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Full Length Article

Weed Competitiveness of some Aerobic Rice Genotypes

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Abstract

The present study was carried out in the field for two rice growing seasons to evaluate the weed competitiveness of some rice genotypes under the aerobic condition for their suitability of growing in tropical southeastern Asia. The experiments consisted of two (2) weeding regime (weed-free and weedy check) and three aerobic rice genotypes (MRIA1, MR219-4 and MR219-9). Results revealed that weeds had negative impact on rice plants. MR219-9 recorded the lowest weed population including weeds biomass and the maximum of it was recorded in MRIA1 in both seasons. The majority of the weeds were grasses that constituted over 46% of the totaled dominance-ratio. *Digitaria horizontalis* Willd., *Paspalum scrobiculatum* L. and *Eleusine indica* (L.) Gaertn were the most dominant weeds in 1st season, while broadleaves highly dominated the weeds flora constituted more than 48% of the totaled dominance-ratio with *Cleome rutidosperma* DC., *Ageratum houstonianum* Mill. and *Mimosa pudica* L. were the most dominant weeds in the 2nd season. When compared with other genotypes, MRIA1 with features of tall plant height, few tillers, less growth period competed poorly with weeds than other genotypes (MR219-4 and MR219-9) with shorter plants, many tillers and long growth duration. Lower weed biomass, higher weed competitive index and comparable loss of yield recorded in MR219-9 showed its greater ability of weed suppression and tolerance. The results of this study, therefore, concluded that MR219-9 is the most competitive genotype against weeds in aerobic condition.

Keywords: Aerobic rice genotypes; Grain yield; Straw yield; Relative yield loss; Weed competitive index; Weed biomass

Introduction

As one of the most edible foods consumed throughout the world, production of rice ought to have increased with almost 50% to reach its rising demand. Apart from being the most demanding food item globally, rice production provides jobs and revenue to over 100 million families within Africa as well as Asia (FAO, 2004). According to Bhattacharjee *et al*. (2002) rice provides 20% of the total calorie intake to world populace. According to Khush (2004); Von Braun and Bos (2004) in Asia, the figure has reached 30-75% of the total calorie provided by rice to over three (3) million people.

One major hindrance to rice production, however, is a shortage of water, which necessitates for an alternative which requires less water. One of the new systems established for the low lying regions with an acute shortage of water is ''Aerobic rice''. The system, according to Tuong and Bouman (2003) and Belder *et al*. (2005) is also advantageous for areas with supplementary irrigation available as in uplands. Aerobic rice systems have been very beneficial due to low use of water because the rice crop is raised through direct seeding in non-puddled and non-flooded fields (Huaqi *et al*., 2002; Tuong and Bouman, 2003; Bhushan *et al*., 2007; Farooq *et al.*, 2011). Aerobic rice system reduces applications of water with forty four percent (44%) compared to the traditional transplanted systems, thereby reducing percolation, seepage, and evaporative losses, while preserving production at a conventional level (6 Mg ha^{-1}) (Huaqi *et al*., 2002; Bouman *et al*., 2005).

Unlike conventional puddled transplanting system, an aerobic-system is subject to more weed pressure (Balasubramanian and Hill, 2002; Rao *et al*., 2007). In the

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former system, transplanted rice seedlings surpass germinating weed seedlings, weed growth is also inhibited by stagnant water and rice seedlings transplanted (Moody, 1983). On the other hand, the alternative wetting and drying conditions of aerobic soil followed by dry-tillage are favorable for the weeds germination and growth resulting in 50% to 91% loss of grain yields (Elliot *et al*., 1984; Fujisaka *et al*., 1993; Rao *et al*., 2007). Therefore, one of the major hindrance on comprehensive adopting of highland as well as aerobic production of rice are the weeds (Moody, 1983; WARDA, 1996; Balasubramanian and Hill, 2002) and an important way to increase production is the prompt management of the weeds in aerobic rice fields (Rao *et al*., 2007).

Also, in many cases, proper use of herbicide has been proven effective, and ensures the success of aerobic rice (Heap, 2012), but improper management such as intensive herbicide and inappropriate use can lead to contamination of the environment, sometimes leading to the development of weeds resistant to herbicides (Carey *et al*., 1995; Fischer *et al*., 2000; Lemerle *et al*., 2001a; Heap, 2012). Recently, there has been increasing concern amongst research community to explore non-chemical methods to control the weeds, thereby reducing the risks of the development of weeds herbicide resistance, and also reduce the costs of production (Chauhan, 2012).

The integrated weeds control programs have been evolved as a result of raising concerns of herbicide resistance weed (Chauhan and Johnson, 2010). It has been revealed that the performance of herbicides can be enhanced where species of crop or genotypes with higher competitiveness are combined especially in herbicide-dominant systems (Lemerle *et al*., 1996; Mahajan and Chauhan, 2011). Various literature for many crops including rice, has been documented on the ability of the cultivars to compete with weeds (Gibson and Fischer, 2004; Zhao, 2006). In any crop, a crucial prerequisite in the formulation of strategies for weed management is the use of weed competitive genotype (Chauhan, 2013). According to Dingkuhn *et al*. (1999), competitive rice cultivar development will usher a safer environmental friendly technique of weeds control devoid of overloaded agro-ecosystem with herbicides.

