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Growth and Yield of Kalimantan Landrace Rice and "IPB 8G" as Affected by Dose and Time of Nitrogen Fertilizer Application

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Abstract

The study aimed to determine the effect of nitrogen fertilizer dose and the frequency of application on the growth and production of landrace rice Kalimantan and a new rice cultivar developed by Bogor Agricultural University, “IPB 8G”. The study was conducted in December 2017 until June 2018 at Sawah Baru Experimental Field, Bogor Agricultural University, West Java, Indonesia. The experimental design was a split-split plot consisting of three treatment factors, i.e. rice cultivars, fertilization time and fertilizing doses. The three rice cultivars used in this trial were landrace cultivars “Mayas” and “Samarinda”, and “IPB 8G”. The rates of nitrogen were 75 and 150 kg N.ha^{-1} applied at different phases of rice growth i.e. 50% at planting, 25% at the vegetative phase, and 25% at the primordial phase, and without N fertilizer as control. Another time of application was 40% at planting, 20% during the vegetative phase, 20% at the primordial phase, and 20% at heading (four times). Each treatment consisted of three replications totalling 54 experimental units. The N fertilizer application gave a significant effect on all growth parameters except for the harvest index. Time of fertilizer application significantly affected rice panicle number per hill and harvest index. There were significant differences in the growth of the three rice cultivars, except for the number of tillers. Rice crops fertilized three times at 75 kg N.ha^{-1} had the highest number of tillers at five week after planting, but it was not significantly different from N at 150 kg.ha^{-1}. The highest grain yield of 2.9 t.ha^{-1} was obtained from “IPB 8G” cultivar fertilized with 75 kg.ha^{-1} of nitrogen.

Keywords : local rice, “Mayas”, “Samarinda”, fertilization

Introduction

Rice is the main staple food in Indonesia with a population of 255.46 million and rice consumption rate of 124.89 kg per capita per year (Pusdatin Kementan, 2016). The rice consumption increases along with the increase in the population. According to the BPS projection (2014), the Indonesian population will reach up to 305.65 million by 2035 which would propose a big challenge to meet the national demand for rice. One of the ways of fulfilling this demand is by increasing rice production. Efforts to increase national rice production could be achieved by optimizing the use of dry lands, both those that have been and have not been used for agricultural land (Abdurachman et al., 2008).

The current production of upland rice in Indonesia is 3,631,345 tons of dry milled grains which accounts for 4.8% of national rice production or 33.39 quintal per ha (BPS, 2016). The productivity of upland rice is still low due to the many limiting factors in its production management. New technological innovation in upland rice farming such as the use of superior cultivar and the correct dose of fertilizer should be investigated. According to Nasirah and Damanik (2015) superior upland rice cultivars have high yields, resistance to major diseases, earlier production, and have acceptable taste. One of the new superior upland rice cultivar with high productivity is “IPB 8G”.

The development of new type superior rice cultivar does not necessarily affect the demand for local rice varieties. Local rice varieties have important traits, including resistance to diseases (Wijayanto, 2013; Ichsan et al., 2015), so they are popular and still produced in many regions in Indonesia. The availability of local rice cultivar assists breeders in developing new rice cultivar. It is very important to preserve the rice local varieties as assets of national genetic resources, so they can be utilized in breeding programs (Sitaresmi et al., 2013; Kurniawan and Widodo, 2009).

“Mayas” and “Samarinda” are Kalimantan landrace rice which local communities continue to grow for their good taste, fragrant aroma and high economic value, high production and the lowest percentage of empty grain compared to other Kalimantan cultivars, Abung and Timur (Arinta and Lubis, 2016). However, Kalimantan landrace rice production in general is still low. Investigation on the suitable cultivation technology is needed to for the landrace rice, including determination of the optimal rates of fertilizers, and the frequency of fertilizer application.

