Field Resistance to Blast Disease and Yield Performance of High Yielding Aromatic Upland Rice in Indonesia

TOTOK A.D.H.[1,2], A. RIYANTO[2], L. SOESANTO[2], SUWARTO[2], ANAS[3] and S.H. ZHENG[1]

[1)]Coastal Bioenvironment Center, Saga University, 152-1 Shonan-cho, Karatsu 847-0021, Japan
[2)]Faculty of Agriculture, Jenderal Soedirman Univ., Purwokerto 53122 Indonesia
[3)]Faculty of Agriculture, Padjadjaran Univ. Bandung 40600, Indonesia

インドネシアにおける多収性香米のいもち病に対する圃場抵抗性および収量性

TOTOK A.D.H.[1,2]・A. RIYANTO[2]・L. SOESANTO[2]・SUWARTO[2]・ANAS[3]・鄭　紹輝[1]

[1)] 佐賀県唐津市松南町152-1　佐賀大学海浜台地生物環境研究センター
[2)] Purwokerto 53122, インドネシア　ジェンデラル・スーデルマン大学農学部
[3)] Bandung 40600, インドネシア　パジャジャラン大学農学部

Summary

Breeding of high yield upland rice with good eating quality have been developed for many years in Indonesia and crossing between aromatic rice 'Mentikwangi' (Mw) and high yielding upland rice cultivar 'Poso' (Ps) was established. Rice blast fungus is recognized as a major constraint in rice production, especially in the upland. The objectives of the present study were: i) to evaluate field resistance to blast disease of nine high yielding aromatic upland rice in Indonesia and ii) to determine a resistant aromatic upland rice to blast disease as a parent in breeding program of blast resistance in tropical country. Results showed that resistance to blast disease varied among 13 genotypes and was classified in to resistant (7 genotypes) and slight resistance categories (6 genotypes). Four high yielding of aromatic upland rice genotype (G9, G10, G13 and G34) showed resistance to blast disease and showed high performance in yield and yield component characters. Indeed yield of G34 was higher than well known upland rice cultivar 'Silugonggo' and its parents, Ps and Mw. Among well known upland rice cultivar, the most resistant cultivar 'Situpatenggang' (DI = 11.93%) showed also the best yield performance. Only one slight resistance in aromatic upland rice genotype (G136) was comparable in yield with that resistant one and could be also considered as a source of high yield genotype in plant breeding program.

Key words: Aromatic upland rice, Blast disease, Field resistance, High yielding, Yield performance.

要　　約

インドネシアにおいては、香米品種Mwと多収性陸稲品種Psを親とした高品質・高収量陸稲香米の育種が進められている．一方，熱帯における陸稲では，いもち病の発生が収量を阻害する大きな要因である．本研究の目的は多収性陸稲香米のいもち病に対する圃場抵抗性の評価，およびいもち病抵抗性育種に利用できる親品種の選抜である．その結果，供試した13品種・系統の圃場抵抗性には明らかな系統間差異がみられ，うち7系統は抵抗性，6系統は微抵抗性に分類された．4つの多収性陸稲香米系統(G9, G10, G13およびG34)はいもち病抵抗性とともに収量および収量構成要素も優れていた．いもち病抵抗性および収量がもっとも高かったのは，多収性陸稲品種のStpであったが，香米系統G34の収量はよく知られている多収性陸稲品種Slgおよびその親であるPsとMwよりも高かった．いもち病に微抵抗性を示した多収性陸稲香米系統のうち，G136だけが抵抗性系統と同等の収量性を示しており，多収性品種育種の親として利用できると考えられた．

Introduction

Recently the world was confronted with serious problems in restrictiveness of food supply. The dilemma of increase in food demand and decrease in production due to climate change contributes to the food crisis in the world. Availability of fresh water worldwide for agriculture is now decreasing due to chemical pollution and salinization and reduction of quantity of available water (Baker *et al*., 1999; Kato *et al*., 2006). Climate change due to global warming and decrease of environment quality caused falling water table that become serious problem in many countries. Therefore development of efficient crops to water consumption is very important in the future agriculture system in the world.

