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Influence of nitrogen rate on competition between tow rice (*Oryza sativa* L.) cultivars and barnyardgrass (*Echinochloa crus-galli* (L.) P. Beauv)

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Key words: Barnyardgrass, competitive ability, nitrogen, rice.

Abbreviations: Barnyardgrass (BYG), nitrogen (N), aboveground dry weight (ADWt), root dry weight (RDWt), tiller number (TNo.), height (H).

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Abstract

The experiment was conducted at Rice Research Station of Tonekabon, Iran to determine the influence of nitrogen (N) rate on competitive ability of two rice cultivars ("Khazar" and "Line843") against barnyardgrass (BYG). Treatments consisted of a factorial combination of two rice cultivars (a high competitive line: "Line843", and a low competitive cultivar: "Khazar" cultivar), three N rates (0, 50 and 100 Kg N ha^{-1}) and five rice:BYG ratios (100:0, 75:25, 50:50, 25:75 and 0:100). Treatments were arranged in a randomized complete block design with three replicates. Replacement series curves showed that "Line843" was more competitive than BYG, while "Khazar" was as competitive as BYG. Moreover, the results showed that relative crowding coefficient based on grain yield, root dry weight and tiller number was significantly higher in "Line843" compared to "Khazar" and BYG (interfere with either "Khazar" or "Line843"). On the other hand, different levels of N fertilizer application had no significant effect on competitive ability of "Khazar" and "Line843". In general, this experiment illustrated that "Line843" was more competitive than "Khazar" cultivar at all N rates and N rate did not influence on competition between rice and BYG.

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Introduction

Weeds are one of the most important limiting factors in rice production systems. They compete with rice for moisture, nutrients, and light during the growing period and when not controlled can cause yield losses approximately 50% in transplanted rice (Ampong-Nyarko and De Datta, 1991). There is also evidence that many weed species exude allelopathic chemicals which inhibit the growth of other nearby plants (Khan et al. 2011). BYG is a widespread and competitive weed in transplanting rice production systems. It grows faster than rice during the early growth season which gives it a competitive advantage. Therefore, Successful weed management is one of the key elements for economical rice production.

Herbicides are effective tools to control weeds, but increasing concerns about the development of weed resistance to herbicides and a scarcity of new and effective herbicides have motivated scientists to integrate other weed management strategies with herbicide use. Growing the cultivars with high competitive ability is an important but often overlooked component of integrated weed management (IWM).

Weed-competitive ability defines as the ability of a crop to tolerate weed pressure and maintain yield, or the ability of a crop to suppress weed growth and seed production. Several early researchers have reported the negative correlation between weed competitiveness and yield (Jennings and Jesus, 1968; Kawano *et al.*, 1974), but other researchers have demonstrated that competitive cultivars could be developed without substantially lowering yields (Garrity *et al.*, 1992; Watson *et al.*, 2006). Not only field crops but also different cultivars in one species vary widely in their ability to compete with weeds. Moreover, nutrient management such as fertilizer placement, timing of fertilizer application, and fertilizer application rate can influence the weed-competitive ability. Research results on the effect of N rate on crop-weed competition has been variable. Several studies have been reported that N fertilizer favored weeds over crops (Andreasen *et al.* 2006; Dhima and Eleftherohorinos 2001). In contrast, other researchers documented that added N increased the competitive ability of crops more than weeds (Abouziena *et al.* 2007; Evans *et al.* 2003). In the meantime, some researchers reported that soil N level had no significant effect on competition between crops and weeds (Gonzalez Ponce 1998). Additionally, some studies indicated that weed biomass could be increased, decreased, or unchanged with higher N levels, depending on the weed species and crop. For example, Van Delden *et al.* (2002) found that the biomass of common chickweed [*Stellaria media* (L.) Vill.] in potato (*Solanum tuberosum* L.) and wheat (*Triticum aestivum* L.) was decreased and increased at higher N levels, respectively. Specific characteristics such as rapid germination and emergence, rapid biomass accumulation and ground cover, high leaf area index and specific leaf area, high ability to intercept light, high tillering capacity, and high plant height can improve crop's competitive ability.

A lack of data exists concerning the effect of nitrogen rates on the competitive ability of rice cultivars, Khazar and Line843, against BYG. Therefore, the aim of this study was to evaluate the effect of nitrogen rate on relative competitive ability of rice cultivars against BYG, in a replacement series study.

Materials and methods

Experimental site and design

This experiment was conducted in plastic pots at Rice Research Station in Tonekabon (360 54' N, 400 50' E; 20 m above sea level), northern Iran, in 2010. Monthly precipitation and temperature are shown in Table 1. Treatments consisted of a factorial combination of two rice cultivars ("Line843" and "Khazar", high and low competitive cultivars, respectively (Aminpanah 2009)), three N rates (0, 50 and 100 Kg N ha^{-1} was applied as Urea) and rice:BYG ratios (100:0, 75:25, 50:50, 25:75 and 0:100). Treatments were arranged in a randomized complete block design with three replicates. Actual plant numbers per pot for each mixture were 8:0, 6:2, 4:4, 2:6 and 0:8, respectively. Pots (35 cm diameter by 30 cm deep) were filled to a depth of 25 cm with clay loam soil from the Tonekabon's Rice Research Station farm and embedded in the ground to imitate the environmental conditions experienced by field-grown plants, especially with regard to temperature. Soil properties are presented in Table 2. Rice seeds were disinfected with thiophanate-methyl 70 WP (20 gL^{-1} H_2O) and subsequently were sown in the nursery on 27 April, 2010. BYG seeds were collected in 2009 form mature plants at the Rice Research Station of Tonekabon. According to rice:BYG ratio in each pot, three healthy seedlings of the rice cultivar (line) or one germinated BYG seed were transplanted (or planted) in hills in a square arrangement, with hills equidistant from the sides of the pot and from each other, on 1 June 2010. One-third amount of N and the entire P (100 kg ha^{-1}) and K (150 kg ha^{-1}) were applied as a basal dose at transplanting stage. The remaining two-thirds of N were provided in two split doses: 30 days after transplanting, and at panicle initiation stage. Consistent with the lowland paddy field practices in north of Iran, a permanent flood 5 cm deep was maintained from approximately 7 days after transplanting until 20 days before harvesting. Moreover, all unwanted weeds were hand-weeded through the experiment.

