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Competition between rice (*Oryza sativa* L.) and (barnyardgrass (*Echinochloa crus-galli* (L.) P. Beauv.) as affected by methanol foliar application

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ABSTRACT

Pot experiment was conducted in Iran, to evaluate the effect of methanol on competition between rice (*Oryza sativa*) and barnyardgrass (*Echinochloa crus-galli*). The experiment was conducted as a randomized complete block design with a factorial treatment arrangement and three replicates. Factors were two aqueous methanol foliar applications (0, and 14% v/v) and five rice: barnyardgrass ratios (100:0, 75:25, 50:50, 25:6, and 0:100). Replacement series diagrams for aboveground dry weight illustrated that 'Shiroudi' was more competitive than barnyardgrass as averaged across methanol foliar applications. When methanol was not sprayed, the lines for 'Shiroudi' and barnyardgrass intersected at 75:25 rice: barnyardgrass ratio, but when methanol was sprayed at 14% v/v, the lines for 'Shiroudi' and barnyardgrass intersect at the left of the 75:25 rice: barnyardgrass mixture proportion. These indicate that methanol application reduced competitive ability of 'Shiroudi' against barnyardgrass for aboveground biomass accumulation. At the same time, Methanol foliar application significantly reduced the relative crowding coefficient of 'Shiroudi' while simultaneously it significantly increased the relative crowding coefficient of barnyard grass. This indicates that methanol foliar application reduced the competitive ability of 'Shiroudi' against barnyardgrass for shoot biomass accumulation. This experiment illustrated that foliar spray of aqueous methanol can not be recommended for rice under weedy conditions**.**

Key words: Barnyardgrass, interference, methanol, rice.

INTRODUCTION

Rice is the most important staple food for more than half of the world's population. It is primarily a carbohydrate source, and also provides a number of trace minerals, proteins, and vitamins, especially B groups vitamins such as niacin and thiamine. In 2012, nearly 719 million metric tonnes of paddy were produced throughout the world and the average productivity increased from 1.23 metric tonnes per hectare in 1961 to 4.41 metric tonnes per hectare in 2012 (FAO 2014). The total rice production in Iran was 2,400,000 tonnes of paddy rice in 2012, which was harvested from 48,000 ha (FAO 2014). Rice is extensively grown in north provinces of Iran, i.e. Mazandaran, Guilan, and Golestan, in irrigated lowland fields.

Weeds reduce rice yield by competing with the crops for light, nutrient, and moisture. The extent of yield loss depends on several factors such as crop

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genotype, weed species, crop and weed density, time of weed emergence, fertilizer management, etc. *Echinochloa crus-galli* (L.) P. Beauv, *Cyperus difformis* L., *Scirpus juncoides* Roxb., *Scirpus maritimus* L., *Scirpus mucronatus* L., *Sagittaria trifolia* L., and *Alisma plantago-aquatica* L. are dominant and persistent weeds in paddy fields of Iran. Among these weeds, BYG is the most aggressive weed and may reduce rice yields from 38% upto 64% depending on the rice cultivar (Smith 1988, Stauber et al. 1991).

Many methods such as replacement series, additive designs, neighbourhood designs, addition series, additive series, nelder design, and mechanical diallel experiments have been used to study plant competition in mixture. Of these, the replacement series model was intensively used to assess the competitive effects of two species at a single total density and to determine the relative effects of interferences within and between species (Harper 1977, Cousens 1991, Gibson et al. 1999). Under this approach, species are grown under a fixed density, varying the mixture proportions of them (Cousens 1991). Replacement series experiments often used to determine which species is the strongest competitor based on variables calculated from replacement series data such as relative yield and relative yield total (Harper 1977).

Methanol is a natural product of plant metabolism (MacDonald and Fall 1993). It has been reported that foliar application of methanol solutions on C_3 crops could improve their growth and yields (Devlin et al. 1994, Hemming et al. 1995, Li et al. 1995, Nishio et al. 1994, Valenzuela et al. 1994). In contrast, some rserchers (Hartz et al. 1994, Mauney and Gerik 1994, McGiffen et al. 1995, Mitchell et al. 1994) reported that methanol had no significant effect on crop growth and yield. It has been suggested that methanol acts as an inhibitor of photorespiration in C_3 plants. At the same time, Nonomura and Benson (1992a, b) declared that plants with C_4 metabolism had no positive growth and yield response to methanol foliar application. Therefore, this experiment was conducted to determine the effect of methanol on competition between rice (C_3 plant) and BYG (C_4 plant).

MATERIALS AND METHODS

Pot experiment was conducted in Bandar Anzali (37° 29' N, 49° 24' E), north of Iran, during rice growing season in 2011 and 2012 in a replacement series study to determine the effect of methanol on competition between rice (*Oryza sativa* L. cv. 'Shiroudi') and barnyardgrass (BYG, *Echinochloa crus-galli* (L.) P. Beauv.). Monthly precipitation and temperature for 2011 and 2012 are shown in Table I.

