Effect of phosphate-solubilizing bacteria on growth and yield of *Arachis hypogaea* L. in varied soil types

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ABSTRACT

Peanut (Arachis hypogaea L.) is widely cultivated both in monoculture and polyculture (usually with corn) on dry land in Madura. Generally, the soil types of Madura are grumusol, regosol, and mediterranean. These three types of soil each have different physical and chemical properties. The effect of the addition of phosphate-solubilizing bacteria on the three soil types is unknown. The study aimed to determine the response of peanut plant growth due to the addition of phosphate solubilizing bacteria, Pseudomonas fluorescens, in three different soil types. The research was conducted in the experimental garden of Agroecotechnology, Faculty of Agriculture, Universitas Trunojoyo Madura. The research design used a non-factorial completely randomized design (CRD) with six treatments and four replications. The treatment consisted of three types of soil, namely regosol, grumosol, and mediteran as well as with and without the addition of P. fluorescens. The results showed that the treatment had a significant effect on the parameters of plant height, number of leaves, number of pods, pod dry weight, seed weight, above-ground biomass, root dry weight, and plant P content. The treatment did not show a significant effect on the root-canopy ratio and P. fluorescens population parameters.

Keywords*: growth, Madura island, peanut, production, Pseudomonas fluorescens*

INTRODUCTION

Peanut (*Arachis hypogaea* L.) is a legume that has a strategic role in national food as a source of protein and vegetable oil. This plant is widely cultivated both in monoculture and polyculture with corn on dry land in Madura which is generally grumusol, regosol, and mediterranean soil. These three types of soil each have different physical and chemical properties. Grumusol soils are generally alkaline, have high water holding capacity and cation exchange capacity, and generally have low organic matter and plant nutrient content (Riantara & Mandala, 2020; Widiasmadi, 2020). Regosol soil is a young soil that develops from loose parent material and has a coarse texture and low organic matter content (Carbajal-Morón et al., 2017; Ji et al., 2023). Mediterranean soils are formed from the weathering of limestone rocks with low organic matter content, moderate to high base saturation, and a pH ranging from 6.0 – 7.50 (Heidari et al., 2022; Sadzli & Supriyadi, 2019).

Phosphate (P) is very important for plants, including for cell division, root development, flower and fruit formation, as well as seeds. The P content is quite high in the soil, very little can be used by plants because it is bound to soil clay minerals. This is where the role of P solubilizing microbes can release P bonds from clay minerals and provide them for plants (Gérard, 2016; Kome et al., 2019; Malhotra et al., 2018; Nkaa et al., 2014; Uchida, 2000).

Previous studies report that some bacteria can produce compounds that play a role in the process of enriching the soil so that it can accelerate plant growth. According to Rao (1994), in the soil, many bacteria can release P from the bonds of Fe, Al, Ca, and Mg so that P which is not available becomes available for plants. Several strains from the genera *Pseudomonas, Bacillus, and Rhizobium* isolated from tropical countries, were reported to be able to dissolve phosphate (Silitonga et al., 2013). According to Lestari (2011), inoculation of phosphate-solubilizing bacteria such as *P. fluorescens* can increase the growth of wheat, corn, and cotton plants (Callan et al., 1991; Shanmugaiah et al., 2009; Smyth et al., 2011). The purpose of this study was to determine the effect of *P. fluorescens* on the growth and production of peanuts in three types of soil in Madura.

MATERIAL AND METHODS

The research was conducted in the experimental field of the Agroecotechnology Study Program, Faculty of Agriculture, University of Trunojoyo Madura, in Telang Village, Kamal District, Bangkalan Regency, Madura. The altitude of the place ± 5m above sea level. This research was conducted in April - June 2019.

The study was arranged using a non-factorial completely randomized design (CRD) consisting of 6 treatments and was replicated 4 times. The treatments included: regosol soil (T1), grumosol soil (T2), and mediterranean soil (T3) as well as with the addition of *P. fluorescens* (P1) and without the addition of *P. fluorescens* (P0). Each treatment consisted of 3 samples.

