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The Effects of Micronutirents on Growth and Yield of Lowland Rice Grown on Typic Dystrudept Soil

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ABSTRACT

Fertilizers and fertilization technology have important roles in increasing crop production including lowland rice. In response to the issue, a field experiment was conducted to study the effects of micronutrients on growth and yield of lowland rice. The experiment was carried out at Cihideung Ilir Village, Dermaga Sub-district, Bogor Regency from November 2015 until March 2016. The experiment consisted of 8 treatments, namely control (without fertilization), NPK-standard, NPK-standard + ¼ dosage of Hortigro Rice fertilizer, and ¾ NPK + ¼ until $1^1/_4$ dosages of Hortigro Rice fertilizer as a source of macronutrients N, P, K and micronutrients of Mn, Cu, Zn, B, and Mo. The treatments were arranged in a Randomized Block Design with 3 replications. Parameters observed during the research were plant height, tiller number, and yield of grain and straw of INPARI-32 lowland rice as crop indicator. The results showed that among other treatments, the highest plant height was resulted from the application of ¾ NPK-standard + ¼ Hortigro Rice, *i.e.* around 124 cm at 60 days after planting. The highest harvesting dry weight of grain and straw were observed in NPK-standard + $^1/_4$ of Hortigro Rice fertilizer treatment, *i.e.* around 9.0 Mg ha^{-1} and 25.9 Mg ha^{-1}, respectively. This yield showed a significant difference with ¾ NPK-standard combined with ¾ -$1^1/_4$ dosages of Hortigro Rice. The highest dry weight of milled grains was resulted in the application of ¾ NPK-standard + $^1/_2$ Hortigro Rice, *i.e.* around 7.3 Mg ha^{-1}, which is significantly different from that in ¾ NPK-standard combined with 1.0 - $1^1/_4$ dosages of Hortigro Rice treatments, while the highest dry weight of straw was provided by NPK-standard, i.e. around 14.0 Mg ha^{-1}. The highest dry weight of 1000 milled grains and ratio of dry weight of milled grain to straw were provided by ¾ NPK-standard + $^1/_2$ Hortigro Rice around 32.0 gram and 0.63, respectively. The results indicated that the application of micronutrient fertilizer of Hortigro Rice in combination with NPK fertilizers can potentially increase lowland rice productivity due to the micronutrients content of Mn, Cu, Zn, B, and Mo in it.

Keywords: Fertilizer, growth, lowland rice, micronutrients, yield

ABSTRAK

Pupuk dan teknologi pemupukan memiliki peran penting dalam peningkatan produksi tanaman, termasuk padi sawah. Berkaitan dengan hal tersebut, sebuah percobaan lapangan dilakukan untuk mempelajari pengaruh unsur hara mikro terhadap pertumbuhan dan hasil padi sawah. Percobaan dilakukan di Desa Cihideung Ilir, Kecamatan Dermaga, Kabupaten Bogor pada November 2015 sampai dengan Maret 2016. Percobaan ini terdiri 8 perlakuan, yaitu kontrol (tanpa pemupukan), NPK standar, NPK standar + ¼ dosis pupuk Hortigro, dan ¾ NPK + ¼ hingga 1¼ dosis pupuk Hortigro sebagai sumber unsur hara makro N, P, K dan unsur hara mikro Mn, Cu, Zn, B, dan Mo. Perlakuan disusun menggunakan Rancangan Acak Kelompok dengan 3 ulangan. Parameter yang diamati adalah tinggi tanaman, jumlah anakan, dan hasil gabah dan jerami padi INPARI-32. Hasil penelitian menunjukkan bahwa di antara perlakuan, tinggi tanaman tertinggi dihasilkan perlakuan ¾ NPK standar + ¼ pupuk Hortigro, yaitu 124 cm pada umur 60 hari setelah tanam. Berat kering panen gabah dan jerami tertinggi diraih perlakuan NPK standar + ¼ pupuk Hortigro, yaitu 9,0 Mg ha^{-1} dan 25,9 Mg ha^{-1}. Hasil ini menunjukkan perbedaan yang signifikan dengan ¾ NPK standar dikombinasikan dengan ¾ - 1¼ dosis pupuk Hortigro. Berat kering gabah tertinggi diperoleh pada aplikasi ¾ NPK standar + ½ dosis pupuk Hortigro, yaitu sekitar 7,3 Mg ha^{-1}, yang sangat berbeda dibandingkan ¾ NPK standar dikombinasikan dengan 1 - 1¼ dosis pupuk Hortigro, sementara berat kering jerami tertinggi diraih oleh NPK standar, yaitu 14,0 Mg ha^{-1}. Berat kering 1,000 gabah giling dan rasio berat kering gabah tertinggi terhadap jerami diraih oleh ¾ NPK standar + ½ pupuk Hortigro, yaitu sebesar 32,0 gram dan 0,63. Hasil penelitian menunjukkan bahwa aplikasi pupuk unsur hara mikro Hortigro dikombinasikan dengan pupuk NPK berpotensi meningkatkan produktivitas padi sawah karena pupuk Hortigro mengandung unsur hara mikro Mn, Cu, Zn, B, dan Mo.

