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Research Paper

BIOFERTILIZER UTILIZATION IN INCREASING INORGANIC FERTILIZER EFFICIENCY AND RICE YIELD AT C-TYPE FLOODING LAND OF TANJUNG LAGO TIDAL LOWLAND

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The effort to increase national food production was conducted through application of production technology such as the use of organic fertilizer enriched with several bacteria types (known as biofertilizer). This fertilizer can restore or regain land fertility through activities of beneficial bacteria. Some of microbe types that are used to make biofertilizer were Azospirillum bacterium and phosphate dissolving bacterium with carrier substance of chicken dunk manure. The research objective was to determine biofertilizer dose that capable to increase inorganic fertilizer efficiency and to increase rice yield at C-type land of tidal lowland area. This reseach was the continuation from the previous research which had already produced the best biofertilizer enriched with Azospirillum bacterium and phosphate dissolving bacterium (BPF). It was conducted at plastic house from March to June 2016 by using Factorial Completely Randomized Design consisting of two treatments. The first treatment was inorganic fertilizer doses which consisted of A_0 (0% of recommended dose), A_1 (25% of recommended dose), A_2 (50% of recommended dose), A_3 (75% of recommended dose) and A_4 (100% of recommended dose), respectively. The second treatment was biofertilizer doses which consisted of H_0 (0 kg.ha^{-1}), H_1 (100 kg.ha^{-1}), H_2 (200 kg.ha^{-1}), H_3 (300 kg.ha^{-1}), H_4 (400 kg.ha^{-1}) and H_5 (500 kg.ha^{-1}), kg/ha), respectively. The results from the first research showed that combination between inorganic fertilizer at 50% recommended dose and biofertilizer at 400 kg.ha^{-1} dose had produced the growth and rice yield of 57.79 g.pot^{-1}.

Keywords: Biofertilizer, C-type land of tidal lowland area, Inorganic fertilizer efficiency, Rice yield

INTRODUCTION

South Sumatra Province had extensive area of tidal lowland with magnitue of more than 1.3 million hectares which is distributed in some deltas (South Sumatra Province and Banyuasin District Governments, 2010). This tidal lowland

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is one of suboptimal land that had important role to support the improvement of national food tenacity and had potential for rice commodity development.

The main problems frequently found in tidal lowland utilization were water excessiveness, high salt content, high pH and relatively low of nutrients content. Tidal lowland of acid sulphate had higher level of constraints because it had phyrite layer which in oxidation state would produce very acid soil pH, high level of toxic elements such as Al. Fe and H_2S as well as low nutrients availability. Other problem found at tidal lowland was that farmers are less interestin using organic fertilizer although local resources for organic fertilizer (such as chicken dunk manure) were abundant in this location.

Fertilizer is absolute requirement for agricultural input in order to achieve maximum production of crops planted in suboptimal land. However, the real problem faced by farmers in increasing productivity of tidal lowland through fertilizing effort was high price of inorganic fertilizer and it is unavailable in site.

The continuous use of inorganic fertilizer without addition of organic fertilizer had impacts on land quality such as the decrease of physical, chemical and biological properties of soil. The use of inorganic fertilizer had impact in form of increasing crop productivity at relatively high magnitude level. However, the use of inorganic fertilizer in relatively long time had caused soil hardness, low water storage capacity of soil and soil was quickly became acid which in turn decrease the crop productivity. One of method that can be used to maintain and to increase soil fertility is by decreasing the use of chemical substance in crop cultivation process and by replacing with organic matters that are more environmental friendly. The use of organic matters available at the vicinity of tidal lowland environment for crop cultivation system such as organic fertilizer by farmers should be increased because it is not only capable to improve soil fertility, but also to decrease the negative impact from excessive use of inorganic fertilizer. Application of this organic fertilizer can be enriched with microbia (biofertilizer) in order to accelerate the decomposition process and nutrients availability which in turn increase soil productivity and rice crop yield.

Biofertilizers such as rhizobium, azotobacter and azospirillum had been utilized for several decades because these fertilizers are more environmental friendly and more economical than that of chemical fertilizers. The benefits obtained from biofertilizer usage were due to its capability to symbiosize with roots of crop, more environmental friendly and more economical than that of chemical fertilizers (Vessey, 2003).

