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EFFECT APPLICATION OF SELECTED BACTERIAL ISOLATE CONSORTIUM AND FERTILIZER TYPES ON THE GROWTH AND PRODUCTION OF RED CHILI PLANTS (Capsicum annum)

PENGARUH APLIKASI KONSORSIUM ISOLAT BAKTERI TERPILIH DAN JENIS PUPUK TERHADAP PERTUMBUHAN DAN PRODUKSI TANAMAN CABAI MERAH (*Capsicum annum*)

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ABSTRACT

Low production of red chili (Capsicum annuum L.) remains a major constraint in meeting market demand and is frequently attributed to suboptimal soil fertility. Enhancing soil fertility through appropriate fertilization strategies, including both chemical and organic inputs, is therefore critical to improving crop yield. In addition, microbial consortia with plant growth-promoting potential are increasingly explored as biofertilizer alternatives to support sustainable agriculture. This study investigated the effects of selected bacterial isolate consortia, types of fertilizers, and their interactions on the growth and production of red chili plants. A 4 × 3 factorial Randomized Group Design with three replications was employed. The first factor was the bacterial consortium: no consortium (K0), consortium from pineapple rhizosphere (PR) (K1), consortium from Empty Fruit Bunches (EFB) (K2), and a combination of PR + EFB (K3). The second factor was fertilizer type: chemical fertilizer (P1), sterile organonitrophos fertilizer (P2), and non-sterile organonitrophos fertilizer (P3). The results indicated that the application of bacterial isolate consortia did not significantly influence red chili growth or production. However, sterile organonitrophos fertilizer enhanced chili production, while non-sterile organonitrophos fertilizer produced the best outcomes for plant growth and soil organic-C content. No significant interaction was observed between bacterial consortia and fertilizer type for any measured parameter. These findings underscore the greater role of organic-based fertilizers, particularly non-sterile organonitrophos, in improving soil quality and crop performance, thereby offering a sustainable alternative to chemical fertilization for red chili cultivation.

ABSTRAK

Rendahnya produksi cabai merah diduga disebabkan oleh kesuburan tanah yang kurang optimal. Masalah kesuburan tanah ini dapat diatasi melalui pemupukan, baik menggunakan pupuk kimia maupun pupuk organik. Penelitian ini bertujuan untuk mengkaji pengaruh konsorsium isolat bakteri terpilih, jenis pupuk, serta interaksi antara keduanya dalam meningkatkan pertumbuhan dan produksi tanaman cabai merah. Penelitian ini menggunakan Rancangan Acak Kelompok (RAK) faktorial 4x3 dengan tiga kali pengulangan. Faktor pertama adalah jenis konsorsium isolat bakteri terpilih, yang terdiri dari: tanpa konsorsium (K0), konsorsium isolat bakteri dari rimpang nanas (K1), konsorsium TKKS (K2), dan kombinasi konsorsium RN+TKKS (K3). Faktor kedua adalah jenis pupuk, meliputi: pupuk kimia (P1), pupuk organonitrofos steril (P2), dan pupuk organonitrofos non-steril (P3). Hasil penelitian menunjukkan bahwa pemberian konsorsium isolat bakteri terpilih tidak memberikan pengaruh signifikan terhadap pertumbuhan dan produksi tanaman cabai merah. Pupuk organonitrofos steril memberikan hasil terbaik dalam meningkatkan produksi tanaman cabai merah, sedangkan pupuk organonitrofos non-steril memberikan hasil terbaik terhadap pertumbuhan tanaman dan kadar C-organik tanah. Tidak ditemukan interaksi antara aplikasi konsorsium isolat bakteri terpilih dan jenis pupuk terhadap semua variabel yang diamati.

1. INTRODUCTION

Curly red chili (*Capsicum annum*) is a plant that contains capsaicin, which gives its fruit a spicy flavor. In addition to capsaicin, this plant is rich in protein, calcium, fats, calories, vitamin A, vitamin B1, and vitamin C. Due to its distinctive spicy taste, curly red chili has become one of Indonesia's most sought-after commodities as a seasoning ingredient (Sastradihardja & Firmanto, 2011).