***Kata kunci*:** Hasil, padi sawah, pertumbuhan, pupuk, unsur hara mikro

INTRODUCTION

Rice is one of the main staple foods of Indonesian people with the average consumption in 2017 was about 81.61 kg person^{-1} year^{-1} (Center for Agricultural Data and Information System 2017). A projection conducted by BPS (2013) showed that the number of Indonesian population over the next twenty-five years are continuously increasing from 238.5 million in 2010 to 305.6 million in 2035. This situation has stimulated an intensive competition between rice demand and supply. On supply side, any efforts have been made by government to match between demand and supply, such as increasing of cropping index, planting area, rice productivity, and using of high yielding varieties, mainly on paddy-producing areas (Haryono 2014). Those efforts have been successful in supporting the sustainability of food sufficiency, mainly for rice.

There is a long story behind the efforts to increase rice productivity. It was started in 1970 with focusing on utilization of macronutrient inorganic fertilizers such as Urea (source of N), TSP/SP-36 (source of P), and KCl (source of K), known as Green Revolution Program. Through this strategy, rice productivity and production increased significantly and could achieve rice self-sufficiency in 1984. However, the strategy also raised the negative impacts on nutrient imbalance in soils, which significantly decreased lowland rice productivity. In order to maintain lowland rice productivity, a new strategy has been developed during the following decades called as balanced fertilization by utilizing an appropriate combination of inorganic and organic fertilizers based on soil capacity in nutrient supply, crop requirement, and productivity targeted (Graham 2008). This concept becomes more important for managing lowland rice areas that apply intensive technologies to support food sufficiency.

Related to balanced fertilization, it is possible to utilize micronutrient fertilizers to achieve an optimum crop productivity in order to substitute the low content of micronutrients in soil. As known, when micronutrients are in short supply, the growth and yield of crops are severely depressed (IPNI 2014). Somani (2008) reported that low capability of soils in supplying micronutrients are alarmingly widespread across the globe due to intensive cropping, loss of fertile topsoil and losses of nutrients through leaching.

Fageria *et al.* (2002) reported that micronutrient deficiencies are widespread because of increased nutrient demands in crop production, soil losses by erosion, soil leaching, liming, decreased manure rates, increased chemical fertilizer inputs, and use of marginal lands for crop production. Micronutrient deficiency in soils affected genetic mechanism in plant as reported for copper, mangan and zinc (Blair *et al.* 2009; Genc *et al.* 2009; Lonergan *et al.* 2009; Iwaya *et al.* 2011). Mineral fertilization, especially nitrogen fertilization contributes to the decrease of soil pH and this enhances mobility of Cu, Fe, Mn and Zn (Fan *et al.* 2011). Alloway (2008) stated that deficiency of microelements in plants results in firstly decreasing plant resistance to harmful environmental factors, followed by declining yields and their quality. Singh *et al.* (2010) showed that NPK fertilization significantly increased Cu and Mn mobility, while organic fertilization reduced the mobility of Cu and Mn. Among all the micronutrients, Zn deficiency is the most widespread micronutrient disorder among different crops (Naik and Das 2008). The main soil factors responsible for causing Zn deficiency in staple food crops, such as rice are low total contents of Zn, high pH, high contents of calcite, high concentrations of bicarbonate ions and salts and high levels of available phosphorus (Alloway 2009). Slaton *et al.* (2001) added that Zn deficiency has increased with the introduction of modern varieties, crop intensification and increased Zn removal.