Biofertilizer is essential component for organic farming in maintaining soil fertility (Mahdil and Hassan, 2010). The use of biofertilizer is an effort to increase the use efficiency of nitrogen fertilizer for rice crop while maintaining the increase of production.

Testing results showed that biofertilizer contains all essential nutrients required by crops growth. It was found that microorganisms were capable to completely decompose the complex organic matter into simple organic matter (Baroste and Joshi, 2009).

Several studies had provided evidences that application of biofertilizer can increase the uptake of micro nutrients as well as macro nutrients. The increase of nutrients uptake is significantly increase the growth and production of crop.

The study results from Marlina *et al*. (2014) showed that application of biofertilizer enriched with N fixation bacterium (*Azotobacter*and *Azospirillum*), phosphate dissolving bacterium (*Bacillus firmus*) and growth stimulator bacterium (*Pseudomonas pseudomallei*) at dose of 389 kg.ha^{-1}in combination with 75% inorganic fertilizer could increased rice crop production at Inceptisol soil of lowland area and could saved 25% inorganic fertilizer from the recommended dose. Results of preliminary research by Marlina *et al.* (2016) showed that biofertilizr enriched with *Azospirillum* bacterium and phosphate dissolving bacterium was signicicantly increased the yield of rice crop at C-type flooding land of tidal lowland area.

The research objective was to determine biofertilizer dose that capble to increase inorganic fertilizer efficiency and to increase rice yield at C-type land of tidal lowland area.

RESEARCH METHODOLOGY

This research was conducted at plastic house from March to June 2016 by using Factorial Completely Randomized Design consisting of two treatments. The first treatment was inorganic fertilizer doses which consisted of A_0 (0% of recommended dose), A_1 (25% of recommended dose), A_2 (50% of recommended dose), A_3 (75% of recommended dose) and A_4 (100% of recommended dose), respectively. The second treatment was biofertilizer doses which consisted of H_0 (0 kg.ha^{-1}), H_1 (100 kg.ha^{-1}), H_2 (200 kg.ha^{-1}), H_3 (300 kg.ha^{-1}), H_4 (400 kg.ha^{-1}) and H_5 (500 kg.ha^{-1}), respectively.

The observed parameters were consisted ofrice growth related to tiller heights and tiller numbers that was measured from 2 weeks up to 8 weeks before planting, NPK uptake of crop tissue and rice crop production covering of productive tiller numbers, fully unhulled rice per midrib, percentage of empty unhulled rice, weight of 1000 grains and weight of harvest dry unhulled rice.

Data analysis was conducted by using computer program of SAS Portable 9.1.3. Further test was done by using Least Significant Different (LSD) and regression analysis.

RESULTS AND DISCUSSION

The previous research had produced the best treatment related to the growth and production of

Figure 1: Biofertilizer Without Bacteria Enrichment (M_0), Enriched with Azospirillum Bacterium (M_1), Enriched with Phosphate Dissolving Bacterium (M_2), Enriched with Azospirillum Bacterium and Phosphate Dissolving Bacterium (M_3)

rice crop, i.e., organic fertilizer enriched with *Azospirillum* bacterium and phosphate dissolving bacterium which was abbreviated as biofertilizer. This biofertilizer was used as a treatment base for the first research (Figure 1).

Soil Analysis Before The First Research

Soil had been analyzed at laboratory of PT Bina Sawit Makmur Palembang (2016) prior to this research. Results of soil analysis before planting at PT Bina Sawit Makmur (2016) and research criteria according to Soil Research Center (1983) and Soil Research Council (2005) showed that soil used in this research was classified as acid (pH H_2O = 5.35), medium value of cation exchange capacity with magnitude of 24.43 me.100g^{-1}, very high C-organic content of 6.20%, medium N-total content of 0.42%, very high P Bray I of 76.75 ppm, very low exchangeable bases such as Ca-dd of 0.14 me.100g^{-1}, very low Mg-dd of 0.04 me.100g^{-1}, low K-dd of 0.30 me.100g^{-1}, very high Na-dd of 1.47 me.100g^{-1} and soil texture of sandy loam (Table 1).

