Application of the arbuscular mycorrhizal fungi inoculant, organic

by S Prabawardani

Submission date: 30-Jun-2023 12:00PM (UTC+0800)
Submission ID: 2124607789
File name: dani_2023_IOP_Conf._Ser.__Earth_Environ._Sci._1192_012032_1.pdf (1.22M)
Word count: 5241
Character count: 28989

Application of the arbuscular mycorrhizal fungi inoculant, organic and NPK fertilizers on the growth and yields of maize (*Zea mays* L.)

Application of the arbuscular mycorrhizal fungi inoculant, organic and NPK fertilizers on the growth and yields of maize (*Zea mays* L.)

S Prabawardani[1], I A F Djuuna[2*], L Kambu[2], N L. Mawikere[3]

[1]Agrotechnology Study Program, Agriculture Faculty, Papua University
[2]Soil Science Study Program, Agriculture Faculty, Papua University
[3]Agriculture Science Study Program, Postgraduate, Papua University

*Corresponding authors: i.djuuna@unipa.ac.id, Orcid id: 0000-0002-1881-4067

Abstract. The objective of this study was to examine the effect of Arbuscular Mycorrhizal Fungi (AMF) inoculant, NPK fertilizer, and organic fertilizers (chicken manure) on maize growth and yield. This study used a completely randomized design (CRD), with 8 fertilizer treatments, namely (1) control or without any fertilizer, (2) inoculation of AMF, (3) NPK fertilizer, (4) chicken manure (CM), (5) FMA + NPK, (6) FMA + CM, (7) NPK + CM and (8) FMA + NPK + CM. Each treatment was repeated 3 times. The results indicated that the fertilization treatment showed a significant and very significant effect for all variables, namely plant height, leaf number, fresh leaf weight, plant fresh weight per plant and per plot, ear diameter with and without husks, cob number per plot, ear weight per plant and per plot and ear weight without husk per plant and per plot, and ears number per plant. The application of AMF + NPK + CM and NPK + CM fertilizers produced the highest maize growth and yields, while each of the AMF and control treatments produced the lowest growth and yield components.

1. Introduction

Consumer demand for maize has increased in line with the advances in the industrial sector made from maize in Indonesia. The increase in maize yields can be fulfilled if the elements that support the growth such as nutrients, superior varieties, and planting areas are available [1]. Nutrients are important in supporting maize growth. The nutrient supply can be done using organic, inorganic, and biological fertilizers.

Organic matter can help in improving the structure of soil because of its function in improving and maintaining soil's physical, chemical, and biological properties. Organic matter can improve soil chemical properties by suppressing the high solubility of Aluminum, Iron, and Manganese in the soil, so that it cannot be toxic to plants [2, 3]. Soil organic matter can be in the form of livestock manure, such as goat, cow, and chicken manure, as well as forage residues from plants [4, 5]. The use of organic matter has an effect in increasing water holding capacity, soil microbiological activity, cation exchange capacity, and improving soil structure, therefore increasing the maximum yield can be done by providing organic materials [6, 7]. Chicken manure is an organic material that can be used to increase soil pH, increase the

activity of soil microorganisms, increase topsoil, and improve soil structure [8]. The application of chicken manure maintains soil structure and moisture, which is good for plant growth and yield.

Inorganic fertilizers are needed for plant growth, especially in maize. Inorganic fertilizers consist of urea, KCl, and NPK fertilizers. Fertilizer from a mixture containing more than one kind of plant nutrient is more efficient than other single fertilizers [9]. Nitrogen has a function as a component of macromolecules such as amino acids, proteins, enzymes [9]. Phosphorus plays an important role in photosynthesis, respiration, cell division and enlargement, root growth and development, stalks and stems firmness, flowers and seeds formation, crop maturity and quality [10, 11, 12). Meanwhile, Potassium functions as an osmotic regulatory mechanism in cells, protein synthesis, and chlorophyll development [13].