Micronutrients can be defined as nutrients that are needed in small amount during the crop cycles. One of important characteristics of micro nutrients is that besides needed in small amount, the optimum dosage for crop growth is also in small range. Taiwo (2001) stated that micronutrients are needed in trace amounts but their adequate supply improves nutrient availability and positively affects the cell physiology that is reflected in yield. Brady and Weil (2008) reported that although micronutrients are taken up in small amount by crops, but all of nutrients should be applied in optimal ways to support an optimal plant growth due to the specific function of each nutrient in crop metabolism.

The importance of micronutrients in agricultural development were reported by Singh (2008) and Knez and Graham (2013). Micronutrients have several advantages such as (a) complementing nutrients that cannot be supplied by macro nutrients of N, P, K, (b) increasing crop resistance to pest and diseases, (c) increasing crop productivity and yield quality, (d) have the lowest negative impacts on environment, and (e) crop yields are free from heavy metal toxicity (Chatterjee and Bandyopadhyay, 2017). Micronutrients in the living organism mainly play roles as structural components of cell constituents and its metabolically active compounds, in the conservation of cellular organization, and in energy transformation (Renwick and Walker 2008). Gupta *et al.* (2008) stated that micronutrients, also known as trace elements, are required in microquantities but their lack can cause serious crop production and animal health problems. Tripathi *et al.* (2015) mentioned that micronutrients play a virtually significant role in a variety of cellular and metabolic processes, such as gene regulation, hormone perception, energy metabolism and signal transductions.

Each crop shows different responses to micronutrients, but cereal crops such as maize, peanut, soybean, and rice generally show higher responses than other crops. Application of micronutrients on rice can affect physiological processes and enhance yield quality, and increase storage period of the seeds (Graham 2008). Balanced and optimum application of macro and micronutrients are closely related to rice seed vigorous. On intensive areas of rice cultivation, this condition can be achieved by application of micronutrient fertilizers to complete crop requirement in order to support crop growth and increase quality of rice seeds (Dobermann and Fairhust 2000).

Based on the overview of the issue above, it is strongly suggested that there are still many problems on imbalanced soil nutrient content. Therefore, increasing the role of micronutrients in managing intensive lowland rice areas toward sustainable lowland rice farming system should be addressed. The purpose of this paper is to discuss the effects of micronutrient application on lowland rice growth and yield.

Table 1. Micronutrient content of Hortigro Rice fertilizer.

Micronutrients	Content
Cuprum (Cu, %)	0.29
Zinc (Zn, %)	11.64
Boron (B, %)	0.63
Mangan (Mn, %)	5.50
Molybdenum (Mo, %)	0.0655

MATERIALS AND METHODS

The Research Site

A field experiment was conducted from November 2015 to March 2016 at lowland rice center areas of Cihideung Hilir Village, Bogor Barat Sub-district, Bogor Regency. The soil on the research site is classified as Typic Dystrudept (Lembaga Penelitian Tanah 1978; Pusat Penelitian dan Pengembangan Tanah dan Agroklimat 2000). Initial chemical soil analyses using Paddy Soil Test Kit showed that nitrogen and phosphate contents of the soil are low, potassium content is low to medium, while the soil pH is classified as acid (pH value around 5.0). Dosages of nitrogen, phosphorus, and potassium fertilizers were determined referring to this result.

Soil Sampling and Analyses

The composite soil sampling on all plots was conducted 2 times, *i.e.* before applying the treatments and after harvesting time. The composite soil samples were taken from 0-20 cm depth, in which 10 sub-samples were taken in each plot by diagonal system, put them into a pail and then stirred to get a homogenous sample. About 1 kg of the soil was taken as composite soil sample, representing each plot. All composite soil samples were analyzed at Soil Chemistry and Fertility Laboratory, Indonesian Soil Research Institute to determine the chemical soil properties such as pH, organic carbon, total nitrogen, phosphate and potassium contents, cation exchange capacity, base saturation, soil texture, and micronutrient contents.

Soil texture was analyzed by pipette method to determine three soil fractions, namely sand, clay, and silt. Soil pH was analyzed by potentiometric method using water extractant with soil:solution ratio of 1:10 to measure actual soil pH and KCl 1M extractant to measure potential soil pH. Organic carbon was determined using Walkey and Black method based on color intensity shown on spectrophotometer. Total nitrogen was analyzed using Kjeldahl method based on titration of NH_3 with H_2SO_4. Potential P and K were analyzed using HCl 25%, while available P was analyzed using Olsen method. Cation exchange capacity was determined using Ammonium acetate 1 N pH 7.

