

A study on inorganic fertilizers and organic materials to increase the productivity of rice crop (*Oryza sativa* L.) in equatorial agroecosystems

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Abstract

The aim is to determine the optimum combination of inorganic fertilizer and organic materials for increasing the productivity of rice crop (*Oryza sativa* L.). The experiment was conducted in February-June 2015 in Kebadu, Sanggau, West Kalimantan, Indonesia. The study area was located at 00°0.08,785'N north latitude and 110°0.07,175'E east longitude with ultisol soil; the altitude is 32 m above sea level, rainfall level ranges between 185-267 mm month⁻¹, and the solar radiation is 375.49-452.58 cal cm⁻² day⁻¹. This study used a factorial randomized block design. The first factor was the inorganic fertilization (without fertilizer, inorganic fertilizer 50%, 100%, and 150%) and the second factor was the addition of organic materials (EM₄ 2 l ha⁻¹, chicken manure 2 t ha⁻¹, and manure 2 t ha⁻¹ + EM₄ 2 l ha⁻¹). Results showed that the application of chicken manure and a combination of chicken manure+EM₄ could reduce the need for inorganic fertilizer NPK by up to 50% with productivity that ranged from 4.18-4.20 t ha⁻¹; this is relatively similar to 100% and 150% inorganic fertilizer NPK, and can increase the harvest by up to 68% compared to the no-NPK inorganic fertilizer.

Introduction

Currently, irrigated rice fields are used for paddy production. However, this is obstructed by the decline in soil fertility and the limited water for irrigation. Paddy production in dry land is one of the efforts to increase the productivity of rice crops. It is supported by the land potential in West Kalimantan that is fairly wide, with a width of 2.2 million ha.¹ West Kalimantan has an equatorial agroecosystem that supports the development of rice crops. It is also supported by an average temperature of 27°C, high

air humidity because of its high air evaporation, bimolar rainfall patterns with two peaks of rainy season in April and December, an annual rainfall of 3095 mm year⁻¹, sun that shines all year round, long exposure of 12 hours a day, and high intensity that reaches 452 cal cm⁻² day⁻¹. However, the productivity of rice crops in West Kalimantan is still low: 1.88 t ha⁻¹.²

Farmers rarely use fertilization technology, which leads to low productivity of rice crops. NPK inorganic fertilizer is a macronutrient that is necessary for plant growth and increasing crop productivity. NPK fertilizer can be used to increase the number of tillers, leaf area, and protein synthesis, as well as the process of grain formation and grain filling in the vegetative phase of the plant.³ The element phosphorus plays a role in cuticle formation, root development, rod reinforcement, and the formation of fruits and seeds.⁴ Phosphorus application in the generative phase can stimulate flowering, fruit ripening, and the improvement of grain quality.⁵ Potassium can stimulate root growth, pest and disease resistance, and grain quality improvement, as well as reducing maturity caused by phosphor. The function of organic materials is to provide water and necessary nutrients for the plants, improve soil structure, and increase the development of microorganisms. A combination of inorganic fertilizer and organic materials is assumed to provide nutrients for the soil in a balanced way so that plants grow in a better way.

Manure from chicken is excrement from chickens that can be used as an organic fertilizer to improve the physical, chemical, and biological nature of the soil. It can neutralize the pH, reducing heavy metals in the soil, improve soil structure and porosity, help with nutrient absorption from chemical fertilizers, improve water absorption, and maintain the temperature fluctuations of the soil. Effective Microorganism (EM₄) is useful for reducing the use of chemical fertilizers and pesticides, and improving the efficiency of organic materials for plants.⁶ In addition, EM₄ is used to accelerate the decomposition of organic substances, increase the availability of nutrients for plants, suppress the activity of the pathogenic soil, reduce the need for chemical fertilizers and pesticides, and increase the activity of beneficial indigenous microorganisms. Fertilization based on changes in soil nutrient status is in line with technological developments. Therefore, the existing fertilizer needs to be reexamined and refined.⁷ The application of EM₄ can be achieved by spraying it on the leaf surface. This is done to increase the activity of plant photosynthesis and suppress the pathogen growth

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Key words: equator, EM₄, manure, NPK, rice crop.

Acknowledgements: The authors would like to thank to the Agency for Agricultural Research (*Badan Litbang Pertanian*) and the Institute of Agricultural Technology of West Kalimantan (*Balai Pengkajian Teknologi Pertanian Kalimantan Barat*) for the research funding support.

Contributions: the authors contributed equally.

Conflict of interest: the authors declare no potential conflict of interest.

Received for publication: 6 April 2017.

Revision received: 11 August 2017.

Accepted for publication: 11 August 2017.