The use of rice variety with competitive ability for suppressing weed tends to significantly lessen stress for selection and use of herbicides including labor cost reduction. As a result of using competitive rice varieties, weeds will be managed by the use of herbicides application at once either pre- or post-emergence or manual weeding (Mahajan *et al*., 2013). The use of pre- or post-emergence herbicide is common among Asian farmers for the weeds management indirect-seeded rice (DSR). Furthermore, hand weeding is also used by farmers. Therefore, competitive cultivars constitute an essential constituents of integrated weed control strategy (Pester *et al*., 1999; Fischer *et al*., 2001; Lemerle *et al*., 2001b). In addition, the deployment of weeds competitive cultivar reduces environmental contamination and is cost effective (Caton *et al*., 2003; Mahajan and Chauhan, 2011; Chauhan, 2012). A competitive cultivar also has the capacity of controlling the dose of the herbicide in DSR through suppression of the emergence and development of weed. Taking wheat as an example, cultivar PBW 343 compared to PDW 233, gives higher competitions with weed due to more number of tillers, thereby helping to curtail of the dose of herbicides in the wheat crop (Mahajan *et al*., 2004). Sanint *et al*. (1998) estimated that the cost of weed control reduces to 30% when enhanced crop competitiveness against weeds is used. For the management of weeds in aerobic rice, the development of weed competitive cultivars is found essential and discovered to be a cost effective constituent of the integrated weed management program. Therefore, the present study was conducted to assess some rice genotypes ability to compete with weeds in aerobic conditions for the selections of appropriate weed competitive genotype(s).

Materials and Methods

Experiment Site

A field experiment was conducted at University Putra Malaysia (UPM), (latitude 3˚ 02'N; longitude 101˚ 42'E and on the altitude of 31 m above sea level) Selangor, Malaysia during the 1st season (May to September 2015) and 2nd season (September to December 2015). The experimental site was previously planted with sweet corn and debris was removed prior to land preparation. During the experiment, the total rainfall received was 548 and 1438 mm in the 1st and 2nd season, respectively. Maximum 33.5 and 33˚C, minimum 25.25 and 24.5˚C, average 29 and 28.5˚C temperatures were recorded in 1st and 2nd season respectively (Table 2). Soil analysis of the experimental site revealed that it was clay loam with pH value of 6.50 and 6.42, total carbon (C) 0.79 and 0.77%, total nitrogen (N) 0.06 and 0.07%, total sulphur (S) 0.02 and 0.0.2%, phosphorus (P) 84.7 and 165.2 µg g^{-1}, potassium (K) 41.24 and 55.07 µg g^{-1} were during 1st and 2nd season respectively (Table 1).

Experimental Materials

The aerobic rice genotype of MRIA1 was obtained from Malaysia Agricultural Research and Development Institute (MARDI) while MR219-4 and MR219-9 from Malaysian Nuclear Agency. The biofertilizer used constituted a consortium of nitrogen-fixing bacteria (*Bacillus sp.* Sb35 and 42) and phosphate solubilizing bacteria (*Bacillus sp.* PSB16). One (1) liter of each inoculum was diluted in 4 liters of dH_2O + molasses in the laboratory. The biofertilizer was then prepared in the biofertilizer processing laboratory using empty fruit bunch (EFB) and peat moss in the ratio of 1:1:1. The prepared biofertilizer was stored for one month

Table 1: Physico-chemical properties of the soil (0–20 cm) at the site collected prior to the onset of the experiment for 1st and 2nd season

Properties	1st season	2nd season
Physical properties		
Sand	37.36	40.46
Silt	37.36	40.46
Clay	29.88	28.99
Soil Texture Class	clay loam	clay loam
Chemical properties		
pH	6.5	6.42
EC (μS/cm)	58	113.9
CEC (cmol/kg)	5.05	5.01
Total C (%)	0.79	0.77
Total N (%)	0.06	0.07
Total S (%)	0.02	0.02
Extractable (μg/g)		
P	84.7	165.2
K	41.24	55.07
Ca	876.7	955.9
Mg	62.7	106.6
Cu	1.595	1.54
Fe	168	145.4
Mn	5.95	11.1
Zn	1.72	2.54

Table 2: Monthly temperature and rainfall at the experimental site from May - December 2015

Months	1st season				Months	2nd season			
	Temperature (ºC)			Rainfall (mm)		Temperature (ºC)			Rainfall (mm)
	Max.	Min.	Ave.			Max.	Min.	Ave.	
May	34	25	29	34	September	33	25	29	98
June	33	26	29	125	October	33	25	29	411
July	34	25	29	65	November	33	24	28	426
August	33	25	29	324	December	33	24	28	503
Average	33.5	25.25	29		Average	33	24.5	28.5	
	Total			548	Total				1438

Source: http://www.accuweather.com/en/my/salak-selatan/228560/august-weather/228560?monyr=8/1/2015&view=table

for the bacteria to multiply prior to application.

Treatments and Experimental Design

The treatments were comprised of two (2) weeding regime (weed-free and weedy check) and three aerobic rice genotypes (MRIA1, MR219-4 and MR219-9) laid out in split-plot in a randomized complete block design (RCBD) with 3 replications. Weeding regime was allocated to the main plot while the sub-plot to the aerobic rice genotypes.

Crop Husbandry Practices

To obtain a fine tilth, the land was ploughed and rotavated; and then marked out into required plot sizes with 1.0 m spacing between blocks and 0.50 m spacing between plots. The gross and net plot sizes were 2.5 m x 1.5 m (3.75 m^2) and 2.0 m x 1 m (2.0 m^2), respectively constituting 6 rows in the gross plots and 4 rows in the net plots, respectively. Seeds were surface sterilized with 70% chlorox (5.25% sodium hypochloride solution) for 30 min then rinsed with sterile water (Amin *et al*., 2004). Sowing was done on 25th May 2015 and 4th September 2015 at an intra and inter-row spacing of 25 cm × 25 cm. Ten (10) dry rice seeds were sown hill^{-1} that was later thinned to 5 seedlings hill^{-1} at 14 days after sowing (DAS). 'Butachlor' herbicide (1.2 kg a.i ha^{-1}) was sprayed 2 DAS in 2nd season only. In both seasons, 'Basagran' herbicide (bentazone 0.8 kg a.i ha^{-1} and MCPA 0.12 kg a.i ha^{-1}) was sprayed 21 and 28 DAS in 1st and 2nd season, respectively. Manual weeding was carried out throughout the growing seasons to control weeds in weed-free plots only. The crop was fertilized with biofertilizer @ 4 tons ha^{-1}. Prior to crop establishment, the biofertilizer was incorporated into the soil. The crop was grown rain-fed but supplemental irrigation was carried out using a sprinkler to retain the soil moisture at field capacity throughout the growing season. The field was netted to prevent birds' damage to the grains. Other pests were controlled following standard practices.

