



## Effects of Different Bioactivator Rates on Growth, Yield and Soil Properties of Two Rice Varieties in Indonesia

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### ABSTRACT

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The progressive decrease in rice production in Indonesia is associated with soil infertility, resulting in inhibited plant growth. This study investigated the impact of bioactivators on soil properties and the growth and yield of two rice (*Oryza sativa* L.) varieties, namely Inpari 32 and IR 64. A factorial nesting design was implemented, taking into account two primary factors: the dose of bioactivator (ranging from 10-30 ml/l, applied pre- or post-plowing) and the rice variety. Two control conditions, namely inorganic and organic fertilizers, were also included. The results demonstrated that both the rice variety and bioactivator application significantly influenced various plant and soil parameters, such as plant height, clump diameter, number of tillers per clump, root length, plant fresh and dry weight, yield, and soil properties. While the control treatments of inorganic and organic fertilizers yielded superior results in terms of clump diameter and number of tillers, bioactivator application resulted in longer roots and higher biomass across both rice varieties. Notably, the application of a 10 ml dose of bioactivator prior to plowing, specifically on the Inpari 32 variety, was found to improve plant dry weight and fresh weight more effectively than the control and other treatments. Moreover, post-plowing application of a 20 ml/l bioactivator concentration increased soil water content, the potential of C-organic, and P<sub>2</sub>O<sub>5</sub>. These findings suggest that bioactivator application could be an effective strategy for enhancing soil fertility and rice crop productivity, thereby addressing the ongoing decrease in rice production in Indonesia.

## 1. INTRODUCTION

Rice is a staple food for 97% of Indonesia's population, thereby playing an integral role in the country's food security. If the increase in national rice demand is not balanced with sufficient rice production, it is feared that the rice supply for the community will not be fulfilled. Despite the country's agricultural land spanning 7.75 million hectares in 2017, a steady decrease has been noted, with the figure plummeting to 7.1 million hectares in subsequent years. Concurrently, the total rice production in 2020 was recorded at approximately 54.65 million tons, reflecting a marginal increase of 45.17 thousand tons (0.08 percent) compared to the previous year. Although a modest annual increase in crop productivity was observed, the yield of 5.2 tons/ha is still considered low.

Rice cultivation plays a pivotal role in fulfilling food demands in Indonesia. In the pursuit of enhancing productivity and rice yields, the utilization of bioactivators has become a focal point of research. Bioactivators are substances that influence plant growth and soil properties through beneficial microbial activities. However, specific research addressing the effects of varying bioactivator application rates on the growth, harvest yields, and soil properties of two rice varieties in Indonesia remains limited.

Farmers grapple with challenges beyond the selection of superior rice varieties, encompassing soil fertility issues and pest invasions. The common recourse to these predicaments has been the use of chemical fertilizers and pesticides, which, while boosting production and curbing pest attacks, can, in the long term, detrimentally affect soil fertility both physically and chemically, and also biologically [1, 2]. Additionally, plant resistance remains insufficient as the nutrient supply predominantly consists of macro minerals, whereas plants require micro minerals for secondary metabolism, necessary for the production of active compounds that shield plants from pests and diseases.

In light of these challenges, biofertilizers have emerged as a potential solution to enhance rice productivity [3-8]. Bioactivators, a type of biofertilizer, have been found to improve soil quality and promote plant growth and yield through mechanisms such as nutrient release, phytohormone production, and alleviation of biotic and abiotic stress [9]. These bioactivators harbor active ingredients including lignolytic, cellulosic, phosphate and potassium solvents, phytate decomposers, tannins, and lignins, as well as decomposers of organochlorine, organophosphate and carbamate pesticides. Many bacteria can coexist and establish mutualistic relationships that benefit both the soil and plant

[10-14]. Thus, the utilization of complex-based biological fertilizers is anticipated to enhance soil quality and stimulate rice growth [15]. In this study, two popular rice varieties in Indonesia, Inpari 32 and IR 64, were chosen.