TABLE I
Monthly precipitation and temperature from April to September in 2011 and 2012 for experimental site.

Month	Precipitation (mm)		Temperature (°C)					
			Maximum		Minimum		Average	
	2011	2012	2011	2012	2011	2012	2011	2012
April	72.2	16.5	17.08	19.24	9.9	13	13.49	16.12
May	54.9	10.7	22.11	25.55	16.1	20.04	19.1	22.79
June	31.9	181.1	26.92	29.07	19.8	22.63	23.36	25.85
July	0.3	118.5	31.6	29.01	22.5	23.35	27.05	26.18
August	166.7	206.5	28.1	30.8	21.6	24.03	24.85	27.41
September	236.2	246.2	25	26.08	18.2	20.12	21.6	23.1

The soil texture was clay (clay 50%, silt 37.5%, sand 12.5%), organic matter content 3.4%, pH = 6.6, total N 0.13%, available N 115.3 mg kg^{-1}, available phosphorous 12.0 mg kg^{-1}, and available potassium 85.0 mg kg^{-1}, EC 0.3 ds m^{-1}. Twenty kilograms of the soil was weighed for each pot (35 cm in diameter and 45 cm deep). Rice seeds were disinfected with thiophanate-methyl 70 WP (20 gL^{-1} H_2O) and subsequently were sown in the nursery on the 30th and on the 28th of April 2011 and 2012, respectively. BYG seeds were collected form adjacent rice fields in September 2010, and were soaked for 72h in tap water at 25 °C before rice transplanting. With regards to the rice:BYG ratio in each pot, three seedlings of 'Shiroudi' cultivar or one germinated BYG seed were transplanted (or planted) on the hills on the 29th and on the 27th of May 2011 and 2012, respectively.

The experiment (for both years) was conducted in a randomized complete block design with three replicates. Treatments were factorially arranged: two foliar applications of aqueous methanol solution (0, and 14% v/v) and five rice:BYG ratios (100:0, 75:25, 50:50, 25:6, and 0:100). Actual plant numbers per pot for each mixture were 8:0, 6:2, 4:4, 2:6, and 0:8, respectively. Aqueous methanol solution was sprayed on the plants with a manual sprayer at a rate of 50 ml per pot (plants were carefully wetted), with the nozzle approximately 20 cm above the leaf surface. Control plants were sprayed with water under the same conditions. Plants were sprayed three times during growing period, i.e. at the stem elongation stage, and at the 15 days intervals. One-half amount of N (100 kg N ha^{-1} as urea) and the entire P (100 kg P_2O_5 ha^{-1} as triple superphosphate) and K (150 kg K_2O ha^{-1} as potassium sulfate) were applied as a basal dose at transplanting stage. The remaining of N was applied at panicle initiation stage. All unwanted weeds were controlled by hand weeding. Consistent with the lowland paddy field practices in north of Iran, a 5- to 10-cm deep permanent flood was established during rice growing period.

Sampling

At maturity stage, plant height was measured from base of plant to the tip of panicle. Plants were harvested in September 2011 and 2012 by hand-cutting from the above soil surface and subsequently aboveground biomass of rice and BYG were separated. To determine rice grain yield, grains were collected from all plants in each pot and were subsequently adjusted to 14% moisture content. Leaves were removed from stems, and leaf areas for green leaves of each pot were measured using a leaf area meter (LI-3000A, LI-COR, Lincoln, Nebraska, USA). To determine rice and BYG aboveground dry weight, grain, stem and leaf of rice and BYG from each pot were placed in separate paper bags, dried at 72 °C for 96h, and weighed. Roots of rice and BYG were washed gently and thoroughly to remove soil particles so that the root tissues remained intact and then were subsequently separated and the root from each pot was placed in a separate paper bag, dried at 72 °C for 96h, and weighed.

Relative yield (RY) and relative yield total (RYT) for aboveground dry weight and root dry weight were calculated according to the following equations (Harper 1977):

$$RY_r = (Yrb/Yrr) \text{ or } RY_b = (Ybr/Ybb) \qquad [1]$$

Where Yrb or (Ybr) = yield per pot of rice or (weed) when grown with weed (or rice) and Yrr or (Ybb) = yield per pot of rice (weed) in monoculture.

$$RYT = RY_r + RY_b \qquad [2]$$

Harper (1977) illustrated in two species mixtures, that a RYT value close to 1.00 indicates that the two species make equal demands on the same limiting resources. RYT values greater than 1.00 indicate that species are making demands on different resources, avoiding competition or maintaining a symbiotic relationship. RYT values less than 1.00 indicate mutual antagonism (Bi and Turvey 1994).

Replacement diagrams (Harper 1977) were constructed by plotting RY means ± 1 SE against the proportion of rice:BYG in the mixtures.