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Parameters observed included plant height (cm), number of leaves (strands), root crown ratio, aboveground biomass (g), dry weight of roots (g), number of pods planted, dry weight of pods planted (g), dry weight of seeds (g), soil P content (ppm), plant P content (ppm) and *P. fluorescens* population (cfu) after planting. Data analysis used analysis of variance (ANOVA), and if there was a significant effect it was continued with the least significant difference (LSD) test at the 5% level.

RESULT AND DISCUSSION

Effect of treatment on plant height

Based on the results of the analysis of variance on the observed parameters for plant height increase, it was shown that the treatment with the addition of *P. fluorescens* to several different soil types had a very significant effect on all ages of observation (Table 1). The result shows that both with and without the addition of *P. fluorescens* at 21 days after planting (DAP) the treatment of regosol and grumosol soils, was not significantly different. The same thing was shown in the treatment of regosol and grumosol both without and with the addition of *P. fluorescens* at 35 to 63 DAP was not significantly different. In the mediterranean soil treatment, both with and without the addition of *P. fluorescens*, there was no significant difference for all ages of observation.

This shows that grumosol soil can bind water so that plants can meet their water needs to carry out their growth process. This condition is the same as Suhartono's (2008) report, a better ability to bind water will affect the division of plant cells and the transport of nutrients from the soil to the plants so that the needs of plants will be fulfilled. In addition, the treatment with *P. fluorescens* is very well used to add soil nutrients to help plant height growth, especially P which is very important for the growth of peanut plants. Phosphate fertilization had a very significant effect on plant height growth (Bukhari et al., 2020). P has an important role in the process of cell elongation and division. so with the availability of sufficient P, the formation of RNA and DNA in the cell nucleus is not hampered (Sutoto, 2008).

Effect of treatment on the number of leaves

The results on the observed parameter for the number of leaves showed that the treatment had a significant effect at the age of 14 DAP and the age of 21 to 63 DAP had a very significant effect. The treatment of regosol soil with or without *P. fluorescens* at 14 DAP shown not significantly different. While the treatment of regosol soil without *P. fluorescens* was not significantly different from the treatment of grumosol soil with the addition of *P. fluorescens* and mediterranean soil without *P. fluorescens*. At the age of observation 28, 35, and 49 HST, the grumosol treatment, both with and without *P. fluorescens* addition, was not significantly different from the regosol soil treatment with *P. fluorescens* addition. For observations of ages 56 and 63 DAP the treatment of grumosol without *P. fluorescens* gave the best results. As for the treatment of mediterranean soils, both with and without *P. fluorescens* addition, there was no significant difference for all ages (Table 2). This is presumably because it is a treatment without *P. fluorescens* on grumosol soil have been able to supply nutrients according to plant needs, especially to support the growth of the number of leaves. In addition, the nature of the grumosol soil which can bind water is better than the regosol and mediterranean soil types. The ability to bind water helps the process of transporting nutrients in plants.

Effect of treatment on pods

The treatment with the addition of phosphate-solubilizing bacteria in three different soil types had a very significant effect on the parameter number of pods. Treatment of regosol and grumosol soil types both without *P. fluorescens* and with the addition of *P. fluorescens* gave results that were not significantly different between treatments. Meanwhile, the treatment of Mediterranean soil types, both without *P. fluorescens* and with the addition of *P. fluorescens*, gave results that were not significantly different (Table 3).

The pod dry weight parameter (g) showed that there were significant differences between the three types of soil treatment. Treatment of regosol soil types without *P. fluorescens* or with the addition of *P. fluorescens* gave results that were not significantly different.

Table 1. Average plant height due to treatment of addition of phosphate solubilizing bacteria in three different soil types at different ages of plants.

Treatment	Plant height (cm) at different plant ages (the day after planting (DAP))							
	14	21	28	35	42	49	56	63
T1P0	22.52 b	23.06 b	24.24 b	25.56 b	28.05 b	28.63 b	29.29 b	29.53 b
T1P1	23.08 b	23.22 b	25.78 bc	26.04 b	28.32 b	28.78 b	29.27 b	29.31 b
T2P0	18.74 a	21.61 b	25.23 bc	26.29 b	28.83 b	29.45 b	29.89 b	30.10 b
T2P1	21.19 b	22.79 b	26.49 c	26.98 b	29.48 b	30.09 b	30.57 b	30.91 b
T3P0	18.18 a	18.30 a	19.18 a	19.18 a	22.82 a	24.17 a	24.84 a	24.54 a
T3P1	18.46 a	18.63 a	19.14 a	20.00 a	24.02 a	25.32 a	25.31 a	25.31 a
LSD 5%	**	**	**	**	**	**	**	**

Note: Numbers followed by the same letters in the same column are not significantly different based on the LSD 5% test; **: very significant effect.

