

Using More Competitive Cultivar against Barnyardgrass (*Echinochloa crus-galli*) to Reduce Herbicide Application Rate in Lowland Rice Fields

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Abstract

In order to reduce the butachlor application rate in low land rice fields using more competitive cultivars, a field experiment was conducted in Rice Research Station of Tonekabon in Iran. The layout of the experiment was a split plot, where the whole plot portion was a randomized complete block design with four replications. Main plots were the butachlor rates (0, 1, 2, 3, 4 and 5 L ha⁻¹) and subplots were two rice cultivars ('Line 843' and 'Khazar' cultivar, more and less competitive rice cultivars, respectively). Results showed that the highest grain yield for 'Line 843' was obtained at 2 L ha⁻¹ butachlor application rate, while for khazar cultivar; the highest grain yield was obtained when 4 L ha⁻¹ of butachlor was applied. Barnyardgrass biomass in 'Line 843' was decreased from 288.3 to 17.4 g m⁻² as butachlor rate increased from 0 to 5 L ha⁻¹, while barnyardgrass biomass in 'Khazar' was decreased from 291.5 to 44.5 g m⁻² as butachlor application rate increased from 0 to 5 L ha⁻¹. For both 'Khazar' and 'Line 843', herbicide efficacy was increased with increasing the butachlor application rate. The herbicide efficacy was higher for 'Line 843' compared to 'Khazar' cultivar in all levels of butachlor rate, except in 5 L ha⁻¹. Therefore, these experiments demonstrated that the 'Line 843' was able to significantly reduce the application rate of butachlor.

Keywords: barnyardgrass, butachlor, competitiveness, rice

Introduction

Weeds are the greatest biological constraint to rice production. It is estimated that rice yield is reduced by 25% due to weed infestation (De Datta, 1980). It has been reported that yield losses due to weeds are more severe than those caused by N deficiency, pests, or diseases (WARDA, 1996). Of the numerous weed species that infest lowland rice fields, barnyardgrass (BYG) is the most troublesome and competitive annual weed in north of Iran. It is a very aggressive invader, difficult to control, and causes major losses in rice production (Lopez-Martinez et al., 1999). Chin (2001) reported

that 25 BYG plants per m² in paddy field reduced grain yield by 50%. Moreover, it has been reported that barnyardgrass can remove 60-80% of the nitrogen (Holm et al., 1977), as well as considerable amounts of other macronutrients (Maun and Barrett, 1986) from the soil under heavy infestations. Moreover, barnyardgrass plant can release allelopathic substances in their surrounding environments that inhibit the growth of rice and reduce rice grain yield (Xuan et al., 2006).

In north of Iran, the most common method currently employed to control weeds in rice fields is the use of herbicides. But, increasing cost of herbicide inputs and incidence of herbicide

resistance in weeds have renewed interest in exploiting crop competitiveness to reduced herbicide use (Mohler, 2001). Blackshaw et al. (2006) stated that combining reduced rates of herbicides with other management practices, such as tillage, increased crop density, competitive cultivars, reduced row spacing, and specific fertilizer placement can noticeably increase the chances of successful weed management. Competitive ability is defined as the ability of a crop to minimize weed growth and competition. Two aspects contribute to crop competitiveness with weeds: weed suppressive ability (WSA), the ability of the crop to reduce weed growth through competition, and weed tolerance (WT), the ability to maintain high yields despite the presence of weeds (Jannink et al. 2000). Rice cultivar differences in competitiveness against weeds were initially reported several decades ago (Jennings and Jesus, 1968; Kawano et al., 1974; De Datta, 1980). Fischer et al. (2001) reported that grain yield losses of semidwarf upland rice cultivars due to weed competition ranged from 18 for 'CT 11891-2-2-7-M' to 55% for 'Colombia 1'. Using more competitive cultivars can be an important component of integrated weed management systems. Competitive cultivars improve weed control by reducing weed biomass and seed-set. Tall, droopy-leafed and vigorous traditional cultivars were reported to be more weed-competitive but lower in yield potential than short-stature, erect modern ones (De Datta, 1980). Recent reports have indicated that using rice cultivars with the stronger weed-suppressive ability may decrease reliance on herbicides and facilitate effective weed control at reduced herbicide rates (Fischer et al. 2001; Gibson et al. 2001). Gealy et al. (2003) suggested that weed control in rice using herbicide rates below the rates recommended by the manufacturer would benefit growers economically. They also reported that with or without propanil application, the Asian rice cultivars, 'PI 312779', 'Guichao', and 'Teqing', consistently suppressed barnyardgrass more and consequently produced higher grain yields than did U.S. cultivars, ('Starbonnet', 'Kaybonnet', 'Lemont', and 'Cypress'. Weed control in rice using herbicide rates below the rates recommended by the manufacturer would benefit growers economically.