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International Journal of Plant Biology 2018; 9:6529

doi:10.4081/pb.2018.6529

on plant surfaces.⁸ The purpose of this research is to identify the optimum combination of inorganic fertilizers and organic materials to increase the growth and productivity of rice crops.

Materials and Methods

This study was conducted in Kebadu, Sanggau, West Kalimantan. It is located at 00°0.08,785'N northern latitude and 110°0.07,175'E east longitude, at the altitude of 32 m above sea level; the average rainfall was 234 mm month⁻¹, solar radiation was 410 cal cm⁻² day⁻¹, and the soil type was ultisol. An factorial randomized block design was used as the experimental design. It consisted of 2 factors and 3 repeats.

The first factor the inorganic fertilization, which consisted of:

(Po) treatment without fertilization

(P1) 50% inorganic fertilizer (45 kg N ha⁻¹, 18 kg P₂O₅ ha⁻¹, 30 kg K₂O ha⁻¹)

(P2) 100% inorganic fertilizer (90 kg N ha⁻¹, 36 kg P₂O₅ ha⁻¹, 60 kg K₂O ha⁻¹)

(P3) 150% inorganic fertilizer (135 kg N ha⁻¹, 54 kg P₂O₅ ha⁻¹, 90 kg K₂O ha⁻¹)

The second factor was the application

of organic materials, which consisted of:
 (O1) 2 t ha⁻¹ of EM₄
 (O2) 2 t ha⁻¹ of chicken manure
 (O3) 2 t ha⁻¹ of EM₄ and 2 t ha⁻¹ of chicken manure

Observation parameters in this study were plant height, number of tillers of rice per clump, index of leaf area, total dry weight of plants per clump, growth rate of plants, number of panicles per clump, empty grain per clump (%), weight of 1000 grains, and weight of dry milled grain per hectare. The data obtained from observations were analyzed using analysis of variance (F-test) with a 5% confidence level (α) and continued with the LSD comparison test (5%) to compare each of the treatments.

Results and Discussion

Plant height

The result of the study showed that the application of 150% inorganic fertilizer could increase crop height to be higher than that with no fertilizers. The application of 50% and 100% fertilizers was done at age 45-75 dap (rice plants vegetative phase). At 90-105 dap (generative phase), the application of 150% inorganic fertilizer resulted in the same plant height with 50% and 100%

of inorganic fertilizer (Table 1). The combination of organic fertilizer and NPK provided high growth in plants, which was better than the application of only NPK fertilizer or only organic fertilizer.⁹ The availability of necessary nutrients in the soil affected the photosynthesis activity and caused an increase in the growth and harvest of products.¹⁰

Number of tillers

Observations 60 dap showed that 100% and 150% inorganic fertilizer treatment resulted in the same number of tillers. Treatment with 100% and 150% inorganic fertilizer resulted in an increased number of tillers than the 50% inorganic fertilizer and no fertilizer at 75-105 dap (Table 2). Lack of nutrient affected the formation of new cells so that plant growth was obstructed. In addition, it caused dwarf plants and tiller formation was decreased. The provision of nitrogen played a role in the growth of stems and leaves, while phosphor was required for the formation of roots on young plants.¹¹ Chicken manure and NPK could increase the plant height and number of tillers because it could provide macro- and micronutrients insufficient and balanced quantities.³

Index of leaf area

The result showed that at the age of 90-

105 dap, 150% inorganic fertilizer had the same index of leaf area with 50% and 100% of inorganic fertilizers. Application of chicken manure and combinations of chicken manure+EM₄ at the age of 60 dap could increase the index of leaf area compared to EM₄ treatment, but at the age of 75 dap, the administration of chicken manure+EM₄ could increase the index of leaf area compared to only chicken manure or only EM₄. The index of leaf area value was at 4-7 inclined ramps.¹² The index of leaf area in rice plants could reach >6 depending on the varieties and the availability of nutrients.¹³ Thus, the optimum supply of nutrients increased the index of leaf area on plants so that more sunlight could be absorbed for photosynthesis. It is useful to produce enough assimilates. The leaves are part of plants influence in the photosynthesis process.⁹ The greatest photosynthesis process in leaves was at the third and fourth sections of rice plant leave.¹⁰

Total dry weight of rice plants

Observations of the total dry weight of rice plants at 60 dap showed that the application of 100% and 150% inorganic fertilizer could increase the total dry weight compared to 50% inorganic fertilizer and without fertilizer. However, at the age of 75-105 dap, 50% and 150% inorganic fertilizer resulted in the same total amount of

Table 1. Average height of rice plants due to the treatment effect of inorganic fertilizers and organic materials in a variety of plant ages.

