

# Response of 10 Elite “Green Super Rice” Genotypes to Weed Infestation in Aerobic Rice Systems

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**Abstract:** In recent years, water and labor shortage in Southeast Asia is driving the farmers towards dry-seeded rice systems. Weed infestation is a serious threat for adoption of these systems. A study was conducted in the wet and dry seasons to evaluate the performance of 10 elite “Green Super Rice” (a recently named group of rice genotypes bred for unfavorable marginal environments) genotypes at two different weed infestation levels (partial and moderate weed control) under dry-seeded conditions. Average yield loss due to weed competition in the partial weed control treatment ranged from 12 – 57% in the wet season and 2 – 23% in the dry season. In the partial weed control plots, the drought pyramiding genotype IR83140-B-11-B performed well, resulting in 2850 and 4610 kg ha<sup>-1</sup> of yield in the wet and dry seasons, respectively. The yield loss of this genotype in the partial weed control plots relative to the moderate weed control plots was only 21% in the wet season and 10% in the dry season. Results clearly showed that grain yield in different genotypes were positively correlated with leaf area at an early stage of the crop. The study also found negative and linear correlation between grain yield and weed biomass at harvest, demonstrating the importance of weeds in dry-seeded rice systems. The study suggested that genotypes with a larger leaf area could be integrated with other weed management strategies to achieve sustainable weed control in dry-seeded rice systems.

**Key words:** Weed biomass, Weed competitiveness, Plant trait.

Dry-seeded rice (DSR) is an emerging establishment method in Southeast Asia in the face of looming labor scarcity and water crisis (Chauhan, 2012). In this production system, however, weeds are the main biological constraint (Chauhan et al., 2012; Mahajan et al., 2013). This constraint is mainly because of the absence of the suppressive effect of standing water at the time of crop emergence and simultaneous emergence of rice and weed seedlings. Due to labor shortage, DSR warrants intensive use of herbicides for weed control. To reduce herbicide use and environmental pollution, there is an urgent need to integrate herbicide with other weed management strategies.

The use of weed-competitive rice genotypes could be another effective weed management strategy, which could be further integrated with herbicide application. Previous studies have documented variations in rice genotypes in their ability to suppress weeds (Gibson and Fischer, 2004; Zhao, 2006). Recently, a breeding strategy was initiated to develop rice genotypes with high nutrient- and water-use efficiency and ability to tolerate various abiotic stresses in different ecosystems (Ali et al., 2012; Marcaida III et al.,

2014). These types of genotypes that gave higher yields with lesser chemical and water inputs were labeled as “Green Super Rice” (GSR) much suited to marginal rainfed lowlands. GSR genotypes responded well under varying environments from fully irrigated to severely drought stressed with a relative yield advantage of 31 – 36% (Marcaida III et al., 2014). Keeping into consideration their superior performance including marginal conditions, it would be worthwhile to evaluate whether these newly developed GSR rice genotypes could be useful in integrated weed management strategies in DSR.

In DSR, the currently available herbicides are not effective when used alone and they do not provide the complete solution for weed control over the entire cropping season (Chauhan, 2012). The use of weed competitive rice genotypes that possess early growth vigor and compete well for resources could provide effective weed control upon integration with one or two applications of herbicides (Chauhan, 2012; Mahajan et al., 2013).

A study was conducted to evaluate the performance of newly developed pre-release GSR genotypes grown under