Despite existing studies on the application of bioactivators in agriculture, a knowledge gap persists concerning the effects of different bioactivator application rates on the growth, yield, and soil properties of specific rice varieties, especially within the Indonesian agricultural context. In addition, there is limited research explicitly examining the implications of bioactivator treatments on the physical, chemical, and biological attributes of soil in relation to rice cultivation.

In response to the increasing food demand and the necessity of maximizing agricultural productivity, this study aims to bridge the aforementioned knowledge gaps. Through the exploration of the impacts of varying bioactivator dosages on the growth and quality of two rice varieties (*Oryza sativa* L.) harvests, and their effects on soil quality, this research seeks to provide a more comprehensive understanding of the interplay between bioactivators and soil, and how this can shape an optimal environment for rice cultivation. By offering novel insights into efforts aimed at boosting agricultural productivity and environmental sustainability in Indonesia, this study can provide practical guidance to farmers in selecting optimal bioactivator dosages to enhance rice growth and yields, while concurrently preserving soil health and fertility.

## 2. MATERIALS AND METHOD

This experiment was conducted in Sumberpucung, Malang, East Java, Indonesia. The bioactivator used in this study was commercialized bioactivator namely Mobilin (produced by CV. Agro Gemilang, Indonesia) which contains bacteria consortium (10 cfu) categorized as lignolytic, cellulolytic, nutrients (phosphorus and potassium) solubilizing bacteria, and pesticide (organochlorin, organophosphate, and carbamate) solubilizing bacteria; macro- and micro-nutrients; and active compound such as terpenoid and alkaloid.

### 2.1 Experimental design

This research was carried out using a nested factorial design with two factors, i.e., bioactivator application dose and rice variety. The first factor was application of several bioactivator dose which applied two weeks before plowing (BP) or two days after plowing (AP) and two controls, i.e., inorganic fertilizer (IF/P7) (Urea, SP 36, and KCl with dose of 45 kg N/ha, 72 kg P<sub>2</sub>O<sub>5</sub>/ha, and 45 kg K<sub>2</sub>O/ha) and organic fertilizer (OF/P8) (manure with dose of 20 kg/ha). There were three bioactivator dose, i.e., 10, 20, and 30 ml/l (equal to 2.8 l/ha, 5.6 l/ha, and 8.4 l/ha, respectively). The treatments were namely P1 and P2 with dose of 10 ml/l, P3 and P4 with dose of 20 ml/l, and P5 and P6 with dose of 30 ml/l which was applied before (P2, P4, and P6) or after (P1, P3, and P5) plowing. The second factor was two local rice varieties namely Inpari 32 and IR 64. So, the treatment combination was 16 and repeated 4 times.

### 2.2 Observed variables

The observed variables consisted of soil chemical properties (determined before (Table 1) and after treatments), growth and

yield components of rice. The chemical soil properties included pH, soil organic carbon (%), total nitrogen (%), P<sub>2</sub>O<sub>5</sub> (mg/100 g), and K<sub>2</sub>O (mg/100 g). The growth variables observed were plant height, clump diameter, number of tillers per clump, root length, plant fresh weight and plant dry weight (biomass). The yield and its related component of paddy variables were potential yield (ton/ha; multiply the weight grain harvest per clump by expected clump number, e.g., 88), yield (ton/ha; actual yield of grain harvest), number of grains per panicle, number of filled grains, number of empty grains, filled grains (%), empty grains (%), and length of panicle (cm).

