Growth, Yield Components, and Yield Asscociations in Rice Grown on Lowland Swamp

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ABSTRACT

Knowledge on trait associations plays an important role in determining the effectiveness of a selection program for improving rice yield performances. This study was conducted to estimate the correlation among growth, yield components, and grain yield of rice grown on inland swamp environment. Experiment was laid on inland swamp area with > 50 cm peat thickness. Five rice varieties, comprising four local Bengkulu rice varieties (Hanafi, Harum Curup, Batubara, and Lubuk Durian) and a released variety (Inpara 3) were evaluated in a randomized block design with three replications. Data were collected for plant height, leaf area, relative growth rate, net assimilation rate, total tiller and productive tiller numbers, panicle length, grain number panicle-1, and grain yield plant-1. No significant difference was found among the varieties for all observed trait. Grain yield plant-1 had strong positive correlation ($r > 0.60$) with leaf area, total tiller and productive tiller numbers, moderate positive correlation ($0.36 < r < 0.39$) with plant height, relative growth rate, and panicle length, but weak negative correlation ($r = -0.26$) with net assimilation rate. Path analysis revealed that the highest positive direct effect on grain yield plant-1 was exhibited by productive tiller number ($p = 0.54$), followed by grain number panicle-1 ($p = 0.43$) and relative growth rate ($p = 0.37$). Present findings suggested that rice grain yield grown on lowland swamp can be improved by indirect selection favoring higher productive tiller number and higher grain density in a panicle.

Key words : rice local varieties, low land swamp, traits association, indirect selection

INTRODUCTION

Rice is the most important grain crop in Indonesia in providing staple food and living for millions people. During last five years, about 60 to 69 millions metric tons of rice are produced annually (BPS, 2014), but with population nearly 250 millions people and with annual rice consumption about 130 kg capita^{-1} has put Indonesia as the major rice importer country. Although the government has been making effort to achieve self-sufficiency in rice by optimizing all available rice fields, but the deficit may continue unless new rice fields are opened. About 46% of 12 million hectares the rice field is located in Java Island, contributing 58 % of the national rice production (BPS, 2012). Rice field expansion in this densely populated island would be limited and, in the long term, it may not contribute significant additional rice supply as to the population growth. Accordingly, new rice fields should be directed to utilize marginal lands outside Java Island, including fast area of lowland swamps that spread over the country.

Indonesia has around 33.4 millions hectares lowland swamp, consisted of 20.1 millions hectares tidal swamp and 13.3 million hectares inland swamp (Nugroho *et al*., 1992; Manwan *et al*., 1992). Nevertheless, most of these areas are currently less developed and underutilized for agriculture activities and only 2.3 million hectares of lowland area are utilized for crop production (Haryono, 2012), while other 7.27 million hectares that were identified readily feasible for agriculture activities remains intact. Naturally, lowland swamp is submerged almost all year around and its exploitation requires a thorough planning as to the balance between ecological integrity and agriculture production. Learning from past decades experience on the Mega Rice Project (MRP) in Kalimantan that the development rice field on swampy areas using gravity irrigated approach has resulted in the ecosystem disorder and eliminated the function of swamp as a catchment area (Boehm and Siegert, 2001). Rice production on lowland area, therefore, would be more sensible in maintaining the ecological balance if it addressed on the use of high yielding varieties possessing better adaptation on swampy environment.

So far, the number of high yielding rice varieties adapted to lowland ecosystems is limited as to the all released varieties. From 260 varieties released between 1943 and 2011, only 26 varieties are specifically bred for lowland swamp ecosystems (Diah and Syam, 2007; BBPADI, 2012). The use of varieties designed for irrigated lowland has commonly resulted in the suboptimal plant performances and produced grain yield far below their genetic potential (Utama and Haryoko, 2009).

Breeding for improved varieties in rice is often hindered the genetic nature of grain yield. Grain yield of rice is a complex quantitative trait that highly affected by environment (Gravois and McNew, 1993). It is also primarily preconditioned by various yield related morphological and physiological traits (Yoshida, 1981). This makes direct selection for grain yield could be misleading. Consequently, the rice breeders commonly suggested to select for growth traits and yield components that indirectly increase the grain yield (Hairmansis *et al*., 2010; Cyprien and Kumar, 2011; Mohamed *et al*., 2012). With this context, the present study was aimed at the determination of the degree and nature of the relationship between grain yield and yield contributing traits as the basis for selection of high yielding rice varieties for production on lowland ecosystems.

MATERIALS AND METHODS

Study was conducted from September to December 2013 on Kandang Limun inland swamp, City of Bengkulu at about 10 m above sea level. The soil was alluvial with pH = 4.5 and peat thickness $\geq$ 50 cm. The water level during the growing season was fluctuate between 0 to 20 cm above the soil surface. A randomized complete block design with three replications was used to allocate five rice varieties, comprising four local Bengkulu rice varieties (Hanafi, Harum Curup, Batubara, and Lubuk Durian) and a released variety (Inpara 3) on the experimental plots. Size of each plot was 3 m x 3 m with 40 cm inter-plot spacing.