Sampling

At maturity stage, plant height was measured from the soil surface to the panicle tip and recorded as the average of all plants per pot. Plants were harvested by hand-cutting at the soil surface and subsequently aboveground biomass of rice and BYG were separated, and tillers of each species were counted. Roots of rice cultivar or line and BYG carefully separated from the soil mixture using a gentle stream of tap water. Rice and BYG above- and belowground (root) tissues from each pot were placed in separate paper bags, dried at 72°C for 96 h and dry weight determined.

To assess the competitiveness of rice cultivars against BYG at different N levels, the four models for interference, proposed by Harper (1977), were used. These models described the possible outcomes of the interaction of two species when grown in a replacement series (Radosevich, 1987). Replacement series diagrams were constructed for the response of aboveground dry weight, root dry weight, and tiller number to species proportion.

Relative crowding coefficient (RCC), a measure of the relative dominance of one species over the other in a mixture, was calculated according to the following equation (Novak *et al.*, 1993):

$$RCC= (W_r^{4:4} / W_b^{4:4}) / (W_r^{8:0} / W_b^{0:8}) \quad [1]$$

Where W_r is aboveground or root dry weight, and tiller number of rice cultivar or line, W_b is aboveground or root dry weight, and tiller number of BYG, and superscripts ratios are the proportions of rice to BYG. The larger the RCC value, the greater the competitiveness with the other species. An RCC value of 1 indicates that the rice and BYG have equal competitiveness, while RCC values > 1 show superior competitiveness of rice over BYG and RCC values < 1 show superior competitiveness of BYG over rice.

Statistical analyses

Data were subjected to analysis of variance (ANOVA), and means were separated using Fisher's Protected LSD at the 0.05 level. All analyses were performed using the procedures PROC GLM module within the Statistical Analysis System version 9.1, software package (SAS Institute, 2002).

Results and discussion

Aboveground dry weight

The cultivar, N rate, and rice:BYG ratio effects were significant ($P < 0.01$) for aboveground dry weight. All 2-way and 3-way interactions were also significant (Table 3). For both cultivars, the greatest and the lowest aboveground dry weight were recorded at 2:6 rice:BYG mixture proportion when N fertilizer was not applied. In unfertilized pots, the aboveground dry weight of "Line843" was significantly higher than that of "Khazar" cultivar at 2:6 rice:BYG ratio (Table 5). At the rate of 50 kg N ha^{-1}, There was a reduction in the aboveground dry weight of both cultivars with increasing rice:BYG mixture proportions. However, "Line843" produced more aboveground dry weight (P < 0.05) than "Khazar" cultivar at all rice:BYG mixture proportions (Table 4). At 100 kg N ha^{-1}, the aboveground dry weigh for "Line843" was significantly higher than for "Khazar" cultivar at all rice:BYG mixture proportions (Table 4). In general, the highest aboveground biomass was observed at N 100 Kg ha^{-1} and 2:6 rice:BYG ratio both for "Khazar" (62.08 g $plant^{-1}$) and "Line843" (82.08 g $plant^{-1}$), the lowest aboveground biomass was recorded at pure stands of "Khazar" (27.21 g $plant^{-1}$) and "Line843" (30.93 g $plant^{-1}$) in unfertilized pots (Table 4).

Table 1. Monthly precipitation and temperature from April to September in 2010 at Tonekabon's Rice Research Station.

Month	Precipitation (mm)	Temperature (°C)		
		Maximum	Minimum	Average
April	94.91	15.4	11.0	13.3
May	16.31	22.3	16.5	19.4
June	1.53	29.4	22.6	26.0
July	8.30	32.7	25.6	29.2
August	87.70	31.9	25.1	28.5
September	96.90	27.5	21.5	24.5

Table 2. Soil properties (0-30 cm) before transplanting.

OC (%)	pH	Sand (%)	Silt (%)	Clay (%)	Total N (%)	P (mg kg^{-1})	K (mg kg^{-1})
2.1	6.9	19	45	36	0.206	9	101

Table 3. Mean squares of ANOVA for aboveground dry weight (ADWt), root dry weight (RDWt), tiller number (TNo.), and height (H) of rice as affected by rice cultivar, N rate and rice:barnyardgrass (BYG) ratio.

Source of Variance	df	ADWt	RDWt	TNo.	H
Block (R)	2	20	1.3	6.6	0.7
Nitrogen rate (N)	2	1784**	171.4 **	1076.7 **	2442.3 **
Cultivar (C)	1	981**	16.3 **	1769.1 **	83.6 **
rice:BYG ratio (P)	3	2253**	57.4**	197.9 **	82.7 **
N × C	2	75**	13.7 **	229.1 **	24.5 **
N × P	6	6*	16.1 **	10.5 *	1.9 ns
C× P	3	134**	38.2 **	53.5 **	7.3 ns
N × C × P	6	36**	11.8 **	12.1 **	4.7 ns
Error	46	8	2.6	3.9	4.3

ns, *, and ** indicate no significant, statistical significance at $P \leq 0.05$ and $P \leq 0.01$, respectively.

N rate, rice cultivar, rice:BYG ratio, and All 2-way interactions effects were significant (P < 0.01) for aboveground dry weight of BYG, but The 3-way interaction was not significant (Table 5). Averaged across rice:BYG ratio, with increasing the N rate from 0 too 100 Kg ha^{-1}, the aboveground dry weight of BYG was increased when grown either "Khazar" or "Line843" (Table 6). However, the aboveground dry weight of BYG was significantly greater when grown with "Khazar" than when grown with "Line843"

(Table 6). Regardless of N rate application, the aboveground dry weight of BYG was significantly lower when grown at all rice:BYG mixture proportions compared to monoculture (Table 7). On the other hand, the greatest BYG aboveground dry weight was observed in 2:6 BYG:"Khazar" ratio (Table 7). At unfertilized pots, the highest aboveground dry weight for BYG was recorded at 2:6 BYG:rice ratio, regardless of rice cultivar (Table 8). At 50 and 100 Kg N rate applications, the greatest aboveground dry weight of BYG was observed when grown in monoculture (Table 8). In general, the aboveground dry weight of BYG was increased with increasing N rate (Table 8).

Table 4. Aboveground dry weighr (ADWt), root dry weighr (RDWt), and tiller number (TNo.) of "Line843" and "Khazar" rice cultivars as influenced by N rate and rice: barnyardgrass (BYG) plant ratio.