Weed and Crop Parameters Measured

Common weed species and weed dry weight (g m-^{2}): Three (3) quadrats, 0.25 m × 0.25 m were placed at randomly in net plot to estimate weed biomass after treatments at harvest and the weeds were cut at the base, separated into categories of grasses, broadleaves and sedges; and their intensity of occurrence (m^{-2}) was recorded. The samples were cleaned and then oven dried at 70˚C for 72 h to a constant weight. The dry weight was taken by weighing on a weighing balance.

Summed Dominance Ratio

Dominant weed species were identified at the experimental sites using the summed dominance ratio (SDR) (Wibawa *et al*., 2007). The comparative influence of the diverse weed species (grasses, broadleaves and sedges) to the flora of the sites was also worked out. The SDR values of the dominant or major weed species were computed as follows:

$$\text{SDR of a species} = \frac{Relative\ density + Relative\ dry\ weight}{2}$$

Relative density and relative dry weight were determined as follows:

Relative density of a species =

$$\frac{Absolute\ density\ of\ a\ species}{Total\ absolute\ density\ of\ all\ species} \times 100$$

Relative dry weight of a species =

$$\frac{Absolute\ dry\ weight\ of\ a\ species}{Total\ absolute\ dry\ weight\ of\ all\ species} \times 100$$

Species absolute density was equal to the total number of plants of that species in the sampled plot and species absolute dry weight was the total dry weight of species.

Plant Height at Harvest, Days to Flowering and Maturity

At harvest, plant height was measured from the base to the longest panicle using a meter ruler. Days to flowering and maturity were determined by counting the number of days from sowing to the time when the plants initiated flowering and when more than 80% of the grains turned to yellow colour.

Number of Panicles, Panicle Length and Weight

A number of panicles were counted manually from five (5) hills, panicle length and weight were measured from fifteen (15) randomly selected panicles.

One Thousand (1000) grain Weight, Number of Filled Grains, Sterility Percentage and Number of Spikes per Panicle

At harvest, one thousand (1000)-grain weight was determined by counting 200 grains manually, weighed and converted to 1000 grain weight. Grain sterility percentage was determined as follows:

$$GS\% = \frac{Unfilled\ grains}{Filled\ grain + unfilled\ grains} \times 100$$

Grain Yield, Harvest Index (HI) and Straw Yield

At harvest, panicles from sixteen (16) hills (1 m^{-2}) in each plot were harvested, threshed, winnowed to remove the chaff, weighed using weighing balance and the grain yield was converted to t ha^{-1}. Harvest index was obtained by taking the ratio of the weight of grains to the total dry plant materials as follow:

$$HI = \frac{Grain\ weight}{Total\ dry\ matter}$$

Sixteen rice hills (1 m^{-2}) in each plot were cut the above-ground of the plant at harvest. These were oven dried at 70˚C for 72 h, weighed using weighing balance and the straw yield was converted to t ha^{-1}.

Relative Yield Loss

This was calculated using the formula of Haefele *et al.* (2004)

$$\text{Relative yield loss} = \frac{Weed\ free\ yield - weedy\ check\ yield}{Weed\ free\ yield} \times 100$$

Weed Competitive Index

Crop competitiveness was measured as weed competitive index (CI) and was calculated as follows:

$$CI = \frac{\left(\frac{Vinfest}{Vmean}\right)}{\left(\frac{Wi}{Wmean}\right)},$$

Where V_{infest} is yield of variety (i) in terms of weed infested, V_{mean} is the average yield of all varieties in the presence of weed, W_i is the weed biomass of varieties i, W_{mean} is average weed biomass in mixed with all varieties.

Data Analysis

Analysis of variance (ANOVA) of the collected data was carried out using SAS statistical software package (SAS, 2004). Significant differences between treatments means were compared using Duncan's New Multiple Range Test (DNMRT) (Duncan, 1955).

Results

Weed Species Composition in Weedy Check Treatments

During 1st season, 14 weed species were identified (Table 3). The weed flora dominantly consisted of 5 kinds of grasses (46.76%), followed by broadleaves 8 (40.17%) and then sedges 1 (13.07%). The most dominant weed species were *Ageratum houstonianum* Mill. (21.18%), *Digitaria horizontalis* Willd. (17.61%), *Cyperusiria* L. (13.07%), *Paspalum scrobiculatum* L. (11.10%) and *Eleusine indica* (L) Gaertn (9.82%).

During 2nd season, 20 weed species were identified (Table 3). The weed flora dominantly consisted of 12 broadleaves (48.39%), followed by sedges 2 (27.75%) and grasses 6 (13.89%). The most dominant weed species were *Cleome rutidosperma* DC. (23.75%), *Cyperusiria* L. (17.22%), *Fimbristylis miliacea* (L.) vahl (10.53%), *A. houstonianum* (7.59%) and *Mimosa pudica* L. (5.61%).

Weeds Density and Dry Weight

During 1st season, weeds density and weeds dry weight were significantly (p=0.05) affected by rice genotypes (Fig. 1). MRIA1 recorded the highest (105.56 no. m^{-2} and 502.64 g m^{-2}) weeds density and dry weight than MR219-4 and MR219-9.

During 2nd season, weeds density was not significantly (p>0.05) affected by genotypes but weeds dry weight was affected by genotypes (Fig. 1) with MRIA1 recorded the highest (213.91 g m^{-2}) weeds dry weight than MR219-4 and MR219-9. Weed density and dry weight of MR219-4 and MR219-9 was similar.

Agronomic and Yield Traits

Plant height at harvest time: In both seasons, plant height at harvest time was not significantly (p>0.05) affected by weeding regime and interaction between weeding regime × genotypes but genotypes had significant (p=0.05) effect (Table 4). At harvesting, plant height of the genotypes ranged from 78.26 to 85.16 cm in the 1st season and 95.28 to 111.05 cm in the 2nd season. MRIA1 seemed to be the tallest genotype (85.16 cm and 111.05 cm) than MR219-4 and MR219-9. Shorter plants were recorded (78.26 cm) for MR219-9 in 1st season and for MR219-4 (95.28 cm) in 2nd season, which was also statistically at par during both seasons.

