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INCREASING THE GROWTH AND YIELD OF RED CHILI WITH PGPR AND NPK FERTILIZER IN ULTISOL DRY LAND

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ABSTRACT

Research aimed at increasing the production and productivity of red chili by using PGPR and NPK fertilizer in dry land has been carried out at the Teaching and Research Farm, Faculty of Agriculture, University of Jambi (35 m asl.). The research uses a Random Block Design with factorial patterns and three replications. The treatment that was tried was the concentration of PGPR and NPK fertilizer dose. The PGPR concentration consists of: 0 mLL^{-1}; 10 mLL^{-1}; 20 mLL^{-1}; 30 mLL^{-1}; and NPK fertilizer doses consisting of: 0 $kgha^{-1}$; 350 $kgha^{-1}$; 700 $kgha^{-1}$. Data were analyzed using Analysis of Variance and continued with the BNT test. The results showed that the interaction of PGPR and NPK fertilizer was not able to increase the growth and yield of red chili, but PGPR was able to increase the number of fruits and the weight of red chili, while NPK fertilizer was able to increase the diameter of red chili plants aged 8 Week After Planting (WAP). PGPR 10 mLL^{-1} concentration gives the highest number of fruit and fruit weight to red chili, and NPK fertilizer dose of 700 kg ha^{-1} is a dose that gives the highest shoot diameter. The provision of PGPR to red chili plants has not been able to reduce the use of NPK fertilizer in Ultisol dry land. The weight of red chili produced by administering PGPR 10 mLL^{-1} is only able to meet 65,33 % of the potential yield of red chili.

KEY WORDS

Capsicum annuum, drought, inorganic fertilizer.

Chili is an important vegetable because of its spiciness, nutritional content, and pigment the fruit. In Indonesia, prices of red chili always fluctuate and are strongly influenced by the season, and participate in determining the level of national inflation. The Ministry of Agriculture (2020) is targeting the production of horticultural commodities, especially red chili, and shallots can increase up to 7% every year. Chili and shallots are commodities that are vulnerable to price increases, especially if there is a weather or supply disorder. Therefore planting chili must continue to be done throughout the year, even during the off-season. Besides that, the expansion of planting red chili on dry land such as Ultisol needs to be increased so that the availability of national chili is safe throughout the year, reducing price fluctuations, and national inflation rates.

The use of plant growth- promoting rhizobacteria (PGPR) is one of the efforts that can be made to improve the ability of red chili planted in dry land can survive drought and can increase growth and results. PGPR is soil bacteria that live around or on the root surface, and directly or indirectly encourages plant growth and development through the production and secretion of various regulatory chemicals around rhizosphere (Nehra and Choudhary, 2015).

One of the plants whose rhizosphere contains a lot of microorganisms is bamboo. The research of Susanti et al. (2015) on various microorganisms that exist in bamboo rhizosphere soil shows that the total bacterial and fungal populations originating from bamboo rhizosphere are higher than bamboo non-rhizospheric soils. These various microbes act as PGPRs that increase plant growth and suppress pathogens.

Various research results show that PGPR can increase plant growth and yield. Inoculation of bacterial Bacillus sonorensis as PGPR in red chili increases dry ingredients, nutrient content, and plant fruit weight. Provision of PGPR can increase soil- P, and produce indol acetic acid, siderophore, chitinase, and hydrogen cyanide, and is good in the formation of biofilm (Thilagar et al*.,* 2016). Giving PGPR Azotobacter chroococcum, Azospirilum brasense, and Bacillus megaterium along with operating (K+P), a plant growth activator, able to reduce nitrogen use by 30%, and increase sugar yields in sugar beets (Artyszak and Gozdowski, 2020).

Furthermore, Rohmawati et al. (2017) stated that the administration of PGPR 30 mLL^{-1} and rabbit dung compost 10 tonha^{-1} gave a number of fruits and higher fruit weight to eggplant plants compared to other treatments. The highest fresh weight of the Pakcoy plant is obtained by giving NPK 25% (12.5 g per planting hole) + PGPR 75% (37.5 g per planting hole) (Rosyida and Nugroho, 2017). The concentration of PGPR 12.5 mLL^{-1} given at the time of seed soaking and vegetative phase, provides the highest growth and results for peanuts (Marom et al., 2017).

