THE RATIO OF N/K AND GRAIN YIELD OF LOWLAND RICE (*Oryza sativa* L.) AS AFFECTED BY DIFFERENT LEVELS OF NITROGEN APPLICATION AND IRRIGATION METHODS

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ABSTRACT

Lowland rice (Oryza sativa L.) still significantly contributes to Indonesian food security. Water shortage and the availability of N fertilizers frequently become major constraints in rice production, so efficient use of N fertilizers and water-saving irrigation are more preferable. The objective of the experiment was to evaluate the ratio of N/K and seed yield of lowland rice under different levels of nitrogen application and irrigation methods. The experiment was conducted in Gadingrejo-Pringsewu in 2011. The treatments were arranged in factorials with Split-Plot in Randomized Complete Block Design with three replications. Irrigation methods as main plots consisted of two levels, namely, conventional irrigation method (continous standing-water with 5 cm in depth) and irrigation method without flooding (continous saturated soil). Sub-plot was N fertilization consisting of four levels, that is, 150, 200, 250 and 300 kg Urea/ha. Lowland rice cv. Ciherang was planted in experimental plots of 4x5 m in size with row spacing of 25x25 cm. The result of the experiment indicated the ratio of N/K in rice leaves at 40 and 60 DAP, and at harvest time was not significantly affected by irrigation methods and N fertilization levels. The performance of yield components and rice production in conventional irrigation method and irrigation without flooding did not a significant diference although irrigation without flooding consumed less water. This means that irrigation without flooding could increase water use efficiency in lowland rice production.
Key words: grain yield, lowland rice, ratio of N/K, yield components

INTRODUCTION

Rice (*Oryza sativa* L.) plays significant role in food security of Indonesia. Most of Indonesian people depend on rice as source of carbohydrate in daily diets. The increase of Indonesian population drives the enhancement of rice demand. According to Suswono (2012), the prediction of Indonesian population in 2030 will be 425 million people and the need for rice is about 59 million ton. If there is no significant increase in rice production, in 2030 Indonesia will experience rice deficit of 26.04 million ton. In this case, lowland rice contributes more than 90% of Indonesian rice production. Thus, research concerning about lowland rice is still important and useful for strengthening national food security.

It has long been known that nitrogen (N) plays a significant role in crop production. N has structural and functional role in relation to plant growth and development (Mengel and Kirby, 1987; Epstein and Bloom, 2005; Taiz and Zeiger, 2010). Photosynthetic organs contain a lot of nitrogen, and synthesis of enzyme highly requires nitrogen. The study reported by Setiawan and Kamal (2008) indicated that the content of nitrogen in rice leaves at vegetative stages was positively correlated to leaf dry-weight and seed yield of rice plants. Although nitrogen is indispensable to plant growth and development, the excessive application of nitrogen in rice production is not beneficial from the standpoint of agronomy and environment.

Another problem related to N fertilization is that the price of N fertilizers is continously increasing. Thus, N fertilization should be done efficiently. Epstein and Bloom (2005) reported that the improvement of fertilization application technique and plant characters could significantly increase N fertilization efficiency. Excessive application of nitrogen could raise the level of NH^+ in paddy soil which leads to NH^+ toxicity and rice yield reduction (Chen *et al*., 2013). Thus, more efficient use of N fertilizer is highly recomended.

From the stanpoint of agronomy, N use efficiency is defined as the ratio of grain yield to N applied (Chen *et al*., 2013; Abbasi *et al*., 2012). The application of N fertilizer in exessive levels reduces nutrient use efficiency (NUE), resulting in reduction in crop yield per unit fertilizer applied. Lopez-Belido *et al*. (2006) reported that proper dosage and timing of N application significantly contributed to the improvement of N use efficiency and reduction of N losses. Since N is prone to leaching, water management in rice production is also critical for high N use efficiency.