Treatment	Plant height (cm), at the age of ... dap					
	30	45	60	75	90	105
Inorganic fertilizer						
Without fertilization	38.51 a	52.19 a	62.38 a	69.34 a	81.74 a	82.00 a
50% of inorganic fertilizer	39.36 a	54.56 a	67.26 b	73.67 b	87.04 b	87.36 b
100% of inorganic fertilizer	36.72 a	54.49 a	68.98 b	74.52 b	86.94 b	87.13 b
150% of inorganic fertilizer	40.18 a	57.76 b	73.00 c	79.83 c	89.02 b	89.46 b
LSD 5%	tn	2.97	3.14	3.79	3.08	3.00
Organic materials						
EM ₄	36.13 a	52.12 a	65.40 a	70.86 a	84.41 a	84.75 a
Chicken manure	39.57 b	56.01 b	68.97 b	75.90 b	86.58 a	86.80 a
Chicken manure + EM ₄	40.38 b	56.12 b	69.35 b	76.27 b	87.50 a	87.91 a
LSD 5%	3.15	3.43	3.62	4.38	tn	tn

Numbers that are accompanied by the same letter in the same column means that there are no significant differences according to LSD 5%, dap (days after planting), tn (not significant).

Table 2. Average number of tillers per clump due to the influence of inorganic fertilizer treatment at various ages of the plant.

Treatment	Number of tillers, at the age of ... dap					
	30	45	60	75	90	105
Inorganic fertilizer						
Without fertilization	11.04 a	22.47 a	27.00 a	22.23 a	17.22 a	15.28 a
50% of inorganic fertilizer	11.26 a	25.00 ab	29.86 ab	25.31 b	20.21 b	18.12 b
100% of inorganic fertilizer	11.41 a	27.90 b	33.58 bc	28.29 c	22.38 c	19.96 c
150% of inorganic fertilizer	12.52 a	29.62 c	35.19 c	29.70 c	23.22 c	20.43 c
LSD 5%	tn	3.70	3.87	2.77	1.67	1.39

Numbers that are accompanied by the same letter in the same column means that there are no significant differences according to LSD 5%, dap (days after planting), tn (not significant).

dry weight on rice plants. The use of a combination of organic and inorganic fertilizers could enhance plant growth. The plants would grow well when the nutrients were available and sufficient.¹¹ Nutrient absorption indirectly increased the photosynthesis process that produced photosynthate, which is stored in plant tissues, and thus increased plant dry weight.¹⁴

Plant growth rate

Inorganic fertilizer significantly influenced rice plants at the age of 30-60 dap and 60-105 dap. Data in Table 3 showed that the plants' growth rate in the vegetative phase is higher than the generative phase. The application of inorganic fertilizer increased the growth rate from the vegetative until the generative phase. On vegetative growth of the plants at ages between 30 and 60 days after planting, the treatment of 150% inorganic fertilizer and 100% inorganic fertilizer resulted in the same growth rate, while generative growth at the age of 60-105 days after planting with application of 50% and 150% inorganic fertilizer resulted in the same growth rate. During vegetative growth, the nutrient phosphor contributed to

optimum plant growth at 0.3-0.5% of the dry weight. C3-plants with a value of CGR 200 kg ha⁻¹ day⁻¹ are considered quite good.¹²

Number of panicles per clump and empty grain per clump (%)

The results showed that the application of 150% inorganic fertilizer results in the same number of panicles per clump with 50% and 100% inorganic fertilizer, but no fertilization treatment resulted in a lower number of panicles per clump. Provision of inorganic fertilizer with a high dose resulted in more tillers but fewer panicles. The decreasing number of panicles formed was influenced by genetic factors. The number of productive tillers affected the amount of crop harvested. This result shows that 10 tillers produce 200 grains per panicle, while 15 tillers only produced 100 grains per panicle.

An increase in the percentage of empty grain was positively correlated with the increased dose of fertilizer. With higher doses of inorganic fertilizer, the empty grain percentage also increased. Application of 100% and 150% inorganic fertilizer has a

higher percentage of empty grain (33.39% and 34.44%), compared to no fertilizer and 50% inorganic fertilizers (29.91% and 30.87%). The intensity of the blast disease increased in accordance with the increasing nitrogen fertilizer, with a percentage of 28.5%. The excessive usage of nitrogen makes the plants susceptible to blast disease pathogens. This result states that the application of 150% NPK inorganic fertilizers in recommended doses on local rice cultivars can lead to blast disease of around 8.41%.¹⁵

Weight of 1000 grains and the weight of dry milled grain per hectare (Ha)

The weight of 1000 grains in Table 4 shows that the treatment of 50% inorganic fertilizers combined with chicken manure+EM₄ weighted 1000 grain higher than other treatments, but did not differ from 50% inorganic fertilizer combined with chicken manure, 100% inorganic fertilizer combined with EM₄, and 100% inorganic fertilizer+chicken manure+EM₄. It was due to the application EM₄, which can be used as a starter or activator for inorganic fertilizers, to improve the response of inor-

Table 3. Total average of dry weight due to the treatment influence of inorganic fertilizer at various ages of the plant.