In an upland rice study, Gibson et al. (2001) reported that 'M-202' cultivar suppressed watergrass [*Echinochloa oryzoides* (Ard.) Fritsch] Dry weight more than 'A-301' cultivar for all propanil rates. At the standard propanil rate (4 kg a.i. ha⁻¹), 'M-202' cultivar suppressed watergrass weight to 29% of the weight of watergrass grown with 'A-301' cultivar.

There is little information on the effect of growing more competitive cultivar on herbicide application rate in lowland rice production systems. Therefore, The objective of this experiment was to investigate whether using more competitive cultivar improves weeds control and reduces butachlor application rate in low land rice fields in north of Iran.

Materials and Methods

Field experiment was conducted on a lowland rice field at rice research station of Tonekabon in Iran (36° 54' N, 40° 50' E). Soil properties are presented in Table 1. The experimental design was a split plot where the whole plot portion was a randomized complete block with four replications. Main plots were Butachlor¹ (Machete®) rates (0, 1, 2, 3, 4 and 5 L ha⁻¹ applied at two or three-leaf stage of barnyardgrass according to the manufactured recommendations). The subplots were two rice cultivars ('Line 843' and 'Khazar' cultivar, the high and low competitiveness cultivars against barnyardgrass, respectively). Rice seeds were disinfected with thiophanate-methyl pesticide and then were sown in the nursery. Cultivar and line seedlings were manually transplanted in plots sized 18 m² (3 m by 6 m) at planting distance 25×25 Cm. All weeds except barnyardgrass were removed by manual weeding at 25 and 40 days after transplanting. The plots fertilized with a basal application of 50 kg N as urea, 70 kg P as triple super phosphate and 100 kg K as KCl per hectare; an additional topdressing of 50 kg N as urea was made at 40 days after transplanting the seedlings.

At maturity stage, rice grain yield (14% moisture) and barnyardgrass seed production were determined from 2.5 m² per plot. For measuring rice biological yield, 16 plants from each plot was

¹- 2-chloro-2-(6'-diethyl-N-(Butoxymethyl) acetanilide (60% EC)

Table 1 Soil characteristics (0-30 cm depth) at the Rice Research Station of Tonekabon before transplanting.

OC (%)	pH	Sand (%)	Silt (%)	Clay (%)	Total N (%)	P (mg kg ⁻¹)	K (mg kg ⁻¹)
1.9	6.8	19	44	37	0.207	11	112

randomly chosen, clipped at ground level, threshed, dried at 70°C for 3 days and weighed. Rice biological yield was expressed as the dry weight of above-ground plant per hectare. Barnyardgrass biomass in each plot was determined by collecting the aboveground portion of barnyardgrass from 2.5 m² (the same sampling area as for rice yield) in each plot at maturity stage, dried at 70°C for 3 days and weighed. It was expressed as the dry weight of barnyardgrass above-ground per m².

The relationship between rice grain yield and butachlor application rate was described using the following exponential model:

$$Y = a/(1+\exp(-(X-X_0)/b))$$

Where Y is estimated rice yield as a function of butachlor rate (X), a is rice yield in the absence of butachlor application, X₀ is the butachlor rate that 50 % inhibition occurred, and b is calculated regression parameter.

