Conference Paper

Responses of Potato (*Solanum tuberosum*) to *Glomus* sp. Combined with *Pseudomonas diminuta* at Different Rates of NPK Fertilizers

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Abstract

Conventional farming for potato production in Indonesia has been using NPK fertilizer at high application rates. Any adverse environmental effects that might arise trough this fertilizer use shall be avoided. Application of bioferrtilizer consisted of ArbuscularMycorrhizal Fungi (*Glomus* sp.) isolated from the potato farming area and Mycorrhizal Helper Bacteria (*Pseudomonas diminuta*) have been tested to reduce the use of NPK rates in the production of potato crops. The inoculant has been pot-cultured prior to its application on potato crops. The controlled-field site experiment, used the mixtures of spores of Glomus sp. and inoculant of *Pseudomonas diminuta*, applied at different rates of NPK fertilizer. Results of the experiment showed that the application of Glomus sp. and *Pseudomonas diminuta* reduced the use of NPK up to 50%, where the growth, nutrients uptake (N,P,K), and tubers of potato had similar effect to the highest recommendation rate of NPK fertilizer (being applied by the farmers). Findings from this experiment confirmed the evidences that application of AM fungi and mycorrhizal helper bacteria could reduce the use of chemical fertilizer which support sustainable farming system. Further step has been done to scale up the production of inoculants for the wider use by local farmers.

Keywords: Glomus, Pseudomonas, mycorrhiza, potato, NPK fertilizer.

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1. Introduction

Potato is one of the high priority crops in the vegetable research and food production as the demand for potato consumption is increasing. However, potato plant need higher fertilizer input than other vegetable crops. The requirements of potato plant for N, P and K are 100%, 100%, and 33%, respectively [1]. Therefore, there is a need to find a more sustainable and efficient farming system. Applying beneficial microbial inoculants are promising technique for the establishment of a sustainable potatoes cultivation system. Some functional soil microorganisms such as fungi and bacteria that can improve soil nutrition (N,P,K) are well documented.

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Arbuscularmycorrhizal fungi (AMF) are almost universally present in all soils that establish an obligate mutualistic symbiosis with many plant species. This symbiosis plays an important role in maintaining soil and plant health [2]. In nature, some bacterias, known as Mycorrhizal Helper Bacteria (MHB), found to have ability to stimulate mycorrhizal fungal activity [3] by releasing some compounds that influence morphology and physiology of the roots [4].

Enhancement of productivity of potatoes after application of AMF has been reported to be related to nutrient uptake, especially P and improvement of soil structure [5-7]. Previous researches on isolation and selection AMF from potato plantation in Andisols West Java showed that *Glomus* sp. was effective as inoculant for potato cultivation [8]. Furthermore, selection of MHB indicated that *Pseudomonas diminuta* was the most effective species in stimulating activity of *Glomus* sp. [6].

The objective of this study was to determine the beneficial effects of AMF *Glomus*sp. and MHB *P. diminuta*on NPK uptake, growth and yield of potato at different NPK levels (decreasing levels from 100% until 25% of recommended rate). It was expected that the application of this biofertilizer could substitute the requirement of heavy chemical fertilizer in potato cultivation system.

2. Materials and Methods

The experiment was conducted in a screen house of Faculty of Agriculture UniversitasPadjadjaran in Jatinangor, with an altitude of 794 m and the temperature range of 21-27°C. The soil used was collected from Lembang, West Java, Indonesia, classified as Andisols (0-20 cm depth). The properties of the soil were: pH (H_2O) 4.95, organic C 2.07%, total N 0.38%, Bray I-P 0.44 ppm, CEC 47.56 cmol.kg^{-1}, exchangeable K, Na, Ca, Mg 0.45, 0.97, 2.96, 1.09 cmol.kg^{-1} respectively; sand 31.78%, silt 58.61%, and clay 9.61%. Experiment was arranged in randomized block design with 9 combination treatments, 1 control and three replicates. The numbers of spores of AMF applied were 50, 100, 150, while the NPK levels were 100%, 75%, 50% and 25% of recommendation rates (Table 1). The control was mimicking conventional potato farming system that has been used by the farmer, 100% recommendation rates (i.e. 1000 kg ha^{-1}) without biofertilizer.