Table 2. The treatments, inorganic fertilizer dosages, and Hortigo Rice Fertilizer dosages used in the field experiment.

Treatment	Inorganic fertilizers dosage (kg ha^{-1})			Hortigo Rice fertilizer dosage (g L^{-1} water)
	Urea	SP-36	KCl	
Control	-	-	-	-
NPK-Standard	300	100	75	-
NPKStandard+¼ Hortigro Rice	300	100	75	16.5
¾ NPKStandard+¼ Hortigro Rice	225	75	56.25	16.5
¾ NPKStandard+½ Hortigro Rice	225	75	56.25	33.0
¾ NPKStandard+¾ Hortigro Rice	225	75	56.25	49.5
¾ NPKStandard+1.0 Hortigro Rice	225	75	56.25	66.0
¾ NPKStandard+1¼ Hortigro Rice	225	75	56.25	82.5

Total content of micronutrients in soil, *i.e.* Cu, Zn, B, Mn, and Fe were analyzed with wet digestion method using HNO_3 and $HClO_4$ extractants, and measured using Atomic Absorption Spectroscopy (AAS) and Spectrophotometer. The micronutrients in the soil samples were determined in order to study the availability of Cu, Zn, B, Mn, and Fe in the soil.

Materials Used in the Field Experiment

The materials used in the field experiment were rice seeds of INPARI-32 variety, inorganic fertilizers, and pesticides. Urea as source of nitrogen, SP-36 as source of phosphorus, and KCl as source of potassium. The source of micronutrients was Hortigro Rice fertilizer that contained of Mn, Cu, Zn, B, and Mo (Table 1). The results of chemical analyses of Hortigro Rice fertilizer showed that zinc (Zn) is predominantly in the fertilizer with the content of around 11.64%, followed by mangan (Mn), boron (B), cuprum (Cu), and molybdenum (Mo) around 5.5%, 0.63%, 0.29%, and 0.0655%, respectively. Interestingly to be noted that around 6290 ppm of total-Fe content in the soil is likely can supply Fe requirement for lowland rice during the life cycle. Like other micronutrients, Iron (Fe) is an essential element for living organisms including plants. Fe-containing proteins play a variety of vital roles in cellular respiration, intermediary metabolism, oxygen transport, and DNA stability and repair, as well as photosynthesis in plants (Li and Lan 2017).

Research Design and Treatments

The field experiment was conducted during one cropping season of lowland rice from November 2015 until March 2016 in collaboration with the skilled farmers. There were eight treatments tested on the field experiment with combinations of inorganic fertilizers (Urea, SP-36, and KCl) and Hortigro fertilizer (Table 2). The treatments were arranged in a Randomized Block Design with three replications. The treatments were Control (1), NPK-standard (2), NPK-standard+ ¼ dosage of Hortigro Rice fertilizer (3), ¾ NPK-standard+ ¼ dosage of Hortigro Rice fertilizer (4), ¾ NPK-standard+½ dosage of Hortigro Rice fertilizer (5), ¾NPK-standard+¾ dosage of Hortigro Rice fertilizer (6), ¾ NPK-standard+1.0 dosage of Hortigro Rice fertilizer (7), and ¾NPK-standard+1¼ dosage of Hortigro Rice fertilizer (8). The NPK fertilizers were applied by spreading them on the soil surface. For Hortigro Rice fertilizer, one gram of the fertilizer was diluted into one litter of water and then sprayed on the rice leaves.

High-yielding variety of lowland rice INPARI-32 was used as crop indicator, with 20 cm × 20 cm planting distance, and 2-3 seeds hole^{-1}. Urea fertilizer was applied twice, ½ dosage at two weeks after planting, and the rest at 30 days after planting. SP-36 fertilizer was applied on the last step of soil tillage by incorporating it into the soil and then mixed by rotary of hand tractor, while KCl fertilizer was applied at the same time with Hortigro Rice fertilizer at two weeks after planting.

Data Analysis

The parameters measured during the experiment were plant height and tiller number at 30 and 60 days after planting, dry weight of grain and straw at harvesting time, dry weight of milled grain and straw, dry weight of 1000 grains, and ratio of dry weight of milled grain and straw.

The collected data were analyzed using analysis of variance (ANOVA). Further, Duncan's Multiple Range Test (DMRT) at $p < 0.05$ was used to determine the significant differences among the treatments.

Table 3. Soil chemical properties of lowland rice areas at Cihideung Hilir Village, Bogor Barat Sub-district, Bogor Regency.