The relationship between barnyardgrass biomass and herbicide rate was described using the following exponential model stated by O'Donovan et al. (2001):

$$Y = a + b[1 - \exp(-cX)]$$

Where Y is estimated barnyardgrass biomass as a function of butachlor rate (x), a is Y intercept at 0 butachlor rate, a + b is the asymptote, and c determines the rate at which the asymptote is approached.

The relationship between barnyardgrass seed production and herbicide rate was described using the following exponential model:

$$Y = a/(1+\exp(-(X-X_0)/b))$$

Where y is barnyardgrass seed production estimated as a function of butachlor rate (X), a is barnyardgrass seed production in the absence of butachlor application, X₀ is the butachlor rate that

50 % inhibition occurred, b is calculated regression parameter.

The herbicide efficacy was calculated from the following equation (Lesnik, 2003):

$$HE = \frac{W_{Un} - W_T}{W_{Un}}$$

Where HE is the herbicide efficacy, W_{Un} is barnyardgrass dry weight in non treated plot with herbicide, W_T is barnyardgrass dry weight in treated plot with herbicide. The relationship between the herbicide efficacy and herbicide rate was described using the following linear model:

$$Y = ax + b$$

Where y is the herbicide efficacy as a function of herbicide rate (x), b is y intercept and a is calculated regression parameter.

Statistical analyses were conducted using SAS procedures (SAS Inst., 2004). Graphic representations and calculations of confidence intervals for regressions were conducted with SIGMA-PLOT.

Results and Discussion

Rice Grain Yield

Analysis of variance showed that the effects of cultivar and herbicide rate were significant for grain yield but the interaction between cultivar and herbicide rate was not significant (Table 2). Regardless of butachlor application rate, grain yield was significantly lower in 'Khazar' cultivar (3020 kg ha⁻¹) than 'Line 843' (5375 kg ha⁻¹). Both in 'Khazar' and in 'Line 843', the grain yield increased with increasing herbicide rate. However, grain yield in 'Line 843' was the highest with using 2 L ha⁻¹ butachlor, while in khazar cultivar; the highest grain yield was obtained when 4 L ha⁻¹ of butachlor was applied (Figure 1). It is seemed that in 'Line 843', the application of 2 L ha⁻¹ butachlor was effectively controlled the weeds, especially

barnyardgrass, and consequently the application of butachlor more than 2 L ha⁻¹ had no further increase in grain yield for 'Line 843'. Gibson et al. (2001) reported that the more competitive M-202 had higher yields than A-301 under weedy and weed-free conditions. They suggested that herbicide rates could be reduced and weed control could be improved if more competitive cultivars were developed for water-seeded rice. Rice grain yield increased with increasing herbicide efficacy (Figure 2). In contrast, the relationship between grain yield and barnyardgrass biomass was expressed by a linear regression model (Figure 3). Rice grain yield decreased as barnyardgrass biomass increased.

Lemerle et al. (2001), Walker (2002) and Kristensen et al. (2008) also found a negative correlation between grain yields and weed biomass.

Barnyardgrass Biomass

Analysis of variance showed that the main effects of cultivar and butachlor rate, and also the interaction between them were significant for barnyardgrass biomass (Table 2). Barnyardgrass biomass in plots grown with 'Khazar' was significantly greater than that grown with 'Line 843' by more than 58%, indicating the cultivar competitiveness in weed controls. Other researchers (Zhao et al., 2006; Aminpanah and Javadi, 2011) also found that cultivars differ in their competitiveness against weeds. With increasing butachlor rate from 0 to 5 L ha⁻¹, the barnyardgrass biomass was significantly decreased by 85% for khzar and 94% for 'Line 843' (Figure 4). Under non-herbicide treatment (Figure 2), there was no significant difference between barnyardgrass biomass in 'Khazar' and in 'Line 843' (291.5 and 288.3 g m⁻² for 'Khazar' and 'Line 843', respectively). When butachlor was applied at the rate of 1 L ha⁻¹, barnyardgrass biomass in 'Khazar' (248.3 g m⁻²) was significantly greater than that in 'Line 843' (140.3 g m⁻²). The same results were observed when butachlor was applied at the rate of 2, 3, 4, and 5 L ha⁻¹ (Figure 4). Moreover, barnyardgrass biomass in 'Line 843' when botachlor applied at the rate of 2 L ha⁻¹ was statistically equal with barnyardgrass biomass in 'Khazar' when botachlor applied at the rate of 4 L ha⁻¹ (Figure 4). Therefore 'Line 843' could reduce