Table 1: Results of Soil Analysis Before Planting

S. No.	Observation	Result	Criterium
1	pH H_20	5.35	Acid
2	pH KCl	4.17	
3	N-total (%)	0.42	Medium
4	C-organic (%)	6.2	Very high
5	CEC (me/100 g)	24.43	Medium
6	K-dd (me/100 g)	0.3	Low
7	Ca-dd (me/100 g)	0.14	Very low
8	Mg-dd (me/100 g)	0.04	Very low
9	Na-dd (me/100 g)	1.47	Very high
10	P_2O_5 (me/100 g)	140.69	Very high
11	K_2O (me/100 g)	10.41	Low
12	P Bray I (ppm)	76.75	Very high
13	Aldd (%)	-	
14	Soil texture		Sandy loam
	Sand (%)	70	
	Loam (%)	13	
	Clay (%)	17	

Note: Results of soil analysis at Laboratory of PT Bina Sawit Makmur (April 2016).

Soil used in this research was categorized as low fertility soil and pH H_2O was classified as very acid. Available P in this soil was medium, but most of this nutrient isabsorbed by metal ions within soil such as aluminium resulting in the formation of Al-P compound so that P can not be absorbed by rice crop. Therefore, soil in this research was added with biofertilizer and inorganic fertilizer. It is expected that addition of biofertilizer and inorganic fertilizercould improve soil fertility in term of physical, chemical and biological aspects.Soil structure is physically became more loose which facilitate good development of crop's roots in absorbing nutrients provided by application of organic fertilizer. The addition of organic fertilizer is chemically can provide NPK nutrients and biologically can activate soil microorganisms to decompose the organic fertilizer.

Growth of Rice Crop

The results of variance analysis given in Table 2 showed that treatments of biofertilizer and inorganic fertilizer had highly significant effect on all of observed parameters, whereas treatments interaction had no significant effect on all of observed parameters.

Results of further test related to the effect of biofertilizer and inorganic fertilizer treatments on the observed parameters can be seen in Tables 3 to 6.

Table 2: Results of Variance Analysis Related to the Effect of Biofertilizer and Inorganic Fertilizer on the Observed Parameters

The Observed Parameters	Treatments			Coefficient of Variation (CV)
	A	H	I	
Crop height at 2 WAP (cm)	ns	ns	ns	10.21
Crop height at 4 WAP (cm)	**	**	ns	5.74
Crop height at 6 WAP (cm)	**	**	ns	6.96
Crop height at 8 WAP (cm)	**	**	ns	6.79
Tiller numbers at 4 WAP (tillers)	**	**	ns	27.24
Tiller numbers at 6 WAP (tillers)	**	**	ns	27.29
Maximum tiller numbers (tillers)	**	**	ns	20.81
Productive tiller numbers (midribs)	**	**	ns	23.99
Fully unhuulled rice numbers per midrib (grains)	**	**	ns	14.86
Percentage of empty unhulled rice (%)	ns	**	ns	29.36
Weight of 100 grains (g)	ns	**	ns	10.95
Weight of harvest dry unhulled rice (g)	**	**	ns	19.02

Note: A = Inorganic fertilizer, H = Biofertilizer, I = Interaction. ** = highly significant effect; ns = not significant, WAP = Week After Planting.

Table 3: The Effect of Inorganic Fertilizers on Crop's Height (cm)

Inorganic Fertilizer	Crop Height at 2 WAP	Crop Height at 4 WAP	Crop Height at 6 WAP	Crop Height at 8 WAP
A_0	36.53 a	55.93 a	79.16 a	97.87 a
A_1	39.32 b	60.04 b	83.00 ab	97.57 a
A_2	37.67 ab	60.00 b	83.50 b	103.77 b
A_3	36.55 a	60.21 b	87.38 c	109.19 c
A_4	36.43 a	58.48 b	86.11 bc	105.72 bc
LSD 0,05 =	2.54	2.26	3.89	4.65

Note: Numbers followed by the same letter in the same column are not significantly different.

The research results in term of rice crop growth showed that application of inorganic fertilizer at 75% recommended dose level gave the highest

Table 4: The Effect of Organic Fertilizers on Crop's Height (cm)

Organic Fertilizer	Crop Height at 2 WAP	Crop Height at 4 WAP	Crop Height at 6 WAP	Crop Height at 8 WAP
H_0	37.15 a A	56.97 a A	75.00 a A	94.50 a A
H_1	36.19 a A	60.88 c B	80.87 b B	99.13 ab AB
H_2	37.87 a A	57.59 ab A	87.69 cd CD	105.67 cd BC
H_3	37.35 a A	61.15 c B	83.67 bc BC	101.73 bc B
H_4	38.47 a A	57.17 a A	90.27 d D	109.67 d C
H_5	36.75 a A	59.83 bc AB	85.73 c ABC	105.29 cd BC
LSD 0,05 =	2.78	2.47	4.26	5.09

Note: Numbers followed by the same letter in the same column are not significantly different.