N rate (Kg ha^{-1})	Rice:BYG ratio	ADWt (g plant^{-1})		RDWt (g plant^{-1})		TNo. Plant^{-1}	
		Khazar	Line843	Khazar	Line843	Khazar	Line843
0	8:0	27.71	30.93	16.24	17.08	5.75	8.58
	6:2	31.83	33.85	17.67	16.58	7.05	9.50
	4:4	40.34	40.61	18.17	15.80	8.00	10.58
	2:6	52.85	60.50	16.79	16.84	9.83	16.16
50	8:0	34.78	43.57	18.82	23.98	9.58	15.25
	6:2	39.33	44.48	21.39	21.27	8.21	17.61
	4:4	42.84	53.51	17.41	20.49	8.94	22.58
	2:6	55.43	69.58	16.13	17.49	12.00	24.50
100	8:0	41.67	51.83	19.86	27.34	12.41	23.54
	6:2	48.73	54.26	21.79	28.48	14.55	26.49
	4:4	51.91	63.99	21.68	23.25	15.25	31.58
	2:6	62.08	82.08	16.69	18.84	17.00	41.16
LSD		4.74		2.69		3.27	

Table 5. Mean squares of ANOVA for aboveground dry weight (ADWt), root dry weight (RDWt), tiller number (TNo.), and height (H) of barnyardgrass (BYG) as affected by rice cultivar, N rate and rice: barnyardgrass (BYG) ratio.

Source of Variance	df	ADWt	RDWt	TNo.	H
Block (R)	2	30.27333	20.59	1.6	8
Nitrogen rate (N)	2	1346**	153.48**	335.2**	4153**
Cultivar (C)	1	663**	4.54^{ns}	92.2**	542**
rice:BYG ratio (P)	3	924**	570.89**	70.7**	748**
N × C	2	39*	0.80^{ns}	8.1*	42*
N × P	6	77*	23.29**	2.8^{ns}	47**
C× P	3	168**	36.94**	12.3^{ns}	72**
N × C × P	6	17^{ns}	2.47^{ns}	2.3^{ns}	20^{ns}
Error	46	11	8.18	2.2	11

ns, *, and ** indicate no significant, statistical significance at P ≤ 0.05 and P ≤ 0.01, respectively.

Table 6. Aboveground dry weight (ADWt), tiller number (TNo), and plant height (H) of barnyard grass (BYG) when grown in mixture with rice cultivars at different N rates.

BYG when grown with	N rate (Kg ha^{-1})	ADWt (g plant^{-})	TNo (No plant^{-1})	H (Cm)
"Khazar"	0	32.47 c	3.4083 d	49.435 e
	50	40.89 b	7.6908 b	63.623 c
	100	49.98 a	11.9783 a	76.766 a
"Line843"	0	29.15 d	2.4642 d	46.431f
	50	34.40 c	4.9958 c	55.338d
	100	41.58 b	8.8250 b	71.593 b
LSD (0.05)		2.745	1.2262	2.7919

Table 7. Aboveground dry weight (ADWt), root dry weight (RDWt), and plant height (H) of barnyardgrass (BYG) as affected by rice cultivar and BYG:rice ratio.

BYG when grown with:	BYG:rice ratio	ADWt (g plant^{-})	RDWt (g plant^{-1})	H(Cm)
"Khazar"	8:0	44.70a	27.32a	69.68a
	6:2	32.77d	14.99c	59.66bc
	4:4	36.34c	16.36bc	60.94bc
	2:6	50.64b	17.90b	62.80b
"Line843"	8:0	44.70a	27.33a	69.68a
	6:2	30.46de	18.09	50.92d
	4:4	27.95de	15.04c	52.79d
	2:6	37.06c	14.12c	57.75c
LSD (0.05)	-	3.16	2.71	3.22

Table 8. Aboveground dry weight (ADWt), root dry weight (RDWt), and plant height (H) of barnyardgrass (BYG) as affected by N rate and BYG:rice ratio.

N rate (kg ha^{-1})	BYG:rice ratio	ADWt (g plant^{-})	RDWt (g plant^{-})	H (Cm)
0	8:0	32.15f	22.27 c	52.68de
	6:2	25.23g	14.67 ef	43.87f
	4:4	27.16g	14.25f	45.02f
	2:6	38.70de	15.06 def	50.15e
50	8:0	44.30c	26.70b	69.33b
	6:2	32.32f	16.94def	53.75de
	4:4	31.43f	14.99def	56.04cd
	2:2	42.52cd	15.50def	58.80c
100	8:0	57.65a	33.00a	87.04a
	6:2	37.29e	18.00d	68.25b
	4:4	37.83e	17.85de	69.54b
	2:6	50.32b	17.48def	71.88b
LSD (0.05)	-	3.88	3.32	3.94

Replacement series diagrams based on aboveground dry weight (Fig. 1) illustrated the competitive effects between rice cultivar or line and BYG at all N rates. The lines for "Line843" and BYG intersect at the right of the 50:50 mixture proportion (point of equivalency of the expected yield), indicating that "Line843" was more competitive than BYG in aboveground biomass production. There was a significant (P < 0.01) effect of species in mixture on RCC of aboveground dry weight, but N rate had no significant effect (Table 9). This suggested that cultivars showed similar responses at all N rates. The interaction effect of species in mixture × N rate was significant at P < 0.05 (Table 9). Averaged across N rates, the RCC value (Table 10) based on aboveground dry weight for "Line843" (2.56) was significantly greater than that for BYG when grown with "Line843" (0.39). Although replacement series diagrams based on aboveground dry weight (Fig. 1) indicated that the lines for "Khazar" cultivar and BYG intersect slightly at the right of the 50:50 mixture proportion, the RCC value (Table 10) for aboveground dry weight was statistically similar between "Khazar" (1.08) and the BYG when grown with Khzar (1.05). This indicated similar competitive ability between "Khazar" and BYG and neither species were dominant in aboveground biomass production. The RCC value for aboveground dry weight also confirmed that "Line843" was more competitive than "Khazar" (Table 10). Fischer *et al.* (2000) reported that when two species competing for limited resources, the stronger competitive species has the greater RCC value in the mixture. Moreover, the RCC value for aboveground dry weight was not significantly different among N rates when averaged across species in mixture (Table 11). Moreover, N rate had no significant effect on the competitive ability of "Line843" or "Khazar" and BYG when grown together (Fig. 1). These findings are in agreement with those of Gonzalez Ponce (1998) who reported that soil N level had little effect on crop–weed Competition. On the other hand, several researchers reported that the added N increased (Andreasen *et al.* 2006; Dhima and Eleftherohorinos, 2001) or decreased (Abouziena *et al.*, 2007; Evans *et al.*, 2003) the competitive ability of weeds more than crops. Moreover, Begum *et al.* (2009) reported that at low weed densities (500 plants m^{-2}), rice yields increased with higher N level. On the other hand, at the higher weed density (1000 plants m^{-2}), increasing N level to 170 kg ha^{-1} had no significant effect on rice yield.