Rice (*Oryza sativa*) is one of the most important staple food crops for more than one-half of the world's population and upland rice is major staple crop in many upland production systems of Asia (George *et al*., 2001; Jantasuriyarat *et al*., 2005). Dry land occupies more than 8 million ha land in Indonesia and only 1.2 million ha land was utilized for upland rice production with productivity of 2.27 ton ha^{-1} (Anas, 2007; Totok *et al*., 2008). Development of high yielding of aromatic upland rice is very important to improve not only land use efficiency but also eating quality for food supply. Furthermore, development of upland rice is also important for some area where competition from urban and industrial water uses is being greater (Kato *et al*., 2006). However, there are also many problems, such as high productivity, drough tolerance, and disease esistance, need to resolvefor extention of aromatic upland rice production.

Rice blast fungus is a major constraint in rice production and is recognized to be a serious threat to food security worldwide (Zeigler, 1998; Kato, 2001; Jia *et al*., 2002; Jantasuriyarat, 2005; Saka, 2006). Rice blast disease is distributed over about 85 countries in all continents where the rice plant is cultivated, in both paddy and upland conditions (Kato, 2001). Saka (2006) reported that breeding of cultivar with field resistance has become a major method of crop improvement. Combinations of high yield, good eating quality and resistance to blast disease have become major target for development of upland rice that should be incorporated in an upland rice cultivar. Therefore breeding of high yielding upland rice and resistance to blast disease is very important to increase rice production in Indonesia. According to this purpose, we bred nine high yielding aromatic upland rice genotypes from previous research and yield stability of these genotypes was tested in eight locations of Indonesia (Totok *et al*., 2008). However, no information about the field resistence to rice blast of selected genotypes before subjected to be released as candidate of new cultivars. The objectives of the present study were: i) to evaluate blast disease resistance of nine high yielding aromatic upland rice in Indonesia and ii) to obtain a resistant upland rice genotype against to blast disease as a parent in plant breeding program, especially breeding of blast resistance in tropical country.

Materials and Methods

1.Plant materials

Nine high yielding of aromatic upland rice was planted on the field located at 600 above the sea level at Sumberwulan village, Wonosobo district, Central Java of Indonesia during June to October 2007. The average temperature during experiment was 27℃ and average rainfall in a month was about 250 mm. The former crop was also rice. These environmental conditions are suitable for blast reproduction and were well-known as endemic area for blast disease. No artificial inoculation of *Pyricularia gricea*, a fungi caused blast disease, was applied in the field.

Four well known rice cultivars of Indonesia i.e. 'Poso' (Ps), 'Silugonggo' (Slg), 'Situpatenggang' (Stp), and 'Mentikwangi' (Mw), where Ps and Slg are non aromatic but Stp and Mw are aromatic rice cultivars, were also planted as comparative cultivars. Thus 13 genotypes in total were used in the field resistance experiment. Ps cultivar is indica type and is high yielding upland rice with drought resistance character. Mw is javanica type and is low land aromatic rice. Slg and Stp are new modern rice cultivars developed for adapting to upland and released in 2002 by Indonesia Ministry of Agriculture. Nine high yielding of aromatic upland rice have been selected from 25 aromatic upland rice genotypes in the previous research. They were originated from progeny of crossing between Ps and Mw (Totok *et al.*, 2008).

2.Experimental design

The field experiment was designed as a randomized complete block design with three replications. The plot size was 5 x 2.5 m^2 with 25cm spacing within and between plants. At each location, Each genotype were sown directly in the rate 3 – 4 seeds per hole on June 6, 2007, and then were thinned to two seedlings per hole. No irrigation was applied and water supply was only depended on the natural rainfall. Fertilizer was applied at the rate of 200 kg ha^{-1} of N, 100 kg ha^{-1} P2O5 and 100 kg ha^{-1} K_2O. Half of N together with P_2O_5 and K_2O were applied before sowing, and another half of N dosage was applied two weeks after sowing.

