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COMPETITION BETWEEN RICE (*ORYZA SATIVA* L.) AND BARNYARDGRASS (*ECHINOCHLOA CRUS-GALLI* (L.) P. BEAUV.)) OR RICE BARNYARDGRASS (*ECHINOCHLOA ORYZICOLA* VASING.)

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ABSTRACT

A pot experiment was carried out to evaluate the competitive interactions between rice cultivar (Daylamani) as grown together with barnyardgrass (BYG) or rice barnyardgrass (ECPH) in a Replacement Series Study. The experiment was conducted as a randomized complete block design with a factorial treatment arrangement and three replications. Factors were two species of *Echinochloa* genus (barnyardgrass and rice barnyardgrass) and five rice: BYG or rice: ECPH mixture proportions (8:0, 6:2, 4:4, 2:6 and 0:8). Relative yield total of aboveground dry weight and root dry weight showed that rice was competing for the same resources with barnyardgrass or rice barnyardgrass. In general, replacement series curves and relative crowding coefficient (RCC) values demonstrated that rice cultivar Daylamani and BYG had equal competitive ability, while Daylamani was more competitive than rice barnyardgrass. Moreover, this experiment indicated that the competitive ability of BYG was higher than that of ECPH.

Key words: Barnyardgrass; competitiveness; relative yield total; rice; rice barnyardgrass.
Abbreviations: BYG, barnyardgrass; ECPH, rice barnyardgrass; RCC, relative crowding coefficient; RY, relative yield; RYT, relative yield total.

INTRODUCTION

Weeds are one of the major constraints in rice production, which cause yield losses approximately 50% in transplanted rice (Ampong-Nyarko and De Datta, 1991). Michael (1983) reported about 50 species of *Echinochloa* genus listed worldwide, and most are important, especially in rice (*Oryza sativa* L.) fields, causing serious competition and high yield reduction. Two important species of *Echonochloa* genus in rice paddy field of Iran are barnyardgrass [*Echinochloa crus-galli* (L.) P. Beauv.)] and rice barnyardgrass (*Echinochloa oryzicola* Vasing (=*Echinochloa phyllopogon* Stapf ex Kessenko). Barnyardgrass is hexaploid, 2n=6x=54 (Carretero, 1981). It is the principal weed in rice production, and is a problem weed in 42 countries (Holm et al., 1979).

Season-long competition from *E. crusgalli* reduced rice yields by 38% to 64% depending on the rice cultivar (Smith, 1988; Stauber et al., 1991). *E. oryzicola* is tetraploid, 2n=4x=34 (Carretero, 1981) and almost exclusively grows as rice weed. Yabuno (1966) reported that *E. oryzicola* is the most dominant and persistent weed in flooded rice of Japan.

Harper (1977) intensively used the replacement series model to measure the aggressiveness of a species. Radosevich (1987) suggested that replacement method is most valuable for assessing the competitive effects of two species at a single total density and for determining the relative effects of interferences within and between species.

Yaghoubi et al. (2006) reported that the dominant species of Echinochloa genus in rice paddy field of Iran is changing from *E. crusgalli* to *E. oryzicola* that has either mimicry or photoperiodic sensitivity synchronizing to that of rice. A lack of data exists concerning the competitive ability of ECPH compared to BYG against rice cultivars.

Therefore, the aim of this study was to evaluate the relative competitive ability of ECPH compared to BYG against a native rice cultivar, Daylamani, which is intensively

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cultivated in north of Iran, in a replacement series study.

MATERIAL AND METHODS

Experimental design, Plant growth conditions, and sampling

A pot experiment was conducted at Rice Research Station in Tonekabon (36° 54' N, 40° 50' E; 20 m above sea level), north of Iran, from June to September of 2010. The experiment was conducted as a Randomized Complete Block Design with a factorial treatment arrangement and three replications. Factors were two species of *Echonochloa* genus, (*E. crus-galli* and *E. oryzicola*) and five rice: BYG or rice: ECPH ratios (8:0, 6:2, 4:4, 2:6 and 0:8).