Soil Parameters	Value	Status*
Soil texture:		
- Sand (%)	11	Soil texture: Clay
- Silt (%)	36	
- Clay (%)	53	
pH:		
- H_2O	6.1	Slightly acid
- HCl	5.0	
Organic matter:		
- Organic-C (%)	1.46	Low
- Total-N (%)	0.15	Low
- C/N ratio	10.0	Low
- P_2O_5-Potential (mg 100 g^{-1})	132.33	High
- K_2O-Potential (mg 100 g^{-1})	14.00	Low
- Available-P (ppm)	80.66	High
Exchangeable Cations		
- Ca ($cmol_c$ kg^{-1})	8.55	High
- Mg ($cmol_c$ kg^{-1})	3.57	Low
- K ($cmol_c$ kg^{-1})	0.23	Low
- Na ($cmol_c$ kg^{-1})	0.17	Low
Cation exchange capacity (CEC, $cmol_c$ kg^{-1})	19.23	Moderate
Base saturation (%)	65.33%	Moderate
Micronutrients:	Total in the soil	Crop requirement**
- Total-Cu (ppm)	40.33	0.2 – >0.20.
- Total-Zn (ppm)	87.67	5 – 1.5
- Total-B (ppm)	220.00	<2.5-2.5
- Total-Mn (ppm)	903.67	1.0 – >10.0
- Total-Fe (ppm)	6290.00	2.0 5.0– 40.0

Note: *: Eviati and Sulaeman (2009).
**: Available micronutrients in soils by DTPA method (Food and Fertilizer Technology Center 2001).

RESULTS AND DISCUSSION

Soil Characteristics

Soil characteristics are the important factor directly affecting crop yield. For this reason, a composite soil sample at a depth of 0-20 cm has been collected at the research site, followed by chemical analyses to determine the chemical properties of the soil. Table 3 showed that the soil texture is clay. Soil pH is slightly acid (6.1 measured in H_2O extraction and 5.0 measured in KCl extraction), organic-C and total-nitrogen contents are low. The content of potential-P is high, K_2O is low, and available-P is high. The content of exchangeable cations showed that only calcium is high, while magnesium, potassium, and sodium are low. The cation exchange capacity (CEC) and base saturation of the soil are moderate.

Table 3 indicated that in general the soil used in the field experiment has low up to moderate fertility status, except for available-P. The limiting factors in this soil are organic matter content, potential-K_2O, and exchangeable-Mg, -K, and -Na cations. It means that additional external inputs are needed for this soil to obtain an optimum growth and yield of rice grown on this soil. As stated by Bitew and Alemayehu (2017) that external crop production inputs such as mineral fertilizers, organic amendments, microbial inoculants and pesticides are applied with the ultimate goal of maximizing productivity.

Table 4. Plant height of lowland rice INPARI-32 at 30 and 60 days after planting.

Treatment	Plant height (cm)	
	30 days	60 days
Control (without fertilization)	56.91 b	89.10 c
NPK- Standard	59.26 ab	97.80 bc
NPK Standard + $^1/_4$ Hortigro Rice	61.25 a	100.80 b
$^3/_4$ NPK Standard + $^1/_4$ Hortigro Rice	62.83 a	124.36 a
$^3/_4$ NPK Standard + $^1/_2$ Hortigro Rice	59.17 ab	102.10 b
$^3/_4$ NPK Standard + $^3/_4$ Hortigro Rice	59.34 ab	97.95 bc
$^3/_4$ NPK Standard + 1.0 Hortigro Rice	61.13 a	97.21 bc
$^3/_4$ NPK Standard + $1^1/_4$ Hortigro Rice	60.27 ab	95.48 bc

Note: The numbers followed by the same letters in the same column showed a non-significant difference at 5% level of Duncan Multiple Range Test (DMRT).

Table 5. Number of tiller of lowland rice INPARI-32 at 30 and 60 days after planting.

Treatment	Tiller number	
	30 days	60 days
Control	19.93 b	18.67 b
NPK- Standard	24.37 ab	25.50 a
NPK Standard + $^1/_4$ Hortigro Rice	22.57 ab	24.37 a
$^3/_4$ NPK Standard + $^1/_4$ Hortigro Rice	25.87 a	23.53 a
$^3/_4$ NPK Standard + $^1/_2$ Hortigro Rice	23.23 ab	23.10 a
$^3/_4$ NPK Standard + $^3/_4$ Hortigro Rice	25.07 a	22.37 ab
$^3/_4$ NPK Standard + 1.0 Hortigro Rice	24.07 ab	21.73 ab
$^3/_4$ NPK Standard + $1^1/_4$ Hortigro Rice	24.30 ab	21.03 ab

Note: The numbers followed by the same letters in the same column showed a non-significant difference at 5% level of DMRT.