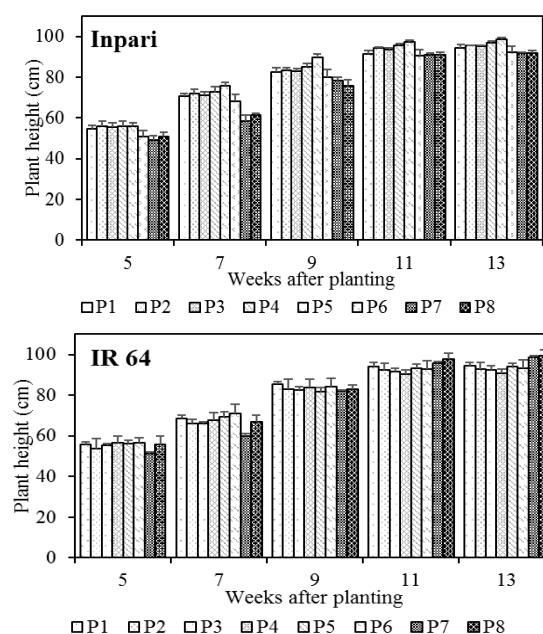
**Table 1.** Soil chemical properties before treatments

Soil Chemical Properties	Analysis Method	Value ± SD
pH	H <sub>2</sub> O (1:5)	6.74±0.23
	KCl (1:5)	5.29±0.21
	Electrometry (pH Meter)	
Organic C (%)	Walkley & Black; Spectrophotometer	3.10±0.19
Total N (%)	Kjeldahl; Titrimetric	0.35±0.03
P <sub>2</sub> O <sub>5</sub> (mg/100 g)	HCl 25%; Spectrophotometer	47.88±9.06
K <sub>2</sub> O (mg/100 g)	HCl 25%; Spectrophotometer	87.38±9.64

### 2.3 Data analysis

Data analysis used analysis of variance (ANOVA), if it had a significant effect, it was continued with the further test of HSD (Tukey) with a level of 5% to compare the effect of each treatment. The software used to start from entering raw data and processing raw data is Microsoft Excel.

## 3. RESULTS AND DISCUSSION



**Figure 1.** Plant height of two rice varieties under different bioactivator treatment

The Inpari 32 variety with a dose of 30 ml/l of bioactivator after plowing showed the best response to plant height (Figure 1), although at weeks 10 to 13 the treatment of the IR 64 control variety of manure showed the highest response to plant

height, but it was still not significantly different from the response given by the variety. Inpari 32 dose of 30 ml/l after plowing.

The response of the clump diameter of inpari 32 and IR 64 varieties was influenced by the high number of tillers in the control treatment of manure (OF/P8), so that the diameter of the clump was also high (Table 2 and Table 3). The application of organic fertilizer made from chicken manure had a good effect on the number of tillers per clump in the treatment of manure, the content of chicken manure which contains potassium and phosphate nutrients is quite high. Nutrient K

has an important role in the process of opening and closing stomata in plants, so that the process of entering and leaving carbon dioxide is also affected, with the entry of carbon dioxide smoothly, it is able to launch the photosynthesis process. affects the process of energy absorption from sunlight which functions in the photosynthesis process, due to the smooth process of photosynthesis, the energy produced also becomes a lot and helps plants to do cell division for the process of forming new tillers [16]. It can also be seen in the results of soil analysis that there was an increase in P<sub>2</sub>O<sub>5</sub> in the P8 treatment.

**Table 2.** Clump diameter of two paddy varieties under different fertilizer treatment

Treatment	5 WAP	7 WAP	9 WAP	11 WAP	13 WAP
<b>Inpari 32</b>					
10 AP	26.83 a	57.69 cd	56.93 de	53.68 b	51.04 ab
10 BP	27.58 a	59.70 cd	54.10 abcd	52.00 ab	49.46 ab
20 AP	29.50 a	60.92 d	56.64 cde	54.38 b	51.80 ab
20 BP	27.79 a	59.40 cd	55.45 bcde	54.08 b	51.28 ab
30 AP	30.92 a	58.45 cd	55.98 bcde	54.36 b	51.11 ab
30 BP	24.08 a	52.23 abcd	51.37 abc	52.63 ab	50.43 ab
IF	38.31 b	48.40 ab	49.82 a	50.88 ab	50.88 ab
OF	39.20 bc	48.23 a	50.51 ab	50.95 ab	52.00 ab
<b>IR 64</b>					
10 AP	42.95 bcde	56.99 abcd	53.15 abcd	54.50 b	54.50 b
10 BP	41.13 bcd	53.83 abcd	52.42 abcd	52.77 ab	52.77 ab
20 AP	45.87 cde	52.69 abcd	53.09 abcd	46.73 a	46.73 a
20 BP	47.18 de	59.49 cd	53.80 abcd	49.65 ab	49.65 ab
30 AP	46.52 cde	58.20 cd	57.43 de	51.77 ab	51.77 ab
30 BP	45.23 bcde	57.63 bcd	55.82 bcde	51.59 ab	51.59 ab
IF	44.53 bcde	51.02 abc	56.41 cde	64.46 c	67.13 c
OF	48.59 e	54.83 abcd	60.37 e	69.37 c	72.21 c
HSD $\alpha$ 5%	7.36	9.28	5.51	6.86	6.78