Actual plant numbers per pot for each mixture were 8:0, 6:2, 4:4, 2:6 and 0:8, respectively. Pots (35 cm average diameter by 30 cm deep) were arranged in a rectangular grid pattern with approximately 40 cm between edges of adjacent pots. Pots were filled to a depth of 25 cm with clay loam soil from the Tonekabon Rice Research station Farm. Soil properties were 2.2% organic matter content, 37% clay, 44% silt, 19% sand, 6.8 pH, 29.9 cation exchange capacity (CEC) (meg 100 g). Rice seeds were sown in the nursery on 1 April, 2010. According to rice : BYG or rice:ECPH ratio in each pot, three seedlings of Daylamani or one germinated BYG or ECPH seed were transplanted (or planted) in hills with a square arrangement, with hills equidistant from the sides of the pot and from each other, on 1 June 2010. Total fertilizer applied was 100 kg N ha^{-1}, 75 kg P ha^{-1} and 150 kg K ha^{-1} with split application broadcast at transplanting stage (30% N and 100% PK), at panicle initiation (35% N), and 5 days before flowering (35% N). Consistent with the lowland paddy field practices in north of Iran, a permanent flood water level was maintained at 10 cm from approximately 7 days after transplanting until 20 days before harvesting stage. Moreover, during the growing season, all unwanted weeds, except the planted BYG or ECPH, were hand weeded.

At maturity stage, plant height (from the soil surface to the top of the plant canopy) was measured. Plants were harvested by hand-cutting at the soil surface and subsequently aboveground biomass of rice, BYG and ECPH were separated, and tillers of each species were counted. Leaf area was measured with a leaf area meter[1]. Roots of rice, BYG and ECPH were washed gently and thoroughly to remove soil particles so that the root tissues remained intact and subsequently were separated. Rice, BYG and ECPH aboveground and belowground (root) biomass from each pot was placed in separate paper bags, dried at 72°C for 96 h, and weighed. From the yield data, the relative crowding coefficients of the species towards each other and RYT of each species combination were computed.

Indices of competition

To assess the competitiveness of either BYG or ECPH against rice cultivar Daylamani, the four models for interference, proposed by Harper (1977) and adapted by Fleming et al. (1988), were used. These models described the possible outcomes of the interaction of two species when grown in a replacement series (Oberg et al., 1996; Radosevich, 1987). Replacement series diagrams were constructed for the response of aboveground dry weight, root dry weight, leaf area and tiller number to species proportion. The following indices were used in the present experiment.

The relative crowding coefficient

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

$$RCC = [((Wr75:25/Wb75:25)\ (Wr50:50/Wb50:50) + (Wr25:75/Wb25:75))/3]/(Wr100:0/Wb100:0) \quad [1]$$

where: Wr n:n is aboveground or root dry weight, leaf area and tiller number of rice at a ratio of n:n and Wb n:n is aboveground or root dry weight, leaf area and tiller number of BYG or ECPH at a ratio of n:n. The larger the RCC value, the greater the competitiveness

[1] LI-3000A Leaf Area Meter (Li-Cor, USA)

with the other species. RCC values of approximately 1 indicate that the two species are equal competitors and values greater than 1 or less than 1 indicate that a species is more or less competitive, respectively, than the other species.

The relative yield total (RYT)

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

$$RY_r = (Yrb/Yrr) \quad or \quad RY_b = (Ybr/Ybb) \quad [2]$$

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.

$$RYT = RY_r + RY_b \quad [3]$$

Harper (1977) advocated that RYT can be used to describe the mutual relationships of pairs of species that may or may not be making demands on the same resources in the environment. In two species mixtures, an 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 that still compete for the same resources, may also make demands on different resources. RYT values less than 1.00 indicate mutual antagonism (Bi and Turvey, 1994).

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 statistical analyses were conducted by using SAS (SAS Institute, Inc, 2002).

To determine whether RYT differed significantly from 1.0 or not, the following equation was used (Gealy et al., 2005):

$$Cutoff = 1 \pm (t^* \times \text{standard error of the mean}) \quad [4]$$

where: t* = the two-sided critical value from the t-table with degree of freedom (df) equal to df associated with the term used as the error term in the F-test.