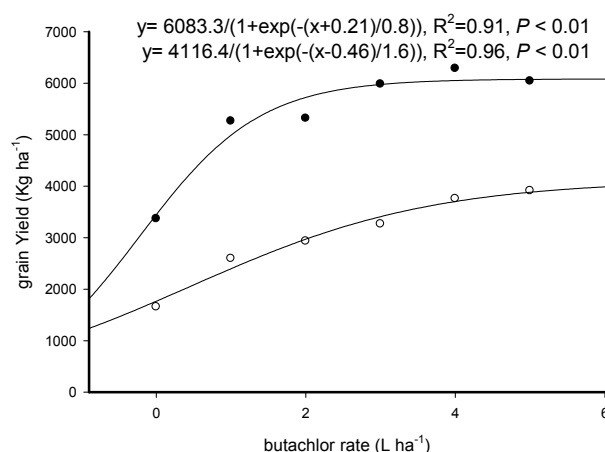


Figure 1 Relationship between rice grain yield and butachlor application rate. Symbols represent actual rice yield (kg ha⁻¹) in 'Line 843' (filled circles) and 'Khazar' (hollow circles). Lines represent estimated rice yield from the model.

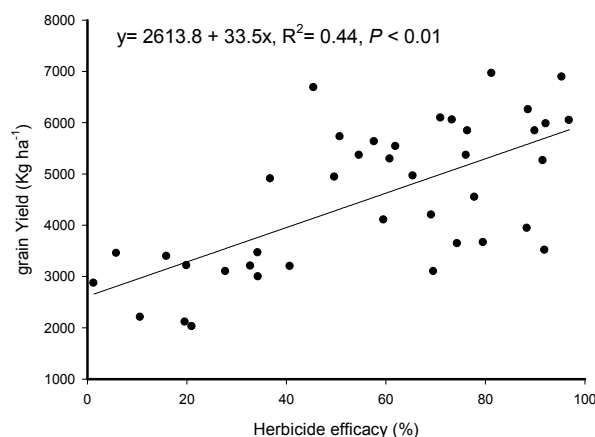


Figure 2 Relationship between rice grain yield (kg ha⁻¹) and Herbicide efficacy. Data correspond to six herbicide application rates and two rice cultivars.

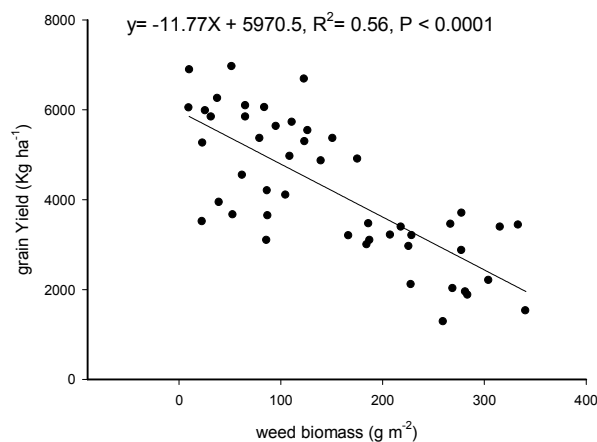


Figure 3 Relationship between rice grain yield (kg ha⁻¹) and weed biomass. Data correspond to six herbicide application rates and two rice cultivars.

Table 2 Analysis of variance for the effects of butachlor rate and rice cultivar on rice grain yield (Y), barnyardgrass biomass (BYG.B), barnyardgrass seed production (BYG.S), and herbicide efficiency (HE).

