COMBINING OF DROUGHT TOLERANCE AND BROWN PLANTHOPPER RESISTANCE TRAITS INTO ELITE RICE CULTIVARS TARGETING RAINFED AREA

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ABSTRACT

Rainfed areas have enormous potential for rice (*Oryza sativa*) production. However, rice cultivation in this unfavourable ecosystem is hampered by various abiotic and biotic stresses. Drought and brown plant hopper (BPH) (*Nilaparvata lugens*) are two major problems of rice cultivation in this area. Improvement of rice cultivars for these two traits are important to increase rice productivity in rainfed areas. Hybrid population was initially developed through top cross involving high yielding and drought tolerant upland rice Inpago 8, BPH resistant rice Ptb33 and popular rice variety IR64. Two times backcrossing was done by crossing the selected lines into Inpago 8 as the recurrent parent to get BC2F1 materials. Selection on agronomic performance of breeding lines from BC2F1 to BC2F4 were carried out using pedigree method in paddy field in Muara experimental station. Screening on drought tolerance was conducted using concrete tank method in seedling stage, while BPH resistance screening was carried out in screen house using three BPH biotypes. Selected breeding lines were evaluated in replicated yield trials in rainfed rice areas in Indramayu (West Java) and Malang (East Java). Among the progenies of Inpago 8*2//Ptb33/IR64, two lines i.e. B15209B-MR-12-5 and B15209B-MR-12-6 were identified to be highly tolerant to drought and moderately resistant to BPH. Yield performance of these two lines were also improved compared to popular rice variety Ciherang in two rainfed lowland rice areas.

Keywords: rice, drought tolerant, BPH resistance, rainfed area

INTRODUCTION

Rice is the staple food in Indonesia, a country with about 250 million people. The total rice production in the country in 2013 is 70.8 million ton with the yield average is 5.14 ton ha^{-1} (MOA, 2013). About 60% of the total rice production in Indonesia come from irrigated lowland areas, while the rest are produced in unfavourable rice ecosystem including rainfed lowland, tidal swamp land, flood-prone land, and upland. The total rice area in Indonesia is about 8.05 million ha consisted of 4.89 ha of irrigated rice areas and 3.16 ha of non-irrigated rice areas (MOA, 2014). It is estimated that drought-prone rainfed lowland in Indonesia covered about 2.08 million ha (Toha *et al.* 2008).

Rainfed lowland rice areas are characterized as a fragile environment with many abiotic and biotic constraints. Drought is considered as the major abiotic problem hampered the rice production in this ecosystem, while the main biotic problem is brown planthopper. The effect of drought in rainfed area was exacerbated by the global climate change which shifted the pattern of cropping calendar in agricultural land. It was estimated that about 50% of agricultural areas in Indonesia experienced shorter rainy season and longer dry season while rice production in rainfed lowland areas is the most affected (MOA, 2015). The effect of drought to rice plants differed among plant growth stage, growing season and sites (Li & Xu, 2007). Rice plants adapted to drought stress through complex physiological and phenological mechanism such as improving water uptake system, reducing transpiration, increasing water use efficiency, osmotic adjustment and adjusting flowering time (Li & Xu, 2007).

Brown planthopper (BPH) is the most important insect which can significantly reduce rice yield not only in Indonesia, but also in Asia (Bottrell & Schoenly, 2012). The intensity of BPH attack generally increased during rainy season (Efendi & Munawar, 2013), which make cultivation of rice in rainfed area during wet season is vulnerable to this insect. A number of genes responsible for BPH resistance have been identified and used in many rice breeding program. One of important source for BPH resistance is the traditional variety from India Ptb33 which showed resistant reaction pattern to many of BPH populations in South East Asia, including Indonesia (Horgan *et al*. 2015). Utilization of this source to improve the BPH resistance of the Indonesian elite rice germplasms would be beneficial.

Abiotic and biotic stresses which threat rice production in rainfed areas has caused the average rice yield in rainfed lowland area of Indonesia remain low compared to irrigated areas. It is therefore needed to develop rice varieties which have better adaptability to environmental problems in rainfed areas. The objective of this study to develop and evaluate rice breeding materials harbouring drought tolerance and brown planthopper resistance traits for rainfed lowland rice areas.