Table 3: Weed species summed dominance ratio in weedy check treatments for 1st and 2nd season

Scientific name	Family	Summed dominance ratio (%)	
		1st season	2nd season
Narrow leaved			
Cynodon dactylon (L.) Pers.	Poaceae	5.69	4.51
Digitaria horizontalis Willd.	Poaceae	17.61	2.10
Ischaemum muticum L.	Poaceae	-	2.56
Eleusine indica (L) Gaertn	Poaceae	9.82	2.14
Paspalum scrobiculatum L.	Poaceae	11.10	1.52
Seteria barbata (Lam.) Kunth	Poaceae	2.54	1.03
Broad leaved			
Ageratum houstonianum Mill.	Asteraceae	21.18	7.59
Cleome rutidosperma DC.	Cleomaceae	4.13	23.75
Commelina diffusa Burm. f.	Commelinaceae	-	4.26
Euphorbia hirta L.	Euphorbiaceae	1.91	0.45
*Jussiaea linifolia*Vahl	Onagraceae	-	3.63
Lindernia dubia (L.) Pennell	Linderniaceae	-	4.77
Ipomoea vagans Baker	Convolvulaceae	2.56	2.38
Mimosa pudica L.	Fabaceae	4.26	5.61
Mitracarpus villosus (Sw.) DC.	Rubiaceae	1.56	0.82
Phyllatus niruri L.	Phyllathaceae	2.95	0.83
Physali minima Linn.	Solanaceae	-	3.63
Sidaacuta Burm. f.	Malvaceae	1.62	0.67
Sedges			
Cyperus iria L.	Cyperaceae	13.07	17.22
Fimbristylis miliacea (L.) Vahl	Cyperaceae	-	10.53

-=not exist weed species

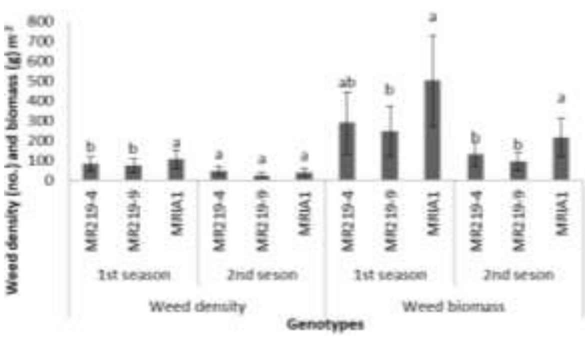

Fig. 1: Weed density and biomass in weedy check treatments based on genotypes for 1st and 2nd season. Note: Different letter (s) above bars indicate a significant difference at p=0.05 according to Duncan's new multiple range test (DNMRT). Error bar is SE values, P value weed density = 0.0054 and 0.1526, P value weed biomass = 0.0519 and 0.001 for 1st and 2nd season, respectively

Days to flowering and maturity: In both seasons, days to flowering and maturity were significantly (p=0.05) affected by weeding regime, genotypes and interaction between weeding regime × genotypes except interaction between weeding regime × genotypes for 2nd season (Table 4). Plants in weed-free condition took more days to flower (79.44 and 78.33 days) and mature (111.44 and 104.11 days) than those in weedy check plots during both seasons, respectively. The growth duration of the genotypes ranged from 82.33 to 121.00 days. MRIA1 took 57.34 and 54.17 days to flower and mature within 85.84 and 82.33 days in 1st and 2nd season, respectively. MR219-4 and MR219-9 initiated flowering between 86 to 89.34 days and subsequently matured between 109.67 to 121 days in 2nd and 1st season, respectively.

The genotypes differed in days to flowering in both weed free and weedy check condition (Fig. 2). MR219-9 took the longer days to flowering (90.67 and 88 days) than MRIA1 which took 58.67 and 56 days in weed free and weedy check condition, respectively. Similar trend was observed in days to maturity for 1st season but for 2nd season, MR219-4 and MR219-9 had similar days for maturity in both weed free and weedy check condition while MRIA1 had less days to mature (84 and 80.67) in weed free and weedy check condition.

Number of panicles, panicle length and weight: In both seasons, the number of panicles and interaction between weeding regime × genotypes were not significantly (p>0.05) affected by weeding regime but genotypes had significant (p=0.05) effect (Table 5). MR219-9 recorded the highest number of panicles (195.68 and 215.52 no. m^{-2}) at par with MR219-4, while MRIA1 recorded the lowest (63.36 and 146.88) in both seasons respectively.

Panicle length was not significantly (p>0.05) affected by weeding regime but genotypes and interaction between weeding regime × genotypes had significant (p=0.05) effect during the 1st season only (p=0.05) (Table 5). MR219-4 and MR219-9 were similarly higher than MRIA1 with shortest panicles (17.34 cm).

Panicle weight was significantly (p=0.05) affected by weeding regime, genotypes and their interaction during 1st season only (Table 5). Plants in weed free condition recorded the highest panicle weight (2.93 g) while among the genotypes, MRIA1 recorded the lowest (1.29 g) different from MR219-4 and MR219-9, which were similar.

MRIA1 recorded the shortest panicles (18.66 cm and 16.01 cm) and lowest panicle weight (1.68 g and 0.90 g) in both weeds free and weedy check conditions respectively different from MR219-4 and MR219-9 that were at par except panicle weight in weed free condition in which MR219-4 recorded the highest panicle weight (3.82 g) different from MR219-9 (Fig. 3).

One thousand (1000)-grain weight, number of filled grains, sterility percentage and number of spikes per panicle: One thousand (1000) grain weight, number of filled grains, sterility percentage and the number of spikes per panicle were not significantly (p>0.05) affected by weeding regime in both seasons except number of filled grains, sterility percentage and number of spikes per panicle for 1st season.