AMF as a biological fertilizer can support sustainable agriculture because it can reduce inorganic fertilizers to produce healthier products [14]. AMF can increase nutrient uptake and increase plant growth [15]. Arbuscular mycorrhizal fungi play a significant role in increasing nutrient uptake through the expanding of surface area as the absorption area. In addition, AMF can protect plant roots from pathogens caused by soil-borne diseases [16], can increase plant resistance to drought, and can increase N, P, and K uptake [17]. The host plant has mutualism symbiosis with AMF, in which AMF provides P in the soil for plants. The advantage of AMF is that it absorbs water in dry soil conditions because AMF has fine hyphae that can absorb water into micro-sized soil pores.

In general, farmers have not applied fertilization according to the needs of the maize plant in a balanced manner [1]. Farmers mostly use urea because the price is relatively cheaper than other fertilizers. Farmers use more chemicals, with the assumption that chemical fertilizers can produce more maize production. However, the continuous use of chemical fertilizers can cause environmental degradation. Therefore, the use of AMF, NPK fertilizer, and organic matter need to be studied, and it is hoped that it can increase maize production. This research aimed to investigate the effect of Arbuscular Mycorrhizal Fungal inoculant (AMF), NPK fertilizer, and organic fertilizer (chicken manure) application on the growth and yields of maize.

2. Methods

2.1. The experimental design

The experiment was carried out in June-August 2019 at the Experimental Field and Soil Biology Laboratory, the Faculty of Agriculture, Papua University, West Papua, Indonesia. The soil of the field research area is inceptisol, a type of soil that is still young but has developed even though it is not yet mature [18]. Inceptisol soils range from dark brown to dark yellowish brown. Because this soil has often been cultivated, the soil color blends between the top layer and the bottom layer. In general, dry land such as inceptisols has low soil fertility (low NPK) and relatively low chemical properties. The research design was a completely randomized design, with 8 treatments that were repeated 3 times. The treatments in this study were (1) Control, (2) AMF inoculant (10 gr), (3) NPK (Nitrogen Phosphorus Potassium) Fertilizer (40 gr), (4) Chicken Manure (800 gr), (5) AMF inoculant (10 gr) + NPK Fertilizer (40 gr), (6) AMF Inoculant (10 gr) + Chicken Manure Fertilizer (800 gr), (7) NPK Fertilizer (40 gr) + Chicken Manure Fertilizer (800 gr), (8) AMF inoculant (10 gr) + NPK Fertilizer (40 gr) + Chicken Manure (800 gr).

The research implementation includes (1). Preparing beds of 2 x 1 m size for each experimental unit, with drainage size of 50 cm width, (2) planting the seeds, (3) application of AMF which was done once at the time of planting according to the treatment. The AMF application was done by inserting the AMF inoculant in the planting hole, and after that, the maize seeds were planted. Meanwhile, the NPK application was carried out by an array between maize plants. The dose of AMF was 10 grams per planting hole and NPK as much as 40 grams per plot. Maize harvesting was done after the maize plants were 12 weeks after planting. The observed variables consisted of plant height, leaf number, leaf fresh weight, plant fresh weight (biomass fresh weight), cob number, and cob weight.

Data were analyzed statistically using ANOVA and continued with the HSD test with a confidence level of 95% if the treatment had a significant effect.

3. Results and discussion

The application of Arbuscular Mycorrhizal Fungi inoculant, NPK fertilizer, and organic fertilizer (chicken manure) showed a significant and very significant effect on most of the growth and yield variables.

3.1. Plant height

The application of AMF inoculant, NPK fertilization, and chicken manure had a significant effect on the maize height in all ages of evaluation (2 - 10 WAP) (Table 2).

Table 1. Average value and results of HSD (Tukey's honestly significant difference) of maize plant height.

Treatment	Plant height (cm) at 2, 4, 6, 8, 10 WAP				
	2	4	6	8	10
Control	3,94 bc	15,99 cd	37,84 c	123,72 b	163,30 bc
FMA	3,43 c	15,55 d	35,13 c	122,72 b	154,81 c
NPK	4,20 abc	18,96 bcd	43,81 abc	175,37 a	198,44 a
CM	8,17 ab	23,01 ab	67,05 ab	186,43 a	200,30 a
FMA+NPK	5,89 ab	24,04 ab	71,57 ab	190,52 a	199,41 a
FMA+CM	4,12 abc	20,11 bcd	55,91 bc	177,56 a	188,61 ab
NPK+CM	4,62 abc	22,14 abc	71,06 ab	197,19 a	207,30 a
FMA+NPK+CM	6,38 a	28,26 a	82,31 a	198,76 a	214,96 a

Note: The numbers followed by the same letter in the same column are not significantly different in the HSD test with a confidence level of 95%. WAP = weeks after planting.