MATERIALS AND METHODS

Development of Breeding Materials

Backcross (BC) breeding method was used to develop rice breeding material for drought tolerance and BPH resistance improvement. Hybrid population was firstly developed through top cross involving three parentals including high yielding and drought tolerant upland rice Inpago 8, BPH resistant rice Ptb33 and popular rice variety IR64 (Figure 1). Backcrossing was done up to BC2 by crossing the selected lines into Inpago 8 as the recurrent parent. The population of BC2F1 of the cross Inpago 8*2//Ptb33/IR64 was designated as B15209. Pedigree method was then used to select breeding lines with desired performance. Individual plants in BC2F1 with good agronomic performance were selected and self-pollinated to develop BC2F2 seeds. Selections were performed in irrigated rice area at Muara experimental station in Bogor. A similar approach was used to advance the material until BC2F4. Selected lines in BC2F4 were then used for further evaluation for their drought tolerance, BPH resistance and yield performance.

Evaluation of Drought Tolerance

Drought tolerance of rice was evaluated at seedling stage using concrete tank method (Lubis *et al.* 2008). Rice breeding lines were grown in a concrete tank (L 5.5 m x W 1.3 m x H 0.6 m) filled with soil collected from paddy field. Ten seedlings were grown for each line with plant spacing of 20 cm within lines and 20 cm between lines. Tolerant check variety Salumpikit and susceptible check variety IR20 were grown in each 20 rice breeding lines. Soil was watered until the seedling were two weeks old. Watering was then stopped until the susceptible check variety was died. Scoring was performed following IRRI (2014) when the susceptible check was died (score 9).

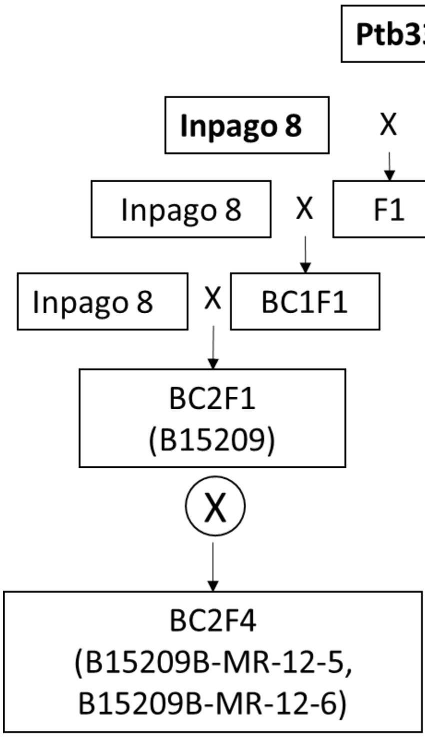

Figure 1. Development of drought tolerant and BPH resistant rice breeding lines

Evaluation of BPH Resistance

BPH evaluation was performed following the method described in Trisnaningsih and Nasution (2015). Three BPH biotype were used to determine the rice breeding lines resistance, including biotype 1, 2 and 3. Scoring on BPH resistance were based on the standard evaluation system for rice (IRRI, 2014).

Yield Trials

In the wet season (WS) of 2015 - 2016 the breeding lines derived from the cross of Inpago 8*2//Ptb33/IR64 were evaluated in rainfed rice ecosystem together with other breeding materials from Indonesian Center for Rice Research (ICRR). The field trials were conducted in two rainfed rice areas in Indramayu (West Java) and Malang (East Java). A total of ten rice breeding lines and check variety Ciherang were evaluated for their yield performance. The trials were designed in randomized complete block design with four replications. Observation were made for agronomic characters of rice including plant height, number of productive tiller, maturity and grain yield.

RESULTS AND DISCUSSION

Development of Breeding Materials

Incorporation of drought tolerance and BPH resistance traits were performed by using drought tolerant upland rice Inpago 8 and BPH resistant variety Ptb33 as the genetic sources. Two times backcross to the recurrent parent Inpago 8 and continued by pedigree selection have resulted several uniform breeding lines in the generation BC2F4 which were potential for further evaluation. We then selected the best six lines for advance yield trials including B15209B-MR-1-2, B15209B-MR-1-3, B15209B-MR-2-1, B15209B-MR-12-5, B15209B-MR-12-6, and B15209B-MR-17-1.