Root dry weight

There were significant (P < 0.01) effects of rice cultivar, N rate, and rice:BYG ratio on root dry weight of rice. All two way and three way interactions were also significant (Table 3). In unfertilized pots (0 Kg N ha^{-1}), the root dry weight of both cultivars was statistically constant at different rice:BYG ratios (Table 4). At 50 kg N ha^{-1}, the root dry weight for "Line843" was generally reduced with decreasing rice:BYG ratio, but in "Khazar" cultivar the highest root dry weight (21.39 g $plant^{-1}$) was recorded at 6:2 rice:BYG ratio (Table 4). At 100 kg N ha^{-1}, the minimum and maximum root dry weight for both cultivars were observed at 2:6 and 6:2 rice:BYG ratio, respectively (Table 4).

Root dry weight of BYG was not influenced (P < 0.01) by rice cultivar, while it was significantly (P < 0.01) affected by N rate and rice:BYG ratio. Moreover, all 2-way interactions except N rate by rice cultivar were significant (P < 0.01) (Table 5). The greatest root dry weight of BYG (27.32 g $plant^{-1}$) was observed when grown in monoculture (Table 7). The root dry weight of BYG was increased when BYG:"Khazar" ratio changed from 6:2 to 2:6 (Table 7). On the other hand, the root dry weight of BYG reduced with decreasing BYG: Line843 mixture proportion (Table 7). At N rate of 0, 50, and 100 Kg ha^{-1}, the greatest root dry weight of BYG was observed when grown in monoculture, while root dry weight of BYG was statistically similar among other BYG:rice mixture proportions (Table 8). The 3-way interaction was not significant for root dry weight of BYG (Table 5).

The replacement series diagrams based on root dry weight (Fig. 2) illustrated that the intersection between "Khazar" and BYG at all N rates was almost in the middle, indicating that Kazar and BYG were equally competitive. On the other hand, the curve representing "Line843" was convex and the curve for BYG was concave at all N rates. This suggests that "Line843" is more competitive than BYG and N rate did not vary the competitive ability of neither "Line843" nor BYG.

Table 9. Mean squares of ANOVA for relative crowding coefficient (RCC) of aboveground dry weight (AWDt), root dry weight (RDWt) and tiller number (TNo.) as affected by rice cultivar and N rate.

Source of variance	Df	ADWt	RDWt	TNo.
block	2	0.005 ^{ns}	0.119 ^{ns}	0.104 ^{ns}
Species in mixture	3	7.610 **	3.162 **	6.511 **
N rate	2	0.002 ^{ns}	0.00006 ^{ns}	0.114 ^{ns}
Species in mixture × N rate	6	0.017 *	0.0055 ^{ns}	0.0359 ^{ns}
Error	22	0.005	0.022	0..186
Coefficient of Variance	-	6.0	12.7	11.7

Ns and ** indicate no significant and statistical significance at $p \leq 0.01$, respectively.

Table 10. Relative crowding coefficient (RCC) for aboveground dry weight (ADWt), root dry weight (RDWt), and tiller number (TNo.) of species in mixture when averaged across N rates.

	Relative crowding coefficient (RCC)		
Species in mixture	ADWt	RDWt	TNo.
"Line843"	2.56 a	1.96 a	2.42 a
Barnyardgrass when Grown with "Line843"	0.39 c	0.53 c	0.38 c
"Khazar"	1.08 b	1.11 b	1.21 b
Barnyardgrass when Grown with "Khazar"	1.05 b	1.07 b	1.07 b

Means within a column followed by the same letter are not significantly different at the 5% level according to Fischer's Protected LSD test.

Table 11. Effect of nitrogen rates (0, 50 and 100 kg ha^{-1}) on Relative crowding coefficient (RCC) for grain yield, root dry weight, and tiller number.

	Relative crowding coefficient (RCC)		
N rates (kg ha^{-1})	ADWt	RDWt	TNo.
0	1.29 a	1.17 a	1.22 a
50	1.26 a	1.13 a	1.21 a
100	1.26 a	1.27 a	1.38 a

Means within a column followed by the same letter are not significantly different at the 5% level according to Fischer's Protected LSD test.

Main effect of species in mixture was significant ($P < 0.01$) for RCC of root dry weight, but N rate had no significant effect on RCC of root dry weight (Table 9). The 2-way interaction was not significant ($P < 0.01$), suggesting that the cultivars which had the highest RCC under no fertilizer application also had the highest RCC under 50 and 100 kg N ha^{-1}. Regardless of N rate application, the highest RCC for root dry weight (1.96) was recorded for Lin843, followed by "Khazar" (1.11) with a value statistically similar to the

BYG (1.07) when grown with "Khazar". The lowest RCC value (0.53) was recorded for BYG when grown with "Line843" (Table 10). The RCC value for root dry weight was statistically similar at different N rates application (1.17, 1.13, and 1.27 at N rate of 0, 50, and 100 Kg ha^{-1}, respectively) when averaged across species in mixture (Table 11).