RESULTS AND DISCUSSION

Aboveground dry weight

Aboveground dry weight (g plant-1) of Daylamani was significantly constant in different rice: BYG mixture proportions (Table 1). In contrast, aboveground dry weight (g plant-1) of Daylamani increased as rice: ECPH ratio decreased (Table 1).

The highest aboveground dry weight for Daylamani was recorded when grown at 2:6 rice:ECPH mixture proportion (Table 1). Moreover, aboveground biomass of Daylamani when grown with ECPH was usually more than that when grown with BYG, especially in 6:2 rice:BYG mixture proportion (Table 1).

Table 1. Aboveground dry weight (ADW), root dry weight (RDW), tiller number (TN), leaf area (LA) and height (H) of rice cultivar Daylamani as influenced by 8:0, 6:2, 4:4 and 2:6 rice: weed mixture proportions

Rice cultivar	Weed species	Rice:weed ratios	ADW (g plant^{-1})	RDW (g plant^{-1})	TN plant^{-1}	LA (cm^2)	H (cm)
Daylamani	BYG	8:0	25.88	7.05	11.01	1013	83
		6:2	25.67	6.09	12.20	921	80
		4:4	26.06	7.19	12.44	860	75
		2:6	26.86	9.60	13.1	790	72
Daylamani	ECPH	8:0	25.88	7.05	11.01	1013	83
		6:2	27.40	6.84	13.42	1064	80
		4:4	29.98	7.86	13.60	1037	80
		2:6	35.76	13.94	16.85	1389	76
LSD (0.05)		-	3.3	1.0	1.14	112	7

Barnyardgrass (BYG); rice barnyardgrass (ECPH)

BYG, when grown at different mixture proportions, had greater aboveground dry weight than ECPH (Table 2).

This indicates that BYG was more competitive than ECPH against rice cv. Daylamani.

Table 2. Aboveground dry weight (ADW), root dry weight (RDW), tiller number (TN), leaf area (LA) and height (H) of barnyard grass (BYG) and rice barnyardgrass (ECPH) as influenced by 8:0, 6:2, 4:4 and 2:6 weed: rice mixture proportions

Weed species	Weed: rice ratio	ADW (g plant^{-1})	RDW (g Plant^{-1})	TN plant^{-1}	LA (cm^2 plant^1)	H (cm)
BYG	8:0	38.28	7.30	15.21	2183	93
	6:2	39.81	6.54	14. 16	2639	87
	4:4	42.30	7.89	13.36	2831	78
	2:6	36.78	13.80	11.87	2664	66
ECPH	8:0	30.15	5.94	15.62	1691	83
	6:2	26.49	6.87	13.17	1443	76
	4:4	30.66	6.65	12.46	1694	66
	2:6	29.65	5.89	11.31	2104	60
LSD (0.05)	-	3.84	1.24	1.03	476	1.86

The competitive ability of each species of *Echinochloa* genus against Daylamani on the basis of the relative aboveground dry weight was evaluated using a replacement series diagram (Figure 1). As shown in the Figure 1, Daylamani and BYG lines intersect almost at the 50:50 mixture proportion (point of equivalency of the expected yield), indicating that Daylamani and BYG have relatively similar interspecific effects on aboveground biomass accumulation of the other. On the other hand, the lines for Daylamani and ECPH intersect at the right of the 50:50 mixture proportions (point of equivalency of the expected yield). This indicates that Daylamani is more competitive than ECPH and gains resources at the expense of the weed. The RYTs ranged from 1.00 to 1.08, but all were not significantly different from 1, on the basis of the cutoff of not > 1.09 or <0.91. This indicates that Daylamani and BYG or ECPH were competing for the same resources. This result was in agreement with some previous studies (Gealy et al., 2005; Estorninos et al., 2002).