Note: Numbers followed by the same letter in the same column and treatment are not significantly different based on the HSD test at 5% level, WAP = week after planting. AP: after plowing, BP: before plowing, IF: inorganic fertilizer, OF: organic fertilizer.

**Table 3.** Number of tillers per clump of two rice varieties under different fertilizer treatment

Treatment	5 WAP	7 WAP	9 WAP	11 WAP	13 WAP
<b>Inpari 32</b>					
10 AP	28.29 ab	45.88 cdef	47.83 def	44.58 c	41.04 ef
10 BP	29.54 ab	48.42 f	44.92 cde	41.50 c	38.33 bcdef
20 AP	30.50 ab	47.38 ef	47.08 def	43.42 c	40.13 def
20 BP	28.96 ab	46.75 def	45.08 cde	42.25 c	39.25 cdef
30 AP	30.79 ab	46.13 cdef	43.88 cd	40.67 bc	37.58 bcdef
30 BP	23.13 a	39.46 abcd	43.38 cd	39.83 bc	37.42 bcde
IF	45.54 d	49.54 f	51.04 ef	51.58 d	51.71 g
OF	47.67 d	50.50 f	52.13 f	52.00 d	52.00 g
<b>IR 64</b>					
10 AP	32.41 b	35.71 ab	32.27 a	32.27 a	32.27 ab
10 BP	32.46 b	32.29 a	30.88 a	30.88 a	30.88 a
20 AP	32.83 b	34.54 ab	32.50 a	32.50 a	32.50 ab
20 BP	31.92 b	38.33 abc	34.46 ab	34.46 ab	34.46 abcd
30 AP	32.33 b	37.21 ab	33.08 a	33.08 a	33.08 abc
30 BP	29.50 ab	35.50 ab	30.83 a	30.83 a	30.83 a
IF	33.71 bc	40.46 bcde	39.92 bc	39.92 bc	39.92 def
OF	41.46 cd	47.54 ef	44.00 cd	44.00 c	44.00 f
HSD $\alpha$ 5%	7.92	7.87	6.69	6.67	6.48

Note: Numbers followed by the same letter in the same column and treatment are not significantly different based on the HSD test at 5% level, WAP = week after planting. AP: after plowing, BP: before plowing, IF: inorganic fertilizer, OF: organic fertilizer.

According to the study [17], the bigger biomass or canopy above ground, the higher photosynthate produce will be and so do yield components. The number of panicles per clump can be determined based on the vegetative phase. During the

vegetative period, if the number of tillers in a clump excess the optimum value, it will negatively correlate with productive tillers. This is caused by soil fertility factors that affect the number of productive tillers, and have an impact on the

photosynthesis process in which affect the number of tillers per clump in rice plants.

Application of bioactivator at a dose of 20 ml/l before plowing in both varieties showed the highest effect on the response of root length, plant wet weight and plant dry weight (Table 4). The addition of a dose of more than 20 ml/l tends to cause a decrease in root length, wet weight and dry weight of the plant. This can be due to the available nutrients are very readily available. The dose of 20 ml/l is thought to be the optimum point for giving the dose of bioactivator. In line with the previos research, the dose of biological fertilizers at 20 g/plot on all types of organic fertilizers showed the best results on the wet weight of the canopy, but tended to decrease when the dose of biological fertilizers was increased to 30 g/plot. Root length, wet weight and dry weight of plants are strongly influenced by the elements of N, P and K and water content. There is an increase in biomass because at that concentration plants absorb more water and nutrients, nutrients stimulate the development of organs in plants such as roots, so that plants can absorb more nutrients and water, then photosynthetic activity will increase and affect the increase in wet weight and dry weight of plants.