The CM treatment produced the highest plants at 2 WAP but was not significantly different from other treatments except Control and AMF treatments (Table 1). At 4 WAP to 10 WAP, the combination of AMF + NPK + CM treatment produced the tallest plants. However, the results of the HSD test indicated that the combination of FMA + NPK + CM was not significantly different from NPK, CM, FMA + NPK, FMA + CM, NPK + CM at 2 WAP. On the other hand, the maize plant's height in the combination of AMF + NPK + CM was significantly different from AMF and Control treatments. Control treatment produced the shortest plant height from the first observation (2 WAP) until the final observation (10 WAP).

At 4 WAP, the combination AMF + NPK + CM treatment produced the tallest plants, but it was not significantly different from CM, AMF + NPK, and NPK + CM. Likewise, at 6 WAP, FMA + NPK + CM treatment was not significantly different from NPK, CM, FMA + NPK, and NPK + CM. Although it produced the tallest plants at 8 and 10 WAP, the combination of AMF + NPK + CM treatment was not significantly different from other treatments, except from AMF treatment and control (Table 1). Although not significantly different from several other treatments, the combination of AMF + NPK + CM produced the tallest maize plants.

A significant difference was observed in all fertilization treatments on plant height from 2 WAP until 10 WAP, presumably because at 2 WAP the roots of maize began to function to absorb nutrients. At 2 WAP, CM (chicken manure) treatment produced the highest plants, indicating that the chicken manure was fully decomposed and readily available for plants. In the following week, AMF + NPK + CM treatment produced the highest plant because the combination of these treatments was able to provide complete nutrients for plant growth. It appears that the AMF + NPK + CM treatment consistently produced the tallest plants from the beginning to the end of the observation.

3.2. Leaf number

The leaf number of all fertilization treatments was not significantly different at 2 WAP, but significantly different at 4-10 WAP. The combination of AMF + NPK + CM produced the highest leaf number, while the application of AMF inoculant and control treatment produced the lowest number of leaves from 4 WAP to 10 WAP. At 4 WAP, although FMA + NPK + CM treatment produced the highest leaf number, it was not significantly different from the applications of CM, AMF + NPK, AMF + CM, NPK + CM. At 6 and 8 WAP, the combination of AMF + NPK + CM was not significantly different from other treatments, but significantly different from Control and AMF treatments.

AMF + NPK + CM treatment was not significantly different from other treatments, except AMF at 10 WAP. However, the combination of AMF + NPK + CM treatment consistently produced the highest leaf number, from 2 WAP to 10 WAP.

Table 2. Average Value and HSD Test Results Number of Leaves **(tambah ".")**

Treatment	Leaf Number at 2, 4, 6, 8 and 10 WAP				
	2	4	6	8	10
Control	4,26 a	7,30 cd	8,70 c	11,44 b	12,70 dc
FMA	3,93 a	7,07 d	8,33 c	11,00 b	12,11 d
NPK	4,60 a	7,89 bcd	10,59 bc	12,89 ab	13,30 bcd
CM	4,52 a	8,93 ab	11,44 ab	14,30 a	14,78 ab
FMA+NPK	4,78 a	8,67 abc	11,52 ab	14,52 a	14,74 ab
FMA+CM	4,19 a	8,11 abcd	10,56 bc	13,15 ab	14,15 abc
NPK+CM	4,04 a	8,41 abcd	12,11 ab	14,67 a	15,00 ab
FMA+NPK+CM	4,74 a	9,48 a	12,96 a	15,15 a	15,60 a

Note: The numbers followed by the same letter in the same column are not significantly different in the HSD test with a confidence level of 95%. WAP = weeks after planting

3.3. Fresh leaf weight and fresh plant weight

Fertilization treatment had a very significant effect on leaf fresh weight. The highest leaf weight was produced by the combination of AMF + NPK + CM (160.44 gr /plant), which was not significantly different from other treatments, but significantly different from the control treatment and AMF treatment. The lowest fresh leaf weight was produced by the control treatment with an average weight of 72.74 g / plant, but it was not significantly different from AMF treatment with a weight of 81.35 g / plant (Table 3).