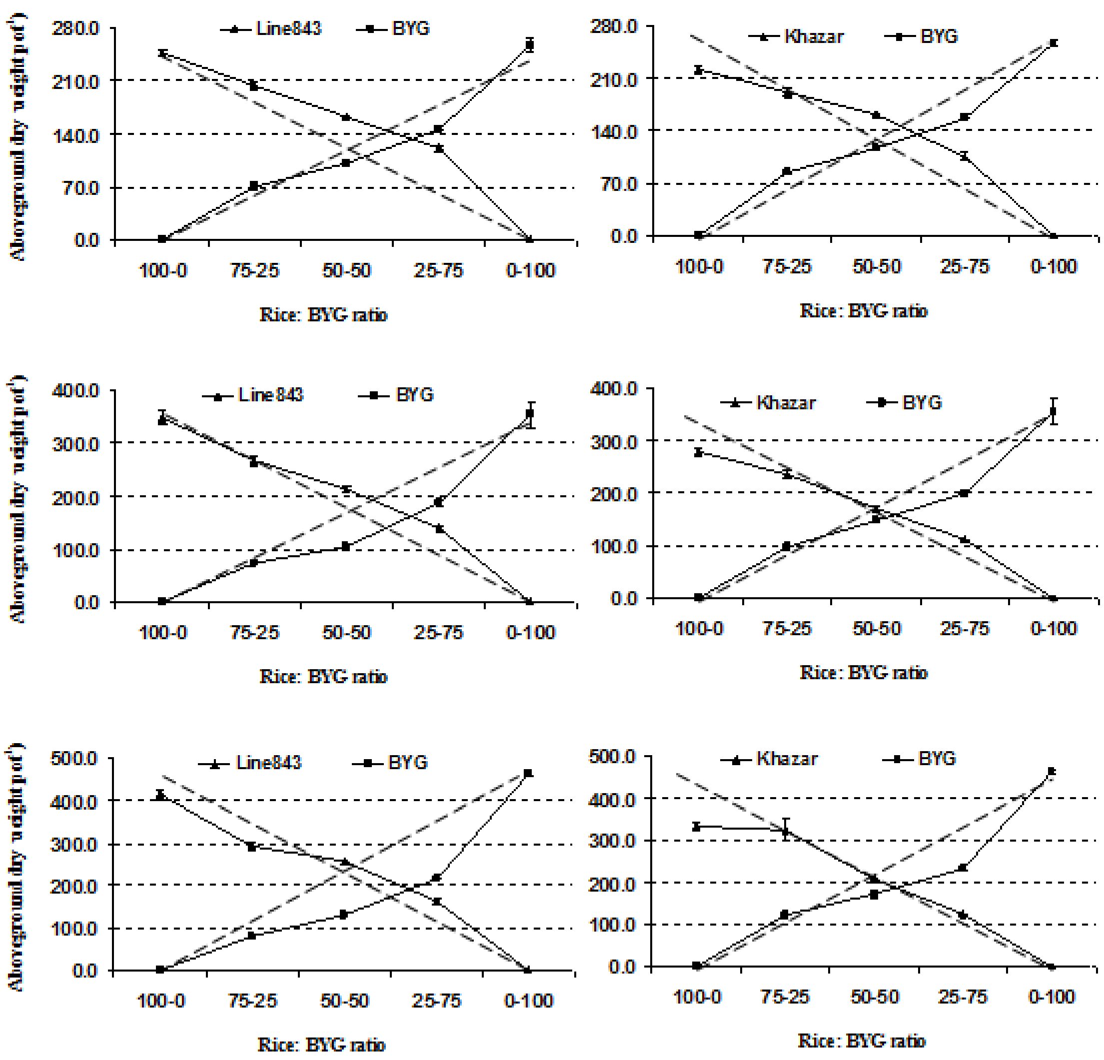

Fig. 1. Replacement series diagrams for aboveground dry weight per pot in different rice:barnyardgrass (BYG) ratios at 0, 50, and 100 Kg N ha-1, respectively. The two straight dashed lines in each frame indicate the theoretically expected responses for two equally competitive species, which intersect at the point of equivalency (Harper 1977). Bars indicate ± standard error.

Tiller number

Cultivar, N rate, and rice:BYG ratio had significant effect ($P < 0.01$) on rice tiller production. Moreover, all two way and three way interactions were also significant (Table 3). In unfertilized pots, tiller number of "Khazar" and "Line843" was increased when rice:BYG ratio decreased (Table 4). Lin843 produced two times more tiller than "Khazar" (20 tiller plant^{-1} for "Line843" vs. 10 tiller plant^{-1} for "Khazar"). High tillering capacity has been recognized as a key to the competitive advantage for crops against weeds (Fischer *et al.*, 1997). In unfertilized pots, the maximum tiller number both for "Khazar" (9.83) and "Line843" (16.16) was recorded at 2: 6 rice:BYG ratio (Table 4). At 50 and 100 kg N ha^{-1}, "Line843" produced greater tiller densities than did "Khazar", when both were planted as monocultures and in mixtures (Table 4).

Moreover, the highest tiller number both for "Khazar" and "Line843" was observed at 2:6 rice:BYG ratio (Table 4).