**Table 4.** Root length, biomass fresh weight, and biomass dry weight of two paddy varieties under different fertilizer treatment at the end of observation

Treatment	Root Length (cm)	Fresh Weight of Biomass (g)	Dry Weight of Biomass (g)
<b>Inpari 32</b>			
10 AP	23.06	268.75	61.33
10 BP	23.73	255.00	61.25
20 AP	22.46	272.09	72.59
20 BP	21.49	281.67	74.59
30 AP	19.01	234.17	61.08
30 BP	18.04	241.25	62.34
IF	20.67	214.17	30.84
OF	22.00	208.34	29.33
<b>IR 64</b>			
10 AP	18.56	290.83	70.70
10 BP	20.54	205.42	59.30
20 AP	21.20	247.08	66.75
20 BP	19.68	325.42	72.50
30 AP	18.67	302.08	66.50
30 BP	19.38	254.17	67.17
IF	20.42	265.00	34.58
OF	19.75	248.75	25.00
HSD $\alpha$ 5%	4.91	90.18	16.75

Note: Numbers followed by the same letter in the same column and treatment are not significantly different based on the HSD test at 5% level, WAP = week after planting, AP: after plowing, BP: before plowing, IF: inorganic fertilizer, OF: organic fertilizer.

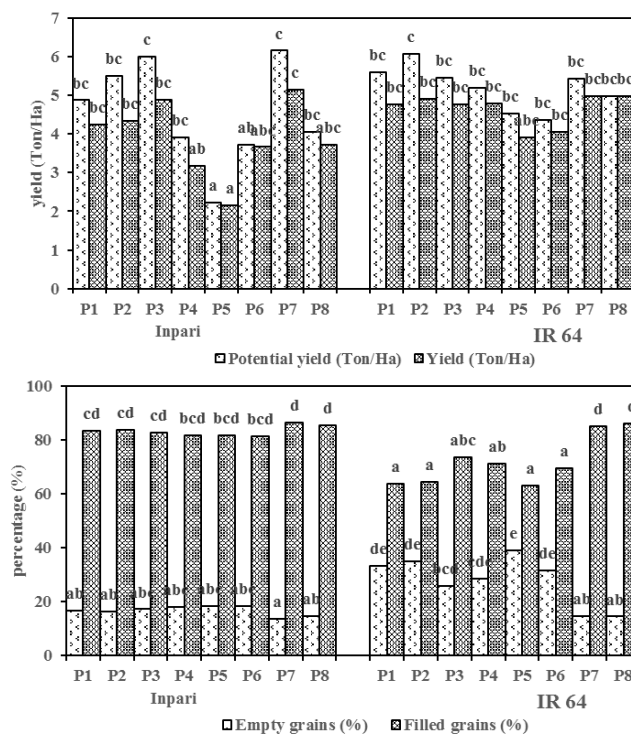
The application of NPK fertilizer which is easily absorbed by plants has an effect on the generative phase of plants (Table 5 and Figure 2), on average the NPK control treatment was able to give better results than other treatments, because the nutrients N, P, and K provided were able to support plants in the generative phase. Nitrogen fertilizer is one of the most important factors that influence rice grain quality [18-25]. Furthermore, sufficient nitrogen rate remarkably increased grain yield and quality [26]. Beside nitrogen, phosphorus has important role as energy storage and transfer within plant [27]. Phosphate has a function in transporting energy from the results of plant metabolism, stimulating root growth, flowering, seed formation and cell division; Potassium has a function in the photosynthesis process, transporting products

from assimilation, water, minerals and enzymes, able to increase plant immunity to disease, and Nitrogen has a function in stimulating growth in plants to synthesize amino acids and proteins in plants [19, 28-31].