Nitrogen (N) fertilizer plays an important role in increasing rice production; sufficient availability of N during rice generative phase is very important in slowing down the leaf aging process, thus maintaining an optimum photosynthesis during the grain filling phase. N deficiency affects plant height, reduced number of tillers, and number of grains per panicle (Siregar and Marzuki, 2011). Leaf color is an indicator of N status in plants as a plant deficient in N will exhibit chlorosis (yellowing) in the older leaves (Siregar and Marzuki, 2011; Syahril et al., 2017).

Upland rice genotypes might have different response to high dose of N fertilizer, and low N did not affect their yield components (Fageria et al., 2010). Hirzel et al. (2011) reported that rice fertilized with N at 120 or 140 kg.ha^{-1} had the highest grain production. The highest productivity was obtained when N was applied in stages, i.e. 33% at planting, 33% at tillering stage, and 34% at panicle initiation. Another option is 50% N at planting, and 50% at panicle initiation. Baretto et al. (2012) showed that N fertilizer at 150 kg.ha^{-1} applied 50% at planting and 50% at tillering increased production of two upland rice cultivars, “BRS MG Curinga” and “BRS Primavera”.

Time of fertilizer application determines the production and rice harvest index. Gebremariam and Baraki (2016) demonstrated that the application of N fertilizer 33% at planting, 34% at the time of tiller formation, and 33% at the initiation of panicles, gave the best yield and harvest index. Moreover, Jemberu et al. (2015) in their study on upland rice reported that application of 50% nitrogen fertilizer at planting and 50% at tillering phase resulted in a higher production compared to 50% N applied at planting and at the primordial stage, 25% each at tillering and flowering stage. Therefore, it is important to study the correct time of application and the optimal dose of N fertilizer on Kalimantan landrace rice. This study investigated the application time and rates of N on rice growth and yields of landrace rice Kalimantan as compared to a new rice cultivar “IPB 8G”.

Materials and Methods

The research was conducted at the Sawah Baru Experimental Station, Dramaga, Department of Agronomy and Horticulture, IPB from December 2017 until June 2018. Fertilizers used were Urea, SP36, and KCl. The equipment used in this experiment was LI-3000C Portable Leaf Area Meter, cameras, stationeries, and moisture meter.

The experiment was organized in a split-split plot design consisting of three treatments, i.e. rice cultivar, fertilization time, and the different doses of fertilizer. Three rice cultivars were tested, local “Mayas”, local “Samarinda”, and “IPB 8G”. The nitrogen fertilizers were applied at 0, 75 and 150 kg N.ha^{-1} at different proportion and at different stages of the crop growth. The first method of application is 50% N at planting, 25% N at vegetative stage, and 25% at primordia stage. With the second method of application, N was applied at four stages of the crop growth, i.e. 40% N at planting, 20% N during the vegetative phase, 20% at the primordia stage and 20% at heading (50% flowering). Each treatment consisted of three replications, so altogether there were 54 experimental units consisting of 10 m^2 plots for each treatment.

The growth parameters measured were plant height (cm), performed weekly by measuring plant height from the base of the stem at the surface of the ground to the longest leaf in one hill. Number of tillers, the number of tillers per hill was measured on five rice hill samples per plot.

Destructive samplings were collected from two hills per plot at vegetative, panicle initiation, heading and maturity. Leaf area (cm^2) was measured by LI-3000C Portable Leaf Area Meter. Dry weight (g) was from two sample plants per plot, and then dried in an oven at 80° C for 48 hours. 1000-grain weight (g), number of grain per panicle, and the number of grains per panicle were calculated from the average of three sample panicles per hill from three sample clusters. The number of panicles per hill is calculated on all panicles in one cluster from three sample plants. The panicle length (cm) was measured from the base of the panicle to the tip of the panicle before the rice grains were separated after the crops were harvested. Three panicles per hill of three sample clusters were measured. Grain weight per hill and estimated yield per hectare were obtained by measuring the yields from 1 m x 1.5 m plots, then multiplied the yield to one hectare area.