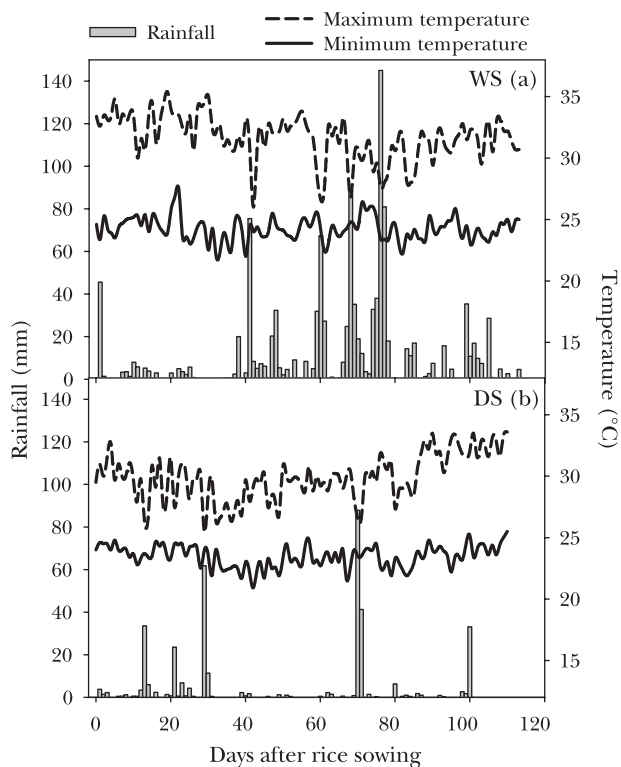


Fig. 1. Rainfall and maximum and minimum temperatures recorded at the experimental site in the wet (WS) and dry (DS) seasons.

two different weed infestation levels under dry-seeded conditions.

### Material and Methods

Field experiments were conducted at the farm of the International Rice Research Institute, Los Baños, Philippines, during the wet season of 2012 and the dry season of 2012/13. The soil at the experimental site had sand, silt, and clay contents of 30, 46, and 24%, respectively. Rainfall and maximum and minimum temperatures recorded at the experimental site are presented in Figure 1.

The experiments in each season were arranged in a split-plot design with GSR genotypes as the main plots and weed control treatments as the subplots. There were three replicates in each season. The experimental area was cultivated twice before crop sowing. Rice seeds were sown in continuous manner by hand at  $100 \text{ kg ha}^{-1}$  in rows with 20 cm spacing between the rows on May 22, 2012 in the wet season and December 13, 2012 in the dry season. Phosphorus (P) and potassium (K) were incorporated into the soil before planting at  $40 \text{ kg P}_2\text{O}_5 \text{ ha}^{-1}$  and  $40 \text{ kg K}_2\text{O ha}^{-1}$ , respectively. Nitrogen (N) was applied at  $150 \text{ kg N ha}^{-1}$  in three equivalent splits: 30% at 14 days after sowing (DAS), 30% at 35 DAS, and 40% at 60 DAS. The field was surface-irrigated immediately after manually direct seeding the 12 experimental seed materials.

The 10 GSR genotypes were carefully selected for this study from several hundreds of GSR materials based on their superior yield performance both under drought and normal irrigated conditions in comparison to the checks (data not shown). The ten promising GSR genotypes were compared with two irrigated check rice varieties, NSICRc222 and PSBRc82 (Table 1), under two different sets of weed control treatments: partial weed control (PWC) and moderate weed control (MWC). In the PWC treatment, oxadiazon ( $0.75 \text{ kg ai ha}^{-1}$ ) was applied at 1 DAS. In the MWC treatment, oxadiazon ( $0.75 \text{ kg ai ha}^{-1}$ ) application was followed by post-emergence herbicides (fenoxaprop + ethoxysulfuron at  $0.045 \text{ kg ai ha}^{-1}$  at 22 DAS and 2,4-D at  $0.5 \text{ kg ai ha}^{-1}$  at 29 – 30 DAS). The herbicides were applied using a knapsack sprayer fitted with flat fan nozzles and it delivered around  $320 \text{ L ha}^{-1}$  of spray solution at a spray pressure of 140 kPa. Completely weedy plots were not included as yield loss in such plots is almost 100%. In addition, it is not common for Asian farmers to leave their rice fields infested with weeds throughout the growing season. The area of each subplot was  $19.2 \text{ m}^2$  ( $3.2 \times 6 \text{ m}$ ).

Rice plant density was counted at 14 DAS from four randomly selected row lengths of 1 m in each plot. Two quadrats of  $40 \text{ cm} \times 40 \text{ cm}$  were placed at random in each plot to determine rice leaf area at the early stage (29 DAS in the wet season and 22 DAS in the dry season) and the late stage (90 DAS) of the crop. Leaf area was measured using a leaf area meter (LI-COR, model #LI-3100, USA). For measuring weed biomass, two quadrats of  $40 \text{ cm} \times 40 \text{ cm}$  were placed at random in each plot at 42 – 45 DAS (around 2 weeks after the last spray of the post-emergence herbicides) and at crop harvest. The biomass was determined after drying the samples at  $70^\circ\text{C}$  for 72 hours. Rice grain yield was determined from the harvested area ( $4 \text{ m}^2$  in the wet season and  $5 \text{ m}^2$  in the dry season) and converted to  $\text{kg ha}^{-1}$  at 14% moisture content.