According to BPS data (2019), the production of red chili from 2014 to 2018 experienced a relatively small increase. In 2018, the production of red chili only rose by 0.04% compared to 2017. This insignificant increase in production raises concerns as the demand for red chili increases yearly. One of the reasons for the low production of chili is the less-than-optimal soil fertility conditions. One of the efforts that can be made to address this issue is through fertilization. Utomo et al. (2016) classified fertilizers into organic and chemical fertilizers. Each type of fertilizer has its advantages and disadvantages. Chemical fertilizers have a high nutrient content but low diversity, while organic fertilizers have high nutrient diversity but relatively low content.

The organic fertilizer used in this study is organonitrophos fertilizer. Organonitrophos fertilizer is a solid organic fertilizer produced from the composting process of various organic materials, such as cow manure, coconut husk, ash from burnt tofu, solid waste from the Monosodium Glutamate (MSG) industry, and empty fruit bunches. During the decomposition process, phosphate-solubilizing microorganisms (P) and nitrogen-fixing microorganisms (N) are added (Dermiyati, 2017). Additionally, there are biofertilizers, which are fertilizers that contain microorganisms. Biofertilizers can be in single or mixed forms, where mixed fertilizers contain more than one type of microorganism and are often referred to as microbial consortia. According to Okoh (2006), a consortium is a combination of various populations of microorganisms within a community that have mutually beneficial relationships. The associated members of this community are more effective in degrading chemical compounds than single microorganisms.

The selected bacterial isolate consortium used in this study was obtained from the suspension of pineapple rhizome extract (RN) and empty fruit bunches of oil palm (TKKS). RN and TKKS have the potential to produce phosphate-solubilizing bacteria (BPF) that can dissolve bound phosphate (P) in the soil. According to research by Dermiyati et al. (2019), four BPF isolates were found from the RN extract suspension and seven BPF isolates from the TKKS extract suspension, which can solubilize bound phosphate. The bacterial isolates from the TKKS extract suspension are also known to be hypovirulent and can function as Plant Growth Promoting Bacteria (PGPB) (Andayani, 2018).

The presence of nitrogen-fixing (N) and phosphate-solubilizing (P) microorganisms in organonitrophos fertilizer is expected to interact with the applied selected bacterial isolate consortium, thereby positively impacting the growth and production of red chili plants. The relationships among these microorganisms will not interfere with each other as long as the substrate conditions are met and may even enhance the efficiency of the decomposition process (Okoh, 2006).

Using chemical fertilizers and biofertilizers is also an interesting aspect to observe. Although chemical fertilizers cannot serve as substrates for soil microorganisms, their high nutrient content can influence their activity. Research by Lovitna et al., (2021) indicates that the application of BPF and inorganic phosphate fertilizers affects the population of BPF, the availability of P, and the dry weight of red chili plants.

This study aims to investigate the effects of the selected bacterial isolate consortium, the type of fertilizer, and the interaction between the two in enhancing the growth and production of red chili plants.

2. MATERIALS AND METHODS

2.1 Time and Place

This research was conducted at the Integrated Field Laboratory of the Faculty of Agriculture, University of Lampung. The selected bacterial isolate consortium was rejuvenated in the Biotechnology Laboratory of the Faculty of Agriculture, University of Lampung.

2.2 Research Design

This study employed a Factorial Randomized Block Design (RBBD) (4x3) with three groups for each treatment. The first factor is the type of selected bacterial isolate consortium, which consists of no consortium (K0), a consortium of bacterial isolates from pineapple rhizome (RN) (K1), consortium of bacterial isolates from empty fruit bunches of oil palm (TKKS) (K2), and consortium of bacterial isolates from the combination of RN+TKKS (K3). The second factor is the type of fertilizer, which includes chemical fertilizer NPK 15:15:15 at a dose of 0.25 tons ha^{-1} (P1), sterilized organonitrophos fertilizer at a dose of 20 tons ha^{-1} (P2), and non-sterilized organonitrophos fertilizer at a dose of 20 tons ha^{-1} (P3). Data were analyzed using analysis of variance (ANOVA) followed by Duncan's Multiple Range Test (DMRT) at a significance level of 5%.