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Table 2. The average number of leaves due to the treatment of the addition of phosphate solubilizing bacteria in three different types of soil at different ages of plants.

Treatment	Leave number (cm) at different plant ages (the day after planting (DAP))							
	14	21	28	35	42	49	56	63
T1P0	47.50 bc	57.50 b	76.42 b	93.33 b	127.50 b	116.67 b	104.83 b	124.84 b
T1P1	51.75 c	61.08 b	85.92 bc	90.00 b	112.75 b	117.67 b	111.42 b	131.08 b
T2P0	34.83 a	54.00 b	91.17 bc	115.00 c	136.00 b	149.00 c	158.67 c	185.67 c
T2P1	39.00 ab	55.25 b	93.25 c	103.00 bc	118.58 b	131.33 bc	122.25 b	137.58 b
T3P0	41.09 ab	42.08 a	52.92 a	50.83 a	66.08 a	78.00 a	63.75 a	70.00 a
T3P1	36. 50 a	44.83 a	51.09 a	55.33 a	68.84 a	75.33 a	52.83 a	52.08 a
LSD 5%	*	**	**	**	**	**	**	**

Note: Numbers followed by the same letters in the same column are not significantly different based on the LSD 5% test; **: very significant effect; *: significant effect.

Table 3. The effect of the addition of phosphate solubilizing bacteria in three different soil types on the average number of pods, dry weight of pods, and dry weight of seeds.

Treatment	The average number of pods (unit)	The average dry weight of pods (g)	The average dry weight of seeds (g)
T1P0	6.84 b	5.06 b	3.67 b
T1P1	6.33 b	4.82 b	3.46 b
T2P0	8.08 b	7.53 c	5.36 c
T2P1	7.08 b	7.28 c	5.38 c
T3P0	2.58 a	2.14 a	1.53 a
T3P1	2.38 a	1.32 a	0.57 a
LSD 5%	**	**	**

Note: Numbers followed by the same letters in the same column are not significantly different based on the LSD 5% test; **: very significant effect.

The treatment of grumosol soil types both without *P. fluorescens* and with the addition of *P. fluorescens* did not give significantly different results as well as for the treatment of mediterranean soil types which showed results that were not significantly different either with the addition of *P. fluorescens* or without *P. fluorescens*. The *P. fluorescens* treatment had no effect because of the three soil types there were significant differences (Table 3).

Based on the results of the best treatment variance, it was shown by the grumosol soil, both without *P. fluorescens* and with the addition of *P. fluorescens*, showed results that were not significantly different. The next best treatment was regosol soil either without *P. fluorescens* or with the addition of *P. fluorescens* which showed results that were not significantly different. while the lowest results were found in the Mediterranean soil treatment both without *P. fluorescens* and with the addition of *P. fluorescens* which were not significantly different between treatments. This shows that there are significant differences between the types of soil treatment.

Effect of treatment on biomass and root-canopy ratio

The treatment of the addition of phosphate-solubilizing bacteria to three different types of soil had a very significant effect on the above-ground biomass parameters. Table. 4 shows that the grumosol soil treatment, both without *P. fluorescens* and with the addition of *P. fluorescens,* had the highest biomass weight, while the regosol soil treatment, both without *P. fluorescens* (P0) and with the addition of *P. fluorescens* (P1), was not significantly different from the mediterranean soil treatment with the addition of *P. fluorescens* (T3P1). The lowest yield was shown by the Mediterranean soil treatment without *P. fluorescens* (T3P0) of 2.50 g.