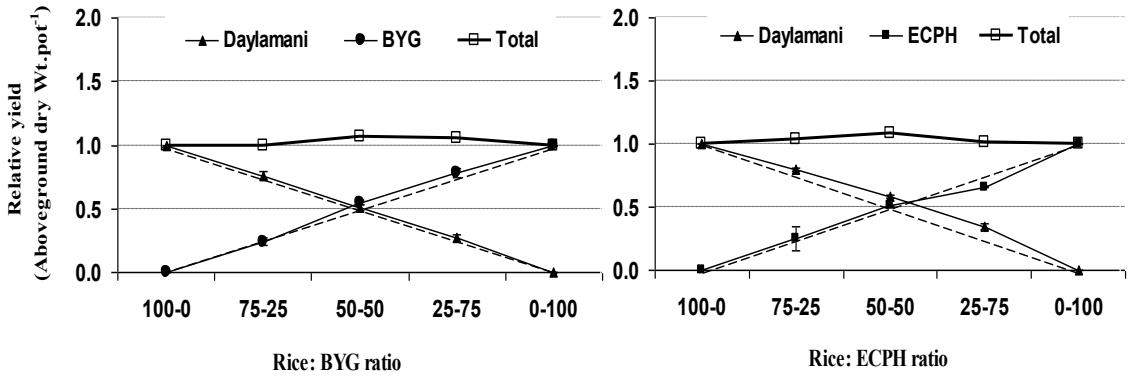

Figure 1. Relative aboveground dry weights of rice cv. Daylamani (▲), barnyardgrass (BYG) (●) and rice barnyardgrass (ECPH) (■), and relative yield totals (RYT) (□) as influenced by rice:ECPH mixture proportions in a replacement series. The two straight dashed lines in each frame indicate the theoretically expected responses for two equally competitive species, which intersect at the point of equivalency (Harper, 1977).

The RCC shows the aggressiveness of one species toward another (Table 3). The greater RCC of Daylamani over ECPH indicates, and also confirms the results of RY for aboveground dry weight, that Daylamani was a superior competitor compared to ECPH. On the other hand, Daylamani showed similar RCC with BYG in aboveground dry weights, thus indicating similar competitiveness between Daylamani and BYG. Fischer et al. (2000) reported that, when competing for limited resources, the species with the greater RCC in the mixture is the stronger competitor. Moreover, the greater RCC of BYG over ECPH indicates the stronger aggressiveness of BYG against ECPH in aboveground dry weights. Gealy et al. (2005) reported that Lemont rice cultivar had lower RCC than BYG, while PI 312777 had similar RCC with BYG. Some researchers reported that differences in weed competitiveness exist between and within crops (Anwar et al., 2010; Gealy et al., 2003; Fofana and Rouber, 2000; Ni et al., 2000; Fischer et al., 1997, 2001; Johnson et al., 1998; Garrity et al., 1992) and weeds species (Fleming et al., 1988; Vangessel & Karen, 1990).

Root dry weight

Maximum and minimum root dry weight for Daylamani rice cultivar were recorded in 2: 6 and 6:2 rice:BYG ratio, respectively. On the other hand, root dry weight of Daylamani increased dramatically at 2:6 rice:ECPH mixture proportion, but it did not vary significantly in the other mixture proportions (Table 1).

Root dry weight (g plant^{-1}) of BYG significantly increased at 4:4 and 2:6 BYG: rice mixture proportions. In contrast, root dry weight of ECPH was constant when grown with Daylamani at different mixture proportions (Table 2).

Replacement series diagrams for relative root dry weight illustrated the competition between Daylamani and BYG or ECPH. As shown in the Figure 2, the lines for BYG or ECPH and Daylamani intersect almost at the point of equivalency of the expected yield, indicating equal competitive ability between Daylamani and BYG or ECPH based on root biomass production.

The RYTs for root dry weight of each species of *Echonochloa* genus and Daylamani ranged form 1.06 to 1.43. In most cases, they were significantly higher than cutoff value (<1.07 or >0.93). This response probably occurred primarily because of the reduced interference in mixtures in relation to the monocultures, due to the differences in paths of resource acquisition by C_3 rice plants and C_4 BYG or ECPH plants, respectively (Fischer et al., 2000). The RCC value for root dry weight did not significantly differ between BYG or ECPH and Daylamani (Table 3). This indicates similar competitive ability between ECPH or BYG and Daylamani and neither species were dominant in root biomass production.