The use of inorganic fertilizer continuously and excessively can have a detrimental impact on the environment, human health, and agricultural sustainability itself. According to Paungfoo-Lonhienne et al. (2018), PGPR can reduce pollution due to the conventional use of N fertilizer. Provision of PGPR in soil which is given 50% organic fertilizer and 50% conventional N fertilizer increases the growth of kikuyu grass (Pennisetum clandestinum), and gives the same result as 100% N. Besides the combination of organic fertilizer + fertilizer N + PGPR reduces washing N by 95% compared to conventional administration.

Various studies above provide information that the provision of PGPR into the soil in addition to increasing plant growth and yield, can also increase plant tolerance to drought and reduce the use of inorganic fertilizer, even so until now the results are still diverse and inconsistent. According to Nehra and Choudhary (2015) and Kumari et al. (2019), soil and climate variations are unpredictable factors and the desired results are sometimes difficult to achieve. Therefore this study aims to examine the role of PGPR interested in NPK inorganic fertilizer in increasing the growth and yield of red chili in Ultisol dry land and getting PGPR consequences and NPK fertilizer doses that provide the highest growth and red chili yield.

METHODS OF RESEARCH

The study was conducted at the Teaching and Research Farm, Faculty of Agriculture, Jambi University. The research uses a Random Block Design with two factors. The first factor is the various concentrations of PGPR from the bamboo roots, namely; 0 mLL^{-1}; 10 mLL^{-1}; 20 mLL^{-1}; 30 mLL^{-1}, while the second factor is the dose of NPK inorganic fertilizer (16: 16: 16) consisting of 0 kg ha^{-1}; 350 kgha^{-1} and 700 kgha^{-1}.

PGPR is given once a week by leaked and starting from 2 WAP (Week After Planting) and until the plant is 12 WAP. Meanwhile, NPK is given when the plant is 1 WAP by being given a circular plant. The treatment is repeated three times. The spacing used is 50 x 50 cm. Before planting the beds were given plastic mulch. Trichocompost gave one week before planting by mixing it into the soil, then stirring with the soil until evenly distributed. The dose of trichocompost is 15 tonha^{-1}.

Red chili seeds are sown in the seedling media, after the seven day seedlings are transferred to the nursery and left in the nursery for 21 days. The seedling and nursery media are a mixture of soil: compost: and sand (2: 1: 1). After one month seedlings are planted on the land. During the nursery, the seedling is sprayed with Bayfolan D fertilizer with a concentration of 2 mLL^{-1}, and insecticide with active ingredients abamectin and mensural, with a concentration of 2 mLL^{-1}. Spraying fertilizers and insecticides is carried out once a week. Before the nursery and planting, media were given carbofuran at a dose of 60 kg ha^{-1}.

Aftershocks in the form of NPK (16:16:16) are given by leaked when the plant is 6, 8, and 10 weeks after planting (WAP), with a concentration 2 gL^{-1} and spray volume of 100 mL per plants. Plant maintenance is carried out including watering, weeding, and controlling pathogens. Harvesting from 14 MST to 16 MST (during the first flowering period), with the color criteria for chili (80% of each fruit has been red).

Observations were made when the plant was 8 WAP during the fruit formation period, by observing the height of the dichotom, the number of branches, the diameter of the shoot, and root dry weight. The number of fruits, fruit weight per plant, and weight per fruit are observed at harvest. Observations were also made on plant chlorophyll content at 8 WAP, and PGPR before being given to the soil. Analysis of soil chemical properties (pH, N, P, K, C-organic) is carried out before planting.

Data were analyzed with an Analysis of Variance and then continued with the BNT test.

RESULTS OF STUDY

The interaction between PGPR and NPK fertilizer influences not significantly on the height of dichotom at 8 WAP, as well as the PGPR and NPK fertilizer treatment singly (Figure 1).

The number of branches was not affected by the interaction between PGPR and NPK fertilizers, nor was the single factor PGPR and NPK fertilizers (Figure 2).

