.B. da Silva, 2017. Arbuscular mycorrhizal fungi increase the phenolic compounds concentration in the bark of the stem of *Libidibia ferrea* in field conditions. Open Microb. J., 11: 283-291.
36. Iritani, W.M., L.D. Weiler and N.R. Knowles, 1983. Relationships between stem number, tuber set and yield of Russet Burbank potatoes. Am. J. Potato Res., 60: 423-431.
37. Aissa, E., A. Mougou and K.K. Khalfallah, 2016. Influence of mycorrhizal inoculation and source of phosphorus on growth and nutrient uptake of pepper (*Capsicum annuum* L.) in calcareous soil. Agri. Biotech., 28: 1589-1595.
38. Oseni, T.O., N.S. Shongwe and M.T. Masarirambi, 2010. Effect of Arbuscular Mycorrhiza (AM) inoculation on the performance of tomato nursery seedlings in vermiculite. Int. J. Agric. Biol., 12: 789-792.