Table 3. Average values of fresh leaf weight and fresh plant weight.

Treatment	FLW (gr/plant)	FPW (gr/plant)	FPW (kg/plot)
Control	72,74 bc	264,35 b	2,38 b
FMA	81,35 c	337,60 ab	3,04 ab
NPK	124,92 ab	546,47 ab	4,92 ab
CM	131,84 ab	554,14 ab	4,99 ab
FMA+NPK	147,45 a	587,20 ab	5,28 ab
FMA+CM	120,49 ab	452,06 ab	4,07 ab
NPK+CM	147,78 a	555,42 ab	5,00 ab
FMA+NPK+CM	160,44 a	726,33 a	6,54 a

Note: The numbers followed by the same letter in the same column are not significantly different in the HSD test with a confidence level of 95%. FLW = Fresh Leaf Weight and FBW = Fresh Plant Weight.

3.4. Plant fresh weight

The results of variance analysis showed a significant effect on plant fresh weight per plant and per plot (Table 3). The highest fresh plant weight per plant and per plot was produced by AMF + NPK + CM treatment (726.33 gr /plant and 6.54 kg /plot, respectively). However, fresh plant weight per plant and per plot was not significantly different among the treatments, except with the control treatment the lowest plant fresh weight was 264.35 gr /plant and 2.38 kg /plot.

3.5. Cob diameter

Based on the variance analysis, the diameter of maize cobs with husks was not affected by the fertilization treatment, on the other hand, the fertilization effect on the diameter of cob without husks (Table 4). The highest diameter of maize cobs without husk was 4.33 cm in the combination of AMF + NPK + CM treatment, but not significantly different from other treatments except Control and AMF. The number of cobs per plant and per plot was not significantly different between fertilization treatments.

Table 4. Diameter and the number of maize cob as affected by different fertilizer treatments.

Treatment	Cob diameter with husk	Cob diameter without husk	Cob number/plant	Cob number/plot
Control	4,16 a	3,65 c	1 a	10 a
FMA	4,12 a	3,68 c	1 a	10 a
NPK	4,76 a	4,14 abc	2 a	15 a
CM	4,63 a	4,08 abc	2 a	14 a
FMA+NPK	4,87 a	4,24 ab	2 a	14 a
FMA+CM	4,25 a	3,76 abc	1 a	11 a
NPK+CM	4,77 a	4,15 ab	2 a	15 a
FMA+NPK+CM	6,76 a	4,33 a	2 a	12 a

Note: The numbers followed by the same letter in the same column are not significantly different in the HSD test with a confidence level of 95%.

Number of cobs per plant and per plot

The number of cobs per plant and per plot was not significantly different in all observed treatments, although the highest number of cobs per plot was found in the NPK and NPK + CM treatments.

3.6. Cob weight per plant

The highest weight of maize cobs with husk per plant was produced by NPK + CM fertilization (269, 27gr/plant) but not significantly different from FMA + NPK + CM, FMA + NPK, FMA + NPK, CM. The highest cob weight without husk per plant was produced by AMF + NPK + CM treatment, which was significantly different from NPK + CM, AMF, and the control treatments. In all the cob weight parameters, the control and AMF treatments produced the lowest results. When maize cobs yield per plot is converted to hectares, the NPK + CM treatment yielded 8.9 tons/ha, and AMF + NPK + CM yielded 8.6 tons /ha.

Table 5. Cob weight with husk (CWH) and cob weight without husk (CWWH).