2.3 Implementation of Research

The soil used as the planting medium was obtained from the Integrated Field Laboratory of the Faculty of Agriculture, University of Lampung (Unila). The soil was sun-dried for one week, then sieved using a sand sieve and sterilized by steam heating for 4 hours. After sterilization, 7 kg of soil (air-dry weight with 40% moisture content) was placed into polybags. The seeds used were of the Kastilo F1 variety. The chili seeds were soaked in water for 3 hours, then planted in polybags containing 100 g of soil (air-dry weight) at a depth of 1 cm. Each polybag was filled with one seed and covered with soil. The polybags containing the seeds were kept in a dark place or away from sunlight for 3 days. Once the seeds began to sprout, the polybags were moved to a location exposed to sunlight.

The selected bacterial isolate consortium was rejuvenated using Potato Peptone Glucose Agar (PPGA) media in test tubes under aseptic conditions in a Laminar Air Flow (LAF) cabinet. A selected bacterial isolate consortium was taken using a sterile inoculating loop and streaked onto slanted PPGA media. Each type of bacterial isolate consortium was multiplied into 6 test tubes, with one tube reserved for rejuvenation the following week. Seedlings four weeks old were transferred to the prepared planting medium. The planting process was carried out carefully to prevent damage to the plants. The plants were moved by lifting the soil from the seedling media, avoiding direct contact with the stems or roots of the seedlings to prevent damage. The new planting medium was slightly dug to create a space for planting the seedlings. The soil around the plants was gently pressed to compact it, and the plants were watered.

The selected bacterial isolate consortium was applied three times, specifically in the first, second, and third weeks after planting. The bacterial isolate consortiums were prepared by harvesting the bacterial isolates using an inoculating loop. Then, they are placed into 10 ml of physiological solution and homogenized using a vortex mixer. This process was repeated until 90 ml of suspension solution was obtained for each isolate type. The suspension solution was then added to 2,150 ml of physiological solution, resulting in a total volume of 2,250 ml. For the mixed bacterial isolate consortium, 60 ml of suspension solution from both RN and TKKS isolates were combined, yielding 120 ml of suspension solution. This suspension was added to 2,130 ml of physiological solution, resulting in 2,250 ml of mixed bacterial isolate suspension.

Some of the organonitrophos fertilizer was sterilized by steam heating for 4 hours. The application of organonitrophos fertilizer was conducted one day before planting at a dose of 20 tons ha^{-1}. Chemical fertilization (NPK 15:15:15) was performed twice: two weeks after planting with a dose of 0.05 tons ha^{-1} and eight weeks after planting with a dose of 0.2 tons ha^{-1}.

Plant care was performed daily, including watering, weeding, and pest and disease control. Watering was done every afternoon. Harvesting was conducted 95-100 days after planting (HST) by carefully picking the fruit from the stem to avoid breaking branches or twigs. The criteria for harvesting include intact, firm, and shiny dark red fruits. The soil analysis conducted in this study includes measurements of organic carbon content, total nitrogen, available phosphorus, and soil pH.

3. RESULTS AND DISCUSSION

The results of the study indicate that the application of selected bacterial isolate consortia from RN (K1), TKKS (K2), and the combination of RN+TKKS (K3) did not have a significant effect on all observed variables. Additionally, no interaction was found between the application of selected bacterial isolate consortia and the type of fertilizer.

Factors suspected to contribute to the ineffectiveness of the bacterial isolate consortia include the application dose and environmental conditions. According to the Decree of the Minister of Agriculture No. 261/KPTS/SR.310/M/4/2019 (Ministry of Agriculture, 2019), one genus in the bacterial consortium must have a minimum live cell count of ≥1x10^{7} cfu g^{-1}, while other genera must have a minimum of ≥1x10^{5} cfu g^{-1}. However, each genus was unknown in the applied bacterial isolate consortia, causing the consortium to fail to develop properly due to insufficient numbers and competition with other soil microorganisms.