**Table 5.** Yield components of two paddy varieties under different fertilizer treatment

Treatment	Length of Panicle (cm)	Number of Grains per Panicle	Number of Filled Grains	Number of Empty Grains
<b>Inpari 32</b>				
10 AP	20.31 a	131.56 abc	109.67 cdef	21.89 a
10 BP	20.84 ab	136.83 abc	114.64 def	22.19 a
20 AP	20.48 a	136.53 abc	113.17 def	23.36 a
20 BP	21.15 ab	129.53 abc	105.86 bcdef	23.67 a
30 AP	20.89 ab	115.64 a	94.44 abcd	21.20 a
30 BP	21.11 ab	127.22 abc	103.39 abcde	23.83 a
IF	22.56 bcd	143.00 bc	123.47 ef	19.53 a
OF	20.25 a	130.75 abc	111.67 cdef	19.08 a
<b>IR 64</b>				
10 AP	24.56 d	130.17 abc	86.67 ab	43.50 bc
10 BP	24.28 d	126.67 abc	81.67 a	45.00 bc
20 AP	24.39 d	125.08 ab	93.25 abcd	31.83 ab
20 BP	23.32 cd	145.25 bc	102.83 abcde	42.42 bc
30 AP	24.24 cd	145.92 bc	89.33 abc	56.42 c
30 BP	23.80 cd	144.17 bc	99.33 abcd	44.83 bc
IF	23.37 cd	149.33 c	127.42 f	21.92 a
OF	22.22 abc	129.00 abc	110.42 cdef	18.58 a
HSD $\alpha$ 5%	2.01	23.49	22.91	15.99

Note: Numbers followed by the same letter in the same column and treatment are not significantly different based on the HSD test at 5% level, WAP = week after planting, AP: after plowing, BP: before plowing, IF: inorganic fertilizer, OF: organic fertilizer.



**Figure 2.** Yield variables of two paddy varieties under different fertilizer treatment

The results of soil analysis showed an increase in  $P_2O_5$  in the NPK control treatment so that during the ripening phase the rice got sufficient nutrients and the percentage of grain

containing it became high. It will affect the yield components. The correlation between yield components of rice is widely studied [32, 33]. It was reported that several yield components of rice have significant correlation and can be used as selection criteria for improving grain yield [34]. Panicle length has an effect on the number of grains per panicle, the number of filled grains, and the percentage of filled grains. An increase in panicle length is able to support an increase in the number of grains, because the longer a panicle is, the biomass in the plant increases, which in turn will increase the number of filled grains per panicle. The high yield of grain containing per panicle affects the dry grain weight. The growth of the number of panicles on rice plants will affect the yield of dry grain

production at different densities. This is in line with the statement of study [19] which said that the greater the weight of the dry grain harvested, the higher the productivity.

The results of soil analysis (Table 6) showed that the bioactivator treatment on average was able to increase the C-Organic number in the soil and was able to maintain soil pH in a near neutral condition. The synthesized soil microbes were able to attach soil grains into soil aggregates. The roles of organic matter in soil fertility are (1) mineralized organic matter which will release the nutrients needed by plants completely, but in relatively small amounts, (2) increase the ability of the soil to hold water so that it can provide more water (3) the life of microorganisms the soil becomes better.