Seedlings were prepared on wet- bed nursery and transplanted on the plot at 21 days old with single seedling per hill and with 20 cm x 40 cm planting space. Basal fertilizers consisted of urea 75 kg ha^{-1}, Ponska 200 kg ha^{-1}, and KCl 75 kg ha^{-1}, were applied at transplanting and additional urea 75 kg ha^{-1} was top dressed at the tillering stage. Both insect pests and diseases were chemically controlled, while weeds were manually controlled by hand.

Data were collected on five randomly selected plant samples from each plot for plant height, leaf area, relative growth rate, net assimilation rate, productive tiller number, panicle length, grain number $panicle^{-1}$, and grain yield $plant^{-1}$. The standard evaluation system for rice (IRRI 1996) was used as the reference for rice traits measurement. Relationships between pairs of observed traits were analyzed using simple correlation analysis and path analysis on single plant basis. A simple correlation analysis was performed using IBM SPSS Statistics v.19. Path analysis with grain yield $plant^{-1}$ as dependent variable and other traits as independent variables was carried out using Microsoft Excel 2007 to estimate the direct and indirect effects as sugested by Singh and Chaudhary (1976).

RESULTS AND DISCUSSION

Degree of association of between pair of observed trait are presented as the estimates of their correlation coefficient (Table 1). Traits association in plant is attributable to pleiotropy or the genetic linkage among the traits (Falconer and McKay, 1996). Here, leaf area and productive tiller number exhibited the highest association (r = 0.87), while net assimilation rate and grain number panicle-1 exerted the lowest association (r = 0.00). To rice breeder, traits showing high association with grain yield is the main concern for the development of high yielding varieties. Four traits were identified to have high and positive association with grain yield plant-1, i.e. leaf area (r = 0.70), tiller number (r = 0.69), productive tiller number (r = 0.76), and grain number panicle-1. These findings were in accordance with Hairmansis et al. (2010), Cyprien and Kumar (2011), and Akhtar et al. (2011). Having high and positive correlation to grain yield implied that selection for these traits can be expected to bring about the improvement on the grain yield. However, the estimate of correlation coefficient does not provide information on the causal association among traits that helps the breeder gaining an efficient selection program.

Table 1. Coefficient of correlation between nine rice traits grown on lowland swamp

	LA	RGR	NAR	TN	PTN	PL	GNP	GY
PH	0.33	0.23	-0.19	0.51	0.40	0.56	0.23	0.36
LA		0.42	-0.15	0.71	0.83	0.58	0.74	0.70
RGR			0.52	0.42	0.47	0.27	0.23	0.39
NAR				-0.22	-0.18	-0.10	0.00	-0.26
TN					0.92	0.47	0.46	0.69
PTN						0.52	0.58	0.76
PL							0.53	0.39
GNP								0.60

Note: PH = plant height, LA = leaf area, RGR = relative growth rate, NAR = net assimilation rate, TN = tiller number, PTN = productive tiller number, PL = panicle length, GNP = grain number panicle-1, and GY = grain yield plant-1.

In this study, path analysis was employed to elucidate the causal relations between the observed traits and grain yield plant^{-1} into direct and indirect effects and, thus, to facilitate better understanding on the nature of association of different traits with rice grain yield. The results as presented in Table 2 reveal that productive tiller number and grain number panicle^{-1} had amenable positive direct effects to grain yield. The important roles of productive tiller number and grain number panicle^{-1} have reported many workers (Yolanda and Das, 1995; Oad *et al*., 2002; Zahid *et al*., 2006; and Hairmansis *et al*., 2011). Moreover, high and positive association of grain yield plant^{-1} with leaf area and tiller number were mainly attributable to indirect effect via productive tiller number. Therefore, productive tiller number and grain number panicle^{-1} can be considered as the selection criteria in rice breeding program for yield improvement under lowland ecosystem.

Table 2. Direct and indirect effects of different traits on grain yield plant-1 in rice grown on lowland swamp

Trait	Direct effect	Indirect effect								Total effect GY
		PH	LA	RGR	NAR	TN	PTN	PL	GNP	
PH	0.08		-0.05	0.09	0.08	-0.06	0.22	-0.10	0.10	0.36
LA	-0.14	0.03		0.16	0.06	-0.08	0.45	-0.10	0.32	0.70
RGR	0.37	0.02	-0.06		-0.21	-0.05	0.25	-0.05	0.10	0.39
NAR	-0.41	-0.01	0.02	0.19		0.02	-0.10	0.02	0.00	-0.26
TN	-0.11	0.04	-0.10	0.16	0.09		0.50	-0.08	0.20	0.69
PTN	0.54	0.03	-0.11	0.18	0.07	-0.10		-0.09	0.25	0.76
PL	-0.17	0.04	-0.08	0.10	0.04	-0.05	0.28		0.23	0.39
GP	0.43	0.02	-0.10	0.09	0.00	-0.05	0.31	-0.09		0.60

Note: PH = plant height, LA = leaf area, RGR = relative growth rate, NAR = net assimilation rate, TN = tiller number, PTN = productive tiller number, PL = panicle length, GNP = grain number panicle^{-1}, and GY = grain yield plant^{-1}.

CONCLUSION

Simple correlation analysis in conjunction with path analysis showed that productive tiller number and grain number panicle^{-1} are important traits for rice grain yield. From practical point of view, rice yield under lowland swamp ecosystem can be improved through indirect selection favoring plants that produce higher productive tiller number and grain number panicle^{-1}.

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