Observations of blast disease resistance of upland rice include appearance of the first disease symptom, scale of damage, disease intensity and rate of infection. Scale of damage was based on Standard Evaluation System for Rice and was divided in to nine categories (IRRI, 1996). Disease intensity and classification of disease resistance was calculated according Amir *et al.* (1999) as follows:

$$\mathrm{DI} = \frac{\sum (n * v)}{(N * V)}$$

where DI is Disease Intensity; N is number of observed leaf; V is the highest numeric value of damage category; n is number of damaged leaf for each category; v is numeric value of damage category. Classification of blast resistance based on disease intensity is shown in Table 1. The rate of infection was observed according Plank (1963):

$$Xt = Xo.\ e^{rt}$$

Where Xt is number of sick plant after t period; Xo is initial number of sick plant (t = 0); e is log2.718; r is rate of infection; t is period of infection. The rate of infection shows the rate of pathogen development per time (Oka, 1993).

Table 1. Classification of Blast Resistance

Disease Intensity (DI)	Resistant classification
0 – 25%	:Resistance (T)
26% – 50%	:Slight Resistance (ST)
51% – 75%	:Slight Susceptibility (SS)
76% – 100%	:Susceptibility (S)

Field performance of aromatic upland rice was evaluated by collecting data of plant height, number of productive tiller per hill, number of grain per panicle and dry weight of grain per hill from 5 randomly chosen plants from each plot. Yield was measured from 1 m^2 effective plots obtained from the middle part of each experimental plot without include border plants. Data were analyzed using comparative description analysis and analysis of variance. Different performances among genotypes were tested by Duncan Multiple Range Test at 5% level according to Steel and Torrie (1980).

Results and discussion

1. Blast disease resistance of high yielding aromatic upland rice

Visual observation showed a variation of first appearance of blast disease symptom among genotypes. The disease attacked the leaves and culms in seedling stage. Generally resistance to blast disease varied among 13 genotypes and they were classified in to resistance group (7 genotypes) and slight resistance group (6 genotypes) (Table 2). Ps and Mw, the parents of these aromatic upland rices genotypes were classified as resistant and slight resistance genotype, respectively. So unsurprisingly their aromatic upland rice progenies were classified in to resistant and slight resistant (Table 2).

Among high yielding aromatic upland rice, the earliest blast disease symptom was observed in genotype G12 and the latest was in genotype G9 (Table 2). This data was in agreement with the disease intensity of these genotypes. Genotype G9 was classified in to resistant group and genotype G12 was in slight resistance group with 37.07 % disease intensity (Table 2). This suggested that the earliest appearance of blast disease symptom occurred in high disease intensity genotype (not resistant genotype).

Bonman (1992) and Saka (2006) described that there were various types of resistance included in field resistance, such as slow blasting and dilatory resistance. Interaction of some genes, pathogen race and environmental factors might contribute to this resistant character. Saka (2006) have recommended for using field resistance method in breeding of blast-resistant plant. However, genetic basis and mechanism of the field resistance is still not fully understood. Various types of resistance and various pathogen races might include in field resistance.

G9, G10, G13 and G34 genotypes showed resistance to blast disease with 16.33% - 23.03% disease intensity. While G12, G19, G35, G39 and G136 genotypes were slight resistance to blast disease and the highest disease intensity was shown by G12 (37.07%) (Table 2). G9 genotype showed the lowest disease intensity (16.33%) among high yielding aromatic upland rice genotypes. All comparative upland rice cultivars (Ps, Spt, Slg) showed more resistance to blast disease than 9 high yielding aromatic upland rice genotypes. Ps which is indica type of upland rice with drought resistance character might have resistant gene to blast disease. Jia *et al*. (2002) described that two major resistant genes *Pi-b* and *Pi-ta* to blast disease were original from indica rice and have introduced into japonica type.