Relative crowding coefficient (RCC) for aboveground and root dry weights were calculated by Novak et al. (1993) equation as follows:

$$RCC = (((Wr75{:}25/Wb75{:}25) + (Wr50{:}50/Wb50{:}50) + (Wr25{:}75/Wb25{:}75))/3) / (Wr100{:}0/Wb100{:}0) \quad \textbf{[3]}$$

Where Wr n:n is aboveground or root dry weights of rice at a ratio of n:n and Wbn:n is aboveground or root dry weights of BYG at a ratio of n:n. When two species compete for limited resources, the species with the greatest RCC is the stronger competitor.

Statistical Analyses

Data were subjected to ANOVA and means were compared with Fisher's Protected LSD at 5% significance level. All statistical analyses were conducted by using SAS (SAS 2004). There were no significant year × treatment interactions for all traits, so data from two consecutive years were combined and years were considered random. Furthermore, as interactions between methanol concentration and mixture proportions were not significant for rice measurements, means for main effects were compared with Fisher's Protected LSD test at 5% significance.

RESULTS AND DISCUSSION

Plant Height

The main effect of rice:BYG mixture proportion was significant for rice plant height, while the main effects of year and methanol were not significant (Table II). Moreover, all 2- and 3-ways interactions were not significant (Table II). So, data were presented over two years. Plant height for 'Shiroudi' significantly increased from 95 to 108 cm as rice: BYG ratio decreased from 100:0 to 25:75 mixture proportions (Table III). In other words, rice plant was taller when grown with BYG compared to when grown in monoculture. This indicates that intra-specific competition was more than inter-specific competition. Contrary to this result, Aminpanah and Javadi (2011) declared that Deylamani and Hashemi plant height reduced significantly as rice:BYG ratio decreased. Moreover, Estorninos et al. (2002) reported that plant height of Kaybonent was significantly shorter when grown with red rice than when grown in monoculture, while PI 312777 height was not affected by red rice competition.

BYG plant height was significantly affected by methanol (M), BYG:rice ratio (P) and M × P interaction, while the effects of year and all 2- and 3-ways interaction were not significant (Table III). When methanol was not sprayed, BYG plant height was significantly reduced from 148.5 ± 2.3 to 103.3 ± 8.4 as BYG:rice ratio decreased from 100:0 to 25:75, indicating that BYG was taller when grown under intraspecific competition than when grown under interspecific competition (Table V). When methanol was sprayed at 15% (v/v), there were no significant differences in BYG plant height among 25:75, 50:50, and 75:25 BYG:rice ratios, but was significantly increased when grown alone (Table V).

Grain Yield

Main effects of methanol foliar application and rice:BYG ratio were significant for grain yield at 0.001% probability level, while the main effect of year and all 2- and 3-way interactions were not significant (Table II). Methanol foliar application significantly increased rice grain yield by 31% (Table III). These results support those of Nonomura and Benson (1992a, b), Devlin et al. (1994), Hemming et al. (1995), Li et al. (1995), Nishio et al. (1994), and Valenzuela et al. (1994) who found remarkable growth enhancement of C_3 plants treated with methanol. Contrary to our result, other publications report no evidence of gain

TABLE II
Mean squares for the combined analysis of variance for rice plant height (H), grain yield (Y), leaf area (LA), aboveground dry weight (ADW), root dry weight (RDW) as affected by methanol foliar application (M) and rice:BYG mixture proportion (P).

Source	df	H	Y	LA	ADW	RDW
Year (Y)	1	3^{ns}	7.9^{ns}	91767*	37.3*	3.9*
R (Y)	4	51^{ns}	1.2^{ns}	8281^{ns}	2.8^{ns}	0.5^{ns}
Methanol (M)	1	159^{ns}	681.0***	1487907***	1598.2**	9.8***
M * Y	1	47^{ns}	0.3^{ns}	1384^{ns}	0.3^{ns}	0.5^{ns}
rice:BYG (P)	3	388***	936.3***	2554180***	2397.7***	47.2***
Y * P	3	29^{ns}	0.6^{ns}	6840^{ns}	2.5^{ns}	0.7^{ns}
M * P	3	43^{ns}	3.8^{ns}	46752^{ns}	11.9^{ns}	0.4^{ns}
M * P * Y	3	15^{ns}	0.4^{ns}	3582^{ns}	1.8^{ns}	0.4^{ns}
Error	28	44	3.0	18126	8.5	0.4

*, **, ***: significant at the 0.05, 0.01, and 0.001 probability levels, respectively.
ns, not significant at the 0.05 probability level.

in biomass in plants treated with methanol (Hartz et al. 1994, Mauney and Gerik 1994, McGiffen et al. 1995, Mitchell et al. 1994). Rice grain yield (g plant^{-1}) was significantly increased as rice:BYG ratio per pot was reduced. The highest (36.4 g plant^{-1}) and the lowest (15.7 g plant^{-1}) grain yields were recorded for plants grown at 25:75 and 100:0 rice:BYG mixture proportions, respectively (Table III). It seems that intraspecific competition reduced grain production.

TABLE III
Rice plant height (H), grain yield (Y), leaf area (LA), aboveground weight (ADW) and root dry weight (RDW) response to methanol foliar application (M) and rice:barnyardgrass (BYG) mixture proportion, averaged across two years.