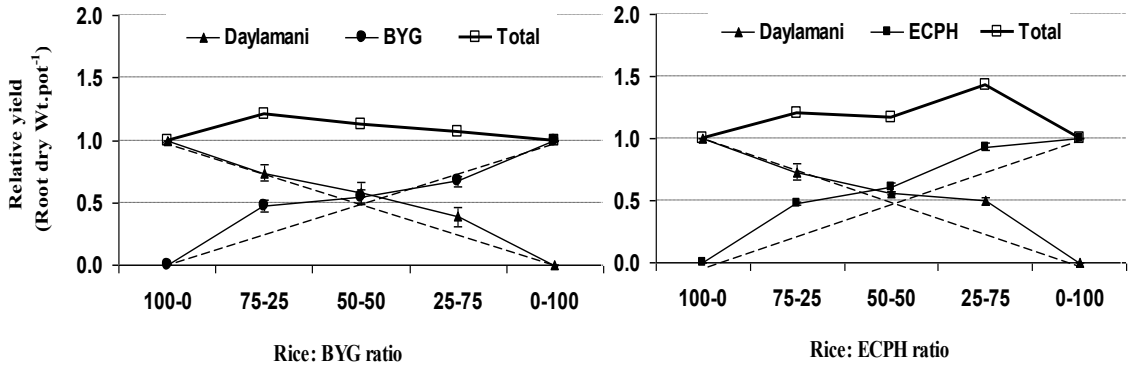

Figure 2. Relative root dry weights of rice cv. Daylamani (▲), barnyard grass (BYG) (●) and rice barnyardgrass (ECPH) (■), and relative yield totals (RYT) (□) as influenced by rice:ECPH mixture proportions in a replacement series. The two straight dashed lines in each frame indicate the theoretically expected responses for two equally competitive species, which intersect at the point of equivalency (Harper, 1977).

Leaf area

Leaf area (cm^2 $plant^{-1}$) of Daylamani decreased as rice: BYG mixture proportion decreased (Table 1). In contrast, leaf area of Daylamani increased as rice: ECPH mixture proportion decreased (Table 1). Moreover, leaf area of Daylamani when grown with ECPH was usually more than that when grown with BYG**.** These data indicate that BYG was more competitive than ECPH against rice cv. Daylamani. Moreover, leaf area for BYG was higher than for ECPH, planted either alone or in the mixture (Table 2). This result indicates that ECPH is less competitive than BYG against Daylamani. Dingkuhn et al. (1999) and Karimmojeni et al. (2010) reported that leaf area was positively correlated with competitiveness. As shown in the Figure 3, Daylamani and BYG lines intersect to the left of the 50:50 mixture proportions. In other words, the curve representing Daylamani cultivar was concave and the curve for BYG was convex. This indicates that BYG was more competitive than Daylamani cultivar and gained resources at the expense of the rice cultivar. On the other hand, the lines for Daylamani and ECPH intersect almost at the 50:50 rice:ECPH mixture proportion, indicating equal competitive ability between Daylamani and ECPH based on leaf area extension. Replacement series diagrams based on relative leaf area also demonstrated that BYG is more competitive than Daylamani rice cultivar. The RYTs for leaf area of Daylamani and both species of *Echonochloa* genus ranged form 0.97 to 1.16. In some cases, they were significantly higher than cutoff value (< 0.90 or >1.10). This response probably occurred primarily because of the reduced interference in mixtures in relation to the monocultures, due to the differences in paths of resource acquisition by C_3 rice plants and C_4 BYG or ECPH plants, respectively (Fischer et al., 2000).

The greater RCC of BYG over ECPH indicates that BYG was superior competitor compared to ECPH (Table 3).