Data were analyzed using analysis of variance (ANOVA) to evaluate the difference between treatments and the means were separated using least significant difference (LSD) at the 5% level of significance (GenStat 8.0, 2005). The relationship between grain yield ( $\text{kg ha}^{-1}$ ) and crop leaf area ( $\text{cm}^2 \text{ m}^{-2}$ ) at the early and late stages of rice, and between grain yield ( $\text{kg ha}^{-1}$ ) and weed biomass ( $\text{g m}^{-2}$ ) at harvest was developed using linear regression analysis (SigmaPlot 10.0).

### Results and Discussion

Rice plant density was similar across the genotypes and weed control treatments in both seasons (data not shown). Rice density ranged from  $203 \pm 26$  to  $258 \pm 33 \text{ plants m}^{-2}$  in the wet season and  $232 \pm 23$  to  $283 \pm 22 \text{ plants m}^{-2}$  in the dry season.

The dominant weed species at the experimental site

Table 1. Characteristic features of the 10 green super rice genotypes and 2 check rice varieties under irrigated growth conditions (Source: IRRI, Philippines)

Cultivars	Cross information	Breeding approach and generation	Maturity (days after sowing)	Plant Height (cm)	Trait and environment
IR83140-B-11-B	IR64/STYH//IR64/BR24/// IR64/BR24//IR64/Binam	Backcross introgression breeding	105	103	High yield, drought tolerance, salinity tolerance, submergence tolerance, suitable for aerobic, rainfed lowland & irrigated conditions
IR83142-B-19-B	IR64/STYH//IR64/BR24/// IR64/BR24//IR64/Binam	Backcross introgression breeding	103	97.2	High yield, drought tolerance, nutrient use efficient, suitable for aerobic, rainfed lowland & irrigated conditions
IR83142-B-60-B	IR64/STYH//IR64/BR24/// IR64/BR24//IR64/Binam	Backcross introgression breeding	105	99.8	High yield, drought tolerance, nutrient use efficient, suitable for aerobic, rainfed lowland and irrigated conditions
IR83142-B-7-B-B	IR64/STYH//IR64/BR24/// IR64/BR24//IR64/Binam	Backcross introgression breeding	105	103.7	High yield, drought tolerance, nutrient use efficient, suitable for aerobic, rainfed lowland & irrigated conditions
GSR IR1-12-Y4-D1-Y1	Huanghuazhan/Teqing //Huanghuazhan	Backcross introgression breeding BC1F9	108	88.8	High yield, drought tolerance, suitable for aerobic, rainfed lowland & irrigated conditions
GSR IR1-8-S9-D2-Y1	Huanghuazhan/Phalguna //Huanghuazhan	Backcross introgression breeding BC1F9	110	113	High yield, drought tolerance, suitable for aerobic, rainfed lowland & irrigated conditions
GSR IR1-12-D10-S1-D1	Huanghuazhan/Teqing //Huanghuazhan	Backcross introgression breeding BC1F9	115	95.3	High yield, drought tolerance, aromatic, salinity tolerance, suitable for aerobic, rainfed lowland & irrigated conditions
GSR IR1-5-S14-S2-Y2	Huanghuazhan/OM1723 //Huanghuazhan	Backcross introgression breeding BC1F9	115	82	High yield, drought tolerance, salinity tolerance, suitable for aerobic, rainfed lowland and irrigated conditions
GSR IR1-8-S6-S3-Y2	Huanghuazhan/Phalguna //Huanghuazhan	Backcross introgression breeding BC1F9	105	87	High yield, drought tolerance, salinity & submergence tolerance, suitable for aerobic, rainfed lowland & irrigated conditions
GSR IR1-1-Y4-Y1	Huanghuazhan/Yue-Xiangzhan//Huanghuazhan	Backcross introgression breeding BC1F9	110	87	High yield, drought tolerance, salinity and anaerobic germination tolerance, suitable for aerobic, rainfed lowland and irrigated conditions
NSIC RC222	IR73012-137-2-2-2 /IRRI 104	F <sub>2</sub> Pedigree breeding	114	101	High yield, irrigated rice variety, intermediate tolerance to blast, bacterial leaf blight and tungro, moderately resistant to brown plant hopper & green leafhoppers
PSBRc 82	IR47761-27-1-3-6 /PSBRc 28	F <sub>2</sub> Pedigree breeding	110	100	High yield, irrigated rice variety, resistance to blast, intermediate reaction to bacterial leaf blight, brown plant hopper & stem borer, moderately susceptible to green leafhopper.