Factors \ Traits	H (cm)	Y (g plant^{-1})	LA (cm^2 plant^{-1})	ADW (g plant^{-1})	RDW (g plant^{-1})
Methanol foliar applications (v/v)					
0	98	20.4	1110	34.6	4.5
14%	101	27.9	1462	46.2	5.5
LSD (0.05)	4	1.0	79	1.7	0.4
Rice:BYG Ratios					
100:0	94	15.7	702	26.2	2.9
75:25	97	20.4	1190	34.7	4.1
50:50	101	24.1	1456	41.7	5.4
25:75	107	36.4	1796	59.3	7.6
LSD (0.05)	5	1.4	112	2.4	0.5

Methanol (M), BYG:rice ratio (P) and M × P interaction had significant effects on BYG seed production, while the effects of year and all 2- and 3-ways interaction were not significant (Table III). In untreated plants, BYG seed production (g plant^{-1}) was significantly increased from 3.8 ± 0.4 to 7.4 ± 1.0 as BYG:rice ratio reduced from 100:0 to 25:75 (Table V). When methanol was sprayed, BYG seed production significantly increased as BYG:rice ratio reduced from 100:0 to 50:50, but there were no significant differences in BYG seed production between 50:50 and 25:75 BYG:rice ratios (Table V).

TABLE IV
Mean squares for the combined analysis of variance for barnyardgrass (BYG) plant height (H), seed production (SP), leaf area (LA), aboveground dry weight (ADW), root dry weight (RDW) as affected by methanol foliar application (M) and BYG:rice mixture proportion (P).

Source	df	H	SP	LA	ADW	RDW
Year (Y)	1	0.01^{ns}	1.93^{ns}	996^{ns}	0.04^{ns}	1.3^{ns}
R (Y)	4	157.38^{ns}	1.22^{ns}	7244^{ns}	2.47^{ns}	2.0^{ns}
Methanol (M)	1	524.23*	20.24***	13^{ns}	18.77*	0.1^{ns}
M * Y	1	5.08^{ns}	0.51^{ns}	2760^{ns}	0.03^{ns}	0.6^{ns}
BYG:rice (P)	3	2925.43***	40.09***	1138262***	394.97***	57.6***
Y * P	3	8.04^{ns}	0.004^{ns}	5396^{ns}	0.49^{ns}	0.5^{ns}
M * P	3	557.97**	2.56*	17055^{ns}	7.07^{ns}	0.3^{ns}
M * P * Y	3	8.42^{ns}	0.08^{ns}	7911^{ns}	0.41^{ns}	0.2^{ns}
Error	28	105.93	0.68	11181	3.74	0.9

*, **, ***: significant at the 0.05, 0.01, and 0.001 probability levels, respectively.
ns, not significant at the 0.05 probability level.

LEAF AREA

Rice leaf area was significantly affected by year, methanol foliar application and rice:BYG ratio, but the all 2- and 3-way interactions were not significant. Rice plant produced significantly greater leaf area in 2011 (1330 cm^2 plant^{-1}) than in 2012 (1242 cm^2 plant^{-1}). However, this greater leaf area did not result in a significant greater grain yield in 2011. Leaf area was significantly increased by 32% as aqueous methanol solution (14% v/v) was sprayed on plants. Methanol foliar application could increase leaves expansion by stimulating genes encoding for pectin methyl esterase, which enhances plant Ca capture for increasing leaf area (Ramirez et al. 2006). Leaf area for rice significantly increased from 702 to 1796 cm^2 plant^{-1} as BYG number increased form 0 to 6 plants per pot (Table III). This indicates that rice produced greater leaf area when grown at 25:75 rice:BYG ratio, probably because of the greater number of tillers produced at this rice:BYG mixture proportion. This result confirmed that intraspecific competition was more severe than interspecific competition from the weed.

Leaf area for BYG was significantly affected only by BYG:rice ratio (Table IV). The highest and the lowest leaf area for BYG was recorded at 100:0 (1033 cm^2 plant^{-1}) and 25:75 (324 cm^2 plant^{-1}) BYG:rice ratios, respectively (Fig. 1).

TABLE V
Mean comparison for methanol foliar application × rice:barnyardgrass ratio interaction for barnyardgrass plant height and seed production (averaged across two years).