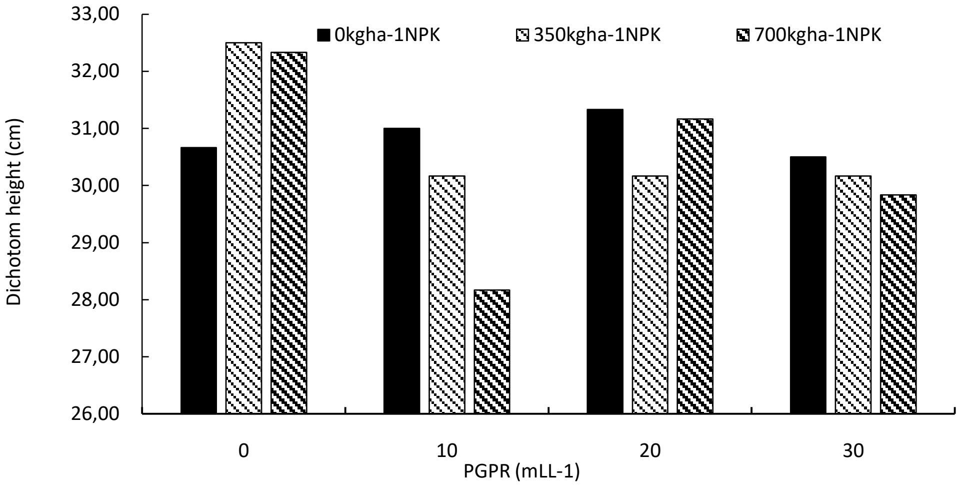

Figure 1 – Dichotom height of red chili at various PGPR concentrations and NPK fertilizer dosage at 8 WAP

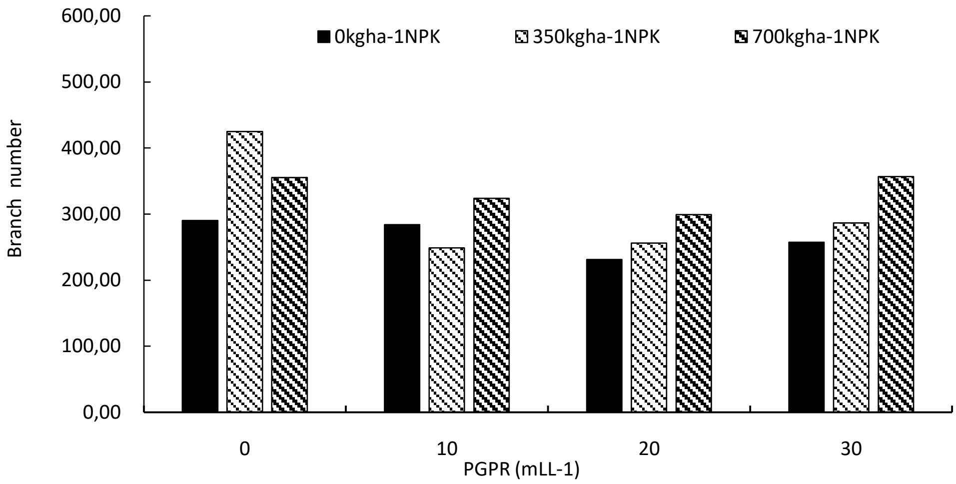

Figure 2 – Branch number of red chili at various PGPR concentration and NPK fertilizer dosage

The treatment of PGPR and NPK does not provide a significant interaction on the diameter of the red chili shoot, but various NPK doses single have a significant effect on the red chili shoot diameter (Table 1).

The dry weight of plant roots observed at 8 WAP was not affected by the interaction between PGPR and NPK fertilizers, but was affected individually by various concentrations of PGPR. The application of NPK fertilizer did not affect the root dry weight of red chili roots (Table 2).

Table 1 – Shoot diameter of red chili (cm) at various PGPR concentrations and NPK fertilizer dosage at 8 WAP

PGPR (mLL^{-1})	NPK ($kgha^{-1}$)			PGPR average
	0	350	700	
0	39,33	51,00	43,50	44,61
10	42,50	40,00	49,67	44,06
20	38,33	42,00	53,00	44,44
30	37,33	38,83	42,17	39,44
NPK average	39,38a	42,96ab	47,08b	

Note: Numbers followed by the same lowercase letter are not significantly different according to the test BNT α = 5%.

Table 2 – The root dry weight of red chili at several of PGPR concentrations and NPK fertilizer dosage at 8 WAP

PGPR (mLL^{-1})	NPK ($kgha^{-1}$)			PGPR average
	0	350	700	
0	1,50	1,42	1,63	1,52a
10	1,54	1,74	1,42	1,57b
20	1,39	1,31	1,88	1,53a
30	1,26	1,23	1,06	1,18a
NPK average	1,42	1,42	1,50	

Note: Numbers followed by the same lowercase letter are not significantly different according to the test BNT α = 5%.

The observed yield of the plants was carried out from 12 WAP to 16 WAP, to fruit ripening. The observation included the number of fruits, fruit weight, and weight per fruit. The results showed that there was no interaction between PGPR and NPK fertilizer doses on the number of red chili peppers, but the number of red chilies was significantly affected by the treatment of various PGPR concentrations (Table 3).