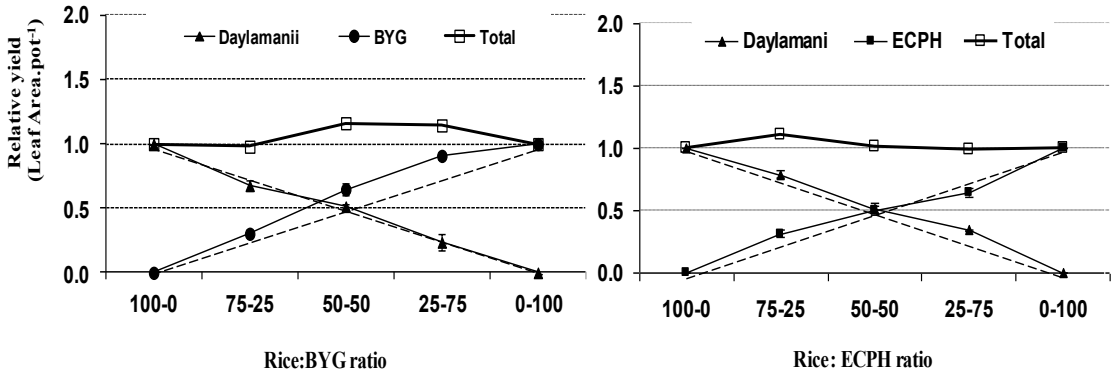

Figure 3. Relative leaf area of rice cv. Daylamani (▲), barnyard grass (BYG) (●) and rice barnyardgrass (ECPH) (■), and relative yield totals (RYT) (□) as influenced by rice:ECPH mixture proportions in a replacement series. The two straight dashed lines in each frame indicate the theoretically expected responses for two equally competitive species, which intersect at the point of equivalency (Harper, 1977).

Table 3. Mean comparison for the effect of rice cultivar Daylamani and species of *Echonochloa* genus (BYG or ECPH) on relative crowding coefficient (RCC) for aboveground dry weight (ADW), root dry weight (RDW), leaf area (LA) and tiller number (TN)

Species in mixture	Relative Crowding Coefficient (RCC)			
	ADW	RDW	LA	TN
BYG	1.00	1.02	1.30	1.12
Vs. Daylamani	1.01	0.99	0.78	0.89
ECPH	0.80	1.05	0.90	1.00
Vs. Daylamani	1.25	0.97	1.13	1.00
LSD (0.05)	0.14	0.16	0.20	0.20

Tiller number

Tiller density of Daylamani when grown with BYG was usually less than that when grown with ECPH (Table 1). Also, Daylamani had lower tiller density when planted as monoculture than when grown at the different rice:ECPH mixture proportions. This indicates that Daylamani grew better with interspecific than with intraspecific competition. Moreover, tiller numbers of both species of *Echonochloa* genus were significantly reduced when grown with Daylamani (Table 2).

Replacement series diagrams based on relative tiller production illustrated the competitive effects between Daylamani and BYG or ECPH (Figure 4).

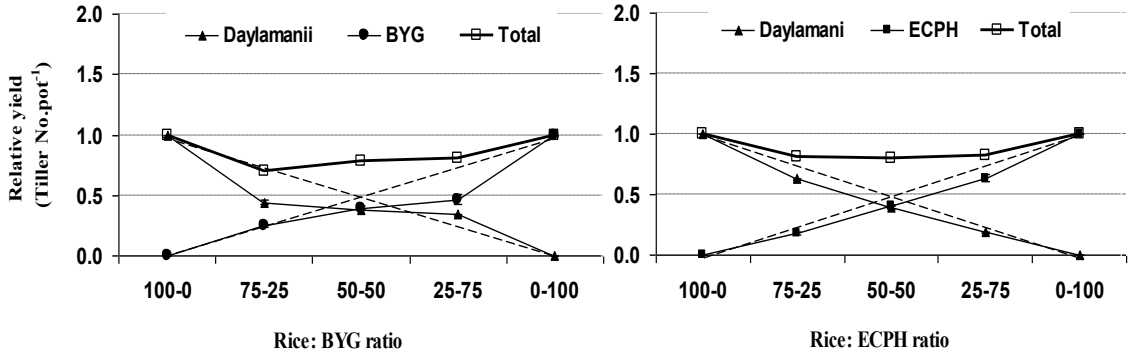

Figure 4. Relative tiller number of rice cv. Daylamani (▲), barnyard grass (BYG) (●) and rice barnyardgrass (ECPH) (■), and relative yield totals (RYT) (□) as influenced by rice:ECPH mixture proportions in a replacement series. The two straight dashed lines in each frame indicate the theoretically expected responses for two equally competitive species, which intersect at the point of equivalency (Harper, 1977).