Methanol foliar application (v/v)	BYG:rice ratio	height (cm)	Seed production (g plant^{-1})
0	8:0	148.5 ± 2.3	3.8 ± 0.4
	6:2	134.7 ± 2.2	5.0 ± 0.3
	4:4	117.6 ± 4.1	5.7 ± 0.6
	2:6	103.3 ± 8.4	7.4 ± 1.0
14%	8:0	153.3 ± 1.7	3.5 ± 0.5
	6:2	125.5 ± 1.6	4.5 ± 0.2
	4:4	124.4 ± 3.7	5.5 ± 0.6
	2:6	127.4 ± 2.4	6.8 ± 0.1

ABOVEGROUND DRY WEIGHT

There were significant differences in rice above-ground dry weight between the years, methanol foliar applications, and rice:BYG ratios (Table III). Aboveground biomass was significantly higher in 2011 (41.3 g plant^{-1}) than in 2012 (39.5 g plant^{-1}), and significantly increased when aqueous methanol solution (14% v/v) was sprayed (Table III). Increases in plant biomass after the exposure of plants to methanol have been reported by other researchers (Devlin et al. 1994, Hemming et al. 1995, Li et al. 1995, Nishio et al. 1994, Valenzuela et al. 1994). Doman and Romanova (1962) indicated that methanol is initially converted in leaves to CO_2, which is rapidly assimilated during photosynthesis. The increased biomass of the methanol-treated C_3 plants was attributed to 1) the use of the methanol as a direct carbon source via serine biosynthesis and 2) decreased carbon loss from photorespiration. Nonomura and Benson (1992a, b) declared that water use efficiency significantly increased in methanol treated plants. Metabolism of methanol to sugars could increase turgor and stomatal conductance, which in turn increase the assimilation rate, plant growth and, subsequently, plant maturation and thus less need for irrigation. McGiffen et al. (1995) and Nonomura et al. (1995) noted that methanol may be an effective carrier of many agrichemicals with low water solubility. Rice aboveground dry weight significantly increased from 26.2 to 59.3 g plant^{-1} when rice:BYG ratio reduced from 100:0 to 25:75, indicating that plants grown with six BYG plants per pot produced the greatest aboveground dry weight. This result suggested that rice was more aggressive than BYG. Similarly, Fleming et al. (1988) reported that the more aggressive species in a mixture, increased in weight with increased proportions of the less aggressive species.

Aboveground dry weight for BYG significantly affected by methanol foliar application and BYG:rice ratio (Table IV). Aboveground dry weight for BYG significantly increased by 9% as methanol was sprayed at 14% (v/v). The highest aboveground dry weight was recorded at 100:0 BYG:rice ratio, while the lowest one was recorded at 25:75 BYG:rice ratio (Fig. 2). This indicates that BYG grew better with intraspecific than with interspecific competition.

The competitiveness of rice cultivar, 'Shiroudi', against BYG on the basis of the relative aboveground dry weight was evaluated using a replacement series diagram (Fig. 3). As shown in the Figure 3, the lines for 'Shiroudi' and BYG intersect at the right of the point of equivalency (50:50 rice:BYG ratio). In other words, the curve representing 'Shiroudi' was convex and the curve for BYG was concave, indicating that BYG was less competitive than 'Shiroudi'. Regardless of methanol foliar application, the RYTs for aboveground dry weight of 'Shiroudi' and BYG ranged from 1.15 to 1.30 and 1.1 to 1.19, respectively. RYTs for aboveground dry weight were often significantly higher one. This response probably occurred because of the reduced interference in mixtures relative to the monocultures due to the differences in paths of resource acquisition by C_3 rice plants and C_4 BYG plants, or from differences in the exploitation of growth factors (Fischer et al. 2000). When methanol was not sprayed, the lines for 'Shiroudi' and BYG intersect at 75:25 rice:BYG ratio, but when methanol was sprayed at 14% v/v, the lines for 'Shiroudi' and BYG intersect at the left of the 75:25 rice:BYG mixture proportion (Fig. 3). This indicates that methanol foliar application reduced competitive ability of rice cultivar against BYG for aboveground biomass accumulation.

The greater RCC of 'Shiroudi' over BYG indicates and also confirms the results of RY for aboveground dry weight that 'Shiroudi' was a stronger competitor than BYG (Table VI). Moreover, methanol foliar application significantly reduced the RCC of 'Shiroudi', while it significantly increased the RCC of BYG (Table IV), indicating that methanol foliar application reduced the competitive ability of 'Shiroudi' against BYG for shoot biomass accumulation.

Root Dry Weight

Year, methanol and rice:BYG ratio were significant for rice root dry weight, while none of the all 2- and 3-way interactions were significant (Table II). Rice

TABLE VI
Effect of methanol foliar application on relative crowding coefficient (RCC) for aboveground dry weight (ADW) and root dry weight (RDW) averaged across two years.

Species in mixture	RCC for ADW		RCC for RDW	
	$M_{0\ (v/v)}$	$M_{14\%\ (v/v)}$	$M_{0\ (v/v)}$	$M_{14\%\ (v/v)}$
Shiroudi	4.02 ± 0.15	2.53 ± 0.49	1.92 ± 0.13	1.72 ± 0.53
BYG	0.35 ± 0.01	0.63 ± 0.05	0.54 ± 0.03	0.74 ± 0.20

BYG: Barnyardgrass.