Air-dried soil was sieved to pass through a 4 mm mesh and placed in pots containing 10 kg of soil according to the treatment. Half of fertilizer NPK (15:15:15) applied to the soil in each pot one week before planting and was reapplied at four weeks after planting (WAP).

The AMF used was *Glomus* sp. AMF inoculant with the number of spores (according to the treatments) per pot were incorporated in the top 10 cm of each pot one week

Table 1: Combination treatment for experiment on application of AMF and MHB at different levels of NPK.

No	Treatments	
	Number of *Glomus* spore per pot + 10^7cfu/ml *P. diminuta*	Rate of NPK (kg ha^{-1})
1	0	1000 *
2	50	750 *
3	50	500 *
4	50	250 *
5	100	750
6	100	500
7	100	250
8	150	750
9	150	500
10	150	250
*1000 = 100%; 750 = 75%; 500 = 50%; 250 = 25% recommended rate of NPK		

before planting to allow the spores to germinate. Un-inoculated pots received an equal amount of autoclaved spores. The MHB used was *Pseudomonas diminuta,* applied to all treatments as a based-treatment. Twenty mL of microbial suspension with the density of 10^7cfu mL^{-1} was incorporated in the top 10 cm of each pot at the day of planting.

Certified tubers of Atlantic cultivars from the Potato Center were placed after microbial inoculants covered with a layer of soil in the pots. The seed-tuber was covered with a 5cm thick layer of soil. The pots were watered every day to maintain 80% of water holding capacity.

The measurements in this study included height of plants, leaves area, shoot-root ratio, and weight of tubers at 12 WAP. Nutrients concentrations (N, P, K) were analyzed in soil (12 WAP) as well as nutrients uptake by planst at maximum vegetative state (7 WAP). Nitrogen measurements used Kjeldahl apparatus, while phosphorus and potassium were determined by acetic acid extraction and measured with spectrophotometer for P (and flame photometer K. All data collected were then analyzed by two-way ANOVA using DAASTAT software (version 7). Differences at the 5% level of significance were tested using DMRT.

Table 2: Nutrient availability in soil (Total N, Available P, Exchangeable K) as the effect of AMF (number of spores of *Glomus* sp.) at different rate of NPK (kg ha^{-1}).

AMF + NPK	Soil total-N (%)	Soil available-P (ppm)	Soil exch-K ($cmol.kg^{-1}$)
0 + 1000	0.16 a	39.48 abc	4.92 a
50 + 750	0.17 a	4.32 bc	5.26 a
50 + 500	0.19 a	38.85 abc	4.89 a
50 + 250	0.16 a	32.59 ab	4.84 a
100 + 750	0.18 a	48.39 c	5.48 a
100 + 500	0.19 a	43.42 bc	5.52 a
100 + 250	0.15 a	49.39 c	5.96 a
150 + 750	0.20 a	47.63 c	6.10 a
150 + 500	0.12 a	29.14 a	4.65 a
150 + 250	0.19 a	35.94 abc	4.08 a

Within each column values followed by the same letter are not different ($p < 0.05$)

3. Results and Discussion

Analysis of the availability of nutrients (N, P, K) in soil revealed that application of AMF gave significant difference on phosphorus availability in soil, while there were no differences between the treatments on soil total nitrogen and soil exchangeable potassium (Table 2). In general, application of FMA combined with reduced rates of NPK gave the same effect as 100% recommended rate of NPK at all parameter measured. This finding indicates that AMF could reduce the amount of excessive NPK needed to produce potato on Andisols.

The highest soil available phosphorus reached when 100 spores of AMF applied combined with 25% NPK recommendation rate, even though this was not significantly different with most other treatments. In Andisols, phosphate is readily fixed through specific adsorption to allophane minerals that are abundant in the weathering products of volcanic ash [9]. Specifically adsorbed phosphate cannot be absorbed by root plant, and therefore to increase the concentration of available P in the soil a high dosage of P fertilizer is necessary, or as in this study, the existence of AMF could increase the availability of P in soil.