Original aromatic low land rice cultivar

Table 2. The first appearance of blast disease symptom, disease intensity (DI), resistant classification and rate of infection among 13 upland rice genotypes.

Genotype	First appearance of disease symptom (day)	Disease intensity (%)	Resistant classification	Rate of infection (per unit per day)
Stp	32	11.93	Resistance	0.074
Slg	28	14.13	Resistance	0.069
Ps	28	14.13	Resistance	0.077
Mw	19	46.70	Slight Resistance	0.082
G9	27	16.33	Resistance	0.074
G10	24	23.03	Resistance	0.090
G12	20	37.07	Slight Resistance	0.074
G13	26	19.30	Resistance	0.073
G19	22	28.93	Slight Resistance	0.087
G34	26	17.07	Resistance	0.074
G35	22	27.37	Slight Resistance	0.082
G39	23	25.23	Slight Resistance	0.083
G136	24	25.23	Slight Resistance	0.084

Note: Stp; Situpatenggang, Slg; Silugonggo, Ps; Poso, Mw; Mentikwangi.

Mw showed highest disease intensity and was grouped in slight resistance to blast disease. Mw is javanica type and might have no resistant gene to blast disease comparing with Ps. Almost high yielding aromatic upland rice in the present study was developed from crossing between Ps and Mw (Totok, *et al.*, 2008). High yielding aromatic upland rice genotypes were separated in to two groups with different blast disease resistance. Four genotypes were resistant and others were slight resistance to blast disease.

Disease intensity could be used as an indicator of blast resistance in field resistance. Increase of disease intensity was in line with the development of plant age due to rapidly increase of inoculum' s source in plant after the first appearance of symptom. Generally increase of disease intensity of blast disease was observed in all genotype at 26 day after planting (Fig. 1). Disease intensity of all high yielding aromatic upland rice was lower than aromatic low land cultivar Mw. While disease intensity of upland rice cultivars (Ps, Stp, Slg) were lower comparing with aromatic upland rice genotypes. Breeding of a cultivar with field resistance is very important to produce durable resistance plant because of various type of resistance might include in field resistance test.

Rate of infection showed rapid development after eight times of observation. Genotype G10 showed the highest rate (0.09 per unit per day) of infection (Table 2). It means that every day 9 plant of 100 rice plants was infected by blast. The lowest rate of infection was observed in G13 (0.07) which was classified as resistant genotype. High rate of infection was caused by rapid continuity of infection cycle of blast disease and lesions on leaves become inoculums source for the other part of plant or another plant (Kato, 2001). Rate of infection was determined by disease intensity that was influenced by gene resistance in plant, virulence of pathogen and environmental factors (Oka, 1993). Average temperature during experiment was around 27℃ with high rainfall (250 mm per month) and located 600 m above the sea level that was suitable for blast.

2.Field performance and yield

Plant height, number of productive tiller per hill, number of grain per panicle, dry weight of grain and yield were different significantly at 0.05 levels (Table 3). This showed