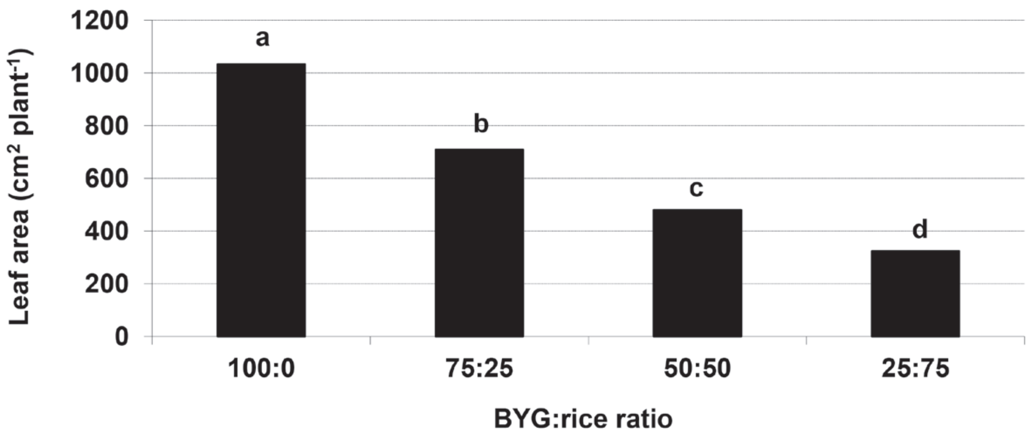

Figure 1 - Effect of barnyardgrass (BYG):rice ratio on leaf area of BYG.

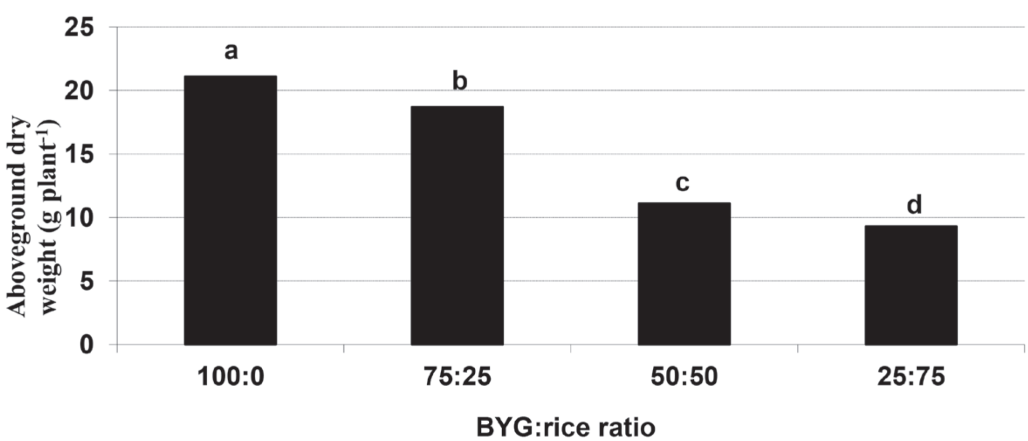

Figure 2 - Effect of barnyardgrass (BYG):rice ratio on aboveground dry weight of BYG.

plant produced greater root dry weight in 2011 (5.3 g $plant^{-1}$) when compared to 2012 (4.7 g $plant^{-1}$). Plants treated with aqueous methanol (14% v/v) produced greater root biomass compared to control plants (Table III). Root dry weight for rice significantly increased as rice:BYG mixture proportion decreased from 100:0 to 25:75 (Table III). The highest (7.6 g $plant^{-1}$) and the lowest (2.9 g $plant^{-1}$) roots dry weight were recorded for plants grown at 25:75 and 100:0 rice:BYG mixture proportions, respectively (Table III).