Related to the purpose of the research, the micronutrient content of the soil was also determined by wet digestion method ($HNO_3 + HClO_4$). The total micro nutrient content of the soil is dominated by Fe around 6290 ppm (or 0.629%), followed by Mn, B, and Zn around 903.67 ppm, 220.00 ppm, and 87.67 ppm, respectively. The highest content of Fe in the soil may be related to higher content of oxides and silicates in this tropical soil. As reported by Brady and Weil (2008) that total Fe content of acidic and dry lands of tropical zone is in the range of 1.32% - 14.54%, whereas the total Mn, B, and Zn contents are in the range of 30-6000 ppm, 7.5-1300 ppm, and 3.3-466 ppm, respectively. Table 3 showed that total micronutrient in the soil are higher compared to the crop requirement as proposed by Food and Fertilizer Technology Center (2001).

Plant Height and Tiller Number

Different treatments applied on the rice fields resulted in the same effect on the plant height at 30 days after planting (DAP), except that in the control (without fertilization) (Table 4). While at 60 DAP, the plant height among the tested treatments showed a significant difference. The highest plant height was measured in the plot applied with ¾ NPK Standard + ¼ Hortigro Rice, namely 124.36 cm, whereas the control treatment resulted in the lowest plant height, namely around 89 cm.

Responses of lowland rice INPARI-32 on the plant height may be related to root capacity in taking up nutrients in the soil. In the early crop growth stage, the root capacity in taking up nutrients from the soil is not optimum so that the applied treatments has not been able to support the rice growth. By time, the tested treatments showed significant effects on the crop growth as the root capacity in taking up nutrients increases.

Tiller number is one of the important yield components of lowland rice INPARI-32. The field experiment showed that the pattern of tiller number is different from that of plant height. Tiller number

Table 6. Harvesting dry weight of grain and straw of lowland rice INPARI-32.

Treatment	Harvesting dry weight (Mg ha^{-1})	
	Grain	Straw
Control	4.6 c	15.7 d
NPK- Standard	8.4 ab	25.7 a
NPK Standard + $^1/_4$ Hortigro Rice	9.0 a	25.9 a
$^3/_4$ NPK Standard + $^1/_4$ Hortigro Rice	8.6 ab	24.9 ab
$^3/_4$ NPK Standard + $^1/_2$ Hortigro Rice	8.9 a	24.3 ab
$^3/_4$ NPK Standard + $^3/_4$ Hortigro Rice	8.2 b	23.5 b
$^3/_4$ NPK Standard + 1.0 Hortigro Rice	8.0 b	21.7 c
$^3/_4$ NPK Standard + 1$^1/_4$ Hortigro Rice	7.5 b	20.6 c

Note: The values followed by the same letters in the same column showed a non-significant difference at 5% level of DMRT.

of lowland rice INPARI-32 showed a non-significant difference among the tested treatments, except at the control treatment both at 30 and 60 DAP (Table 5). This result is related to the roles of macro and micronutrients in crop metabolism. Macronutrients such as nitrogen, phosphate, and potassium have important roles in crop growth during the vegetative phase including plant height and tiller number. Micronutrients such as molybdenum, cuprum, iron, boron, zinc, and manganese have important roles as catalysts of enzymatic reactions and improving quality of crop yield.

The results of current study showed that the application of macronutrients on those tested treatments increased the tiller number of lowland rice INPARI-32 in comparison to that in the control treatment (without fertilization). At 60 DAP, the NPK-standard treatment resulted in the highest tiller number of INPARI-32 variety, *i.e.* around 25.50, and the control treatment resulted in the lowest tiller number, *i.e.* around 18.67. The results of the study by Sumarji (2013) reported that the application of macronutrients combined with liquid micronutrients resulted in a significant difference on the tiller number of lowland rice Ciherang variety between tested treatments and the control treatment. Macronutrients have important roles during vegetative growth of crop to support the growth of generative parts of the crop such as flower, seed, grain or other economic yield of the crop.