Potassium (K) is also highly required for better grain yield of lowland rice. The involment of K in yield-developing processes of rice plants is well documented (Yoshida, 1981). Potassium plays significant role in photosyntate translocation as well as in carbohydrate accumulation (Taiz dan Zeiger, 2010). The application of potassium could increase the strength of rice stems, resulting in reduction of rice yield loss caused by lodging. In addition, proper application of potassium could increase the resistance of rice plants to pest and diseases (Gething, 1993), while excessive application of N fertilizers frequently induces the susceptibility of rice plants to lodging and plant diseases. This indicated the importance of the balance between N and K in rice production. Kavitha dan Balasubramanian (2006) reported that the productivity of hybrid rice could be maximized through the application of nitrogen (N) and potassium (K) at active tillering.

During its growing season, lowland rice requires a lot of water, so irrigation plays an important role in rice production. In Asia, lowland rice has been cultivated with high water inputs since rice plants were irrigated with continous standing water (Tabbal *et a*l., 2002). Indonesian farmers generally also implemented inefficient irrigation system during cultivating lowland rice (Kamal and Hadi, 2010), resulting in low water use efficiency. On the other side, several studies indicated that lowland rice could be cultivated by implementing the irrigation system without continous standing water, resulting in the use of irrigation water is more efficient (Mohyudin and Tarique, 2010; Tabbal *et al*., 2002; Kamal and Hadi, 2010; Kamal *et al*., 2013). However, the information about nutrient use efficiency in relation to the increase in water use efficiency during rice production is little documented.

The objective of the present study was to evaluate the ratio of N/K and yield of lowland rice under different levels of nitrogen application and irrigation methods. This information would be useful for increasing the efficiency of nitrogen fertilization and developing water-saving irrigation in rice production.

MATERIALS AND METHODS

Field experiment was conducted in Gadingrejo, District of Pringsewu, Lampung Province in 2011. Based on soil analysis, the experimental site had soil pH of 4.56 and contained 0.21% N, 8.05 ppm P and 4.26 K.

Rice seeds of Ciherang cv. were used in this experiment, while the fertilizers used were Urea, SP-36, and KCl. The dosage of SP-36 and KCl was 150 and 100 kg/ha, respectively, while the dosage of Urea was reffered to the treatment.

The treatments were arranged in factorials with Split-Plot in Randomized Complete Block Design with three replications. Main plots were irrigation methods and subplots were N fertilization levels. The irrigation methods consisted of two types: conventional irrigation (the irrigation system with continous standing water/flooding) and the irrigation without standing water (no flooding). The treatment of N fertilization consisted of four levels, that is, 150, 200, 250 and 300 kg Urea/ha.

Rice seedlings were planted in experimental plots of 4x5 m in size with row spacing of 25x25 cm. Then, rice were irrigated, reffering to irrigation method treatment. The conventional method meant that rice plants were continously flooded with 5 cm water, while water-saving irrigation was implemented without continous standing water (no flood). Urea fertilizer was applied two times, that is, one-half dosage at 7 days after planting and another one-half dosage at 30 days after planting. The fertilizer of SP-36 and KCl was once applied at 7 days after planting. During the experiment, pest and disease were controlled by using pesticides, while weeding was done manually.

Variables observed were N and K content in leaves and stems, yield components, and grain yield of rice plants. The content of N and K in leaves and stems of rice plants were measured at 40, 60 and 117 days after planting. N content was analyzed by Kjeldahl method, while K content was analyzed by Atomic Absorption Spectrophotometer (AAS). Rice grain yield was determined at the moisture content of 14%. All data were subjected to Analyses of Variance (ANOVA), and the differences between mean values of the treatments were determined by LSD test at P=0.05.

RESULTS AND DISCUSSIONS

The ratio of N/K in rice leaves

The effect of irrigation methods on N/K ratio in rice leaves at 40 days after planting (DAP) was not significantly difference, while the increase of N fertilization dosages tended to increase N/K ratio in rice leaves (Figure 1). This indicated that the differeces in irrigation methods did not cause a significant difference in the nutrient uptake of N and K. But, the increase of N/K ratio in response to the increase of N fertilization dosages was most likely due to the enhancement of N content in rice leaves. Yoshida (1981) reported that the application of N fertilization could increase the content of N in rice plants.