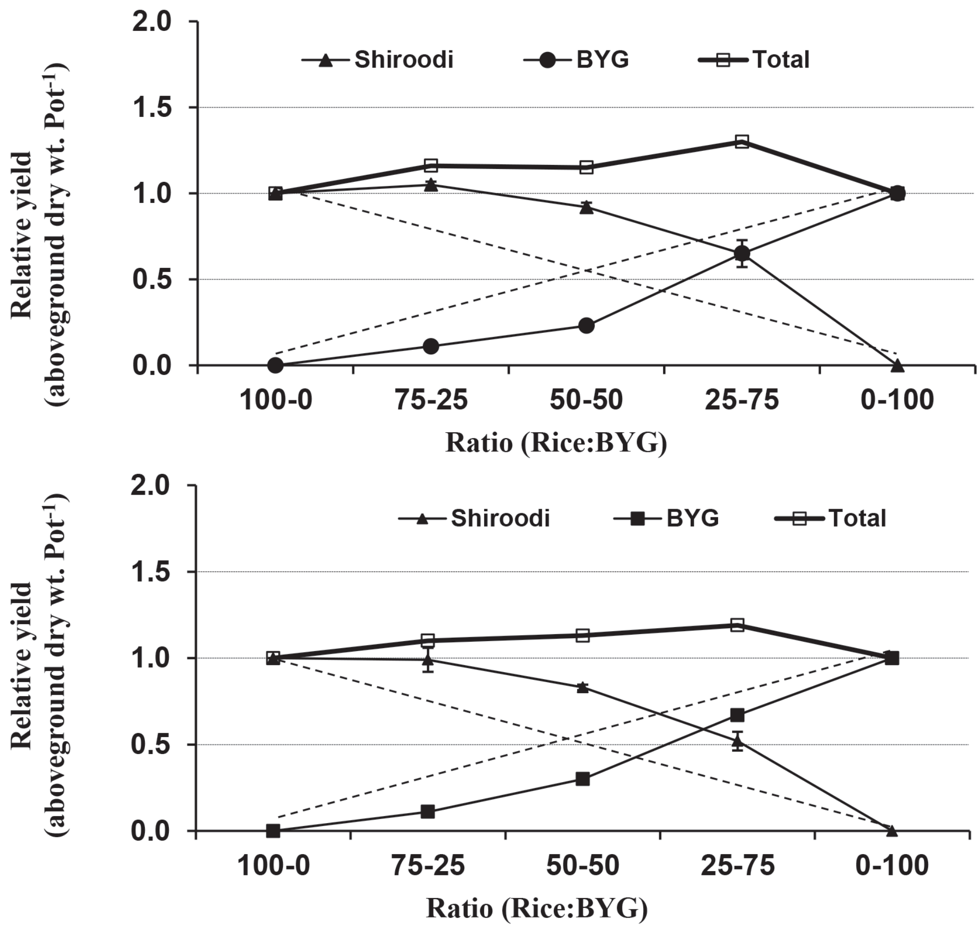

Figure 3 - Relative aboveground dry weights of rice 'cv. Shiroudi' (▲), barnyardgrass (BYG) (●) and relative yield totals (RYT) (□) as influenced by methanol foliar application [above: methanol was not sprayed, and below: methanol sprayed at 14% (v/v)] and rice: BYG ratios in a replacement series over two years. The two straight dashed lines in each frame indicate the theoretically expected responses for two equally competitive species, which intersect at the point of equivalency (Harper 1977). Error bars represent ± standard errors of the mean.

Main effects of rice:BYG ratio were significant for BYG root dry weight, while other main effects (year, methanol) and all 2- and 3-way interactions were not significant (Table II). Root dry weight for BYG significantly reduced as BYG:rice ratio decreased from 100:0 to 50:50, but was not reduced further when grown at 25:75 BYG:rice ratio (Fig. 4).

As shown in the Figure 5, 'Shiroudi' and BYG lines intersect almost at the 75:25 rice:weed mixture proportions, whether methanol was sprayed or not. This result suggested that 'Shiroudi' was more aggressive than BYG in root biomass accumulation and methanol foliar application did not affect the relative competitive abilities of rice and BYG or the impact of the BYG on rice with regard to root biomass accumulation. The RYTs for root dry weights of 'Shiroudi' and BYG were higher than one, which implies the species are making demands on different resources and avoiding competition.

The greater RCC of 'Shiroudi' over BYG indicates the aggressiveness of 'Shiroudi' against BYG in root dry weights (Table VI). Furthermore, the RCC value for root dry weight was not significantly affected by methanol foliar application (Table VI).

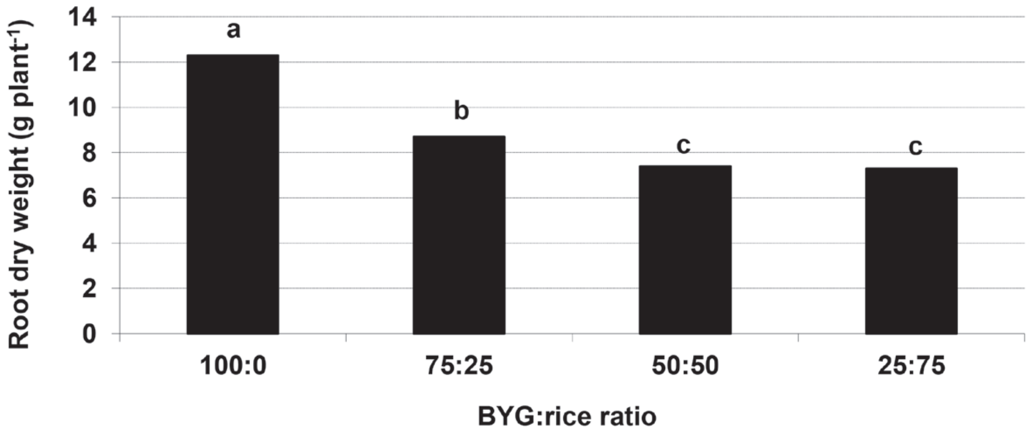

Figure 4 - Effect of barnyardgrass (BYG):rice ratio on root dry weight of BYG.