Dry Weight of Grain and Straw

Dry weight of grain and straw of lowland rice INPARI-32 at harvesting time showed a significant difference among the tested treatments (Table 6). The highest harvesting dry weight of grain and straw was resulted from the application of NPK Standard + $^1/_4$ Hortigro Rice around 9.0 Mg ha^{-1} and 25.9 Mg ha^{-1}, respectively. In contrast, the lowest harvesting dry weight of grain and straw was resulted in the control treatment, *i.e.* around 4.6 Mg ha^{-1} and 15.7 Mg ha^{-1}. Another interesting result is that the

Table 7. Dry weight of milled grain and straw of lowland rice INPARI-32.

Treatment	Dry weight of milled grain (Mg ha^{-1})	Dry weight of straw (Mg ha^{-1})
Control	3.8 c	7.3 d
NPK- Standard	6.7 ab	14.0 a
NPK Standard + $^1/_4$ Hortigro Rice	7.2 a	13.5 a
$^3/_4$ NPK Standard + $^1/_4$ Hortigro Rice	7.1 ab	12.5 ab
$^3/_4$ NPK Standard + $^1/_2$ Hortigro Rice	7.3 a	11.7 bc
$^3/_4$ NPK Standard + $^3/_4$ Hortigro Rice	6.9 ab	11.7 bc
$^3/_4$ NPK Standard + 1.0 Hortigro Rice	6.3 b	11.3 bc
$^3/_4$ NPK Standard + 1$^1/_4$ Hortigro Rice	6.1 b	10.6 c

Note: The values followed by the same letters in the same column showed a non-significant difference at 5% level of DMRT.

Table 8. Dry weight of 1000 milled grains and ratio of dry weight of milled grain to straw of lowland rice INPARI-32.

Treatment	Dry weight of 1000 milled grains (g)	Ratio of dry weight of milled grain to straw
Control	27.87 c	0.43 c
NPK- Standard	29.47 bc	0.49 bc
NPK Standard + $^1/_4$ Hortigro Rice	28.93 bc	0.55 ab
$^3/_4$ NPK Standard + $^1/_4$ Hortigro Rice	29.93 ab	0.58 ab
$^3/_4$ NPK Standard + $^1/_2$ Hortigro Rice	32.00 a	0.63 a
$^3/_4$ NPK Standard + $^3/_4$ Hortigro Rice	30.80 ab	0.60 ab
$^3/_4$ NPK Standard + 1.0 Hortigro Rice	30.13 ab	0.56 b
$^3/_4$ NPK Standard + $1^1/_4$ Hortigro Rice	29.87 ab	0.58 ab

Note: The values followed by the same letters in the same column showed a non-significant difference at 5% level of DMRT.

harvesting dry weight of grain in the NPK Standard + $^1/_4$ Hortigro Rice treatment showed no significant difference from that in the NPK standard, $^3/_4$ NPK Standard + $^1/_4$ Hortigro Rice and $^3/_4$ NPK Standard + $^1/_2$ Hortigro Rice treatments, *i.e.* around 8.4 Mg ha^{-1}, 8.6 Mg ha^{-1} and 8.9 Mg ha^{-1}, respectively. A similar trend was also found for the dry weight of straw in which there were no significant difference on the dry weight of straw among the treatments of NPK + ¼ Hortigro Rice, NPK standard, $^3/_4$ NPK Standard + $^1/_4$ Hortigro Rice and $^3/_4$ NPK Standard + $^1/_2$ Hortigro Rice. A significant increase of dry weight of grain and straw in this case may be related to the compound fertilizer quality which consists of macronutrients (N, P, and K) and also micronutrients (Mn, Cu, Zn, B, and Mo). Formulation of compound fertilizer completed by micronutrients has some advantages such as (a) completing essential nutrients required by crop, (b) increasing crop vigorous and crop resistance to any diseases, (c) increasing quantity and quality crop yield (Gustomo *et al.* 2017).

The same trend for the results of the field experiment was reported by Divangsari (2015) in which the compound fertilizer consisting of macronutrients (NPK) completed by micronutrient of Zn could increased tiller number, grain number per panicle, grain vigorous, and crop yield of lowland rice grown on Vertisol at Sambungmacan, Sragen, Central Java. Other source reported that the application of NPK fertilizer combined with high quality of organic fertilizer that completed by micronutrients could increase yield of lowland paddy. In addition, this yield closely correlated to the increase of grain number per panicle and vigorous grain number per panicle (Kaya 2013).