Table 3 – Fruit number of red chili at various PGPR concentrations and NPK fertilizer dosage

PGPR (mLL^{-1})	NPK ($kgha^{-1}$)			PGPR average
	0	350	700	
0	79,33	90,67	65,00	78,33a
10	98,33	93,67	93,33	95,11b
20	80,33	66,00	73,00	73,11a
30	70,00	76,33	84,33	76,89a
NPK average	77,00	83,33	78,92	

Note: Numbers followed by the same lowercase letter are not significantly different according to the test BNT α = 5%.

The fruit weight per plant of red chili was also not significantly affected by the interaction between PGPR and NPK fertilizer; however, the PGPR treatment had a significant effect on the fruit weight per plant of red chili (Table 4).

Table 4 – Fruit weight of red chili (g) at various PGPR concentrations and NPK fertilizer dosage

PGPR (mLL^{-1})	NPK ($kgha^{-1}$)			PGPR average
	0	350	700	
0	201,21	259,14	185,54	215,30a
10	270,59	232,69	234,70	245,99b
20	216,80	159,31	183,37	186,49a
30	169,39	180,63	249,08	199,70a
NPK average	214,50	207,94	213,17	

Note: Numbers followed by the same lowercase letter are not significantly different according to the test BNT α = 5%.

The analysis of variance showed that the weight per fruit of red chili was not affected by the interaction of PGPR and NPK, as well as PGPR and NPK fertilizer alone. The average weight per fruit of red chili is in Table 5.

The physiologist analysis is the chlorophyll content of red chili at 8 WAP. The result is in Table 6.

Table 5 – Weight per fruit of red chili (g) at various PGPR concentrations and NPK fertilizer dosage

PGPR (mLL^{-1})	NPK ($kgha^{-1}$)			PGPR average
	0	350	700	
0	2,51	2,81	2,89	2,74
10	2,72	2,50	2,51	2,58
20	2,66	2,39	2,54	2,58
30	2,42	2,33	2,94	2,56
NPK average	2,58	2,51	2,76	2,58

Note: Numbers followed by the same lowercase letter are not significantly different according to the test BNT α = 5%.

Table 6 – Chlorophyll content (Mg/L) of red chili at various PGPR concentrations and NPK fertilizer dosage at 8 WAP

PGPR (mLL^{-1})	NPK ($kgha^{-1}$)		
	0	350	700
0	31,1	72,1	48,92
10	62,84	47,04	49,82
20	48,34	37,94	47,97
30	60,98	43,73	36,11

**) Basic and Integrated Laboratory, University of Jambi (2021).*

DISCUSSION OF RESULTS

The results showed that there was no significant interaction between PGPR and NPK fertilizer on all observed growth and yield variables of red chilies, but the concentration of PGPR had a significant effect on the number of fruits and fruit weight per plant, while NPK fertilizer had an on the shoot diameter of plants aged 8 WAP.

PGPR are soil bacteria that live around or on the surface of roots, and directly or indirectly promote plant growth and development through the production and secretion of various regulatory chemicals around the rhizosphere (Nehra and Choudhary, 2015). The administration of PGPR in this study was not able to increase the height of the dichotom and the number of branches of red chilies. In addition, PGPR activity is also strongly influenced by environmental conditions, including the C and N content of the soil where the soil used contains C and N with low criteria (2.25% and 0.11%). If the C and N levels of soil organic matter are low, the available energy sources for bacterial growth and development are also low (Kamsurya and Botanri, 2022) thereby affecting their activity. However, as time went on, the PGPR bacteria grew and increased in number so that their activity increased, and in the end, they were able to stimulate plant growth by increasing the number and weight of red chili.

The increase in growth and yield of red chilies that were given PGPR was also due to the increased ability of plant roots to absorb water and nutrients from the soil. An increase in the number and mass of root tissue increases the reach of plant roots for water and nutrient uptake which allows roots to thrive in water-scarce environments (Enebe and Babalola, 2018). The results showed that the administration of PGPR was able to increase the root dry weight of red chilies, and PGPR $10mLL^{-1}$ gave a higher root dry weight compared to other concentrations (Table 2). Furthermore, Barnawal et al. (2019) explained that PGPR can change the architecture of plant roots thereby increasing the total surface area of roots which causes increased absorption of nutrients and water, which in turn has a positive effect on plant growth and health.