Table 5: The Effect of Inorganic Fertilizers on Tiller Numbers (Tillers)

Inorganic Fertilizer	Tiller Numbers 2 WAP	Tiller Numbers 4 WAP	Tiller Numbers 6 WAP	Tiller Numbers 8 WAP
A_0	-	6.22 a	14.06 a	18.11 a
A_1	-	7.78 b	15.11 ab	20.39 ab
A_2	-	6.28 ab	15.83 ab	21.94 bc
A_3	-	5.50 a	20.72 c	24.00 c
A_4	-	5.17 a	17.17 b	22.78 bc
LSD 0,05 =	-	1.54	3.02	2.98

Note: Numbers followed by the same letter in the same column are not significantly different.

Table 6: The Effect of Biofertilizers on Tiller Numbers (Tillers)

Organic Fertilizer	Tiller Numbers 2 WAP	Tiller Numbers 4 WAP	Tiller Numbers 6 WAP	Tiller Numbers 8 WAP
H_0	-	6.60 bc	10.87 a	14.33 a
H_1	-	4.17 a	12.93 ab	17.67 b
H_2	-	7.4 cd	20.87 cd	25.27 de
H_3	-	5.20 ab	14.93 b	20.53 bc
H_4	-	8.47 d	21.60 d	27.73 c
H_5	-	4.80 a	18.27 c	23.13 cd
LSD 0,05 =	-	1.68	3.31	3.26

Note: Numbers followed by the same letter in the same column are not significantly different.

values of crop height and tiller numbers than that of 0%, 25%, 50% and 100% of recommended dose levels. This was due to the fact that inorganic fertilizer at 75% recommended dose provided the sufficient amount of nutrients which subsequently affect crop height and tiller numbers. The increase of crop height caused the increase of tiller numbers and leave numbers formation. High tiller numbers might caused good photosynthesis process due to sufficient level of chlorophyle content (this is due to the role of nitrogen nutrient supported by phosphorus and potassium availability in inorganic fertilizer). The increase of photosynthesis process can increase high quantity of photosynthate which subsequently distributed to all parts of rice crop resulting in the increase of rice crop growth.

This was in accordance to statement of Rauf *et al.* (2000) which explained that nitrogen nutrient has a role in stimulating the vegetative growth portion (trunks and leaves) and increasing of tiller numbers, whereas phosphorus nutrient has a role in increasing the development of micro roots, hair roots, strengthening rice straw so that rice crop is not easily fall down and increasing tiller numbers, while potassium nutrient has a role in stimulating the root growth. The NPK fertilizer is the addition of nutrients to the one that had already available within soil so that numbers of N, P and K nutrients available for rice crop are in balance condition and have optimum effect on rice crop growth.

This was supported by research results from Kaya (2013), Simanjuntak *et al.* (2015) and Marlina *et al.* (2016) which showed that nutrients available in NPK fertilizer had worked optimally in increasing crop height (107.51 cm, 94.23 cm and 108.03 cm) and tiller numbers (19.07 tillers, 32.22 tillers and 24.50 tillers).

The best growth of rice crop (crop height and tiller numbers) was found on treatment of 400 $kg.ha^{-1}$ biofertilizer dose. This was due to the fact that biofertilizer enriched with Azospirillum bacterium and dissolving phosphate bacterium (BPF) was capable to provide sufficient quantity of N, P and K nutrients for rice crop which increase crop height and tiller numbers indicated by high uptake level of N, P and K nutrients with magnitudes of 2.64% N, 0.199% P and 2.35% K, respectively.

Compost from chicken dunk manure enriched with Azospirillum bacterium and phosphate dissolving bacterium had a role as organic acids resource which capable to control metals solubilitywithin soil or had a role as nutrients resource for crops. The above decomposition product might be in form of organic acids that capable to chelate metal ions so that P nutrient fixed by metal ions (Fe-P) can be released and become available for crop. The availability of phosphatedissolvingbacterium that can release phosphatase enzym and organic acids is also capable to dissolve phosphateelement fixed by metal ions so that P nutrient become available again and can be used by rice crop for good growth and production.