S.O.V.	Df	Y	BYG.B	BYG.S	HE
Block	3	501522.22 ns	904.66 ns	67.38 ns	0.0074 ns
Butachlor rate (B)	5	6999455.97**	68890.82 **	5093.18 **	0.8118 **
Error (a)	15	207716.11	781.90	134.01	0.0056
Cultivar (C)	1	66590644.92**	56114.67**	5093.35 **	0.6097**
B×C	5	303419.65ns	4905.05 **	215.32 ns	0.0553 **
Error (b)	18	175766.5	1045.61	104.90	0.0084
CV (%)		9.9	21.4	24	19.2

*, ** and ns indicate significance at $P < 0.05$, 0.01 , and not significant, respectively.

the butachlor rate as equal as 2 L ha^{-1} . Other researcher reported that more competitive cultivar reduced weed biomass (Gibson et al., 2001).

Herbicide Efficacy

Herbicide efficacy was significantly affected by cultivar and butachlor rate, while the interaction between them was not significant (Table 2). For both 'Khazar' and 'Line 843', herbicide efficacy was significantly improved as herbicide application rate increased from 0 to 5 L ha^{-1} . However, the herbicide efficacy was significantly higher for 'Line 843' compared to 'Khazar' cultivar at all levels of butachlor, except 5 L ha^{-1} of butachlor. It was seemed that low application rate of butachlor in 'Line 843' cause an effective control of barnyardgrass, resulted in increasing herbicide efficacy and decreasing in butachlor application rate. On the other hand, in recommended application rate of butachlor (3 L ha^{-1}), the herbicide efficacy was significantly higher in 'Line 843' compared to 'Khazar' cultivar (Figure 5). It was seemed that high leaf area index, crop growth rate, specific leaf area and tillering capacity in 'Line 843' (data not shown) could reduce adverse effect of barnyardgrass competition rather than 'Khazar' cultivar, resulted in reducing barnyardgrass biomass and increasing the herbicide efficacy in competition with 'Line 843'.

Barnyardgrass Seed Production

barnyardgrass grain production was significantly influenced by cultivar and butachlor rate, but the

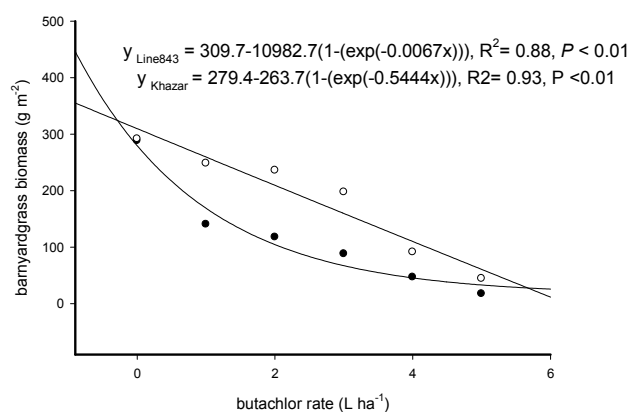


Figure 4 Relationship between barnyardgrass biomass (g m^{-2}) and herbicide rate. Symbols represent actual barnyardgrass biomass (g m^{-2}) in 'Line 843' (filled circles) and 'Khazar' (hollow circles). Lines represent estimated rice yield from the model.

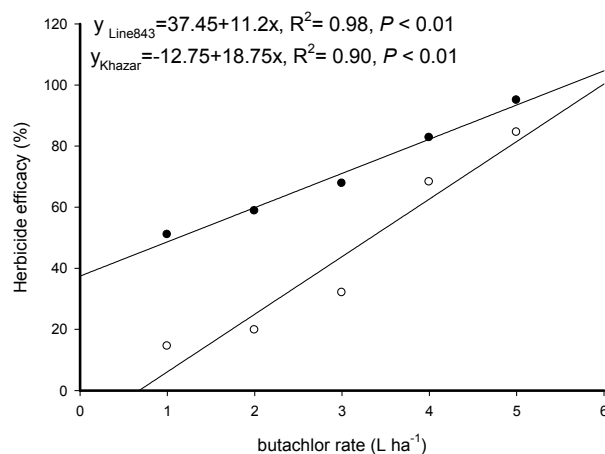


Figure 5 Relationship between the herbicide efficacy (%) and herbicide rate. Symbols represent actual herbicide efficiency (%) in 'Line 843' (filled circles) and 'Khazar' (hollow circles). Lines represent estimated herbicide efficacy from the model.