Treatment	CWH (gr/plant)	CWWH (gr/plant)	CWH (kg/plot)	CWWH (kg/plot)
Control	171,14 cd	127,18 c	1,37 cd	1,02 c
FMA	161,09 d	123,88 c	1,29 d	0,99 c
NPK	255,24 abc	180,32 ab	2,30 ab	1,62 ab
CM	234,99 ab	187,57 ab	2,11 abc	1,69 ab
FMA+NPK	272,46 a	200,52 ab	2,45 a	2,02 ab
FMA+CM	196,47 bcd	146,58 a	1,71 bcd	1,28 bc
NPK+CM	269,27 ab	203,84 bc	2,42 a	1,77 a
FMA+NPK+CM	278,06 a	206,63 a	2,32 a	1,72 ab

Note: The numbers followed by the same letter in the same column are not significantly different in the HSD test with a confidence level of 95%.

3.7. Cob weight per plot

The AMF + NPK treatment produced the highest cob weight with and without husk per plot (2.45 kg /plot with husk and 2.02 kg /plot without husk), but it was not significantly different from all other treatments except AMF and Control treatments.

3.8. AMF inoculant treatment

The results indicated that the treatment of AMF inoculant + NPK + CM (chicken manure) produced the best growth and maize yield and was significantly different from other treatments in plant height, leaf number, fresh leaf weight, fresh plant weight, cob diameter, and cob weight.

To achieve optimal growth and yield in maize, proper fertilization is needed. The fertilizer should contain all nutrients needed by the maize plant. From the results of this study, the AMF inoculant + NPK + CM is the right fertilizer combination for maize in inceptisol soil. The NPK + CM combination was also able to produce greater cobs weight per plot equivalent to the combination of FMA + NPK + CM treatment.

Arbuscular Mycorrhizal Fungi (AMF) have the advantage of being able to absorb nutrients, especially phosphate nutrients for plants. The application of AMF inoculant can provide P nutrients that are absorbed by plants in the form of H_2PO_4 and HPO_4^{2-}, which are needed in vegetative development such as plant height, stem diameter and provide maximum yield because they function in transferring ATP and ADP energy, stimulating cell division, helping the process of assimilation and respiration, the development of meristem, thereby accelerating the flowering, seed development and fruit ripening [19]. Besides increasing P, AMF increases the absorption of N, K, Ca, and Mg which are mobile [20]. AMF is a fungus that can symbiosis with plant roots, so AMF requires a host plant to grow and develop [21]. Maize is one of the plants that have great potential to be a host plant for AMF growth [22]. The application of AMF inoculant to maize should be in the right amount and in the appropriate environment so that AMF can function optimally in absorbing nutrients for plants, especially P.

Organic matter can be used as an alternative to overcome soil infertility. Organic material comes from plant and animal tissue that decomposes in the soil [21]. Organic fertilizers are useful for improving soil fertility, and if organic fertilization is supplemented with inorganic fertilizers, it improves maize growth and yield [23]. With the addition of organic matter, the nutrient content in the soil will accelerate plant growth, including in maize plants [24].

NPK fertilizer supports the availability of nutrients that are take up by roots and transferred to all plant parts for protein and chlorophyll synthesis to carry out metabolic processes [25]. The application of NPK fertilizer can provide nutrients quickly in helping cell division and elongation of stem segments, leading to increased plant height and an increase in leaf number. However, to reduce the dependence on inorganic fertilizers, biological and organic fertilizers should be incorporated. Biological fertilizers increased plant height, flowering, biomass weight, and root weight [26]. The supply of bio-fertilizers without chemical fertilizers can support plant growth, but not maximally because the nutrients provided by biological fertilizers are limited in number [26]. Manure in general has natural properties and does not harm the soil, provides a macro and micro elements, increases water retention, microbiological activity in soil, cation exchange capacity and improve soil structure [27].

Chicken manure improves the physical, chemical, and biological properties of soil, and it also contains higher N, P, and K than other types of manures [28]. Chicken manure combined with AMF inoculant and NPK fertilizer simultaneously can complement the nutrient needed by maize plants. A mixture of AMF inoculant, NPK fertilizer, and chicken manure enriches macro and micronutrient content by increasing plant height. P nutrient is absorbed from organic fertilizers, supporting plant height [29], and plant height correlated positively with total yield in wheat [30].