were *Cyperus iria*, *C. rotundus*, *Echinochloa colona*, *Eclipta prostrata*, *Eleusine indica*, and *Murdannia nudiflora*. At 42 – 45 DAS, weed biomass in the MWC treatment was similar among rice genotypes (Table 2), suggesting that the sequential application of pre- and post-emergence herbicides nullified the effect of genotypes. In this treatment, weed biomass ranged from 2.3 – 10.1 g m<sup>-2</sup> in the wet season and 4.0 – 16.6 g m<sup>-2</sup> in the dry season. In the PWC treatment, however, rice genotypes showed differences in weed biomass. In the wet season, for

example, IR83142-B-7-B-B had the smallest weed biomass. In the dry season, GSR IR1-1-Y4-Y1 and GSR IR1-12-Y4-D1-Y1 had the largest weed biomass; i.e., 49 and 45 g m<sup>2</sup>, respectively. In the dry season, GSR IR1-12-D10-S1-D1 recorded the smallest weed biomass.

The test genotypes showed greater yield reduction during the wet season than in the dry season (Table 3). In the MWC treatment, IR83142-B-7-B-B produced the highest grain yield (3860 kg ha<sup>-1</sup>) in the wet season, which was closely followed by GSR IR1-12-D10-S1-D1 (3750 kg ha<sup>-1</sup>).

Table 2. Effect of rice genotypes and weed control treatments (PWC: partial weed control; MWC: moderate weed control) on weed biomass at 42–45 days after sowing in the wet and dry seasons.

Genotypes	Weed biomass (g m <sup>-2</sup> )			
	Wet season		Dry season	
	PWC	MWC	PWC	MWC
IR83140-B-11-B	44.7	5.0	26.9	9.6
IR83142-B-19-B	21.4	2.3	26.3	12.9
IR83142-B-60-B	25.6	6.1	26.2	12.6
IR83142-B-7-B-B	17.2	4.9	22.5	9.0
GSR IR1-12-Y4-D1-Y1	35.1	10.1	45.0	12.4
GSR IR1-8-S9-D2-Y1	39.8	4.8	25.5	11.9
GSR IR1-12-D10-S1-D1	43.9	7.3	13.9	12.0
GSR IR1-5-S14-S2-Y2	21.2	4.0	27.8	5.9
GSR IR1-8-S6-S3-Y2	27.9	6.3	27.6	10.2
GSR IR1-1-Y4-Y1	19.6	3.5	48.6	10.7
NSICRc222	30.1	5.5	29.6	4.0
PSBRc82	28.1	5.9	21.0	16.6
LSD <sup>a</sup>	32.7		28.1	
LSD <sup>b</sup>	17.5		27.7	

<sup>a</sup>LSD for comparing means of two weed treatments.<sup>b</sup>LSD for comparing means of 12 genotypes.

Table 3. Effect of rice genotypes and weed control treatments (PWC: partial weed control; MWC: moderate weed control) on grain yield of rice in the wet and dry seasons. Values in parentheses are yield loss (%) in the partial weed control plots relative to the moderate weed control plots.

Genotypes	Grain yield (kg ha <sup>-1</sup> )						Advantage over NSICRc222 (%)	
	Wet season		Dry season		Mean of both seasons		PWC	MWC
	PWC	MWC	PWC	MWC	PWC	MWC		
IR83140-B-11-B	2852 (21)	3607	4612 (10)	5125	3732	4366	34.8	6.4
IR83142-B-19-B	2386 (28)	3333	3728 (19)	4630	3057	3982	10.4	-3.0
IR83142-B-60-B	2391 (23)	3101	3928 (15)	4602	3160	3852	14.1	-6.1
IR83142-B-7-B-B	3384 (12)	3859	4179 (14)	4886	3782	4373	36.6	6.6
GSR IR1-12-Y4-D1-Y1	1098 (49)	2142	3311 (23)	4274	2205	3208	-20.4	-21.8
GSR IR1-8-S9-D2-Y1	1743 (45)	3178	4582 (3)	4725	3163	3952	14.2	-3.7
GSR IR1-12-D10-S1-D1	1769 (53)	3748	4560 (2)	4630	3165	4189	14.3	2.1
GSR IR1-5-S14-S2-Y2	1853 (41)	3159	3968 (5)	4184	2911	3672	5.1	-10.5
GSR IR1-8-S6-S3-Y2	1288 (57)	2970	4296 (13)	4940	2792	3955	0.8	-3.6
GSR IR1-1-Y4-Y1	1919 (37)	3044	4166 (5)	4392	3043	3718	9.9	-9.4
NSICRc222	1385 (54)	2985	4153 (20)	5222	2769	4104	0.0	0.0
PSBRc82	1751 (31)	2540	4344 (4)	4540	3048	3540	10.1	-13.7
LSD <sup>a</sup>	1085		719					
LSD <sup>b</sup>	1126		720					

<sup>a</sup>LSD for comparing means of two weed treatments.<sup>b</sup>LSD for comparing means of 12 genotypes.