Soil analysis was conducted at Biotrop Seameo Soil Laboratory, Bogor, Indonesia, to determine the levels of organic C, N, C/N ratio, P_2O_5, K, CEC and base saturation using the soil analysis method by Sulaeman et al. (2005).

Results and Discussion

Soil Properties

The soil type in the research site is latosol with a pH of is 5.4, which is classified as low. The soil has low organic C level (1.33%), moderate level of N (0.23%), low C / N ratio (6), high P_2O_5 (122.2 ppm), very low level of K (0.19 cmol.kg^{-1}), moderate level of CEC (18.26 cmol.kg^{-1}), and high saturation base (66.81%).

Plant Height

Different rice cultivars showed different responses to nitrogen fertilizer rates (Table 1). "IPB 8G" has a shorter life cycle (10 weeks) than "Mayas" and "Samarinda" cultivars (Table 1). "Samarinda" was the tallest cultivar with the height of 110.6 cm at week 9 and 128.7 cm at week 13 (Table 1). This is in line with the results of Arinta and Lubis's (2018) that "Samarinda" is classified as tall, whereas "Mayas" and "IPB 8G" are classified as medium height. Differences in plant height among cultivars or varieties are likely due to the differences in genetic traits (Nazirah and Damanik, 2015), which can affect plant adaptation to the environment (Alavan et al, 2015).

N application increased the rice height as shown in Figure 1. There was a significant effect of the different rates of N on plant height of the three rice cultivars starting at 3 WAP. These results are in line with Alim (2012) which reported that application of nitrogen increases plant height, and Mahajan et al. (2010) reported that nitrogen enhances vegetative growth through increasing cell division and enlargement in the meristem tissue, resulted in expansion of the width or diameter of plant organs (Gardner et al. 1991)

Number of Tillers

Time and dose of nitrogen application interacted in affecting the number of tillers (Table 2), as also reported by Amrutha et al. (2016). Tiller growth is strongly influenced by nitrogen; urea application at planting can supply nitrogen requirement for the optimal growth (Abu et al., 2017). Jemberu et al. (2015) showed that the application of 50% nitrogen fertilizer at planting and 50% in the early stages of tillering to upland rice gave the greatest number of tillers, and there was no interaction between the rice variety and time of application of nitrogen fertilizer.

Leaf Area

Leaf area varies with rice cultivars and rates of N fertilizer (Table 3). At the vegetative and the primordial stage, there was no significant difference in the leaf area amongst the three rice cultivars as affected by the different rates of N fertilizer. However, N fertilization at 150 kg.ha^{-1} significantly increased leaf area during the heading stage (2952.5 cm^2) (Table 3).

"Mayas" and "Samarinda" had a relatively large leaf area compared to "IPB 8G"'s at vegetative and primordia stage, but there were no significant differences amongst the cultivars at the heading stage. The leaf area of all cultivar showed similar growth pattern, with an increase in leaf area in the early stages, and decreased after entering the heading phase. Maya and "Samarinda" have greater leaf area than "IPB 8G" as these two local rice cultivars have a longer leaves. Similarly, Wahyuti et al. (2013) reported that local superior cultivar "Rojolele" and "Pandan wangi" have longer leaves compared to

Table 1. Height of different rice cultivars at different rates of N fertilizer

Treatment	Plant height (cm)					
	Weeks after planting					
	3	5	7	9	11	13
Cultivar						
"Mayas"	32.8b	58.8b	80.5c	95.0b	107.6b	107.7b
"Samarinda"	37.2a	66.2a	93.2a	110.6a	124.3a	128.7a
"IPB 8G"	36.1a	63.2a	88.4b	97.0b	-	-
N doses (kg.ha^{-1})						
0	33.3c	56.4c	80.2b	93.6b	102.3c	106.2b
75	35.6b	63.9b	88.4a	102.4a	119.4a	121.0a
150	37.3a	68.0a	93.5a	106.5a	126.1a	127.3a