**Table 6.** Soil chemical properties under different fertilizer treatment

Treatment	pH <sub>H<sub>2</sub>O</sub>	pH <sub>KCl</sub>	Organic C	Total N	P <sub>2</sub> O <sub>5</sub>	K <sub>2</sub> O
Inorganic fertilizer	6.50	5.10	2.84 <sup>a</sup>	0.32 <sup>a</sup>	58.25 <sup>b</sup>	82.25 <sup>c</sup>
Organic fertilizer	6.60	4.90	3.20 <sup>a</sup>	0.34 <sup>a</sup>	63.25 <sup>c</sup>	85.50 <sup>c</sup>
P1	7.00	5.68	3.40 <sup>b*</sup>	0.36 <sup>a</sup>	67.00 <sup>c</sup>	70.00 <sup>c</sup>
P2	6.98	5.58	3.40 <sup>b</sup>	0.35 <sup>a</sup>	53.75 <sup>b</sup>	67.75 <sup>c</sup>
P3	7.05	5.60	3.37 <sup>b*</sup>	0.48 <sup>a</sup>	56.50 <sup>b</sup>	84.00 <sup>c</sup>
P4	7.00	5.80*	3.30 <sup>b</sup>	0.25 <sup>a</sup>	46.75 <sup>b</sup>	85.25 <sup>c</sup>
P5	6.65	5.53	3.32 <sup>b</sup>	0.36 <sup>a</sup>	112.25 <sup>c</sup>	102.50 <sup>c</sup>
P6	6.48	5.33	2.97 <sup>a</sup>	0.33 <sup>a</sup>	68.75 <sup>c</sup>	100.50 <sup>c</sup>

Notes: P1 (10 ml/l, after plowing); P2 (10 ml/l, before plowing); P3 (20 ml/l, after plowing); P4 (20 ml/l, before plowing); P5 (30 ml/l, after plowing); P6 (30 ml/l, before plowing). \* Significantly different based on before-after analysis (paired t-test  $\alpha$  5%).

The results of soil N-Total analysis in plot P4 decreased from high to medium. There are several factors that affect the uptake of N and P in plants, namely the time of application in the rainy season which can affect the availability of N and P in plants. This is what causes even though at a dose of 20 ml before plowing the number of filled grains per panicle is high, the percentage of empty grain is also high so that the yield is low. Plant growth at a dose of 30 ml after and before plowing went well, but during the generative phase, plots P5 and P6 were still waterlogged so that plant growth was hampered. Flooded rice fields have anaerobic conditions so that nutrients in the soil cannot be absorbed optimally.

The results of the soil analysis showed that the 30 ml dose plots after and before the plow, the available K<sub>2</sub>O tended to be more than the others, this was because the land in waterlogged conditions was able to increase the availability of K<sub>exchangable</sub> because in flooded land the redox potential of the soil decreased, so the solubility of Fe<sup>2+</sup> and Mn<sup>2+</sup> increase, these cations can replace the adsorbed K so that K is released into the soil solution.

#### 4. CONCLUSION

Varieties and application of bioactivator significantly affected plant height, clump diameter, number of tillers per clump, root length, wet and dry weight of plants, yield and soil properties. The control treatment of inorganic and organic fertilizer showed better performance on clump diameter and number of tillers but application of bioactivator produced longer root and higher biomass on both rice varieties. The application of 10 ml dose of bioactivator before plowing on the Inpari 32 variety was able to affect the dry weight and fresh weight of the plant better than the control and other treatments. Application of bioactivator with a concentration of 20 ml/l

after plowing was able to increase soil water content, C-organic and P<sub>2</sub>O<sub>5</sub> potential also maintain the soil reaction near to netral than control.

In an effort to enhance the efficiency and sustainability of rice production, several recommendations and areas of research need to be considered. Firstly, further research is necessary regarding the optimal dosage and timing of bioactivator application for various rice varieties in order to maximize growth and harvest yields. Additionally, evaluating the long-term effects of bioactivator application on soil health is crucial for understanding its impact on soil structure, soil microbial biodiversity, and agricultural productivity over an extended period.

Economic aspects should also be taken into account through comprehensive analyses, including application costs and the potential for increased yields resulting from bioactivator use. Further studies on the interaction of bioactivators with other agricultural inputs, such as pesticides or chemical fertilizers, will provide insights into the best ways to optimize their combined use. Continued development of more effective and environmentally friendly bioactivator formulas is also essential, with a focus on enhancing efficiency and positive environmental impact. Through research and the implementation of these recommendations, it is hoped that agriculture can become more sustainable, yielding improved harvests, while safeguarding soil health and fertility for the future.

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