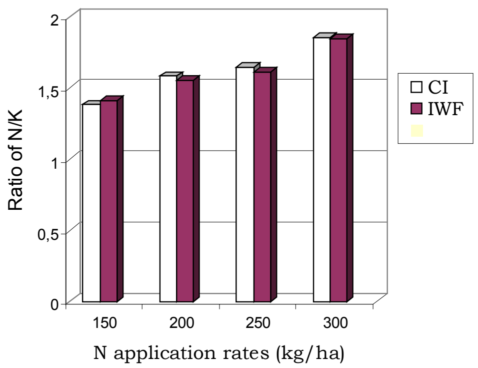

Figure 1. The ratio of N/K in leaf of lowland rice at 40 DAP under different N fertilization and irrigation methods (CI = conventional irrigation, IWF = irrigation without flooding)

Unlike the ratio of N/K in rice leaves, the ratio of N/K in rice stem at 40 DAP was not significantly affected by both irrigation methods and N fertilization. The performance of N/K ratio in rice stems at 40 DAP as afffected by irrigation methods and N fertilization was presented in Figure 2.

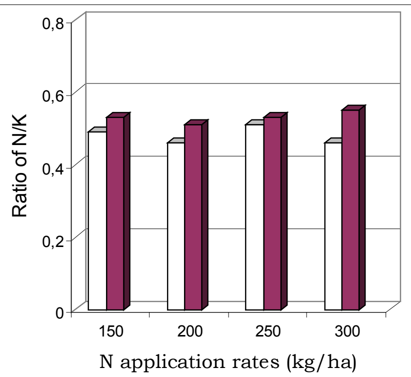

Figure 2. The ratio of N/K in stem of lowland rice at 40 DAP under different N fertilization and irrigation methods (CI = conventional irrigation, IWF = irrigation without flooding)

As presented in Figure 3, the performace of N/K ratio in rice leaves at 60 DAP under conventional irrigation (CI) was relatively similar to irrigation without flooding (IWF). This means that the content of N and K in rice leaves was not affected by different irrigation methods, proving that the irrigation method without flooding could supply N as much as the conventional irrigation did. The ratio of N/K in rice leaves was also not affected by different dosages of N fertilization. This may be due to the growth stage of rice plants. At 60 DAP, rice plants had begun flowering, so rice plants started remobilizing carbohydrate and nutrients to support reproductive structure development (Ishii, 1995). Moreover, in this present study based on plant analysis, the content of N in rice plants was 3.15 %. According to Jones, Jr. (2003), the sufficiency range of N in rice plants was 2.9—4.2 %. Thus, it was not surprising if there was no significat response to N fertization. Mengel and Kirby (1987) also reported that the nutrient status of plants highly determined plant response to fertilization rates.

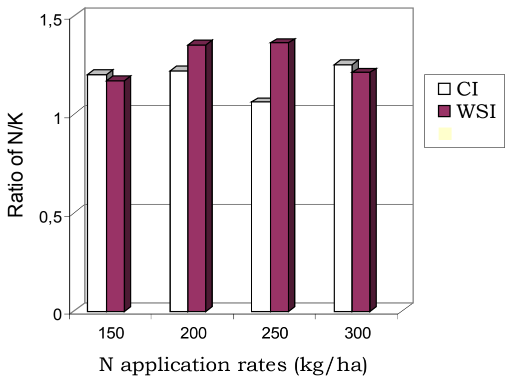

Figure 3. The ratio of N/K in leaf of lowland rice at 60 DAP under different N fertilization and irrigation methods (CI = conventional irrigation, IWF = irrigation without flooding)

At harvest, the ratio of N/K in rice leaves was also not affected by N fertilization and irrigation methods. The performance of N/K ratio under different dosages of N fertilization and irrigation methods was presented in Figure 4. As mentioned earlier, the growth stages of rice plants influenced the content of N in rice leaves. As rice plants grew and developed, the content of N and K in rice leaves changed (Yoshida, 1981). The result of the experiment presented in Figure 1, 3 and 4 indicated that the ratio of N/K decreased. The highest ratio of N/K was at 40 DAP (Figure 1) compared to the ratio of N/K at 60 DAP (Figure 3) and at harvest (Figure 4). However, from this data the ratio of N/K in rice leaves under conventional irrigation and irrigation without flooding was not significantly different. Gething (1993) reported that the role of N and K in plant growth and development is very important and both are interrelated. Nitrogen uptake and utilization were dependent on K availability. Thus the ratio of N/K in plant tissue could influence growth and yield of rice plants.