In addition, Azospirillum bacterium and phosphatedissolvingbacterium within carrier compound of compost can stimulate ammonification, nitrification, N fixation and phosphorilation activities. This was in accordance to statement of Sastraatmadja *et al.* (2001) which showed this process was due to several microbia activities available within biofertilizer and it was related to mutual function between crop and microbiaavailable within biofertilizer which was given to rice crop. Moreover, Atlas and Bartha (1993) showed that activity and effectivity of

microbia within growing medium (soil) would be stimulated together and developed microbia community that could accelerate mineralization of macro and micro nutrients. These nutrients are required by crops for their growth such as for crop height development.

N, P and K Uptakes of Crop Tissue (%)

The N, P and K uptakes of crop tissue was occurred when rice crop age was at 8 Week After Planting (WAP) because rice crop in this period had entered the primodia phase such as shown in Tables 7-9, respectively. The highest average value of N, P and K nutrients uptake was found on treatment with 50% recommended dose of inorganic fertilizer with magnitudes of 2.42% N, 0.189% P and 2.31% K, respectively; treatment with 400 kg.ha^{-1} biofertilizer had magnitudes of 2.64% N, 0.199% P and 2.35% K, respectively; Treatments interaction of 50% recommended dose of inorganic fertilizer and 400 kg.ha^{-1} biofertilizer had magnitudes of 2.95% N, 0.323% P and 2.88% K, respectively.

Table 7: The Effect of Inorganic Fertilizer Treatments on N, P and K Nutrients Uptake (%)

Inorganic Fertilizer (%)	N Nutrient Uptake (%)	P Nutrient Uptake (%)	K Nutrient Uptake (%)
0	1.77	0.14	1.21
25	1.96	0.146	1.47
50	2.42	0.189	2.31
75	1.89	0.143	1.39
100	2.05	0.146	1.54

Table 8: The Effect of Biofertilizer Treatments on N, P and K Nutrients Uptake (%)

Biofertilizer (kg.ha^{-1})	N Nutrient Uptake (%)	P Nutrient Uptake (%)	K Nutrient Uptake (%)
0	1.46	0.121	0.91
100	1.65	0.141	1.19
200	2.29	0.157	2.07
300	1.88	0.145	1.34
400	2.64	0.199	2.35
500	2.13	0.151	1.65

Table 9: The Effect of Treatments Interaction on N, P and K Nutrients Uptake (%)

Inorganic Fertilizers	Biofertilizers					
	H_0	H_1	H_2	H_3	H_4	H_5
..... N Nutrient Uptake (%)						
A_0	1.08	1.45	2.1	1.67	2.39	1.95
A_1	1.37	1.55	2.23	1.87	2.64	2.09
A_2	2.13	2.18	2.49	2.2	2.95	2.48
A_3	1.32	1.52	2.21	1.77	2.55	2.02
A_4	1.38	1.55	2.31	1.89	2.68	2.1
..... P Nutrient Uptake (%)						
A_0	0.105	0.136	0.154	0.14	0.164	0.142
A_1	0.12	0.138	0.154	0.14	0.173	0.151
A_2	0.157	0.158	0.167	0.162	0.323	0.164
A_3	0.11	0.137	0.155	0.14	0.165	0.148
A_4	0.114	0.138	0.156	0.156	0.141	0.152
..... K Nutrient Uptake (%)						
A_0	0.01	0.97	1.83	1.04	2.16	1.22
A_1	0.93	1	1.96	1.14	2.26	1.54
A_2	1.96	2.01	2.5	2.23	2.88	2.34
A_3	0.71	0.97	1.94	1.11	2.18	1.44
A_4	0.95	1.01	2.12	1.19	2.28	1.69

The highest NPK nutrients uptake was found on treatment combination of 50% recommended dose of inorganic fertilizer and 400 kg.ha^{-1} biofertilizer. However, the best treatment was found on 75% recommended dose of inorganic fertilizer in term of crop height and tiller numbers. This was interesting phenomenon because after entering the

primordia phase, biofertilizer had been highly decomposed by Azospirillum bacterium and phosphate dissolving bacterium through mineralization process (the change of organic matter from unavailable condition into inorganic matter which was available for crop) which provide N, P and K nutrients for rice crop.