Note: The values followed by the same letters within the same column are not significantly different according to Tukey Test at 5%

Table 2. The effect of dose and time of fertilization on the average number of tillers

Treatment	Time of observation (WAP)							
	3		4		5		6	
N dose (kg.ha^{-1})	W_1	W_2	W_1	W_2	W_1	W_2	W_1	W_2
0	6.0c	6.0c	7.3b	7.6b	7.9c	8.8c	8.1a	8.2a
75	6.2bc	7.6ab	8.1b	10.3a	9.6bc	11.7ab	9.8a	11.3a
150	7.7a	7.2abc	11.2a	10.6a	13.1a	11.9ab	11.7a	11.3a

Note: The values followed by the same letters within the same column are not significantly different according to the Tukey Test level at 5%. WAP: weeks after planting. W_1: N fertilizer were applied three times, 50% dose at planting, 25% at vegetative phase, and 25% at primordial phase. W_2: N fertilizers were applied four times, 40% at planting, 20% during the vegetative phase, 20% at the primordial phase, and 20% at heading.

Table 3. Leaf area of different rice cultivars fertilized with different doses of Nitrogen at the vegetative, primodial and 50% blooming stage.

Treatment	Leaf area (cm^2) at different stage of growth		
	Vegetative	Primordia	Heading
Cultivar			
"Mayas"	933.7a	3457.6a	2335.9a
Samarida	909.9a	2791.3ab	2489.9a
"IPB 8G"	271.7b	2256.5b	2256.4a
N dose (kg.ha^{-1})			
0	376.7c	1963.7b	1785.5c
75	753.3a	3017.1a	2344.0b
150	985.2a	3524.6a	2952.5a

Note: The values followed by the same letters within the same column are not significantly different according to Tukey Test at 5%

"IR64" and "Fatmawati". Longer rice leaves will result in a drooping leaf canopy, which causes leaves to be less efficient in utilizing solar radiation.

The application of N at 150 kg.ha^{-1} resulted in the greatest leaf area which was significantly different from the control (without fertilizer), but it was not significantly different from those fertilized with N at 75 kg.ha^{-1} at the vegetative and the primordial phase. At the heading stage there were significant differences between the application of 0 kg.ha^{-1}, 75 kg.ha^{-1} and 150 kg.ha^{-1}. The leaf area in one hill of rice is influenced by the number of tillers as the greater the number of tillers the greater the leaf area. These results confer with Rahman et al. (2014) that an increase in leaf area is caused by an increase in the number of tillers and leaf sizes in accordance with increasing doses.

Shoot and Grain Dry Weight

"Samarinda" fertilized with 150 kg.ha^{-1} N produced the greatest shoot dry weight in even though it was not significantly different from that of "IPB 8G" (Table 5). According to Bustami et al. (2012) the shoot dry weight is related to plant height and number of tillers. Nitrogen application significantly affects dry matter production during the plant growth cycle (Haque and Haque, 2016). According to Dordas et al. (2008) nitrogen is the most important nutrient for crop production because it greatly affects the production of shoot dry weight, leaf area development and photosynthetic efficiency. In the primordial stage "IPB 8G" fertilized with 150 kg N.ha^{-1} had the highest dry weight, and the shoot dry weight was higher than those at the vegetative phase. Dry matter production has a higher correlation with plant height and number of tillers at seed filling, flowering, and physiological maturation stages than the initial stages of growth. Increase in dry weight is an effect of an increase in nitrogen doses (Fageria, 2007; 2011).