Based on the DMRT test at a 5% significance level, treatments P2 (sterilized organonitrophos fertilizer) and P3 (non-sterilized organonitrophos fertilizer) showed the best results in terms of growth variables (Table 1), production (Table 2), and soil organic carbon content (Table 3). Meanwhile, treatment P1 (chemical fertilizer) did not yield the best results in all observed variables. This is suspected because chemical fertilizers only improve soil chemical properties. In contrast, in the short term, using chemical fertilizers shows low bacterial growth and basal respiration rates (Lazcano et al., 2013). Bacteria are known to be the most sensitive microorganisms to differences in fertilizers due to their shorter life cycle and ability to respond quickly to changes in soil environment (Kuzyakov, 2010).

Research by Septima et al., (2014) showed that applying chemical fertilizers at the recommended dose did not result in significant differences compared to applying organonitrophos fertilizer at 5,000 kg ha^{-1} in terms of plant growth. In this study, the dose of organonitrophos fertilizer applied was higher, at 20,000 kg ha^{-1}, resulting in better performance of plants treated with organonitrophos fertilizer than those treated with chemical fertilizer (P1) at the recommended dose.

Table 1. Effects of Fertilizer Type on the Growth of Red Chili Plants.

Treatment	PH (cm)	NL (helai tan^{-1})	PWW (g tan^{-1})	PDW (g tan^{-1})	WRW (g tan^{-1})
Chemical Fertilizer (P1)	58.2 a	51 a	33.5 a	10.8 a	8.63 a
Sterillised Organonitrofos (P2)	94.8 b	141 b	73.8 b	22.9 b	10.67 b
Organonitrofos Fertilizer (P3)	99.5 b	148 c	83.5 c	21.2 b	13.28 b

Note: PH= Plant Height; NL= Number of Leaves; PWW= Plant Wet Weight; PDW= Plant Dry Weight; WWR= Wet Root Weight.

Table 2. Effect of Fertilizer Type on Red Chili Plant Production.

Treatment	FWW (kg ha^{-1})	FDW (kg ha^{-1})	FL (cm)
Chemical Fertilizer (P1)	73.1 a	14.0 a	11.11 a
Sterillized Organonitrofos (P2)	302.4 c	55.3 c	13.00 b
Organonitrofos Fertilizer (P3)	159.9 b	28.5 b	12.22 b

Note: FWW= Fruit Wet Weight; FDW= Fruit Dry Weight; FL= Fruit Length.

Table 3. Effect of Fertilizer Type on Soil Organic C.

Treatment	Organic C (%)
Chemical Fertilizer (P_1)	1.11 a
Sterillized Organonitrofos Fertilizer (P_2)	1.24 a
Organonitrofos Fertilizer (P3)	1.36 b

Note: Mean values followed by the same letter are not significantly different based on the 5% DMRT test.

Table 4. Correlation between Soil Chemical Variables and Yields of Red Chilli Plants Variables.

Variable	Coeficient Correlation (r) and Significancy					
	PH	WRW	DRW	PWW	PDW	FD
P-available	-0.004ns	0.620*	0.535 ns	0.028 ns	0.304 ns	-0.262 ns
N-total	0.553 ns	0.582*	0.594*	0.641*	0.626*	-0.041 ns
C-organic	-0.092 ns	-0.031 ns	0.085 ns	-0.082 ns	-0.254 ns	0.588*
pH	0.98*	0.254 ns	0.352 ns	0.508 ns	0.284 ns	0.522 ns

Note: *= Significant at 5% level; ns= not siginificance at 5% level; PH= Plant Height 6 WAP; WRW= Wet Root weight; DRW= Dry Root Weight; PWW= Plant Wet Weight; PDW= Plant Dry Weight; FD= Fruit Diameter.

The sterilization process applied to sterilized organonitrophos fertilizer is suspected to be the factor causing higher production of red chili plants compared to treatments with non-sterilized organonitrophos fertilizer and chemical fertilizer. This sterilization affects the life cycle of microorganisms. According to Maier (2009), the life cycle of microorganisms is divided into four phases: the lag phase, the log phase (exponential phase), the stationary phase, and the death phase. It is suspected that there is a difference in the growth rate of bacteria between treatments P2 and P3, where in treatment P3, the exponential phase of microorganisms occurs faster, as reflected in the higher plant growth variables observed in P3.