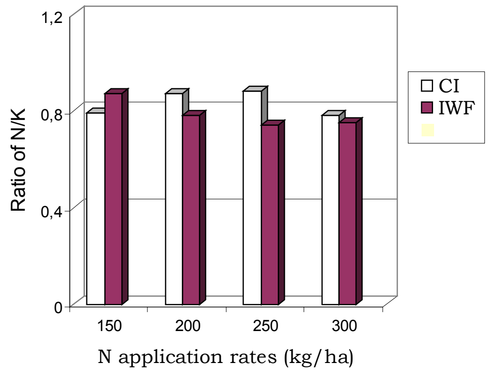

Figure 4. The ratio of N/K in leaf of lowland rice at harvest under different N fertilization and irrigation methods (CI = conventional irrigation, IWF = irrigation without flooding)

Yield components and grain yield of rice plants.

Most of rice yield components and rice production were not significantly affected by irrigtion methods and N fertilization dosages (Table 1). This means that both conventional irrigation and irrigation without flooding have the same ability to support the development of rice yield components until maturity, especially in terms of water supply. Yield components have a great contribution to rice production (Matsushima, 1995), so the effect of irrigation methods on rice production depends on yield component response to irrigation methods. The differences in N fertilization dosages also did not cause a significant effect on most rice yield components and rice production. This was most likely attributed to the sufficiency range of N nutrient in rice plants. As mentioned earlier, in the present study the status of N nutrient were sufficient (Jones, Jr., 2003). Thus, the effect of N application on rice yield was not significant (Epstein and Bloom, 2005).

No significant differences in yield component and grain yield of rice plants under different irrigation methods and N fertilization (Table 1) was consistent with the result of N/K ratio presented in Figure 1, 2, 3 and 4 in which the effect of irrigation methods and N fertilization was not significant. Gething (1993) reported that the ratio of N/K plays a significant role in yield-developing process. Changes in N/K ratio could influence the growth and development of yield components, resulting in different grain yield.

From the stand point of water consumption, irrigation without flooding consumed less water than conventional irrigation (with flooding) in rice cultivation, resulting in higher water use efficiency. This was substantiated by other results of the study (Kamal dan Hadi, 2010; Kamal *et al.*, 2013). Fageria *et al*. (2003) reported that higher water use efficiency could be achieved by reducing water consumption without yield reduction.

CONCLUSION

The ratio of N/K in rice leaves was not significantly affected by different N application levels and irrigation methods. The performance of yield components and grain yield of lowland rice under irrigation method without flooding and conventional irrigation method was not significantly different, reflecting that the implementation of irrigation

Table 1. Yield components and seed yield of low land rice as affected by irrigation methods and N fertilization dosages

Treatments	Panicle number	Panicle Length (cm)	Seed number/ panicle	Seed weight/ panicle (g)	Weight of 1000 seeds (g)	Unfilled seed number	Seed production/ plot (g)
Irrigation methods							
Conventional irrigation	13.70a	19.91a	115.95a	3.96a	29.42a	7.31a	13.43a
Irrigation without flooding	14.05a	20.40a	130.75b	4.32a	30.83a	6.61a	15.06a
N fertilization dosages (kg ha^{-1})							
150	14.37a	19.86a	120.35a	4.12a	30.17a	7.09a	13.77a
200	13.73ab	20.27a	121.58a	4.10a	30.17a	7.27a	14.32a
250	13.58b	20.16a	124.32a	4.16a	29.50a	6.71a	14.11a
300	14.82a	20.31a	127.04a	4.20a	30.67a	6.78a	14.77a

Note: The numbers followed by the letters in the same column and treatments are not significantly different with LSD test at P = 0.05

without flooding in lowland rice production could save irrigation water.

Lowland rice growth stages influenced the ratio of N/K in rice leaves. At maturity (harvest time), the ratio of N/K in rice leaves was the lowest compared to N/K ratio at 40 and 60 days after planting (DAP) under different N application levels and irrigation methods. It seems that the increase of N appliction rates requires the enhancement of K availability to increase rice production.

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