Drought Tolerance of Rice Breeding Materials

Drought tolerance level of rice breeding materials derived from the population of Inpago 8*2// Ptb33/ IR64 were evaluated during vegetative stage (Table 1). Three lines, including B15209B-MR-12-5, B15209B-MR-12-6, and B15209B-MR-17-1 demonstrated highly tolerant response to drought which were better than tolerant check Salumpikit and popular variety Ciherang. Other lines from the same crossing showed moderate to tolerant response. Drought could threat rice plants in rainfed areas both during crop establishment (vegetative stage) and reproductive stage. In this study, we screen the drought tolerance of rice breeding materials in vegetative stage in the greenhouse. Even though the selection of drought tolerant rice lines through managed drought stress experiment such as done in this study has been shown to be effective, the selection of drought tolerant rice lines would be more effective by directly targeting yield trait in target environments (Bernier *et al.* 2008).

Table 1. Drought tolerant level of rice breeding lines

Genotype	Score	Level
B15209B-MR^{-1}-2	3	Tolerance
B15209B-MR^{-1}-3	5	Moderately Tolerance
B15209B-MR-2^{-1}	3	Tolerance
B15209B-MR^{-1}2-5	1	Highly Tolerance
B15209B-MR^{-1}2-6	1	Highly Tolerance
B15209B-MR^{-1}7^{-1}	1	Highly Tolerance
B14954-MR-3-3-0	5	Moderately Tolerance
B14909B-MR-2-3^{-1}	7	Susceptible
B14909B-MR-9^{-1-1}	7	Susceptible
B15277-MR-9	3	Tolerance
Ciherang	3	Tolerance
Salumpikit (Tolerant check)	3	Tolerance
IR20 (Susceptible check)	9	Highly Susceptible

Response of Rice Breeding Materials to Brown Plant hopper

Brown planthopper resistance of rice breeding materials have been evaluated using mass screening method in the seedling stage using three BPH biotypes. Result from this study showed variation in BPH resistance of rice lines derived from the crossing of Inpago 8*2// Ptb33/ IR64. Five lines derived from the crossing of Inpago 8*2//Ptb33/IR64 showed moderate tolerant response against the biotype 1. While against the two-other biotypes (2 and 3), only three lines from Inpago 8*2// Ptb33/ IR64 population which had moderate resistant level including B15209B-MR-1-2, B15209B-MR-12-5, and B15209B-MR-12-6. Thus, these three lines were moderately resistant to all three biotypes of BPH.

The reaction of the breeding lines against BPH was better compared to popular rice variety Ciherang which was susceptible to all three BPH biotype. However, the resistance level of the progenies of Inpago 8*2//Ptb33/IR64 was lower compared to resistant parent Ptb33. Ptb33 was known as rice variety with a broad spectrum of resistance. It was suggested that Ptb33 has resistance genes *bph2* and *Bph3* (Horgan *et al.* 2015). The *bph2* gene was effective resistance genes for BPH biotype 1 and 2, while Bph3 was effective for BPH biotype 1, 2, 3 and 4 (Cheng *et al.* 2013). It is probably that in this study not all BPH resistance genes from Ptb33 have been transferred to the progenies. Further analysis is needed to clarify the BPH resistance gene(s) which are present in the progenies of Inpago 8*2// Ptb33/ IR64.