AMF plays a role in fixation and provides P elements for plants, NPK fertilizer, and chicken manure provide nitrogen, phosphate, and potassium elements required by maize plants. With the completeness of the elements available from AMF, NPK fertilizer, and organic matter in the form of chicken manure, maize plants are able to increase their growth and yields.

NPK fertilizer has a significant effect on cob weight, and is needed to support the establishment of plants along with the formation of plant height [31]. It stimulates the enlargement of stem diameter, root formation and also significantly affects the diameter of the cob and the weight of 100 maize kernels. Nitrogen stimulates vegetative growth which is expressed by the increment in plant height, leaf number, leaf weight, and maize crop biomass [32]. The nitrogen element is stored in the tissue in the vegetative phase, while in the generative phase it will be transferred to the seeds so that if the cob perfectly emerges it will give a high cob weight. The P element plays a role in stimulating root formation, strengthening stems, stimulating flowers and fruits formation, and improving cob weight. K plays a role as an enzyme activator in metabolic reactions and stimulates the transport of glucose from photosynthetic organs to other plant parts such as maize cobs, thereby affecting the diameter and weight of maize cobs. Given the role of these elements, maize plants that only received AMF inoculant treatment and without the application of other fertilizers produced lower growth and yield than other fertilization combination treatments.

4. Conclusions

The combination of AMF inoculant + NPK fertilizer + CM (chicken manure) and the combination of NPK + CM produced higher growth and maize yield. In the growth component, AMF + NPK + CM treatment produced the highest plant height, leaf number, leaf weight, and plant weight. In the yield components, the combination of FMA + NPK + CM produced the highest cob diameter and cob weight per plant, while the NPK + CM treatment resulted in the highest cob number and cob weight per plot. The NPK + CM treatment was able to produce a productivity of 1.77 kg of fresh maize cobs per plot or equivalent to 8.9 tons of fresh maize cobs per ha, while the productivity of maize in the FMA + NPK + CM treatment was 1.72 kg of fresh maize cobs per plot or equivalent. 8.6 tons of fresh maize cobs per hectare.

Inoculation of AMF without the combination with organic fertilizers did not increase the growth and yield components of maize. The combination of biological fertilizers of AMF inoculant + inorganic fertilizer (NPK) + organic fertilizer (CM) produced good growth and maize yields.

Acknowledgments
Sincere thanks to the Indonesian Directorate of Higher Education, Research and Technology for the research funding assistance so that this research could be carried out successfully.