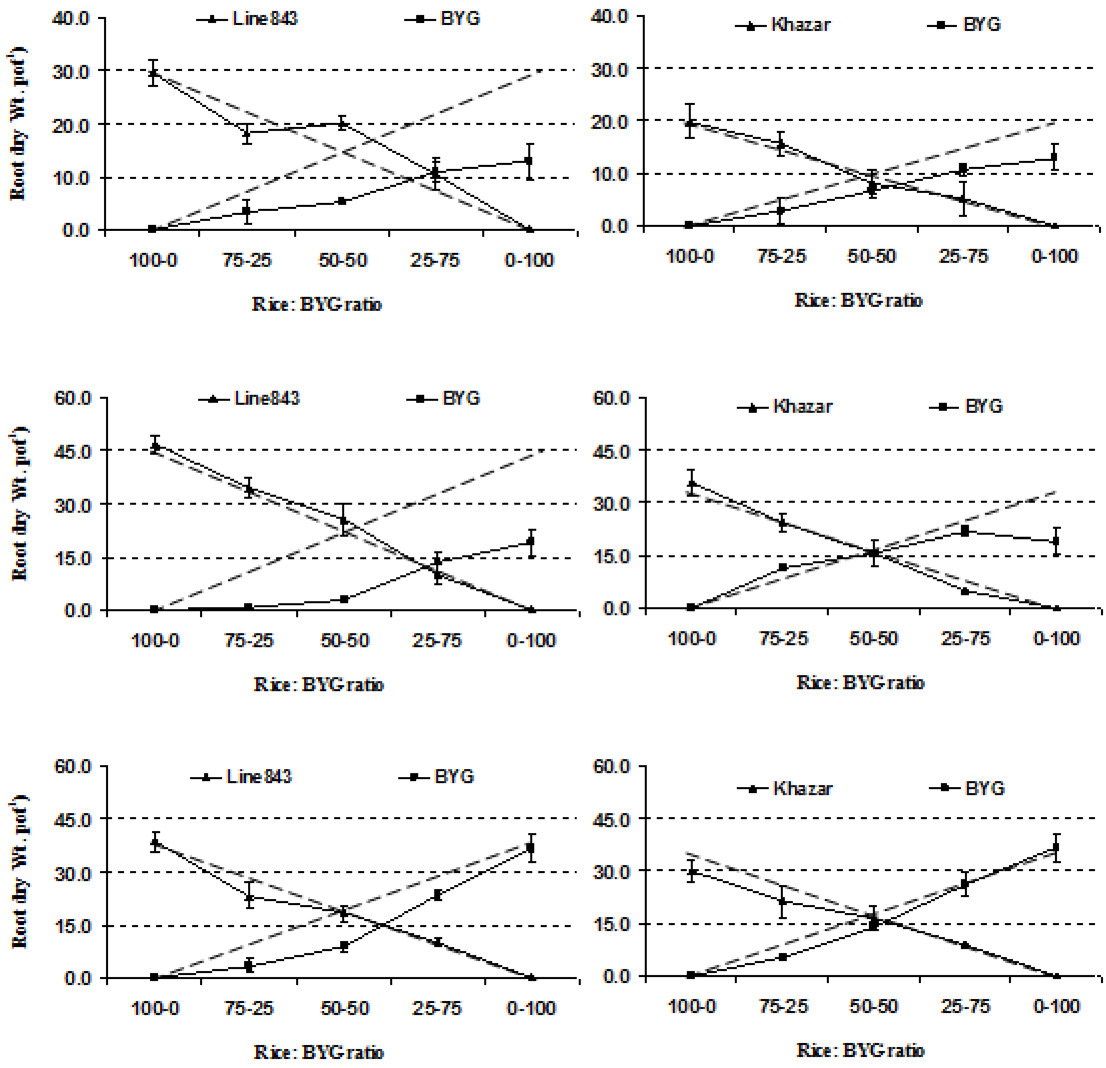

Fig. 2. Replacement series diagrams for root dry weights per pot in different rice:(barnyardgrass) BYG ratios at 0, 50, and 100 Kg N ha-1, respectively. The two straight dashed lines in each frame indicate the theoretically expected responses for two equally competitive species, which intersect at the point of equivalency (Harper 1977). Bars indicate ± standard error.

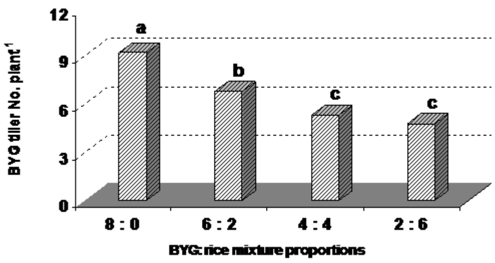

Fig. 3. Effect of barnyardgrass (BYG):rice ratio on BYG tiller number when averaged across N rate and rice cultivar.

Main effects of N rate, cultivar, and rice:BYG ratio were significant (*P* < 0.01) for BYG tiller number (Table 5). The interaction between N rate and cultivar was also significant (*P* < 0.05), but other 2-way interactions (N rate by rice:BYG ratio and rice cultivar by rice:BYG ratio) and 3-way interaction (N rate by rice:BYG ratio by cultivar) were not significant (Table 5). BYG tiller number was significantly increased as N rate increased from 0 to 100 Kg ha^{-1}. It was 2.9, 6.3 and 10.4 at 0, 50, and 100

Kg N ha-1, respectively. BYG produced more tiller when grown with "Khazar" (7.5 tiller plant-1) than when grown with "Line843" (5.4 tiller plant-1). This indicates that "Line843" was a superior competitor compared to "Khazar" and reduced significantly BYG tiller production. When grown in monoculture, BYG produced a significantly higher tiller than when grown with rice. The greatest reduction in BYG tiller production was occurred at 4:4 and 6:2 BYG:rice mixture proportions (Fig. 3). In unfertilized pots, tiller densities of BYG were statistically similar when grown either "Line843" or "Khazar". At 50 and 100 Kg N ha-1, BYG had lower tiller density when grown with "Line843" than when grown with "Khazar" (Table 6).