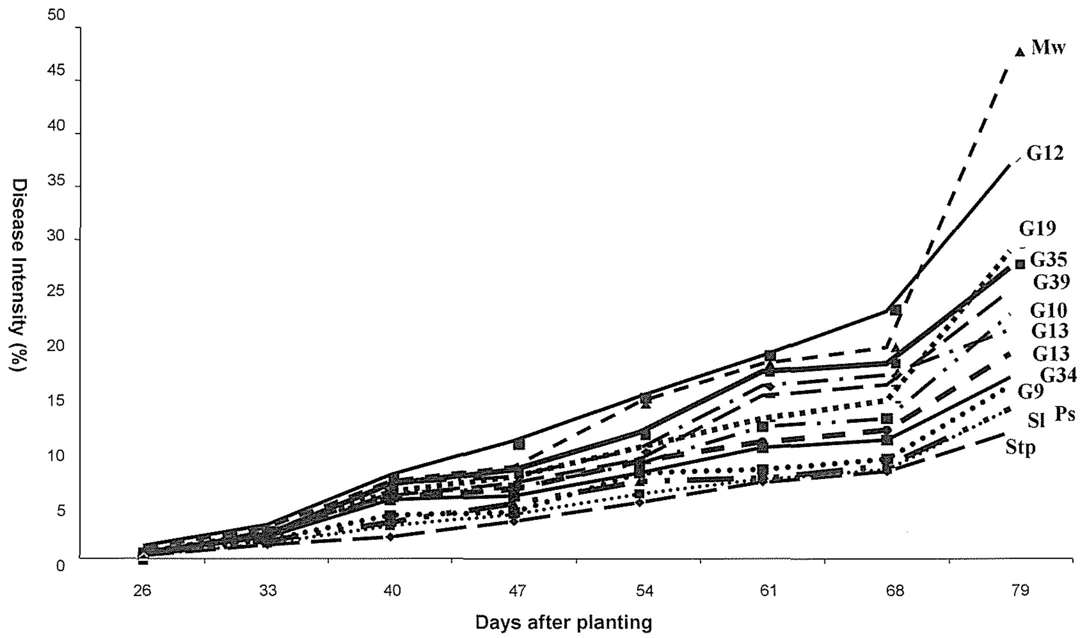

Fig. 1. Development of leave blast disease.

Table 3. Plant height, yield component and yield of 13 upland rice genotypes

Genotype	Plant height** (cm)	Number of productive tiller*	Number of grain per panicle**	Grain weight per hill** (g)	Yield (kg m^2)
Stp	87.70 cde	20.30 b	102.00 d	58.40 j	0.62 f
Slg	64.00 a	16.70 ab	63.30 abc	32.88 e	0.30 de
Ps	83.70 cde	16.70 ab	57.00 ab	30.92 d	0.15 ab
Mw	68.70 ab	13.70 a	53.70 ab	16.04 b	0.17 ab
G9	83.70 cde	17.00 ab	80.70 abcd	34.46 f	0.21 bcd
G10	81.00 bcde	16.70 ab	84.00 bcd	35.08 f	0.26 bcd
G12	82.30 bcde	12.70 a	54.70 ab	18.44 c	0.16 ab
G13	74.70 abcde	13.70 a	84.70 bcd	36.85 g	0.29 cde
G19	71.70 abc	13.30 a	59.30 abc	31.75 de	0.17 abc
G34	87.30 de	16.00 a	85.00 bcd	40.51 h	0.40 e
G35	85.00 cde	13.70 a	48.30 a	9.55 a	0.07 a
G39	90.00 e	13.00 a	51.00 ab	15.60 b	0.07 a
G136	82.70 bcde	14.70 a	93.00 cd	50.27 i	0.40 e

Note: * and **; significant difference at P= 0.05 and 0.01 by F test, respectively. Value with the same letter in a column was not different at P=0.05 level by Duncan Multiple Range Test.

significant difference of field performance among high yielding aromatic upland rice. The plant height varied significantly from 64 – 90 cm. The plant height was the lowest in Slg and the highest in G39 (Table 3). Generally plant height of all genotype in the present study (blast field resistance test) was lower than average of plant height in previous yield-testing at free-blast disease area (Totok *et al*., 2008). Kato (2001) described that lesion formation of the n-leaf (where n is the top developing leaf), causes shortening of the n + 1 leaf sheath and the n + 2 leaf blade, with consequent stunting of the whole plant.