References

[1] de Souza T A F and Santos D 2018 Effects of using different host plants and long-term fertilization systems on population sizes of infective arbuscular mycorrhizal fungi *Symbiosis* **76** 2 139-149
[2] Abud Y C and Gavito M E 2021 Tolerance of arbuscular mycorrhizal fungi and microorganisms associated to their hyphosphere to aluminum in soil *Scientifia Fungorum* **51** e1304 DOI: 10.33885/sf.2021.51.1304
[3] Jamil N, Zairi M N M, Nasim N A I M and Pa'ee F 2018 Influences of environmental conditions to phytoconstituents in Clitoria ternatea (butterfly pea flower)–A review *Journal of Science and Technology* **10** 2
[4] Bhatt M K, Labanya R and Joshi H C 2019 Influence of long-term chemical fertilizers and organic manures on soil fertility-A review *Universal Journal of Agricultural Research* **7** 5 177-188
[5] Suherman C, Indri F, Rosniawaty S and Arief M 2022 Oil palm (*Elaeis guineensis* Jacq.) shaded model at immature stage II and application of arbuscular mycorrhizal fungi (AMF) on growth and yields of soybean (*Glycine max* (L.) Merrill *Sains Malaysiana* **51** 10 3183-3194
[6] Fabricio T Ramos F T, de Carvalho Dores E F G, dos Santos Weber O L, Beber D C, Campelo Jr J H, de Souza Maia J C 2018 Soil organic matter doubles the cation exchange capacity of tropical soil under no-till farming in Brazil *Journal of The Science of Food and Agriculture* 98 9 3595-3602 https://doi.org/10.1002/jsfa.8881
[7] El Maaloum S, Elabed A, Alaoui-Talibi Z E, Meddich A, Filali-Maltouf A, Douira A, Ibnsouda-Koraichi S, Amir S and El Modafar C 2020 Effect of arbuscular mycorrhizal fungi and phosphate-solubilizing bacteria consortia associated with phospho-compost on phosphorus solubilization and growth of tomato seedlings (*Solanum lycopersicum* L.) *Communications in Soil Science and Plant Analysis* **51** 5 622-634
[8] Kantikowati E, Karya, Yusdian Y and Suryani C 2021 Chicken manure and biofertilizer for increasing growth and yield of potato (*Solanum tuberosum* L.) of Granola varieties *IOP Conf. Series: Earth Environ. Sci.* **393** 012017
[9] Lahay R R, Sipayung R & Sabrina T 2019 The growth and yield of sweet corn (*Zea mays* saccharata Sturt.) with anorganic and organo-bio fertilizer *IOP Conference Series: Earth and Environmental Science* **260** 1 012156
[10] Tian J, Ge F, Zhang D, Deng S and Liu X 2021 Roles of phosphate solubilizing microorganisms from managing soil phosphorus deficiency to mediating biogeochemical P cycle *Biology* **10** 2 158
[11] Kumar A, Kumar A and Patel H 2018 Role of microbes in phosphorus availability and acquisition by plants *International Journal of Current Microbiology and Applied Sciences* **7** 5 1344–1347
[12] Satyaprakash M, Nikitha T, Reddi E U B, Sadhana B and Vani S S 2017 A review on phosphorous and phosphate solubilising bacteria and their role in plant nutrition *International Journal of Current Microbiology and Applied Sciences* **6** 2133–2144
[13] Hasanuzzaman M, Bhuyan MHMB, Nahar K, Hossain Md S, Al Mahmud J, Hossen Md S, Masud AAC, Moumita and Fujita M 2018 Potassium: A Vital Regulator of Plant Responses and Tolerance to Abiotic Stresses *Agronomy* **8** 3 31 https://doi.org/10.3390/agronomy8030031