Rice Yield Components

The rice yield components, i.e. 1000-grain-weight, the number of grains per panicle, length of panicles, number of panicles per hill, percentage of empty grain, grain yield and the harvest index are described in Table 5. The different rice cultivars showed differences in the weight of 1000-grains and panicle length, but

Table 4. Effect of interactions between cultivars and nitrogen fertilization dose on rice shoot and grain dry weight at vegetative and primordial stage

Rice cultivar	Shoot and grain dry weight (g)					
	Vegetative stage			Primordial stage		
	N (kg.ha^{-1})					
	0	75	150	0	75	150
“Mayas”	2.6c	7.0b	8.3ab	18.2cd	28.7bc	28.0bc
“Samarinda”	3.7c	7.2b	10.a	21.4cd	38.2ab	42.9a
“IPB 8G”	1.6c	2.5c	2.6c	10.2d	26.6bc	37.0ab

Note: The values followed by the same letter within the same column are not significantly different according to Tukey Test at 5%

did not show significant differences in the number of grains. “IPB 8G” had the highest 1000-grain-weight compared to “Mayas” and “Samarinda”. The local rice cultivars have relatively small seed sizes so the 1000-grain-weight is lighter than that of superior cultivar (Rusdianyah et al, 2015). The panicle length of “IPB 8G” (Figure 1C) are longer than those of “Mayas” (Figure 1A) and “Samarinda” (Figure 1 B). According to Jahan et al. (2014) the panicle length variation was due to the different genetic backgrounds of each variety. Similarly, Getachew and Birhan (2015) reported different number of panicles in rice cultivars “Ediget”, “Gumara” and “Nerica-4”.
N application at 150 kg.ha^{-1} resulted in a significantly higher number of panicles per hill relative to the control, but it was not significantly different from application of N at 75 kg.ha^{-1}. N fertilization can increase the number of panicles and the number of grains per panicle (Tayefe et al., 2014; Firouzi, 2015).

Rice cultivars, the time of fertilization, and the dose of fertilizer significantly affected the percentage of empty grain. “Mayas” had a lower percentage of empty grain compared to “Samarinda”, but it was not significantly different from “IPB 8G”. The difference percentage of empty grain of each cultivar is likely due to the genetic makeup of the different cultivars. According to Asaad and Warda (2016), the differences in yield components amongst rice cultivar, including percentage of empty grains, is due to differences in the physical characteristics of each variety and the environment in which they grow.

A split N application where 40% N is applied at planting, 20% N during the vegetative stage, 20% at the primordial stage, and 20% at heading (W2), showed that the application of nitrogen fertilizer at heading stage had improved fruit filling and reduced percentage of empty grain. According to Bah et al. (2009) N fertilization at 55 days after planting increased the amount of filled grain. The

Figur 2. Length of rice panicles “Samarinda” (A), “Mayas” (B) and “IPB 8G” (C)

application of 150 kg.ha^{-1} nitrogen fertilizer resulted in the lowest percentage of empty grain compared to without nitrogen, whereas Khalifa (2012) showed that treatment without nitrogen produced the lowest seed filling percentage.

Each rice variety showed different responses to the increase in nitrogen doses and time of nutrient application; this difference in responses could be influenced by differences in morphological and physiological characters between cultivars. According to Soplanit and Nukuhaly (2012), supplying sufficient N during the generative phase is very important in slowing down the aging process of leaves, so photosynthesis process can be maintained during the grain filling phase.

The rice yields varied with rice cultivar and nitrogen dose. “IPB 8G” had the highest yield of 2.9 t.ha^{-1} which was significantly different from “Samarinda”, but it was not significantly higher than “Mayas” (Table 5). “IPB 8G” had high yield due to the heavier 1000-seeds weight, longer panicles, and the greater weight per hill compared to the local cultivars. The results of a study by Arinta and Lubis (2018) showed that the higher yield of “IPB 8G” compared to local cultivars was due to more number of grains per panicle and greater 1000-grain weight. “IPB 8G” is a new plant type (NPT) that has high yield potential. According to Abdullah et al. (2008), NPT with high yield potential generally have medium number of tillers but all productive (12-18), number of grain per panicle of 150–250, percentage of rice grain of 85–95%, weight of 1,000-grain of 25−26 g, have sturdy and short stems (80−90 cm), early maturing (110–120 days), erect leaves, green to dark green, have dense and deep roots, good quality rice grains, and resistant against major pests and diseases.