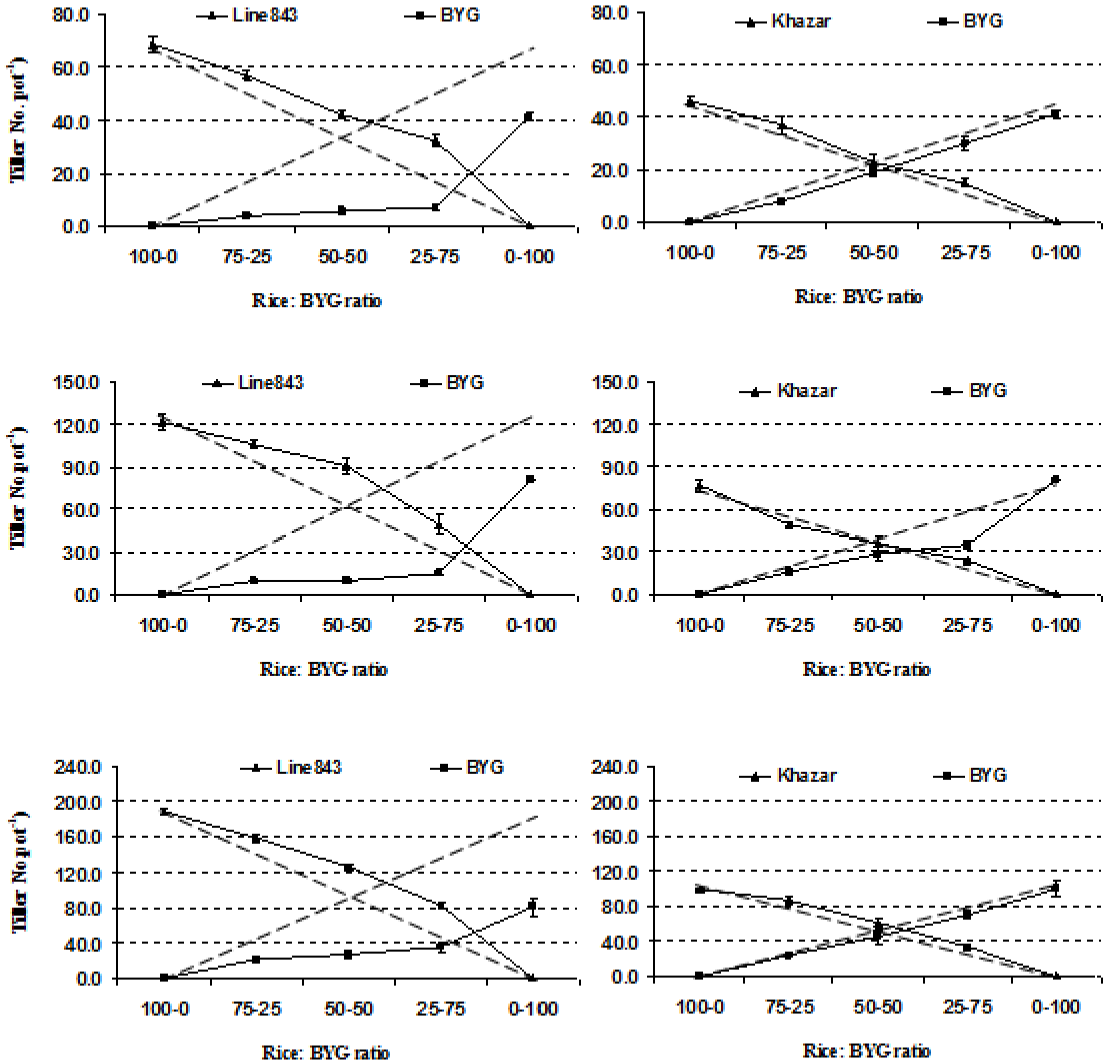

Fig. 4. Replacement series diagrams for tiller number per pot in different rice:barnyardgrass (BYG) ratios at 0, 50, and 100 Kg N ha-1, respectively. The two straight dashed lines in each frame indicate the theoretically expected responses for two equally competitive species, which intersect at the point of equivalency (Harper 1977). Bars indicate ± standard error.

Replacement series diagrams for tiller number (Fig. 4) showed that the lines for "Khazar" and BYG intersect almost at the 50:50 mixture proportion (the point of equivalency of the expected yield) at all N rates. Similarly, the RCC value for tiller number did not significantly differ between "Khazar" (1.21) and BYG (1.07), when averaged over N rates (Table 10). These findings indicate that "Khazar" and BYG have relatively similar interspecific effects on tiller number of the other, and N rate had no significant effect on the competitive ability of "Khazar" and BYG when grown together. On the other hand, the intersection between "Line843" and BYG shifted right of the 4:4 ratio at all N rates, indicating a competitive advantage for "Line843" when compared with BYG at all N rates. The greater RCC of "Line843" (2.42) over BYG (0.38) indicates the stronger aggressiveness of "Line843" against BYG in tiller production (Table 10). This finding also confirmed that "Line843" was more competitive than "Khazar" and BYG. Moreover, the RCC value based on Tiller number was not significantly different among N rates when averaged across cultivars (Table 11). Fischer *et al.* (2000) reported that when two species competing for limited resources, the stronger competitive species has the greater RCC value in the mixture.

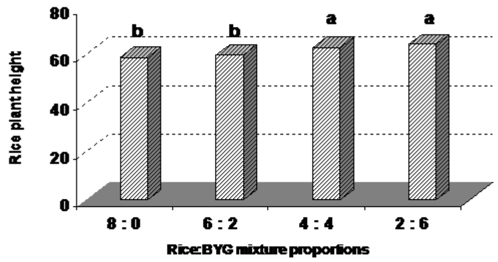

Fig. 5. Effect of barnyardgrass (BYG):rice rati on rice plant height when averaged across N rate and rice cultivar.

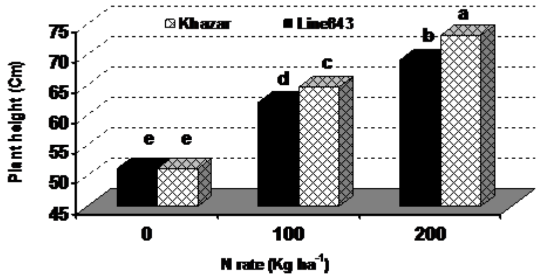

Fig. 6. Plant height of Khazar and Line843 at different N rates when averaged across rice:barnyardgrass (BYG) ratio.

Plant height

There were significant (P < 0.01) effects of rice cultivar, N rate, and rice:BYG ratio on rice plant height. The interaction between N rate and rice cultivar was also significant (*P* < 0.05), but other 2-way interactions (N rate by rice:BYG ratio and cultivar by rice:BYG ratio) and 3-way interaction (rice cultivar by N rate by rice:BYG ratio) were not significant for rice plant height (Table 3). "Khazar" was significantly taller than "Line843" (63 vs. 60 Cm) when averaged across N rate and rice:BYG ratio. Regardless rice cultivar and Rice:BYG ratio, rice plant height was significantly increased with increasing nitrogen rate (51, 63, and 71 Cm at 0, 50, and 100 Kg N ha^{-1}, respectively). Averaged across N rate and rice cultivar, rice plant height was tallest at 2:6 and 4:4 rice:BYG ratios (64 and 63 Cm, respectively). At 6:2 and 8:0 rice:BYG ratios, rice plant height was significantly reduced (Fig. 5). In other words, the shortest rice plant height was recorded when grown in monoculture (Fig. 5). This indicates that rice grew taller with interspecific than with intraspecific competition. In unfertilized pots, "Line843" was as tall as "Khazar", but "Khazar" was significantly taller than "Line843" when 50 and 100 Kg N ha^{-1} were applied (Fig. 6). Our finding that the taller cultivar was affected more than the shorter cultivar by weeds is in agreement to Estorninos *et al.* (2002) and in contrast to Garrity *et al.* (1992), Drews *et al* (2009) and Aminpanah and Haghighat (2011) findings.

There were significant (P < 0.01) effects of rice cultivar, N rate, and rice:BYG ratio on BYG plant height (Table 4). All 2-way interactions were also significant, but the 3-way interaction was not significant (Table 4). Regardless N rate and BYG:rice ratio, BYG was significantly taller when grown with "Khazar" (63 Cm) than when grown with "Line843" (57Cm). Averaged across rice cultivar and BYG:rice ratio, BYG height was significantly increased as N rate increased from 0 to 100 Kg ha^{-1} (BYG plant height was 47, 59, and 74 Cm at 0, 50, and 100 Kg ha^{1}, respectively). BYG plant height increased with increasing rice population when averaged across rice cultivar and N rate. The highest plant height (69 Cm) was recorded when BYG grown monoculture and the lowest was recorded at 4:4 (56 Cm) and 6:2 (55 Cm) rice:BYG ratios. Regardless of rice:BYG mixture proportion, plant height of BYG when grown either "Khazar" or "Line843" were increased with increasing N rate from 0 to 100 Kg ha^{-1} (Table 6).