The genotypes had significant (p=0.05) effect on one (1000) grain weight, number of filled grains, sterility percentage and the number of spikes per panicle in both seasons except number of filled grains and spikes per panicle for 2nd season. The interaction between weeding regime × genotypes was significant (p=0.05) for number of

Table 4: Plant height at harvest time, days to flowering and maturity based on weeding regime and genotypes for 1st and 2nd season

Treatments	Plant height at harvest time (cm)		Days to flowering		Days to maturity	
	1st season	2nd season	1st season	2nd season	1st season	2nd season
Weeding regime (W)						
Weed free	83.89a	97.54a	79.44a	78.33a	111.44a	104.11a
Weedy check	77.65a	103.75a	76.56b	73.00b	105.44b	97.33b
Genotypes (G)						
MR219-4	78.89b	95.28b	87.33b	86.00a	118.50b	109.67a
MR219-9	78.26b	95.61b	89.34a	86.83a	121.00a	110.17a
MRIA1	85.16a	111.05a	57.34c	54.17b	85.84c	82.33b
W	ns	ns	***	**	**	**
G	*	*	***	***	***	***
W ×G	ns	ns	***	ns	***	**
SEM						
W	2.981	2.864	0.079	0.36	0.272	0.342
G	1.759	3.659	0.245	0.441	0.319	0.419
W × G	2.488	5.175	0.347	0.624	0.451	0.593

Means with the same letter within columns for each factor are not significantly different at P=0.05 using Duncan's new multiple range test (DNMRT), *, **, *** represent significant at $P \leq 0.05$, $P \leq 0.01$ and $P \leq 0.001$ respectively, ns = not significant at $P > 0.05$

Table 5: Number of panicles, panicle length and panicle weight based on weeding regime and genotypes for 1st and 2nd season

Treatments	Number of panicles (m^{-2})		Panicle length (cm)		Panicle weight (g)	
	1st season	2nd season	1st season	2nd season	1st season	2nd season
Weeding regime (W)						
Weed free	175.04a	200.48a	22.52a	25.12a	2.93a	3.29a
Weedy check	118.56a	181.12a	20.79a	25.17a	1.69b	3.68a
Genotypes (G)						
MR219-4	184.32a	210.08a	24.21a	26.22a	2.88a	3.46a
MR219-9	195.68a	215.52a	23.41a	25.91a	2.75a	3.52a
MRIA1	63.36b	146.88b	17.34b	23.32a	1.29b	3.48a
Significance level						
W	ns	ns	ns	ns	**	ns
G	***	***	***	ns	***	ns
W × G	ns	ns	*	ns	*	ns
SEM						
W	12.096	12.048	0.551	0.477	0.096	0.16
G	10.672	8.496	0.361	0.874	0.132	0.324
W ×G	15.088	12.016	0.511	1.236	0.187	0.458

Means with the same letter within columns for each factor are not significantly different at P=0.05 using Duncan's new multiple range test (DNMRT), *, **, *** represent significant at $P \leq 0.05$, $P \leq 0.01$ and $P \leq 0.001$ respectively, ns = not significant at $P > 0.05$, SEM = Standard error of means

filled grains per panicle for 1st season only (Table 6). Weed free plots recorded the highest number of filled grains per panicle (84.85) and number of spikes per panicle (9.07), while weedy check recorded the highest percent grain sterility of virtually 21.49%. MRIA1 genotype recorded the highest 1000 grain weight (29.52 g and 32.69 g) in both seasons; and percent grain sterility per panicle was 23.61% for 1st season and the lowest number of filled grains per panicle (37.82) was recorded for 1st season, percent grain sterility (13.38%) for 2nd season and number of spikes per panicle (5.80) in 1st season than MR219-4 and MR219-9 were at par with each other.

In weed free condition, the three genotypes significantly differed from each other (Fig. 4) with MR219-4 recording the highest (112.76), followed by MR219-9 recording (93.33) and MRIA1 recording the lowest (48.44) while in weedy check condition MR219-4 and MR219-9 were similar higher than MRIA1 which recorded the lowest number of filled grains per panicle (27.20).

Grain Yield, Harvest Index and Straw Yield

Grain yield, harvest index and straw yield were significantly (p=0.05) affected by weeding regime in 1st season, genotypes in both seasons except grain yield in 2nd season and the interaction between weeding regime × genotypes on grain yield in 1st season (Table 7). Weed free treatment recorded the highest grain yield (1.34 t ha^{-1}), harvest index (0.46) and straw yield (6.45 t ha^{-1}) higher than weedy check. In 1st season, MRIA1 recorded the lowest grain yield (0.72 t ha^{-1}), harvest index (0.27) and straw yield (2.90 t ha^{-1}) than MR219-4 and MR219-9 which were similar while in the 2nd season, MRIA1 recorded the highest harvest index (0.53) than MR219-4 and MR219-9, which were also similar. In contrary to harvest index, MR219-9 recorded the highest straw yield (7.41 t ha^{-1}) similar to MR219-4 but higher than MRIA1 which recorded the lowest (5.03 tons ha^{-1}).