At this growth stage, microorganisms in treatment P2 are suspected to still be in the lag phase. However, when the plants enter the generative stage, microorganisms in treatment P2 begin to enter the exponential phase, resulting in higher observed values during the generative stage. The fruits produced from treatment P2 also showed greater length than those from treatments P1 and P3. This is supported by the results of soil organic carbon content observations at the end of the study, which showed that the organic carbon content in treatment P2 was lower than in P3, as microorganisms in P2 require more carbon as a substrate. Meanwhile, the soil organic carbon content in treatment P1 was relatively low due to the absence of organic matter added to the soil.

The correlation test results between soil chemical properties and the growth and production of red chili plants showed that soil chemical properties correlate with several growth and production variables (Table 4). The available phosphorus (P) content in the soil was found to have a positive correlation with root fresh weight. This is due to the positive influence of phosphorus on root morphology, which generally stimulates root growth (Williamson et al., 2001). Additionally, phosphorus also affects the diameter of the root collar (Hudai et al., 2007).

The total nitrogen (N) content in the soil has a positive correlation with fresh and dry root weight and fresh and dry shoot weight. Nitrogen plays a crucial role in plant metabolism, as all essential processes in plants are related to proteins, of which nitrogen is a key component (Leghari *et al*., 2016). Nitrogen contributes to enhancing growth during the early stages of plant development, improving fruit quality, increasing leaf number, boosting protein content, and promoting the absorption and utilization of other nutrients such as potassium (K) and phosphorus (P) (Bloom, 2015). Nitrogen also stimulates the formation of photosynthetic pigments (chlorophyll) by increasing the number of stroma and thylakoids in leaves (Filho et al., 2011).

The organic carbon content in the soil has a positive correlation with the diameter of red chili fruits. The ability of the soil to provide nitrogen (N) is greatly influenced by the condition and amount of organic matter in the soil (Cookson et al., 2002). It is known that the organic carbon content in the soil affects the mobilization of N within the soil (de Graaff et al., 2010). Soil microorganisms require N to synthesize proteins, nucleic acids, and other cellular components (Geisseler et al., 2010). The quality of organic carbon can also influence the mobility of N in the soil (Cao, 2021). This is consistent with the findings of Gentile et al. (2008), Cheng et al. (2017), and Mehnaz et al. (2019), which report that the quality of organic matter controls N immobilization. The ability of organic matter to reduce N mobility is considered to impact the growth and production of plants, as the plants can utilize the immobilized N.

The soil pH positively correlates with the height of red chili plants. Research by Lubis et al. (2015) indicates that soil pH affects the number and weight of root nodules at the end of the vegetative phase and N absorption. Nitrogen stimulates plant growth, particularly in stems, branches, and leaves (Rusmana & Salim, 2003).

A significant difference in available phosphorus (P) content was found in the soil after harvest compared to the conditions before planting. The available P content in the soil after harvest was classified as high to very high, which is markedly different from the low available P content before planting. This may be due to the addition of organonitrophos fertilizer, which has a very high P content of 0.31% or equivalent to 3,100 ppm (Deviana et al., 2014). Additionally, the application of organic matter to acidic soils can enhance P absorption and corn yield, as the decomposition of organic matter produces nutrients such as N, P, and K, as well as humic and fulvic acids that play a crucial role in binding soluble Fe and Al in the soil, thereby increasing P availability (Hasanudin, 2003).

4. CONCLUSION

The application of selected bacterial isolate consortia did not significantly affect the growth and production of red chili plants, nor did it affect the soil's chemical properties. Sterilized organonitrophos fertilizer (P2) can increase the production of red chili plants compared to chemical fertilizer (P1) and non-sterilized organonitrophos fertilizer (P3). Meanwhile, non-sterilized organonitrophos fertilizer (P3) has been shown to enhance the growth of red chili plants and the organic carbon content in the soil better than chemical fertilizer (P1) and sterilized organonitrophos fertilizer (P2). No interaction was found between the selected bacterial isolate consortium and the type of fertilizer across all observed variables regarding the growth and production of red chili and the soil's chemical properties.

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