Grumosol soil treatment without *P. fluorescens* (T2P0) gave the best results for root dry weight parameters of 0.92 g. For the treatment of grumosol soil with the addition of *P. fluorescens* (T2P1), the results were not significantly different from the treatment of regosol tapa *P. fluorescens* or with the addition of *P. fluorescens* and mediterranean soil with the addition of *P. fluorescens*. Meanwhile, mediterranean soil treatment without *P. fluorescens* gave the lowest yield of 0.34 g (Table 4).

Table 4. The effect of phosphate solubilizing bacteria addition in three different soil types on canopy biomass, root dry weight, and root canopy ratio.

Treatment	Average of canopy Biomass (g)	Average of root dry weight (g)	Root canopy ratio
T1P0	3.97 ab	0.46 ab	11.81
T1P1	4.54 b	0.52 ab	9.54
T2P0	7.76 c	0.92 c	8.61
T2P1	6.65 c	0.66 b	9.95
T3P0	2.50 a	0.34 a	7.49
T3P1	2.66 ab	0.53 ab	5.42
LSD 5%	**	**	ns

Note: Numbers followed by the same letters in the same column are not significantly different based on the LSD 5% test; **: very significant effect; ns: not significant.

Table 5. Differences in phosphate content and population of *P. fluorescens* in each treatment

Treatment	Phosphate content in the plant (ppm)	Phosphate content in soil (ppm)	The population of *P. fluorescence* in the rhizosphere (cfu g^{-1})
T1P0	63.40 a	36.05	2.26×10^7
T1P1	91.05 d	30.56	2.18×10^7
T2P0	71.54 c	38.92	2.53×10^7
T2P1	100.36 f	26.11	2.26×10^7
T3P0	68.47 b	33.42	0.94×10^7
T3P1	94.04 e	25.43	1.98×10^7
LSD 5%	**	ns	ns

Note: Numbers followed by the same letters in the same column are not significantly different based on the LSD 5% test; **: very significant effect; ns: not significant.

The treatment of soil type due to the addition of *P. fluorescens* did not have a significant effect on the root canopy ratio parameter, but the tendency for the highest value was obtained in the regosol soil treatment without *P. fluorescens* (T1P0) of 11.81 and the lowest value was obtained in the Mediterranean soil treatment with the addition of *P. fluorescens* (T3P1) of 5.42 g (Table 4).

Effect of Treatment on phosphate content and *P. fluorescens* population

The analysis results of the P content in the soil due to the addition of phosphate solubilizing bacteria in several different soil types showed that the P content in the treatment without the addition of *P. fluorescens* (P0) in all soils gave higher yields than the treatment with the addition of *P. fluorescens* (P1). Ng et al. (2022) also reported that *P. fluorescens* a very small increase with no significant differences of P content. But, Table 5 shows that all treatments show different results. The grumosol soil treatment with the addition of *P. fluorescens* (T2P1) had the highest value of 100.36 ppm, while the regosol soil treatment without the addition of *P. fluorescens* (T1P0) had the lowest value of 63.40 ppm. Combination *P. fluorescens* with others could increase P content in maize until 156.5% (Sahi et al., 2022).

Table 5 shows that the treatment of soil type due to the addition of *P. fluorescens* has no significant effect on the *P. fluorescens* population parameter. However. the tendency for the highest value was found in the grumosol soil treatment without the addition of *P. fluorescens* (T2P0) of 2.53×10^7 cfu g^{-1}. while the lowest value was in the mediterranean soil treatment without the addition of *P. fluorescens* (T3P0) of 0.94×10^7 cfu g^{-1}. In other report, *P. fluorescens* showed a steady decline and no significant rhizosphere effect on different soil (Van Elsas et al., 1986).

CONCLUSION

There are differences in the growth and production of peanut plants due to the addition of phosphate-solubilizing bacteria, *P. fluorescens,* in three different types of soil. Treatment without or with the addition of *P. fluorescens* in three different types of soil showed a very significant effect on the parameters of plant height, number of leaves (except 14 DAP), number of pods, dry weight of pods, seed weight, above-ground biomass, root dry weight, and plant P content. The treatment of adding *P. fluorescens* to different soil types showed no effect on the root canopy ratio parameter and *P. fluorescens* population in the rhizosphere.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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