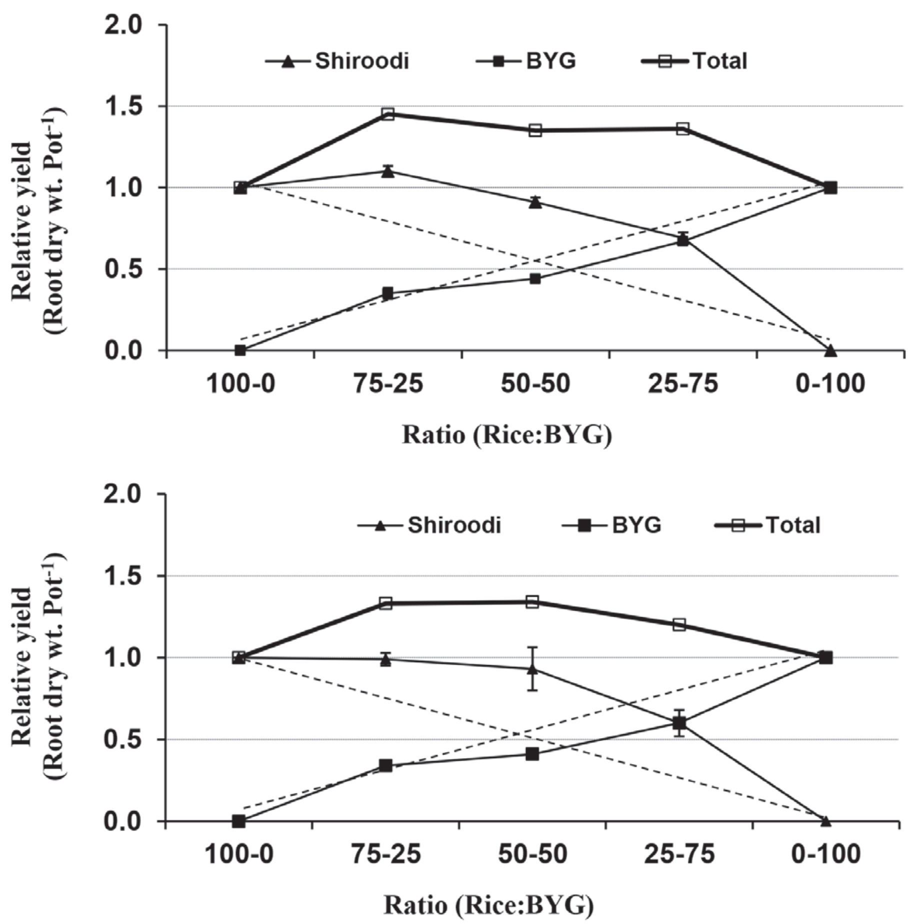

Figure 5 - Relative root dry weights of rice 'cv. Shiroudi' (▲), barnyardgrass (BYG) (●) and relative yield totals (RYT) (□) as influenced by methanol foliar application [above: methanol was not sprayed, and below: methanol was sprayed at 14% (v/v)] and rice:BYG ratios in a replacement series over two years. The two straight dashed lines in each frame indicate the theoretically expected responses for two equally competitive species, which intersect at the point of equivalency (Harper 1977). Error bars represent ± standard errors of the mean.

CONCLUSIONS

This experiment indicated that 'Shiroudi' was stronger competitive than BYG, and methanol foliar application reduced the competitive ability of 'Shiroudi' against BYG. Therefore, foliar application of aqueous methanol can not be recommended for rice under weedy conditions.

RESUMO

O experimento foi conduzido no Irã, para avaliar o efeito do metanol sobre a competição entre o arroz (*Oryza sativa*) e capim-arroz *(Echinochloa crus-galli*). O experimento foi conduzido no delineamento de blocos ao acaso em arranjo fatorial sendo desenvolvido em triplicata. Duas frações de metanol aquoso (0, e 14% v / v) eram aplicados em conteudos foliares em cinco frações de arroz e capim-arroz (100: 0, 75:25, 50:50, 25: 6, e 0: 100). Na serie de diagramas de substituição mostrou valores de peso seco acima como ilustrado "Shiroudi" e assim foi mais competitivo do que o capim como media entre as aplicações foliares de metanol. Quando o metanol não foi pulverizado, a razão das linhas de 'Shiroudi' e de capim-arroz se cruzaram em 75:25: entre arroz e capim-arroz, mas quando o metanol foi pulverizado a 14% v / v, para as linhas de 'Shiroudi' e de capim-arroz se intersectam a esquerda de 75:25 da mistura entre arroz:capim–arroz. Estes resultados indicam que a aplicação de metanol reduz a capacidade competitiva de 'Shiroudi' contra capim-arroz para a acumulação de biomassa no solo. Ao mesmo tempo, a aplicação foliar do metanol reduziu significativamente o coeficiente de aglomeração relativa de 'Shiroudi', e simultaneamente aumentou significativamente o coeficiente de aglomeração relativa de capim-arroz. Isso indica que a aplicação foliar de metanol reduziu a capacidade competitiva de 'Shiroudi' contra capim-arroz para a acumulação de biomassa da parte aérea. Dessa forma a experiência mostrou que a pulverização foliar de solução aquosa de metanol não pode ser recomendada para o arroz em condições de convivência.

Palavras-chave: capim, interferência, metanol, arroz.

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