Plant height of high yielding aromatic upland rice was not significant difference (Table 3). However, plant height of Mw which was considered as susceptible cultivar to blast disease was significant lower than others. Mw showed highest disease intensity and its plant height was significant difference comparing with other blast resistance genotype (Stp, Ps, G9 and G34) (Table 2 and 3).

Number of productive tiller per hill significantly varied with the genotype at present study and ranged from 12.7 – 20.3 (Table 3). Only the number of productive tiller per hill in Mw was significant difference from Stp (the highest productive tiller). However G9 genotype that was considered as resistant aromatic upland rice to blast disease showed the highest number of productive tiller. Indeed number of productive tiller of G9 was higher than Slg and Ps that were classified as drought resistance of upland rice cultivars. Two aromatic upland rice G9 and G10 (resistance to blast) showed same performance with Stp.

Different performance in number of productive tiller was shown by genotypes in the field with blast disease and free blast disease at the previous research. In the present study the upland rice cultivar Stp that was grouped in to resistance to blast disease showed superiority in number of productive tiller per hill. On the other hand, Stp showed the smallest average number of productive tiller at eight free-blast disease location (Totok *et al*., 2008).

Number of grain per panicle varied significantly among genotypes and ranged from 48 - 102 (Table 3). The smallest number of grain per panicle was shown in Mw which was considered as slight resistance to blast disease. Among upland rice cultivars, number of grain per panicle of Stp was different significantly from Slg and Ps (Table 3). While, number of grain per panicle of all blast resistance of aromatic upland rice genotype (G9, G10, G13 and G34) was not different significantly from Stp (the highest number of grain per panicle). Only one genotype G136 which was considered as slight resistance to blast disease showed same performance with Stp in the number of grain per panicle.

Grain weight per hill also varied significantly among genotypes and ranged from 9.55 - 58.40 g (Table 3). The lowest grain weight per hill was observed in G35 genotype which was classified as slight resistance to blast disease. The aromatic cultivar Mw showed also small grain weight per hill. Grain weight per hill of all genotype except G136 which was considered as no-resistance to blast disease was significant difference from resistant genotypes. Grain weight per hill of slight resistance genotype was smaller that resistant genotypes. Grain weight per hill of G9, G10, G13 and G34 was higher than G12, G19, G35 and G39.

Among upland rice cultivars, Stp was significant difference from Slg and Ps in grain weight per hill. Grain weight per hill of all resistant aromatic upland rice to blast disease was higher than upland rice cultivars Slg and Ps (Table 2 and 3).

Yield varied significantly among genotypes and ranged from 0.07 - 0.62 kg per m^2 (Table 3). Yield in all blast-resistant genotypes were significant different from yield in slight resistance genotypes. Generally, yield performance of all genotypes except Stp in the present study was lower than their performance in the field of free blast disease at the previous research (Totok *et al.*, 2008). In the present study, the upland rice cultivar Stp which was classified in to resistance to blast disease showed superiority in yield. Yield of upland rice cultivar Stp was significant difference from the others. The lowest yield was performed by aromatic Mw that was also classified as slight resistance to blast disease (Table 2 and 4).

Yield of high yielding aromatic upland rice G34 was different significantly from their parents (Mw and Ps). Yield of G34 was equivalent to 4 ton per ha, which was higher than existing productivity of upland rice in Indonesia (Indonesia Department of Agriculture, 2007). Only one slight resistant of aromatic upland rice genotype (G136) was comparable in yield with that resistant one and could be also considered as a source of high yield genotype in plant breeding program.

As conclusion, this study showed that resistance to blast disease varied among 13 genotypes and these genotypes were separated by 7 resistant and 6 slight resistance genotypes. Four high yielding of aromatic upland rice genotypes i.e. G9, G10, G13 and G34 showed both resistance to blast disease and high performance in yield and yield component characters. The yields of blast-resistant aromatic upland rice genotypes G9, G10, G13 and G34 were higher than their origin parents Mw and Ps, indicating these genotyples might be used in breeding of blast resistance of aromatic upland rice. However, slight resistant of aromatic upland rice genotype G136 might be also considered as a source of high yield aromatic upland rice in plant breeding program.