Similar to the harvesting dry weight of grain and straw, dry weight of milled grain and straw of lowland rice INPARI-32 showed a significant difference between the tested treatments (Table 7). The highest dry weight of milled grain was resulted from the application of $^3/_4$ NPK Standard + $^1/_2$ Hortigro Rice, *i.e.* around 7.3 Mg ha^{-1}, and the lowest dry weight of milled grain was obtained in the control treatment, *i.e.* around 3.8 Mg ha^{-1}. Interestingly, the highest dry weight of straw was observed in the NPK-standard treatment, *i.e.* around 14.0 Mg ha^{-1}, which is not significantly different from that in the NPK Standard + $^1/_4$ Hortigro Rice, *i.e.* around 13.5 Mg ha^{-1} and ¾ NPK standard + ¼ Hortigro Rice (12.5 Mg ha^{-1}). This result is in line with the highest harvesting dry weight of straw that was obtained on NPK Standard + $^1/_4$ Hortigro Rice, which is not significantly different from that on NPK-standard treatment, *i.e.* around 25.9 Mg ha^{-1} and 25.7 Mg ha^{-1}, respectively.

Table 7 showed that there is no significant difference between dry weight of milled grain and straw of NPK Standard + $^1/_4$ Hortigro Rice and NPK-standard treatment. These results were different from the results of other sources. Devangsari (2015) reported that the application of micronutrients could increase dry weight of milled grain and straw of lowland rice significantly compared to those without micronutrients treatment. Hartatik and Widowati (2015) also reported that the application of compound fertilizer consisting of macro and micronutrients up to 600 kg ha^{-1}, provided the highest dry weight of milled grain and straw of lowland rice around 4.7 Mg ha^{-1} and 5.2 Mg ha^{-1}, respectively.

Dry Weight of 1,000 Milled Grains and Ratio of Dry Weight of Milled Grain to Straw

The same trend was observed for the dry weight of 1,000 milled grains and ratio of dry weight of milled grain to straw. The highest dry weight of 1000 milled grains and ratio of dry weight of milled grain to straw were resulted from the application of $^3/_4$ NPK Standard + $^1/_2$ Hortigro Rice, *i.e.* around 32.00 g and 0.63, respectively. Meanwhile, the lowest dry weight of 1000 milled grains and ratio of dry weight of milled grain to straw was obtained in the control treatment, *i.e.* around 27.87 gram and 0.43, respectively. In addition, the dry weight of 1000 milled grains and the ratio of dry weight of milled grain to straw in the NPK-standard treatment showed no significant difference from that in the control treatment.

One of the significant effects of micronutrients on lowland rice yield is increasing dry weight of grain and straw as reported by Sumarji (2013). From an intensive field experiment, he found that the application of macronutrients combined with liquid micronutrients showed a significant dry weight of 1000 milled grains of lowland rice Ciherang variety, *i.e.* around 27.10 g. Meanwhile, Putra (2012) found that the application of 200 kg ha^{-1} NPK fertilizer combined with 50 kg ha^{-1} Urea and 3 liters of leaf fertilizer which contains micronutrients, could increase the vigorousness of grain and dry weight of 1000 milled grains around 57% and 25.38 g, respectively.

CONCLUSIONS

Application of micronutrient fertilizer of Mn, Cu, Zn, B, and Mo in combination with NPK fertilizer significantly increased growth and yields of INPARI-32 lowland rice variety grown on Typic Dystrudept soil. The application of ¾ NPK Standard + ½ Hortigro Rice resulted in the highest dry weight of grain and straw, dry weight of milled grain, and dry weight of 1,000 milled grains and ratio of dry weight of milled grain to straw. In addition, the application of ¾ NPK Standard + ½ Hortigro Rice resulted in no significant difference of plant height at 30 and 60 days after planting (DAP) with NPK-Standard treatment. Thus, besides improving the growth and yield of rice, the application of ¾ NPK Standard + ½ Hortigro Rice can reduce 25% of NPK Standard dosage.

The highest tiller number at 60 DAP was achieved by NPK-Standard treatment, but it was not significantly different from that in ¾ NPK Standard + ½ Hortigro treatment, while the highest tiller number at 30 DAP was achieved by ¾ NPK Standard + ¼ Hortigro Rice, but it was not significantly different from that in NPK Standard and ¾ NPK Standard + ½ Hortigro Rice treatments.

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