As shown in the Figure 4, the two species of Echonochloa genus and Daylamani lines intersect almost at the 50:50 rice:ECPH ratio. These results suggested that the weeds were as competitive as Daylamani in tiller production. The RYTs for tiller number of BYG or ECPH and Daylamani (ranging from 0.69 to 0.82) were lower than the cutoff values (0.95-1.05). Harper (1977) suggested that RYT value less than 1 imply mutual antagonism.

The RCC value for tiller density did not significantly differ between BYG and ECPH (Table 3). This indicates that neither species were dominant in tiller production. Moreover, the RCC value for tiller number was significantly greater in BYG over Daylamani cultivar, indicating BYG is more aggressive than Daylamani in tiller production.

Plant height

Daylamani height was reduced significantly when grown at 4:4 and 2:6 rice:weed ratios (Table 1). On the other hand, both BYG and ECPH heights were reduced when grown with Daylamani (Table 2). Moreover, both species of Echinochloa genus were shorter when grown together with rice at all mixture proportions than when planted alone (Table 2). This indicates that both BYG and ECPH responded to interspecific competition more than to intraspecific competition. Garrity et al. (1992) and Drews et al. (2009) reported that weeds reduced significantly rice plant height. Also, BYG was higher than ECPH at the all mixture proportion. Some researchers found that height can be associated with competitiveness (Karimmojeni et al., 2010; Garrity, 1992; Jennings and Herrera, 1968).

CONCLUSIONS

The results of this experiment indicated that rice cultivar Daylamani was competing for the same resources with barnyardgrass or rice barnyardgrass. In general, replacement series curves and RCC values demonstrated that Daylamani and BYG had equal competitive ability, while Daylamani was more competitive than rice barnyardgrass. Moreover, this experiment demonstrated that the competitive ability of ECPH was less than

that of BYG, but in spite of this ECPH could be a serious and dangerous weed in rice paddy fields because:

- EPCH seeds germinate and seedlings emerge very well under anaerobic conditions.

- ECPH mimics the rice plant throughout its development from seedling to heading. This helps the weed to escape weeding before heading. During the heading period of rice, the growers are reluctant to walk in the rice paddy to weed, because it may disturb crop growth. When weeding begins after heading of the rice plants, the weed already started shattering seeds (Yamasu, 2001).

REFERENCES

Ampong-Nyarko, K., De Detta, S.K., 1991. *A Handbook for Weed Control in Rice*. IRRI, Manila: 113.

Anwar, M.D.P., Juraimi, A.S., Man, A., Puteh, A., Selamat, A., Begum, M., 2010. *Weed suppressive ability of rice (Oryza sativa L.) germplasm under aerobic soil conditions.* Aus. J. Crop. Sci., 4: 706-717.

Bi, H., Turvey, N.D., 1994. *Inter-specific competition between seedlings of Pinus radiata, Eucalyptus regnans and Acacia melanoxylon.* Aus. J. Bot., 42: 61-7.0

Carretero, J.L., 1981. *El genero Echinochloa Beauv. en el suroeste de Europa*. An. Jard. Bot. Madr.: 389-108.

Dingkuhn, M., Johnson, D.E., Sow, A., Audebert, A.Y., 1999. *Relationships between upland rice canopy characteristics and weed competitiveness*. Field Crops Res., 61: 79-95.

Drews, S., Neuhoff, D., Kopke, U., 2009. *Weed suppression ability of three winter wheat varieties at different row spacing under organic farming conditions*. Weed Res., 49: 526-533.

Estorninos, L.E., Gealy, Jr.D.R., Talbert, R.E., 2002. *Growth response of rice (Oryza sativa) and red rice (O. sativa) in a replacement series study.* Weed Technol., 16: 401-406.

Fischer, A.J., Ateh, C.M., Bayer, D.E., Hill, J.E., 2000. *Herbicide-resistant Echinochloa oryzoides and E. phyllopogon in California Oryza sativa fields*. Weed Sci., 48: 225-230.

Fischer, A.J., Ramirez, H., Gibson, K.D., Pinheiro, B.D.S., 2001. *Competitiveness of semidwarf upland rice cultivars against palisadegrass (Brachiaria brizantha) and signalgrass (B. decumbens).* Agron. J., 93: 967-973.