Acknowledgements

This work was supported in part by a grant from Directorate General of Higher Education, Department of National Education Indonesia.

References

Amir, M., Nasution, A., Santoso. 1999. Rice field testing of blast disease (*Pyricularia grisea*). Proceeding of 15th of the National Congress of Phytopatology Society of Indonesia. Purwokerto, Indonesia.153 – 157*.

Anas, Sumadi and Irwan, A.W. 2007. Genetic variability and heritability of several important characters of 19 elite sorghum genotypes (*Sorghum bicolor* (L.) Moench) at dry season cultivation. Proceeding of 9th of the National Congress of Agronomy Society of Indonesia. Bandung, Indonesia. 167 – 172*.

Baker, R., Dawe, D., Tuong, T.P., Bhuiyan, S.I. and Guerra, L.C. 1999. The outlook for water resources in the year 2020: challenges for research on water management in rice production. In: Assessment and orientation toward the 21st century. Proceedings of 19th session of the International Rice Commission, Cairo, Egypt. Rome, Italy: FAO. 96 – 109.

Bonman, J.M. 1992. Durable resistance to rice blast disease environmental influences. Euphytica 63: 115 – 123.

Department of Agriculture. 2007. Ministry of Agriculture, Centre for agriculture data and information. On-line Pub. http://www.deptan.go.id/

George, T., Magbanua, R., Roder, W., Keer, K.V., Trebuil, G. and Reoma, V. 2001. Upland rice response to phosphorus fertilization in Asia. Agron. J. 93: 1362 – 1370.

IRRI. 1996. Standard *Evaluation System for Rice*. 4th ed. International Rice Research Institute. Manila, Philippines. 17 – 18.

Jantasuriyarat, C., Gowda, M., Haller, K., Hatfield, J., Lu, G., Stahlberg, E., Zhou, B., Li, H., Kim, H., Yu, Y., Dean, R. A., Wing, R. A., Soderlund, C. and Wang, G.L. 2005. Large-scale identification of expressed sequence tags involved in rice and rice blast fungus interaction. Plant Physiology 138: 105 – 115.

Jia, Y., Wang, Z., Singh, P. 2002. Development of dominant rice blast *Pi-ta* resistance gene markers. Crop Sci. 42: 2145 – 2149.

Kato, Y., Kamoshita, A., Yamagishi, J. and Abe, J. 2006. Growth of three rice (*Oryza sativa* L) cultivars under upland condition with different levels of water supply 1. Nitrogen content and dry matter production. Plant Proc. Sci. 9: 422 – 434.

Kato, H. 2001. Rice Blast Disease. The Royal Society of Chemistry. 23 – 25.

Oka, I. N. 1993. Introduction to Plant Disease Epidemiology. Gadjah Mada University Press, Yogyakarta. 92*.

Plank, J.E.V. 1963. Plant Disease: Epidemics and Control. Academic Press, New York. 206.

Saka, N. 2006. A rice (*Oryza sativa* L) breeding for field resistance to blast disease (*Pyricularia oryzae*) in mountainous region agricultural research institute, Aichi Agricultural Research Center of Japan. Plant Proc. Sci. 9: 3 – 9.

Steel, R.G.D. and Torrie, J.H.1980. Principles and Procedures of Statistic. A Biometrical Approach. 2nd.ed. McGrow-Hill, New York. 401-437.

Totok, A.D.H., Suwarto, Yoshida, T. 2008. Yield stability of aromatic upland rice with high yielding ability in Indonesia. Plant Proc. Sci. 11: 96 – 103.

Zeigler, R S. 1998. Recombination in *Magnaporthe grisea*. Ann. Rev. Phytopathol 36: 249 – 275.

---

* In Indonesian