In soil inoculated by AMF, nutrients are obtained by hyphae, which can penetrate and exploit a larger volume of soil. From uptake by hyphae, nutrients are translocated within the hyphal network to the fungal sheath. The fungal sheath can act as a storage

Table 3: Nutrient uptake in plants (N, P, K) as the effect of AMF (number of spores of *Glomus* sp.) *at different rate of NPK (kg ha*$^{-1}$*).*

AMF + NPK	N uptake (mg.kg^{-1})	P uptake (mg.kg^{-1})	K uptake (mg.kg^{-1})
0 + 1000	7.12 a	0.55 a	11.81 a
50 + 750	5.66 a	0.61 a	12.90 a
50 + 500	4.36 a	0.49 a	11.39 a
50 + 250	6.22 a	0.76 a	13.73 a
100 + 750	6.94 a	0.61 a	14.17 a
100 + 500	6.48 a	0.61 a	14.61 a
100 + 250	4.50 a	0.49 a	12.36 a
150 + 750	8.18 a	0.85 a	19.24 a
150 + 500	6.77 a	0.80 a	18.66 a
150 + 250	5.29 a	0.55 a	10.57 a
Within each column values followed by the same letter are not different ($p < 0.05$)			

site for nutrients; allowing the fungus to continue to provide nutrients to the plant host when soil concentrations decrease [10].

Arbuscularmycorrhizal fungi play an essential role for the nutrient uptake in plants. Result from this experiment showed that nutrient uptake (N, P, K) in mycorrhizal potato plants combined with reduced NPK fertilizer's rate have same effect with the control or 100% NPK rate (Table 3).

The contribution of the AM symbiosis to the phosphate nutrition has long been known, but whether AM fungi contribute similarly to the nitrogen [5] and potassium nutrition of their host is still conferred. Several experiments carried out in P-deficient soils have shown improved nitrogen-fixation on inoculation of the plants with mycorrhiza [11].

A comprehensive characterization of the influence of AM infection on mineral physiology of potato showed that although low P plants had significantly lower rates of root respiration, the activities of root microsomal ATPases and extracellular acid phosphatases were higher [12]. Mineral nutrient such as potassium is also assimilated more quickly and in greater amounts by mycorrhizal plants [10].

Overall, some mechanisms of enhanced plant growth by mycorrhiza include increasing the surface area of absorption within the soil, mobilisation of sparingly-available nutrient sources from unavailable compounds and excretion chelating compounds or ectoenzymes [10].

Table 4: Effect of AMF (number of spores of *Glomus* sp.) at different rate of NPK (kg ha^{-1}) on yield of potato.

AMF + NPK	Number of tuber plant[1]	Tuber yield (g $plant^{-1}$)
0 + 1000	8	456.33 a
50 + 750	9	390.67 a
50 + 500	9	442.67 a
50 + 250	9	413.00 a
100 + 750	8	470.33 a
100 + 500	9	468.00 a
100 + 250	8	455.33 a
150 + 750	9	400.00 a
150 + 500	9	441.00 a
150 + 250	8	486.33 a

Within each column values followed by the same letter are not different ($p < 0.05$)

Application of AMF at reduced rates (25% to 75%) of NPK fertilizer gave similar effect to that of recommendation rate (100%) without AMF on number of tuber and tuber yield (Table 4). These results were concurred with nutrient uptakes of potato plants. [13] also found no significant difference between 75% and 100% P recommended on yield of potato. In their research, application of AMF in the presence of 50% P recommended had a favorable result and could increase tuber yield to an acceptable level. High level rate of chemical P fertilizers, leads to antagonistic interaction with mycorrhiza. Resistance of AM infection due to increasing P supply could partially because of Restoration of the capacity of roots to produce ethylene [12].

In relation to the yield, mycorrhizal symbiosis known could increase the units of photosynthesis and imporoves the rate of photosynthetic storage [2]. Mycorrhizal helper bacteria (*Pseudomonas diminuta*) applied in this experiment had also role in increasing the available P in the soil which could enhance the yield of potato as this species was also identified as the phosphorus solubilizing bacteria that can increase the tuber of potato [8].

4. Conclusion

Application of mycorrhiza and mycorrhizal helper bacteria in the presence of 25% to 75% NPK recommended rate had positive effect on nutrient availability and uptake by plants, and also the yield of potato. Therefore, this biofertilizer could be considered as a suitable substitute for chemical fertilizer in potato cultivation system.

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