The results of the analysis performed showed that most of the bacteria in the PGPR used were Bacillus sp. with densities of 42^4 and 40^6 respectively (dilutions 10^{-4} and 10^{-6}). Bacillus sp is an ePGPR bacterium that can increase the availability of P and K in soil solution (Zaidi, et al., 2009; Liu et al., 2012). Bacillus sp can release soil-bound P (Al-P, Fe-P), especially soils with low pH such as Ultisol, by producing organic compounds such as lactic acid and acetic acid which can increase the release of phosphorus, and a combination of Bacillus megaterium with "fishbone" 5 mgL^{-1} is the best combination (Saeid et al., 2018). Furthermore, Mahaputra et al., (2022) stated that the application of Bacillus sp to the soil is part of a soil remediation technology that can eliminate soil contamination from heavy metals. In addition, Bacillus sp can also reduce the negative influence of microbial diversity in the soil. Soil texture, soil pH, and soil microbial concentrations play an important role in the process of increasing soil fertility, plant growth, and yields

The increase in the number and weight of fruit due to the addition of PGPR was also due to the increase in the amount of plant chlorophyll (Table 6). These results are in line with research conducted by Li et al. (2016) on Vicia faba plants, where administration of Bacillus subtilis bacteria can increase plant photosynthetic activity by increasing photosynthetic efficiency and leaf chlorophyll content. The increase in the number and weight of red chilies due to PGPR administration was also caused by the presence of growth hormones produced by PGPR bacteria. The results of this study are in line with the results of research conducted by Moustaine et al. (2017) on tomato plants. Various strains of PGPR bacteria inoculated on tomato plants were able to increase plant total chlorophyll, increase IAA production, nitrogen fixation activity, anti-microbial enzyme activity (cellulase, chitinase, and protease), as well as increase root growth and stem diameter of tomato plants.

The results showed that the application of NPK fertilizer had a significant effect on the shoot diameter of red chilies, where the highest shoot diameter was obtained at NPK of 700 kgha^{-1}. The increase in plant growth in the form of shoot diameter is due to the role of N, P, and K in plant growth, as macro-essential nutrients needed by plants. Research of Nafiu et al. (2011) and Nwokwu, et al. (2020) showed that the application of NPK fertilizer was able to increase the growth and yield of eggplant plants. NPK fertilizer application can also increase growth and yield in carrot and potato plants (Agbede et al*.,* 2017; Achiri et al., 2018).

The results of soil analysis showed that the soil P content was included in the high criteria (17.47 ppm Bray), but this high soil P content did not inhibit the growth of red chili plants, even though a high dose of NPK fertilizer was added. This is due to the slow solubility of P in the soil (Firnia, 2018). Application of NPK fertilizer also increases the availability of soil N and K. Soil N and K content is included in the low criteria (0,11% dan 0,22 ppm). K plays an important role in the process of photosynthesis by increasing plant growth and leaf area index, increasing CO_2 assimilation and photosynthetic translocation (Hasanuzzaman et al., 2018). The increase in plant growth is thought to be due to the increased K content in plant tissues. K also plays a role in regulating the opening and closing of stomata, so increasing the K content of plant tissues is very important for plants cultivated on dry land where water availability is limited. Increasing the dose of NPK to 700 kgha^{-1} increases the shoot diameter, and the pattern of increase is still linear, so to know the need for NPK which gives the maximum shoot diameter, the dose of NPK fertilizer given needs to be increased.

NPK fertilizer does not affect crop yield parameters in the form of number and fruit weight. This shows that there is no close correlation between plant growth and crop yield due to the application of NPK fertilizer. A high soil P content at the beginning of plant growth can increase its growth, but during the generative phase, the high soil P content does not have a significant effect on increasing the number and weight of fruit. This is thought to be due to the high amount of P in the soil, and the impact of competition between nutrients, especially micro-essential nutrients such as Cu and Zn, causing plants to experience a shortage of these nutrients. The results show that P uptake is negatively correlated with Zn uptake in citrus seeds of the Japanese citroen variety, Zn and P elements have an antagonistic relationship (Juliati, 2018), as well as between P and Cu (Feil et al., 2022). Therefore, the application of NPK fertilizer with a high dose of 700 kgha^{-1} is only good when used to increase the diameter of the shoot. However, the increase in shoot diameter did not affect the increase in the number and weight of red chilies.

CONCLUSION

Plant Growth Promoting Rhizobacteria (PGPR) and NPK fertilizer have not been able to increase the growth and yield of red chili grown on Ultisol dry land.

The growth of red chilies in the form of shoot diameter increased with increasing doses of NPK fertilizer given, and a dose of 700 kgha^{-1} was the dose of NPK fertilizer that produced the highest shoot diameter.

Various concentrations of PGPR increased root dry weight, number of fruits, and fruit weight of red chili, and a concentration of 10 mLL^{-1} gave the highest yield.

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