Moreover, BYG when grown with "Khazar" was consistently taller than that of when grown with "Line843" at all N rates (Table 6). Averaged across N rate, the highest plant height of BYG was recorded at 8:0 BYG:rice mixture proportion (Table 7). Plant height of BYG was reduced when grown with "Khazar", Although it was statistically constant in all BYG:Khazar mixture proportions. On the other hand, BYG plant height when grown with "Line843" was also reduced, but it was significantly taller at 2:6 than 4:4 and 6:2 BYG:Line843 mixture proportions (Table 7). In unfertilized pots, BYG plant height was the highest at 8:0 and 2:6 BYG:rice ratios and it was significantly reduced at 4:4 and 6:2 BYG:rice mixture proportions (Table 8). At the N rate 50 Kg ha^{-1}, the maximum (66.33 Cm) and minimum (53.75 Cm) plant height of BYG was recorded at 8:0 and 6:2 BYG:rice mixture proportions, respectively. At the N rate 100 Kg ha^{-1}, BYG height was significantly taller at 8:0 BYG:rice ratio than the other BYG:rice ratios (Table 8).

Conclusions

The results of this experiment showed that there was severe competition between rice cultivars and BYG. Replacement series curves revealed that "Khazar" cultivar and BYG had equal competitive ability, but "Line843" was more competitive than BYG. Moreover, different rates of nitrogen fertilizer application had no significant effect on competitive ability of "Khazar" and "Line843". In general, this experiment illustrated that "Line843" was more competitive than "Khazar" cultivar at all N levels and N rate did not influence on competition between rice and BYG.

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References

Abouziena HF, El-Karmany MF, Singh M, Sharma SD. 2007. Effect of nitrogen rates and weed control treatments on maize yield and associatedweeds in sandy soils. Weed Technology **21**,1049–1053. http://dx.doi.org/10.1614/WT-07-084.1

Aminpanah H. 2009. Investigation of Competitive Ability of Rice Cultivars against Barnyardgrass (*Echinochloa crus-galli*) in Order to Optimize the Rate of Herbicide Application in Low Land Rice. Tarbiat Modares University, Ph.D thesis, p. 135.

Aminpanah H, Javadi M. 2011. A replacement series evaluation of competition between rice (Oryza sativa L.) and rice barnyardgrass (Echinochloa oryzicola Vasing). Scientific Research and Essays **6(23)**, 5065-5071.

Ampong-Nyarko K, De Detta SK. 1991. A Handbook for Weed Control in Rice. IRRI, Manila, p. 113.

Andreasen C, Litz AS, Streibig JC. 2006. Growth response of six weed species and spring barley (Hordeum vulgare) to increasing levels of nitrogen and phosphorus. Weed Research **46**, 503–512. http://dx.doi.org/10.1111/j.1365-3180.2006.00519.x

Begum M, Juraimi AS, Amartalingum R, Omar SRS, Man A. 2009. Effect of *Fimbristylis miliacea* competition with MR220 rice in relation to different nitrogen levels and weed density. International Journal of Agriculture and Biology **11(2)**, 183-187.

Dhima KV, Eleftherohorinos IG. 2001. Influence of nitrogen on competition between winter cereals and sterile oat. Weed Science **49**, 77–82. http://dx.doi.org/10.1614/0043-1745(2001)049[0077:IONOCB]2.0.CO;2

Drews S, Neuhoff D, Kopke U. 2009. Weed suppression ability of three winter wheat varieties at different row spacing under organic farming conditions. Weed Research **49**, 526–533. http://dx.doi.org/10.1111/j.1365-3180.2009.00720.x

Estorninos LE, Gealy JrDR, Talbert RE. 2002. Growth response of rice (*Oryza sativa*) and red rice (*O. sativa*) in a replacement series study. Weed Technology **16**, 401–406. http://dx.doi.org/10.1614/0890-037X(2002)016[0401:GROROS]2.0.CO;2

Evans SP, Knezevic SZ, Lindquist JL, Shapiro CA. 2003. Influence of nitrogen and duration of weed interference on corn growth and development. Weed Science **51**, 546–556. http://dx.doi.org/10.1614/0043-1745(2003)051[0546:IONADO

Fischer AJ, Ateh CM, Bayer DE, Hill JE. 2000. Herbicide-resistant *Echinochloa oryzoides* and *E. phyllopogon* in California *Oryza sativa* fields. Weed Science **48**, 225-230. http://dx.doi.org/10.1614/0043-1745(2000)048[0225:HREOAE]2.0.CO;2

Fischer AJ, Ramirez HV, Lozano J. 1997. Suppression of junglerice (Echinochloa colona (L.) Link) by irrigated rice cultivars in Latin America. Agronomy Journal **89**, 516-521. http://dx.doi.org/10.2134/agronj1997.00021962008900030023x

Garrity DP, Movillon M, Moody K. 1992. Differential weed suppression ability in upland rice cultivars. Agronomy Journal **84**, 586-591. http://dx.doi.org/10.2134/agronj1992.00021962008400040009x

Gonzalez Ponce R. 1998. Competition between barley and Lolium rigidum for nitrate. Weed Research **38**, 453–460. http://dx.doi.org/10.1046/j.1365-3180.1998.00116.x

Harper JL. 1977. Substitutive experiments. In Population Biology of Plants. New York: Academic Press. pp. 255–267.

Jennings PR. and Jesus JrJD. 1968. Studies on competition in rice. I. Competition in mixtures of varieties. Evolution **22**, 119-124. http://dx.doi.org/10.2307/2406878

Kawano K, Gonzalez H, Lucena M. 1974. Intra-specific competition, competition with weeds, and spacing response in rice. Crop Science **14**, 841-845.

Khan M, Ibrar M, Musharaf S, Hussain F, Ali SG, Hameed I, Imdadullahd. 2011. Effect of aqueous extracts of *Chrozophora obliqua* (Del) Juss. on germination and seedling growth of *Zea mays*. International Journal of Biosciences **1(4)**, 94-99.

Novak MG, Higley LG, Christiansses CA, Rowling WA. 1993. Evaluating larval competition between Aedes albopictus and A. triseriatus (Diptera: Culcidae) through replacement series experiments. Environmental Entomology **22**, 311-318.

Radosevich SR. 1987. Methods to study interaction among crops and weed. Weed Technology **1**, 190-198.

SAS Institute Inc. 2002. SAS System, Version 9.1. SAS Institute Inc., Cary, NC.

Van Delden A, Lotz LAP, Bastiaans L, Franke AC, Smid HG, Groeneveld RM, Kropff MJ. 2002. The influence of nitrogen supply on the ability of wheat and potato to suppress *Stellaria media* growth and reproduction. Weed Research **42**, 429–445. http://dx.doi.org/10.1046/j.1365-3180.2002.00303.x

Watson PR, Derksen DA, Van Acker RC. 2006. The ability of 29 barley cultivars to compete and withstand competition. Weed Science **54**, 783–792. http://dx.doi.org/10.1614/WS-05-020R3.1