Nitrogen treatment had a significant effect on the yield; rice fertilized with N at 75 kg.ha^{-1} had the highest grain yield and was significantly higher compared to control, but it was not significantly different from those fertilized with N at 150 kg.ha^{-1}. The result shows that increasing N rate up to 75 kg.ha^{-1} increased the yield, but the effect diminished as the N rate was increased to 150 kg.ha^{-1}. This results confirms the study by Firouzi (2015) that rice yield increases with increasing nitrogen fertilizer doses from 0 to 75 kg.ha^{-1}, but the yield did not increase with higher N doses (150 kg.ha^{-1}). Moreover, Hirzel et al. (2011) also showed that an optimal dose of nitrogen had a positive effect on grain yield compared to without nitrogen. Application of N at several stages of rice growth is one of the important fertilizer recommendations. However, time of application, especially at critical stages, varies depending on the type of rice cultivars. The application of N during the critical stage can optimize the distribution of N in the leaves, thus maintaining photosynthesis, particularly during the seed filling stage (Bah et al., 2009)

“Mayas” had the highest harvest index, but it was not significantly different from “IPB 8G”. According to Fageria (2007) the harvest index varies among cultivars and is greatly influenced by environmental

Table 5. Rice 1000-grain-weight, number of grains per panicle, panicle length, number of panicles per hill, empty grain, and grain yield of different rice cultivars at different rates and time of fertilizer application

Treatment	1000-grain weight (g)	Number of grains per panicle	Length of panicles (cm)	Number of panicles per hill	Empty of grain (%)	Grain yield (t. ha^{-1})	Harvest index
Cultivar							
“Mayas”	18.2c	242.7a	21.1b	9.9a	13b	2.5ab	48.8a
“Samarinda”	20.6b	232.7a	21.9b	7.1b	16a	2.4b	33.4a
“IPB 8G”	26.8a	257.3a	28.3a	7.7b	14ab	2.9a	47.0a
Frequency of fertilizer application							
3	21.9a	240.3a	23.8a	7.8a	16a	2.7a	46.1a
4	21.8a	244.8a	23.7a	8.6a	13b	2.5a	40b
N dose (kg.ha^{-1})							
0	21.5a	257.6a	23.9a	7.1b	17a	2.1b	4.0a
75	22.2a	236.5a	23.7a	8.5a	14b	2.9a	4.0a
150	21.7a	233.6a	23.7a	9.0a	13b	2.8a	4.0a

Note: The values followed the same letters within the same column are not significantly different according to Tukey Test at 5%.

and nutritional factors. Frequency of nitrogen application showed significant effects on harvest index; N fertilization applied three times resulted in a higher harvest index compared to when N was applied four times. This showed that nitrogen application time at each growth stage has influences on the harvest index. According to Fageria (2010) time of nitrogen application affects the rice harvest index, the harvest index varies from 45 when all N was applied at planting to 53 when two third of N was applied at planting, and 1/3 is applied at panicle initiation.

Conclusion

N fertilizer significantly affected rice height, number of tillers, leaf area, dry weight and yields. The Kalimantan rice cultivar Mayas, Samarinda, and "IPB 8G" have similar number of tillers, but vary significantly in the other growth traits. The new rice cultivar "IPB 8G" had the highest grain yield of 2.8 ton per ha. Nitrogen fertilizer at 75 kg.ha^{-1} applied three times resulted in the highest grain yields, therefore nitrogen fertilization at this level to "IPB 8G" and Kalimantan landrace cultivars is already sufficient.

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