Treatment	Total average of dry weight (g clump ⁻¹), at the age of ... dap					
	30	45	60	75	90	105
Inorganic fertilizer						
Without fertilization	2.49 a	11.27 a	26.08 a	31.22 a	48.01 a	53.52 a
50% of inorganic fertilizer	3.07 a	13.11 a	27.83 a	44.44 b	62.01 b	77.45 b
100% of inorganic fertilizer	3.09 a	11.57 a	34.44 b	45.61 b	64.32 b	79.37 b
150% of inorganic fertilizer	2.84 a	16.70 a	37.49 b	50.13 b	73.58 b	79.32 b
LSD 5%	tn	tn	6.90	6.86	13.59	10.39

Numbers that are accompanied by the same letter in the same column means that there are no significant differences according to LSD 5%, dap (days after planting), tn (not significant).

Table 4. Average weight of 1000 grain, grain weight per square meter, and grain weight per hectare, due to the treatment effect of inorganic fertilizer and organic materials (conversion of GKP to MPD).

Treatment	Weight of 1000 grain (g)	Weight of grain per hectare (t ha ⁻¹)
Without fertilization + EM ₄	22.21 abc	2.50a
Without fertilization + chicken manure	22.10 ab	2.66 ab
Without fertilization + chicken manure+EM ₄	22.17 abc	2.99 abc
50% of Inorganic fertilizer + EM ₄	21.94 ab	3.05 abc
50% of Inorganic fertilizer + chicken manure	23.21 d	4.18 f
50% of Inorganic fertilizer + chicken manure+EM ₄	23.23 d	4.20 f
100% of Inorganic fertilizer + EM ₄	23.09 cd	3.95 ef
100% of Inorganic fertilizer + chicken manure	21.84 ab	3.36 cde
100% of Inorganic fertilizer + chicken manure+EM ₄	22.55 bcd	3.92 ef
150% of Inorganic fertilizer + EM ₄	22.10 abc	3.76 def
150% of Inorganic fertilizer + chicken manure	21.55 a	3.19 bcd
150% of Inorganic fertilizer + chicken manure+EM ₄	22.02 ab	3.59 cdef
LSD 5%	0.57	0.79

Numbers that are accompanied by the same letter in the same column means that there are no significant differences according to LSD 5%.

ganic fertilizer on plant growth and improve the productivity. Organic fertilizer could be a supplement for inorganic fertilizer so the plants grow better, resulting in better harvest crop.⁹

The result showed that 150% inorganic fertilizer generated the same 1000 grain weight with the treatment without fertilization. The inappropriate use of inorganic fertilizer would reduce nutrients in the soil so that plant responses were decreased. It was caused by the unutilized nutrients that could turn into pollutant.¹⁶

Data of dry milled grain weight per hectare in Table 4 showed that 50% inorganic fertilizer combined with chicken manure+EM₄ was higher by 4.20 t ha⁻¹, but did not differ from 50% inorganic fertilizer combined with chicken manure, as well as 100% and 150% inorganic fertilizer combined with chicken manure+EM₄ and also treatment with EM₄ only. The application of inorganic fertilizer and organic materials on rice crops could increase the harvest by 68% compared with crops without chemical fertilizers. The direct application of inorganic fertilizer resulted in a quick response to plant growth so that it could increase plant productivity. This is in accordance with the results showing that 1.5 t ha⁻¹ organic fertilizer combined with 50% inorganic fertilizers in recommended doses gave the best results, compared to inorganic fertilizers (NPK 100:50:50 kg ha⁻¹) or 2 tons ha⁻¹ of organic fertilizers.⁹ The harvested crop of treatment NPK+pig manure produced 8572 kg ha⁻¹ grains, while the use of NPK fertilizer produced 7795 kg ha⁻¹ grains, which was an increase of 9.06%.¹⁷

Conclusions

The use of organic materials (chicken manure and chicken manure + EM₄) can reduce the need for NPK inorganic fertilizer with increasing productivity up to 50%

from 4.18-4.20 t ha⁻¹ and are relatively the same with 100% and 150% NPK inorganic fertilizer. In addition, the harvest results increased by 68% compared to treatment without NPK inorganic fertilizer on the equatorial agro-ecosystem.

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