Table 2. Response of rice breeding lines against three biotype of brown plant hopper in screenhouse screening

Genotype	Resistance score (Level) for each biotype		
	Biotype 1	Biotype 2	Biotype 3
B15209B-MR^{-1}-2	3 (MR)	3 (MR)	3 (MR)
B15209B-MR^{-1}-3	3 (MR)	5 (MS)	5 (MS)
B15209B-MR-2^{-1}	3 (MR)	5 (MS)	5 (MS)
B15209B-MR^{-1}2-5	3 (MR)	3 (MR)	3 (MR)
B15209B-MR^{-1}2-6	3 (MR)	3 (MR)	3 (MR)
B15209B-MR^{-1}7^{-1}	5 (MS)	5 (MS)	5 (MS)
B14954-MR-3-3-0	3 (MR)	3 (MR)	3 (MR)
B14909B-MR-2-3^{-1}	Na	Na	Na
B14909B-MR-9^{-1-1}	Na	Na	Na
B15277-MR-9	5 (MS)	5 (MS)	5 (MS)
Ciherang	7 (S)	7 (S)	7 (S)
Ptb33 (Resistant check)	1 (R)	1 (R)	1 (R)
Rathu Heenati (Resistant check)	3 (MR)	3 (MR)	3 (MR)
TN1 (Susceptible check)	9 (S)	9 (S)	9 (S)
Pelita (Susceptible check)	9 (S)	9 (S)	9 (S)

R= resistant, MR= moderately resistant, S=Susceptible, MS= moderately susceptible, Na= data not available

Agronomic Performance of Rice Breeding Lines

Rice breeding lines derived from the crossing of Inpago 8*2// Ptb33/ IR64 showed variation in their agronomic traits including plant height, tiller number, flowering time and maturity. Two lines B15209B-MR-12-5 and B15209B-MR-12-6 had higher plant architecture compared to other lines in Indramayu, but showed similar plant height with their sister lines in Malang (Figure 2). Meanwhile the number of productive tiller of breeding lines derived from Inpago 8*2// Ptb33/ IR64 varied within locations and between locations. Number of productive tiller in Malang was higher compared to in Indramayu. Both in Indramayu and Malang, the tiller number of the progenies of Inpago 8*2// Ptb33/ IR64 were lower compared to check variety Ciherang (Figure 1).

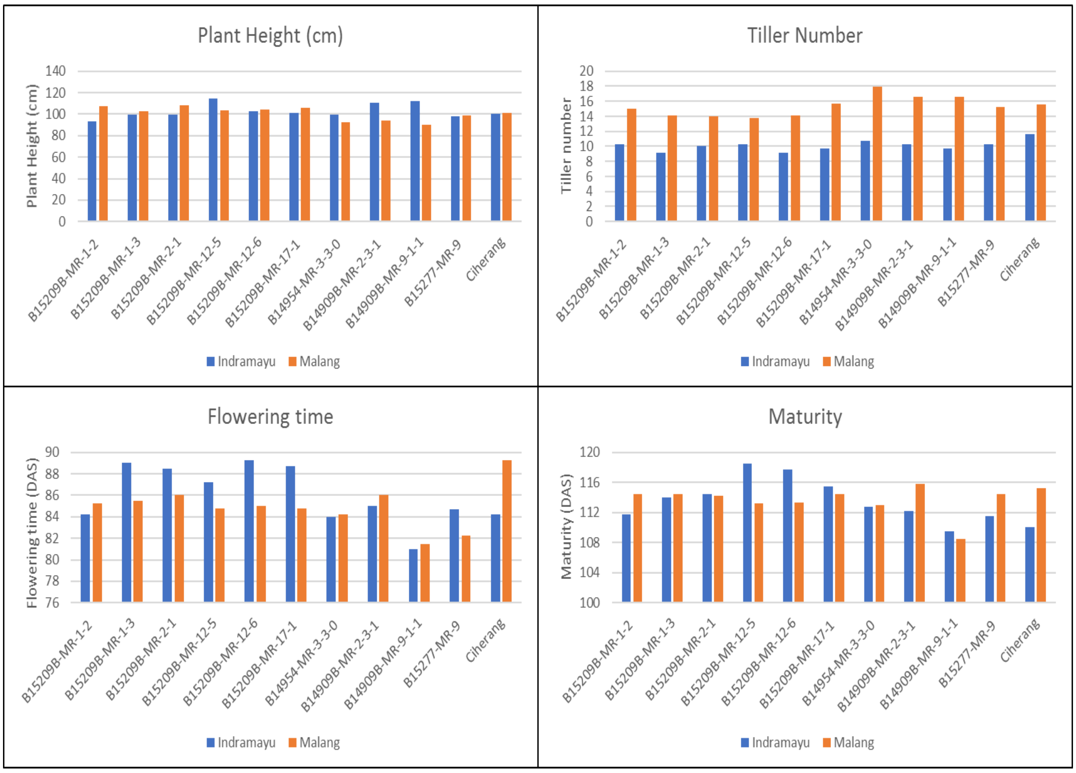

Figure 2. Plant height, tiller number, flowering time and maturity of rice breeding lines in Indramayu and Malang, WS 2015-2016