The interaction between weeding regime × genotypes

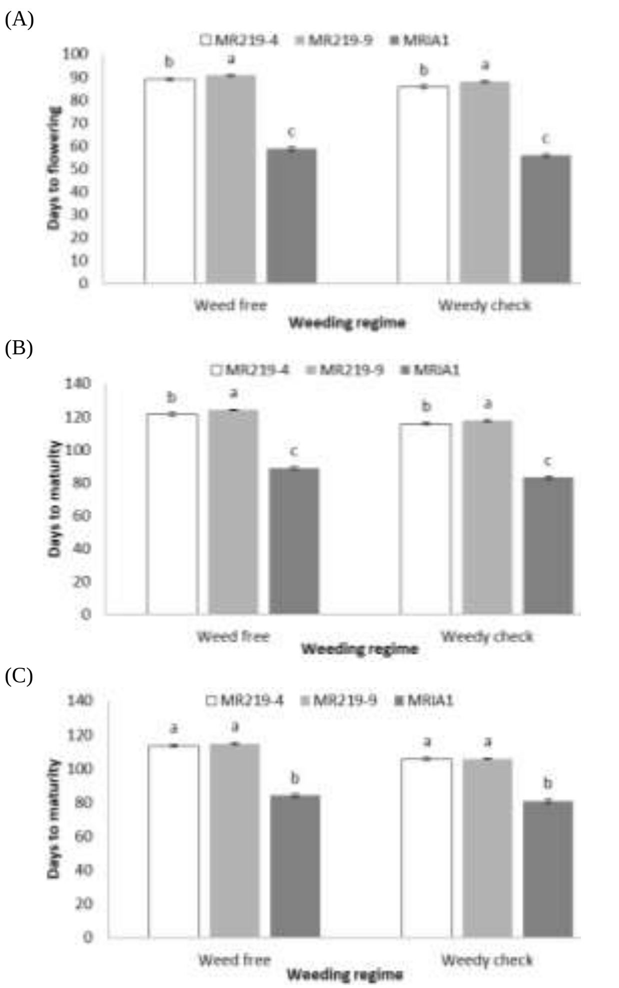

Fig. 2: Days to flowering and maturity based on interaction between weeding regime × genotypes (A) days to flowering for 1st season, (B) days to maturity for 1st and (C) days to maturity for 2nd season. Note: Different letter(s) above bars indicate a significant difference at p=0.05 according to Duncan's new multiple range test (DNMRT). Error bar is SE values, P value = <0.0001, <0.0001 and 0.0031 for A, B and C, respectively

Note: Different letter(s) above bars indicate a significant difference at p=0.05 according to Duncan's new multiple range test (DNMRT). Error bar is SE values, P value = <0.0001, <0.0001 and 0.0031 for A, B and C respectively

on grain yield for 1st season is presented in Fig. 5. MR219-4 and MR219-9 were similar in both weed free and weedy check higher than MRIA1, which was similar to MR219-4 in weedy check.

Weed Competitive Index

MR219-9 recorded the highest (2.31 and 1.60) while MRIA1 recorded the lowest (0.18 and 0.73) weed competitive index in both 1st and 2nd season, respectively (Fig. 6).

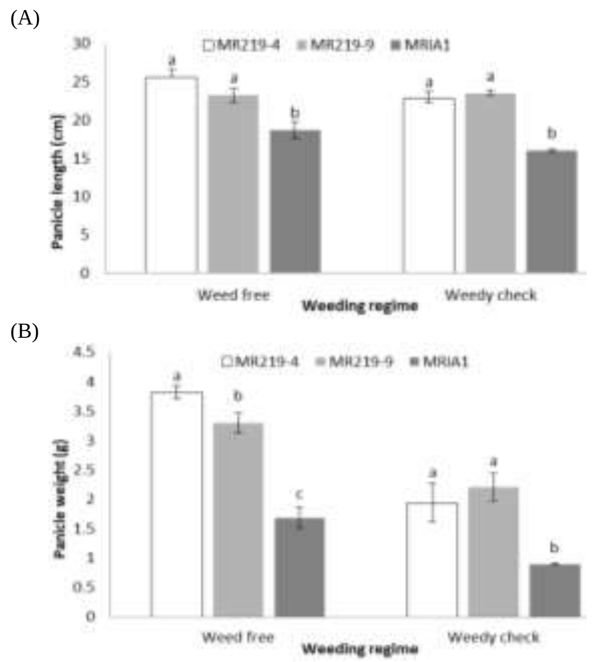

Fig. 3: Panicle length and weight based on interaction between weeding regime × genotypes for 1st season (A) panicle length and (B) panicle weight. Note: Different letter(s) above bars indicate a significant difference at p=0.05 according to Duncan's new multiple range test (DNMRT). Error bar is SE values, P value = 0.0279 and 0.0458 for panicle A and B, respectively

Relative Yield Loss (Grain)

MR219-9 recorded the lowest relative yield loss (40.35 and 20.83) in both 1st and 2nd season, respectively. MRIA1 recorded the highest relative yield loss (69.09%) in 1st season while MR219-4 recorded the highest (28.32%) in 2nd season (Fig. 7).

Discussion

In this present study, weed flora density involved in the field differ with the season. Bhagat *et al*. (1999) discovered that the contribution of a species in the community is showed by totaled weed-species'summed dominance-ratio (SDR) which is more revealing than any single measurement taken in the field. Varying weed species were observed in the two seasons. Grasses were dominant where *D. horizontalis*, *P. scrobiculatum* and *E. indica* showed more than 38% SDR in the 1st season, while *C. rutidosperma*, *A. houstonianum* and *M. pudica* were dominant in the 2nd season exposed more than 36% of the SDR. The difference has been attributed to variations in seasonal soil moisture and the cropping history. In aerobic rice, about 80% of the total weed community was grassy (Jaya Suria *et al*. 2011). The high weed pressure can be associated with soil dry-tillage as well as alternating wet and dry condition at the time of crop growth that were

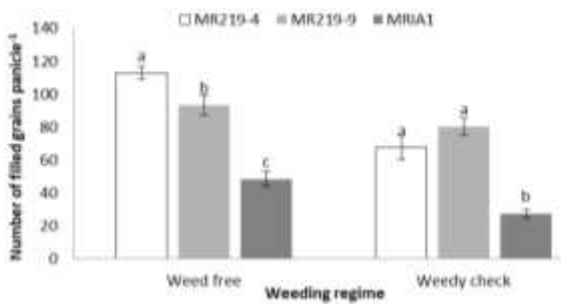

Fig. 4: Number of filled grain based on interaction between weeding regime × genotypes for 1st season. Note: Different letter (s) above bars indicate a significant difference at p=0.05 according to Duncan's new multiple range test (DNMRT). Error bar is SE values, P value = 0.044