Fischer, A.J., Ramirez, H.V., Lozano, J., 1997. *Suppression of junglerice [Echinocloa colona (L.) Link] by irrigated rice cultivars in Latin America*. Agron. J., 89: 516-552.

Fleming, G.F., Young, F.L., Ogg, Jr. A.G., 1988. *Competitive relationships among winter wheat (Tritichum aestivum), jointed goatgrass (Aegilops cylindrica), and downy brome (Bromus tectorum).* Weed Sci., 36: 479-486.

Fofana, B., Rouber, R., 2000. *Weed suppression ability of upland rice under low–input conditions in West Africa.* Weed Res., 40: 271-280.

Garrity, D.P., Movillon, M., Moody, K., 1992. Differential weed suppression ability in upland rice cultivars. Agron. J., 84: 586-591.

Gealy, R.D., Estorninos, Jr.L.E., Gbur, E.E., Chavez, R.S.C., 2005. *Interference interactions of two rice cultivars and their F3 cross with barnyardgrass (Echinochloa crus-galli) in a replacement series study.* Weed Sci., 53: 323-330.

Gealy, R.D., Wailes, E.J., Leopoldo, E., Estorninos, Jr., Chavez, R.S.C., 2003. *Rice cultivar differences in suppression of barnyardgrass (Echinochloa crus-galli) and economics of reduced propanil rates.* Weed Sci., 51: 601-609.

Harper, J.L., 1977. *Substitutive experiments: In Population Biology of Plants*. New York: Academic Press: 255-267.

Holm, L.G., Pancho, J.V., Herberger, J.P., Plucknett, D.L., 1979. *A Geographical Atlas of World Weeds.* New York: J. Wiley.

Jennings, P.R., Herrera, R.M., 1968. *Studies on competition in rice. II. Competition in segregating populations.* Evolution, 22: 332-336.

Johnson, D.E, Dingkuhn, M., Jones, M.P., Mahamane, M.C., 1998. *The influence of rice plant type on the effect of weed competition on Oryza sativa and Oryza glaberrima*. Weed Res. ,38: 207-216.

Karimmojeni, H., Mashhadi, H.R., Shahbazi, S., Taab, A., Alizadeh, H., 2010. *Competitive Interaction between Maize, 'Xanthium Strumarium and Datura Stramonium' affecting some canopy characteristics.* Aus. J. Crop Sci., 4(9): 684-694.

Michael, P.W., 1983. *Taxonomy and distribution of Echinochloa species with special reference to their occurrence as weeds of rice*. In: Weed Control in Rice. International Rice Research Institute, Laguna, Philippines: 291-306.

Ni, H., Moody, K., Robles, R.P., Paller, E.C., Lales, J.S., 2000. *Oryza sativa (L.) plant traits conferring competitive ability against weeds.* Weed Sci., 48: 200-204.

Novak, M.G., Higley, L.G., Christiansses, C.A., Rowling, W.A., 1993. *Evaluating larval competition between Aedes albopictus and A. triseriatus (Diptera: Culcidae) through replacement series experiments*. Environ Entomol., 22: 311-318.

Oberg, A.L., Young, L.J., Higley, L.G., 1996. *A comparison of two measures of competition*. J. Agric. Biol. Environ. Stat., 4: 393-403.

Radosevich, S.R., 1987. *Methods to study interaction among crops and weed*. Weed Technol., 1: 190-198.

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

Vangessel, M.J., Karen, A.R., 1990. *Redroot pigweed (Amaranthus retroflexus) and barnyardgrass (Echinochloa crus-galli) interference in potatoes (Solanum tuberosum*). Weed Sci., 38: 338-343.

Yabuno, T., 966. *Biosystematic study of the genus Echinochloa*. Jpn. J. Bot., 19: 277-323.

Yaghoubi, B., Zand, E., Joharali, A., 2000. *New specie of Echinochloa a serious problem for Iran paddy.* The 17th Iranian Plant Pathology Congress, Karaj, Iran.

Yamasu, Y., 2001. *Strategy of Echinochloa oryzicolaVasing. for survival in flooded rice*. Weed Bio. Manag.. 1: 28-36.