Table 3. Grain yield of rice breeding lines in Indramayu and Malang, WS 2015-2016

	Grain yield (ton ha^{-1})		
Genotype	Indramayu	Malang	Mean
B15209B-MR^{-1}-2	4.14	7.77	5.96
B15209B-MR^{-1}-3	5.68	7.89	6.79
B15209B-MR-2^{-1}	5.69	7.46	6.57
B15209B-MR^{-1}2-5	5.78	7.18	6.48
B15209B-MR^{-1}2-6	5.69	7.71	6.70
B15209B-MR^{-1}7^{-1}	5.90	8.02	6.96
B14954-MR-3-3-0	6.40	6.26	6.33
B14909B-MR-2-3^{-1}	6.39	7.07	6.73
B14909B-MR-9^{-1-1}	5.84	6.06	5.95
B15277-MR-9	6.46	6.69	6.58
Ciherang	5.32	7.42	6.37
Mean	5.75	7.23	6.49
CV (%)	19.70	7.70	13.54

The rice lines derived from Inpago 8*2// Ptb33/ IR64 showed delayed flowering time and maturity compared to Ciherang in Indramayu (Figure 1). However, the lines showed shorter duration in Malang. The maturity of rice breeding lines from the crossing Inpago 8*2//Ptb33/IR64 in Indramayu ranged from 111 to 118 days after sowing (DAS), while in Malang ranged from 113 to 116 DAS.

Grain yield of rice breeding materials developed from the crossing of Inpago 8*2/ /Ptb33/IR64 was evaluated in Indramayu and Malang to determine their potential yield in target area. The yield of six rice lines from the crossing of Inpago 8*2//Ptb33/IR64 in Malang ranged from 7.18 to 8.02 ton ha^{-1} (Table 3). Average rice yield was higher in Malang (7.23 ton ha^{-1}) compared to Indramayu (5.75 ton ha^{-1}). In Indramayu, six lines of crossing Inpago 8*2// Ptb33/ IR64 showed grain yield from 4.14 to 5.90 ton ha^{-1}. Five of those lines demonstrated higher yield compared to Ciherang which yielded 5.32 ton ha^{-1} (Table 3). The highest yield was achieved by B15209B-$MR^{-1}7^{-1}$ (8.02 ton.ha^{-1}).

Drought and BPH were two major problems which damage rice yield in rainfed lowland rice areas. Improved rice varieties harbouring drought tolerance and BPH resistance are expected to be important technology to increase rice stability in rainfed ecosystem. Combining these two traits in elite rice cultivars is a promising approach to overcome the problem. In this study drought tolerance trait from upland rice cultivar Inpago 8 has been successfully combined with BPH resistance from traditional variety Ptb33 resulted some potential lines with improved characters for the two traits. The lines B15209B-MR^{-1}2-5 and B15209B-MR^{-1}2-6 which were developed from the crossing of Inpago 8*2// Ptb33/ IR64 have been identified to be highly tolerant to drought and moderately resistant to BPH. More importantly the grain yield of these two lines were also improved compared to popular rice variety Ciherang in rainfed lowland rice areas.

CONCLUSION

Improvement of rice varieties for abiotic and biotic stress tolerance is important to maintain sustainability of rice production in rainfed rice areas. Backcross breeding has been shown to be effective to combine drought tolerance and BPH resistance traits. There were two breeding lines derived from the cross of Inpago 8*2// Ptb33/ IR64 which were highly tolerant to drought and moderately resistant to three BPH biotypes i.e. B15209B-MR^{-1}2-5 and B15209B-MR^{-1}2-6. Drought tolerant and BPH resistant rice breeding lines developed in this study have potential to be deployed in rainfed rice areas.

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