interaction between cultivar and butachlor rate was not significant (Table 2). Regardless of butachlor rate, Barnyardgrass seed production was 20% less in 'Line 843' (41.22 g m^{-2}) compared with that in 'Khazar' (51.82 g m^{-2}) (Figure 6). In both cultivar and 'Line 843', barnyardgrass seed weight decreased as butachlor rate increased from 0 to 5 L ha^{-1} . At all levels of butachlor, except in 5 L ha^{-1} , barnyardgrass produced greater seed yield when grown with 'Khazar' than when grown with 'Line 843'. On the other hand, application of butachlor in 'Line 843' as 2 L ha^{-1} can considerably reduced seed production in barnyardgrass, but in 'Khazar' cultivar considerable reduction in seed production of barnyardgrass occurred when the butachlor was applied at the rate of 4 L ha^{-1} . This implies that there may be a decrease in the number of barnyardgrass seeds return to the weed seedbank in the soil if competitive cultivars are grown and that there will be less weed infestation and yield losses in future seasons. Rasmussen (1993) noted that one-half to one-sixteenth of recommended dose of herbicide can be sufficient to reduce weed seed production by 85%.

Conclusions

This experiment illustrated that the highest grain yields for 'Line 843' and 'Khazar' were obtained when butachlor was applied at the rate of 2 and 4 L ha^{-1} , respectively. Barnyardgrass biomass in 'Line 843' was decreased from 288.3 to 17.4 g m^{-2} as butachlor rate increased from 0 to 5 L ha^{-1} . In contrast, barnyardgrass biomass in 'Khazar' was decreased from 291.5 to 44.5 g m^{-2} as butachlor rate increased from 0 to 5 L ha^{-1} . For both 'Khazar' and 'Line 843', herbicide efficacy was increased with increasing the butachlor rate. The herbicide efficacy was higher for 'Line 843' compared to 'Khazar' cultivar in all levels of butachlor, except in 5 L ha^{-1} . Regardless of butachlor rate, Barnyardgrass seed production was 20% less in 'Line 843' (41.22 g m^{-2}) compared with that in 'Khazar' (51.82 g m^{-2}). Therefore, these experiments demonstrated that the 'Line 843' was able to significantly reduce the application rate of butachlor.

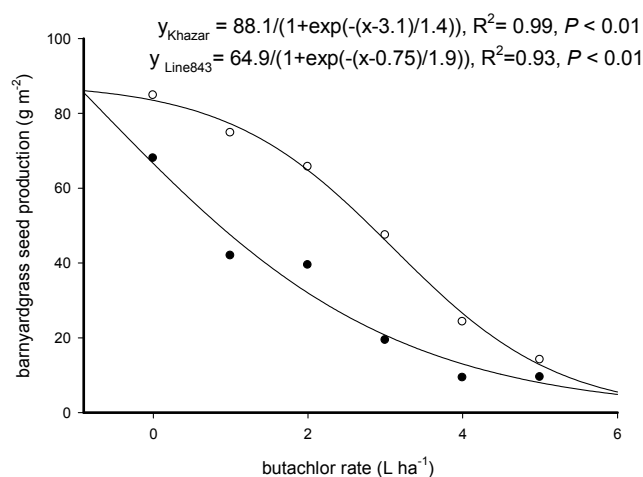


Figure 6 Relationship between barnyardgrass seed production (g m^{-2}) and butachlor rate. Symbols represent actual barnyardgrass seed production (g m^{-2}) in 'Line 843' (filled circles) and 'Khazar' (hollow circles). Lines represent estimated barnyard grass seed production from the model.

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