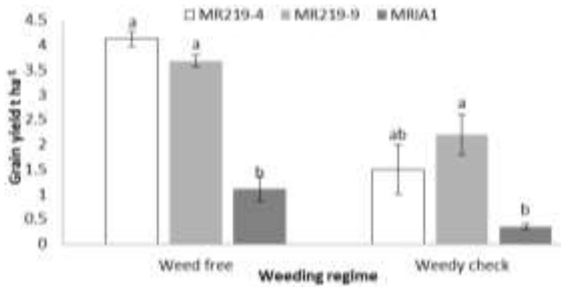

Fig. 5: Grain yield based on interaction of weeding regime × genotypes for 1st season. Note: Different letter(s) above bars indicate a significant difference at p=0.05 according to Duncan's new multiple range test (DNMRT). Error bar is SE values, P value = 0.0186

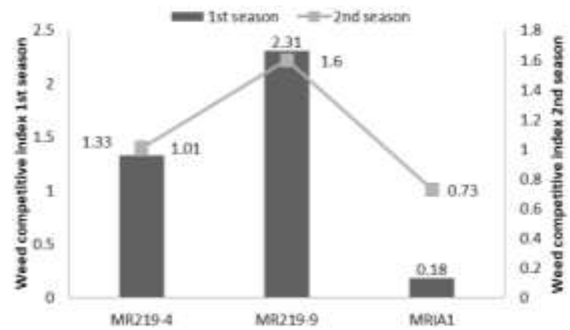

Fig. 6: Weed competitive index for 1st and 2nd season

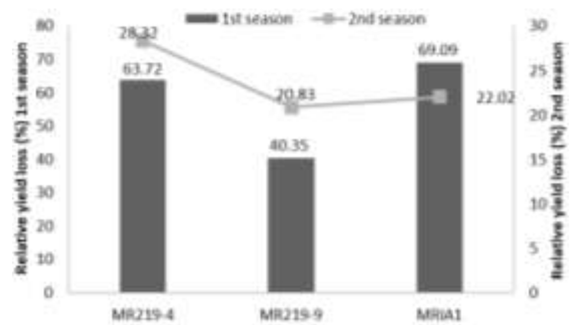

Fig. 7: Relative yield loss for 1st and 2nd season

favourable for the weeds' sprouting and development (Elliot *et al*., 1984; Fujisak*a et al*., 1993; Rao *et al*., 2007).

The higher dry weight of the weed observed in the 1st season might be due to the differences in size of dominant weed *P. scrobiculatum* and *E. indica* (exceeded the height of rice plant during maturity) thereby possess greater weeds biomass relative to the 2nd season in which *C. rutidosperma* and *A. houstonianum* were shorter than the rice plants. Under the interference of neighbors, biomass accumulation designates the ability of the plant to utilize scarce environmental resources (Fernando *et al*., 2006).

Under weedy environment, weeds biomass or weeds seed were assessed by determining the weed-suppressive ability (WSA) (Zhao *et al*., 2006). Genotypes with weak WSA were less capable of accumulating more biomass and production of more tillers at the period of vegetative-growth as compared to those with strong WSA. In both seasons, the result of the dry weight of weed with lower weed density for MR219-4 and MR219-9 and high density for MRIA1 might be associated with the plant's morphological features of MR219-4 and 219-9, which were shorter with more tillers compared to the taller MRIA1 with few tillers that tend to lodge allowing weed to grow faster. Plant height plays a positive part in weed suppression and significant but negative correlation with weeds biomass (Ekeleme *et al*., 2007). Gibson *et al*., (2001) added that some shorter cultivars were discovered to be good competitors in rice.

The possible reason for plants in a weed-free situation to be taller than in weedy check in the 1st season, and plants in weedy check to be taller than in weed free in the 2nd season is that, in the 1st season, there tends to be intensive weeds and rice plants competitions probably causing somewhat short plant than in weed-less conditions. In the 2nd season, however, there was extended anaerobic soil condition in weed-free plots, which resulted in the shortness of the plants. From the measurement of the growth as well as rice development in this study, the height of the crop has highest effects on the ability to compete. According to Fischer *et al*. (2001); Fukai (2002) cultivars that are somewhat shorter have ability to compete like the cultivars that are tall. Thus, for direct seeding, the stature between traditional tall and the new somewhat short (intermediate height) tends to be more suitable.

Plants in weedy plots took lesser days to flower and mature probably due to the competition for scarce resources between weeds with the crop, which tends to influence days to flower and maturity. According to Dingkuhn *et al*. (1999), the time of flowering and duration of crop tend to affect genotypes' ability to recuperate from initial competition and proved to be useful traits in the selection of weed competitive rice cultivar. They added that genotype with late maturity appeared to have high weeds suppression.

Table 6: One thousand (1000)-grain weight, number of filled grains, sterility percentage and number of spikes based on weeding regime and genotypes for 1st and 2nd season

Treatments	1000-grain weight (g)		Number of filled grains per panicle		Sterility percentage per panicle (%)		Number of spikes per panicle	
	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
Weeding regime (W)								
Weed free	28.08a	30.63a	84.85a	91.72a	12.90b	18.88a	9.07a	10.72a
Weedy check	27.31a	29.92a	58.40b	104.88a	21.49a	19.43a	8.38b	11.26a
Genotypes (G)								
MR219-4	26.91b	29.55b	90.18a	101.14a	15.59b	22.18a	10.35a	11.93a
MR219-9	26.66b	28.58b	86.87a	107.24a	12.39b	21.89a	10.02a	11.53a
MRIA1	29.52a	32.69a	37.82b	86.53a	23.61a	13.38b	5.80b	9.52a
Significance level								
W	ns	ns	**	ns	*	ns	*	ns
G	***	**	***	ns	*	**	***	ns
W × G	ns	ns	*	ns	ns	ns	ns	ns
SEM								
W	0.53	0.726	2.225	2.62	1.137	2.284	0.097	0.125
G	0.33	0.747	3.846	9.213	2.352	1.567	0.167	0.709
SEM W × G	0.467	1.056	5.439	13.029	3.326	2.216	0.236	1.002