[14] da Silva F A, Sampaio E V D S B, da Silva F S B and Maia L C 2021 Use of arbuscular mycorrhizal fungi and phosphorus for increase in the concentration of compounds with antioxidant activity in Libidibia ferrea *Research, Society and Development* **10** 4 e13010413827-e13010413827
[15] Mbusango A, Nurbaity A, Fitriatin B N, Solihin M A and Istifadah N 2019 Arbuscular mycorrhiza increased N, P, K, and Fe uptake, growth and yield of vegetables grown on Andisols with different rates of NPK fertilizers *IOP Conference Series: Earth and Environmental Science* **393** 1 012009.
[16] da Silva Campos M A 2020 Bioprotection by arbuscular mycorrhizal fungi in plants infected with Meloidogyne nematodes: A sustainable alternative *Crop Protection* **135** 105203
[17] Barq M G, Hassan M M, Lorenz N, Malik N H, Dick R and Ali N 2021 Variation in microbial community profiles and their energy metabolism predictions under the influence of pure and mixed fertilizer in soil microcosms DOI: https://doi.org/10.21203/rs.3.rs-319529/v1
[18] Wang Y, Zhong B, Shafi M, Ma J, Guo J, Wu J, Ye Z, Liu D and Jin H 2019 Effects of biochar on growth, and heavy metals accumulation of moso bamboo (*Phyllostachy pubescens*), soil physical properties, and heavy metals solubility in soil *Chemosphere* **219** 510-516
[19] RAI I N, Suada I K, Proborini M W, Wiraatmaja I W, Semenov M and Krasnov G 2019 Indigenous endomycorrhizal fungi at salak (*Salacca zalacca*) plantations in Bali, Indonesia and their colonization of the roots *Biodiversitas Journal of Biological Diversity* **20** 8 2410-2416
[20] Ogbeide C E and Ibiremo O S 2018 Soil and fertilizer management in cashew (*Anacardium occidentale* L.) production in Nigeria: a Review. *Horticultural Society of Nigeria (Hortson)*
[21] Ardestani M M and Frouz J 2020 The arbuscular mycorrhizal fungus Rhizophagus intraradices and other microbial groups affect plant species in a copper-contaminated post-mining soil *Journal of Trace Elements in Medicine and Biology* **62** 126594
[22] Benami M, Isack Y, Grotsky D, Levy D and Kofman Y 2020 The economic potential of arbuscular mycorrhizal fungi in agriculture *Grand challenges in fungal biotechnology* pp. 239-279
[23] Wang S, Huang X, Zhang Y, Yin C and Richel A 2021 The effect of corn straw return on corn production in Northeast China: An integrated regional evaluation with meta-analysis and system dynamics *Resources, Conservation and Recycling* **167** 105402
[24] Garcia de Leon D, Vahter T, Zobel M, Koppel M, Edesi L, Davison J, Al-Quraishy S, Hozzein W N, Moora M, Oja J and Öpik M 2020 Different wheat cultivars exhibit variable responses to inoculation with arbuscular mycorrhizal fungi from organic and conventional farms *PLoS One* **15** 5 e0233878
[25] Wang Y, Zhu Y, Zhang S and Wang Y 2018 What could promote farmers to replace chemical fertilizers with organic fertilizers? *Journal of Cleaner Production* **199** 882-890
[26] Tadeu H C, Carneiro M A C, Miranda, M R, Alho, L C, de Araújo Neto P I and Viana Á L 2018 Influence of Arbuscular Mycorrhizal Fungi and Phosphorus Doses in the Production of Parkia nitida (Miquel) in Seedling Nursery in the South of Amazonas *Journal of Experimental Agriculture International* **28** 4 1-10
[27] Karagöz I 2021 *Fertilization and fertilizer types* In: Applied Soil Chemistry (Inamuddin, Ahamed M I, Boddula R, Altalhi T (Eds) pp 123-148 John Wiley & Sons, Inc.) https://doi.org/10.1002/9781119711520.ch7
[28] Taberima S, Prabawardani S, Sarwom R and G Lyons 2020 Organic fertilizer applications improve the growth of vegetable crops and chemical properties in the tailings deposition area at Timika, Papua, Indonesia *Natural Bioscience* **12** 2 134-142. https://doi.org/10.13057/nusbiosci/n120208
[29] Oyeyiola Y B 2020 Organic based amendments for the management of tropical acid soils: Potentials and challenges *IOSR Journal of Environmental Science, Toxicology and Food Technology* **14** 6 36-46 DOI: 10.9790/2402-1406033646

[30] Oladosu Y, Rafii M Y, Magaji U, Abdullah N, Miah G, Chukwu S C, Hussin G, Ramli A and Kareem I 2018 Genotypic and phenotypic relationship among yield components in rice under tropical conditions *BioMed Research International* https://doi.org/10.1155/2018/8936767

[31] Sudding A F, Maintang, Asri M, Rauf W A, Syam A and Adriani W A 2021 The effect of NPK 15-15-6-4 compound fertilizer on corn growth and yield *IOP Conf. Series: Earth and Environmental Science* **911** 012047 doi:10.1088/1755-1315/911/1/012047

[32] Hammad H M, Abbas F, Saeed S, Fahad S, Cerdà A, Farhad W, Bernardo C C, Nasim W, Mubben M and Bakhat H F 2018 Offsetting land degradation through nitrogen and water management during maize cultivation under arid conditions *Land degradation & Development* **29** 5 1366-1375

Application of the arbuscular mycorrhizal fungi inoculant, organic

ORIGINALITY REPORT

1%	%	%	1%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	Submitted to CSU, San Jose State University Student Paper	<1%
2	Submitted to University of St La Salle Student Paper	<1%
3	Submitted to University of Hull Student Paper	<1%
4	Submitted to University of Greenwich Student Paper	<1%

Exclude quotes	Off	Exclude matches	Off
Exclude bibliography	Off		

Application of the arbuscular mycorrhizal fungi inoculant, organic

GRADEMARK REPORT

FINAL GRADE

/0

GENERAL COMMENTS

Instructor

PAGE 1

PAGE 2

PAGE 3

PAGE 4

PAGE 5

PAGE 6

PAGE 7

PAGE 8

PAGE 9

PAGE 10

PAGE 11