Compared with the MWC plot, the grain yield loss in the PWC plots was 12 to 57% in the wet season; and 2 to 23% in the dry season (Table 3). In the dry season, NSICRc222 in the MWC treatment and by IR83140-B-11-B in the PWC

treatment. Interestingly, mean values of the PWC treatment over both seasons (wet and dry) clearly showed the superiority of the newly IRRI bred GSR materials, IR83142-B-7-B-B, IR83140-B-11-B, and GSR IR1-12-D10-S1-D1,

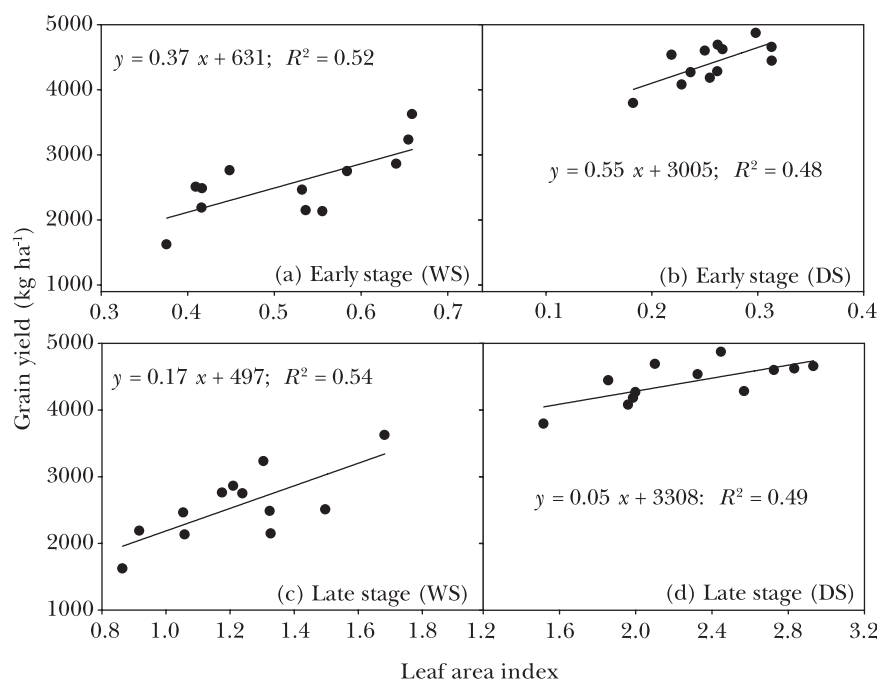


Fig. 2. Relationship between grain yield ( $\text{kg ha}^{-1}$ ) and leaf area index at the early (a and b) and late (c and d) stages in the wet (a and c) and dry (b and d) seasons. Data included are the average of partial and moderate weed control treatments.

to outperform the best check NSICRc222 for grain yield in the range of 14 to 37%. These seed materials were developed for aerobic and drought conditions primarily and therefore showed weed suppressive traits during the first few months of their establishment. The above mentioned three GSR entries provided significantly higher mean yields, especially in the PWC treatment, as compared to both checks (Table 3). Two drought pyramiding GSR lines IR83142-B-7-B-B and IR83140-B-11-B, bred for aerobic conditions, were of early duration with 110 days and plant height of 93 and 90 cm, respectively. Early growth vigor could be associated with weed competitive ability in these genotypes (Zhao, 2006). Interestingly, the third best entry GSR IR1-12-D10-S1-D1 is an aromatic pre-release genotypes that is tolerant to drought, salinity, and low input, and its duration is about 115 days with 87 cm plant height. MWC treatment for this GSR entry provided better yields than PWC, indicating better response to weed control.