Means with the same letter within columns for each factor are not significantly different at P=0.05 using Duncan's new multiple range test (DNMRT), *, **, *** represent significant at P≤0.05, P≤0.01 and P≤0.001 respectively, ns = not significant at P>0.05, SEM = Standard error of means

Table 7: Grain yield, harvest index and straw yield based on weeding regime and genotypes for 1st and 2nd season

Treatments	Grain yield t ha^{-1}		Harvest index		Straw yield t ha^{-1}			
	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd
Weeding regime (W)								
Weed free	2.96a	3.10a	0.44b	0.48a	6.45a	6.60a		
Weedy check	1.34b	2.74a	0.46a	0.45a	2.69b	6.18a		
Genotypes (G)								
MR219-4	2.80a	2.97a	0.54a	0.44b	5.14a	6.73a		
MR219-9	2.94a	3.17a	0.53a	0.43b	5.68a	7.41a		
MRIA1	0.72b	2.61a	0.27b	0.53a	2.90b	5.03b		
Significance level								
W	*	ns	**	ns	*	ns		
G	***	ns	***	*	***	**		
W × G	**	ns	ns	ns	ns	ns		
SEM								
W	0.2067	0.134	0.001	0.036	0.528	0.434		
G	0.1791	0.223	0.030	0.026	0.374	0.456		
SEM W × G	0.253	0.316	0.043	0.037	0.529	0.644		

Means with the same letter within columns for each factor are not significantly different at P=0.05 using Duncan's new multiple range test (DNMRT), *, **, *** represent significant at P≤0.05, P≤0.01 and P≤0.001 respectively, ns = not significant at P>0.05, SEM = Standard error of means

Weed competition with the crop had evidently reduced panicle weight which in turn, reduced the number of filled grains and yield of grain produced. Deihimfard *et al*. (2006) stated that among cultivars grain yield loss manifested. The maximum number of panicle m^{-2}, panicle length and weight, the number of filled grains $panicle^{-1}$, the number of spikes $panicle^{-1}$, grain and straw yield recorded by MR219-4 and MR219-9 might be due to the genotypes' long season accumulations of dry matter and the highest 1000 grain weight and lesser days took to flowering and maturity by MRIA1 probably might be due to genetic make-up of the genotype.

Weed caused severe declines to yield donating characters (Munene *et al*., 2008). The decreased in yield of rice in the 1st season compared to the 2nd season might be due to the degree of increasing weeds invasions due to the aerobic condition as a result of short supply of rain water (Becker and Johnson, 1999). Between MRIA1 and MR219-4 genotypes, the comparative ranking of yield loss varied in both seasons. Comparably loss of yield in 1st season was more than in the 2nd season. Dingkuhn *et al*. (1999) reflected that relative yield loss was an indicator of weed competitiveness. Differences in the comparative loss of yield was affected by the variation in the dominance and compositions of weed including variation in the moisture in the soil climatic elements in the two seasons. Different performance of the cultivars can also vary depending on areas and growth condition (Mason and Spaner, 2006). In relation to size, *D. horizontalis*, *P. scrobiculatum* and *E. indica* in the 1st season, were denser and taller than *C. rutidosperma*, *A. houstonianum* and *M. pudica* in the 2nd season showed that *D. horizontalis*, *P. scrobiculatum* and *E. indica* in 1st season had more grain yield affected negatively in comparison with *C. rutidosperma*, *A. houstonianum* and *M. pudica* in the 2nd season. All weed species present tend to contribute to yield losses. Azmi (1992) estimated that losses of rice yield caused by narrow leaves (grasses), broad-leaves weed and sedge were in the range of 41%, 28% and 10%, respectively while in totality an average of 10 to 35% yield losses was caused by weeds.

This study discovered that some genotypes have the capacity to produced lower 1000 grain weight but produced greater grain yield while other could produce higher panicle length and weight, the number of filled grains, weight of 1000 grains and harvest index, but still lower in grains and straw yields. This result can be associated with the number of panicles (effective tillers) m^{-2} that resulted in higher grain yield and straw yield. According to Anwar *et al*. (2012), lengthy weeds competition caused less accumulation of biomass and a number of panicle m^{-2} which ultimately transformed into lower grain yield. In this study, MR219-9 indicated highest weed suppressive and tolerance ability by producing the lowest relative yield loss. Callaway (1992); Jannink *et al*. (2000) reported that competitive ability has a relationship with lower yield potential for some crop species. Also, Rodenburg *et al*. (2009) pointed out that, under weedy conditions, prolong period and high yield prevailing in weed-less environments were linked with higher grain yields. The significant effect of interaction between weeding × genotypes on grain yield and yield contributing characters found in this study designated that genotypes performing superior in weed free condition is likely don't perform well under weed competition condition. These findings are in contrary with Goldberg and Landa (1991) who reported that a neighboring species does not convey any variation in suppressive ability of a particular species. The dissimilarities in performance level of a particular species due to intra specific (rice-rice) and inter specific (rice-weed) competition may differ in amount but certainly not in kind.

Conclusion

The results showed that major weeds in the field were grasses that constituted over 46% of the summed dominance-ratio. *D. horizontalis*, *P. scrobiculatum* and *E. indica* were the most dominant weeds in 1st season, while broadleaves formed the major weedand constituted over 48% of the summed dominance-ratio with *C. rutidosperma*, *A. houstonianum* and *M. pudica* as the most dominant weeds in the 2nd season. When compared with other genotypes, MRIA1 with features of tall plant height, few tillers, and lesser period of growth strived poorly with weeds than other genotypes (MR219-4 and MR219-9) with shorter plants, many tillers and longer growth duration. Lesser weeds dry weights with comparatively higher weed competitive index and lesser loss of yield recorded in MR219-9 showed its greater weeds' suppression, competitiveness and toleration capability. The results of this study, therefore, concluded that MR219-9 is the most competitive genotype against weeds in aerobic condition.

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