Rice Crop Yield

Observation results of production parameters can be seen in Tables 10 and 11 as well as Figure 2. These tables showed that treatment of 50% recommended dose of inorganic fertilizer and 400 kg.ha^{-1} biofertilizer were capable to increase productive tiller numbers, fully unhulled rice per midrib, weight of 100 grains, weight of harvest dry unhulled rice as well as to decrease the percentage of empty unhulled rice.

Table 10: The Effect of Inorganic Fertilizer on Production Components

Inorganic Fertilizer (%)	Productive Tiller Numbers (Midrib)	Fully Unhulled Rice Numbers Permidrib (Grains)	Weight of Harvest Dry Unhulled Rice (g)
0	15.11 a	57.77 a	34.02 a
25	16.28 ab	65.30 b	39.51 b
50	17.44 abc	71.28 c	46.62 c
75	20.11 c	63.37 ab	36.44 ab
100	18.72 bc	67.68 bc	41.39 b
LSD 0.05=	2.81	6.49	5.02

Note: Numbers followed by the same letters in the same columns are not significantly different.

Figure 2: Observation Results of Production Parameters

Note: A_2H_4 = 50% recommended dose of inorganic fertilizer and 400 kg.ha^{-1} biofertilizer. A_0H_2 = 0% recommended dose of inorganic fertilizer and 200 kg.ha^{-1} biofertilizer.

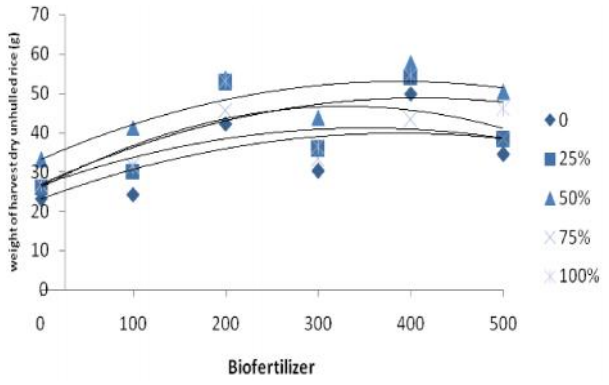
Figure 3 showed that inorganic fertilizer at 50% recommended dose had regression coefficient of b_1 = 0.102 x, which means that every application of 1 kg biofertilizer on inorganic

Table 11: The Effect of Biofertilizer on Production Components

Biofertilizer (kg.ha^{-1})	Productive Tiller Numbers (Midrib)	Productive Tiller Numbers (Midrib)	Percentage of Empty Unhulled Rice (%)	Weight of 100 Grains (g)	Weight of Harvest Dry Unhulled Rice (g)
0	12.73 a	41.15 a	65.37 c	3.03 a	27.14 a
100	13.27	59.46 b	55.78 bc	3.06 a	31.72 ab
200	21.20 bc	72.94 d	48.42 ab	3.39 bc	49.47 d
300	15.00 a	63.07 bc	52.45 ab	3.18 ab	35.82 b
400	24.13 c	88.36 e	41.79 a	3.51 c	51.93 d
500	18.87 b	67.92 cd	49.54 a	3.25 abc	41.51 c
LSD 0.05=	3.07	7.11	11.19	0.26	5.5

Note: Numbers followed by the same letters in the same columns are not significantly different.

Figure 3: The Relationship Between Biofertilizer and Weight of Harvest Dry Unhulled Rice at Several Inorganic Fertilizer Levels



Note: Y0% = 23.03+0.086x-0.0001x^2, R^2 = 0.502. Y25% = 26.16 + 0.124x – 0.0001x^2, R^2=0.519. Y50% = 33.09+ 0.102x-0.0001x^2, R^2 = 0.697. Y75% = 26.53+0.082-0.001x^2, R^2 = 0.545. Y100% = 26.89+0.106x-0.0001x^2, R^2 = 0.583.

fertilizer at 50% recommended dose could increased the weight of harvest dry unhulled rice with magnitude of 0.102 x.

CONCLUSION

The combination between inorganic fertilizer at 50% recommended dose and biofertilizer at 400 kg.ha^{-1} dose had produced the growth and yield of rice with magnitude of 57.79 g.pot^{-1}.

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