The results of our study varied with the season. Such a difference could be due to differential weather data and/or due to differential pest infestations between the seasons. We had observed rice bug damage in the wet season. Higher rainfall was observed in the wet season, which could have also influenced performance of some genotypes as rice genotypes are known to have differential response to low solar radiation on account of days with cloudiness. In spite of such differences, some rice genotypes showed clear response to weed competition. IR83140-B-11-B, for example, produced high yield in the

PWC plots in both seasons ( $2850 \text{ kg ha}^{-1}$  in the wet season and  $4610 \text{ kg ha}^{-1}$  in the dry season). The yield loss of this genotype in the PWC plots relative to the MWC plots was only 21% in the wet season and 10% in the dry season (Table 3). These values for GSR IR1-12-Y4-D1-Y1 were 49% and 23%, respectively.

Regression analysis showed that grain yield was highly correlated with rice leaf area at the early and late stages (Figure 2). There was a positive and linear relationship between rice grain yield and rice leaf area, with 48 – 54% of the variation in grain yield explained by the relationship. The results of our study support the findings of other researchers (Gibson et al., 2001; Caton et al., 2003) that high leaf area index at early stage of the crop is an important trait for weed competitiveness as light plays an important role in plant growth. Another study also showed that leaf area index during early crop development was a major plant trait contributing to weed competitiveness (Coleman et al., 2001). Another study correlated higher grain yields, in competition with weeds, with a higher leaf area index (Zhao, 2006). A recent study suggested that rice genotypes that produced a higher grain yield in competition with weeds had a larger crop biomass at an early stage (Namuco et al., 2009).

A linear relationship was found between grain yield and weed biomass at harvest (Figure 3). The slope of the regression equations in the dry season was less than the corresponding values in the wet season, indicating less susceptibility of grain yield to weed biomass in the dry

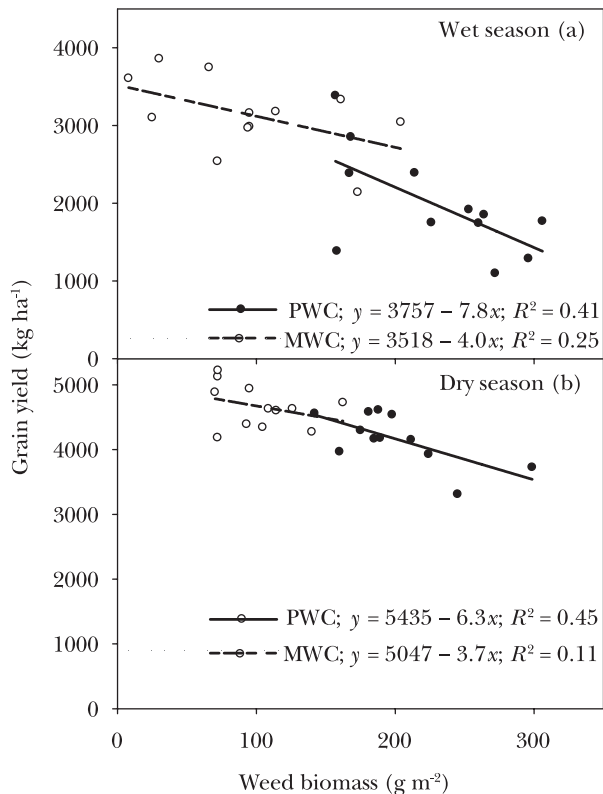


Fig. 3. Relationship between grain yield ( $\text{kg ha}^{-1}$ ) and weed biomass ( $\text{g m}^{-2}$ ) at harvest in partial weed control (PWC) and moderate weed control (MWC) treatments in the wet (WS) and dry (DS) seasons.

season. In both seasons, grain yield was negatively correlated with weed biomass regardless of the weed control treatment. However, the PWC treatment had higher slope values than the MWC treatment. Our results clearly demonstrate that weeds are an important biological constraint in DSR systems. This was also found in earlier studies in DSR, in which grain yield was negatively correlated with weed biomass (Chauhan et al., 2011; Chauhan and Opeña, 2013). The MWC plots had smaller weed biomass than the PWC plots at crop harvest; however, this amount of weed biomass is also capable of reducing grain yield. These observations suggest the possibility of improving weed management and increasing grain yields in DSR systems.

The results of our study suggest that the weed competitive ability of rice genotypes is a complex trait and difficult to explain by one or two plant traits. Interactions between plant traits at an early stage could be explored to improve weed competitiveness in DSR systems. Our study showed that the leaf area was positively correlated with grain yield. Genotypes with the development of leaf area at an early stage could be integrated with herbicide use to achieve effective and sustainable weed control.

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