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Integrating Allelopathy, Plant Population and Use of Herbicides for Weed Control of Six Rice Genotypes

[1]U.A. Abd El-Razek, [1]R.A. El-Refaey, [2]S.M. Shebl and [2]S.S.M. Abd El-Naby

[1]Department of Agronomy, Faculty of Agriculture, Tanta University, Egypt
[2]Rice Research Training Center, Sakha, Kafr El-Sheikh, Egypt

Corresponding Author: U.A. Abd El-Razek, Department of Agronomy, Faculty of Agriculture, Tanta University, Egypt

ABSTRACT

Two field experiments were carried out in the experimental farm of Rice Research and Training Center (RRTC), Sakha-Kafr-El Sheikh, Egypt during two summer seasons of 2009 and 2010. The aimed of the study is to investigate the effects of some allelopathic genotypes of rice, transplanting spaces and weed control treatments on weed characters, yield and its components. A strip split plot design with three replicates was used. The most important findings of this study could be summarized as follow: Regarding rice genotypes, both of Gz 7955 and Gz 8565 lines not only achieved the lowest values in weeds fresh and dry weights (g m^{-2}) but also recorded the high yield and its attribute in the two seasons. Transplanting spaces varied in biomass, the closer space recorded the significantly lower weed character which subsequent gave higher grain yield. The full dose of penoxsulam 24% sc (35 mL fed^{-1}) ranked as the best weed control treatment in reducing all weed characters and increasing rice yield followed by herbicidal application at half dose as compared to weedy check that recorded the highest weeds traits and the lowest rice yield characters.

Key words: Allelopathy, plant population, herbicides, weed control, rice genotypes

INTRODUCTION

Rice (*Oryza sativa* L.) considered as the most important cereals in Egypt. Meanwhile, its the principle food of the majority of the Egyptians.

Rice faces some problems from sowing to maturity i.e., low plant population density and the weeds which cause a great loss in yield of the crop. Weeds competitive the rice plants in nutrition, water and land spaces. Moreover, the weeds may carry insects, pest and diseases, which produce low rice quality and may cause a complete failure of the crop. So, it is imperative to look into the ways to control weeds. Chemical weed control is a commonly used and reliable method to control weeds in rice fields, but it leads to environment pollution and development of herbicide-resistant weeds.

Allelopathy refers to any direct or indirect harmful or beneficial effects of one plant on another through the production of chemical compounds. The use of biological weed control via explore the phenomenon of allelopathy which appeared in some rice varieties is alternate option to manage the weed problem in rice fields (Christensen, 1995; Iqbal *et al.*, 2009). Allelopathy can be used in weed control through two ways: (a) Selecting an appropriate cultivar or incorporating an allelopathic characters into a desired cultivar, (b) Applying residues and straw as mulches or growing an allelopathic cultivar in rotational sequence that allows residues to remain the field (Rice, 1995).

Plant population density through the different hill spaces in very important factor in transplanted rice. Ray *et al*. (2000) found that growth-attributing characters like leaf area index, dry matter accumulation and crop growth rate were considerably affected by transplanting spaces. Closer spacing (15×20 cm) increased rice competition against weeds resulting in a good rice growth sequently, yielding higher grain yield and increased net income (Verma *et al*., 2002; El-Shayieb, 2003). The use of the optimum crop density may increases the efficiency of herbicide and to exhibit the effective of weed management and keep the environment without pollution it may cultivate allelopathic potential varieties of rice (Lesnik, 2003).

Weed management is a combination of several factors, including allelopathic rice cultivars, planting methods, land preparation, date of planting, plant population, preventive weed control methods and chemical control (Smith, 1993). The objectives of this work are to: (1) Study the capability depending on allelopathy phenomena in controlling weeds, (2) Comparing among different transplanting spaces and their effects on weeds, rice growth and yield, (3) Evaluation of different weed control treatments under different rice genotypes and transplanting spaces and (4) Study the integration among allelopathy, transplanting spaces and herbicide rates in controlling weeds, rice growth, yield and its components.

MATERIALS AND METHODS

Two field experiments were carried out at the experimental farm of Rice Research and Training Center (RRTC), Sakha, Kafr El-Sheikh, Egypt, during 2009 and 2010 rice growing seasons. This study aimed to compare the effect of six rice genotypes allelopathic ability, transplanting spacing and weed control on weeds, rice yield and its component. A strip split plot design with three replications was used, which rice genotypes were assigned to the horizontal plots and transplanting spaces were allocated to vertical plots, while weed control treatments were distributed in sub-plots.

Rice genotypes: Gz 6522, Gz 5702, Gz 7764, Gz 8565, Gz 7955 and Sakha 103 as non-allelopathic check cultivar.

Transplanting spaces: Three row spaces were conducted as follows:

- 20×15 cm, rice seedlings were manually transplanted with space 15 cm between rows
- Recommended transplanting space (20×20 cm), where rice seedlings were transplanted with 20 cm between rows and hills
- The largest spaces (20×25), with 25 cm between the rows

Weed control treatment:

- Herbicidal recommended dose of penoxsulam 24% sc, at 35 mL fad^{-1}
- Half dose of penoxsulam 24% sc, at 17.5 mL fad^{-1}
- Weedy check (untreated)

Plot size was 15 m^2. All agricultural practices were applied as recommended in its certain times and rates under the recommended methodology.

All rice genotypes planting with 60 kg seeds fad^{-1} (one faddan = 4200 m^2), rice seeds were soaked for 24 h in running water then incubated for 48 h as recommended the pre-germinated seeds were manually broadcasted in a separate nursery for each genotype on 5th and 2nd of May for first and second season, respectively. Herbicidal treatments were applied as spraying at 4-7 days after transplanting using knap sake sprayer (160 L of water fad^{-1}) on a saturated land, then the field was flooded after 24 h after herbicidal treatments applied and keep the water flooded for 3-5 days after treatments.

Data collection: Data on weeds (fresh and dry weights) for each experimental plot was sampled at 35 Days After Herbicide application (DAT), weeds were counted for every weed species in a square meter after clipped from ground surface. Weed samples were air dried for two days then oven dried at 70°C for 48 h or up to the stability of the weight, then the average weight was recorded. No. of panicles m^{-2} was calculated as average of ten random hills in transplanted rice, then transfer these numbers into No. of panicles $sq^{-1}m$. Rice grain yield of guarded 10 m^2 for each plot was weighted and adjusted at 14% moisture content after harvesting then converted into tons per faddan.

Statistical analysis: The collected data were subjected to proper statistical analysis of variance, according to Snedecor and Cochran (1971). Weed data were transformed then analyzed by MSTATC program, while rice data were directly analyzed by MSTATC program. Duncan multiple range test (Duncan, 1955) was used for comparison among mean values.

RESULTS AND DISCUSSION

Weed growth: The major weed species associated with rice crop during the two growing seasons were grassy weeds including: (a) *Echinochloa crus-galli* (Barnyard grass), (b) *Echinochloa colona* (Jungle rice) and (c) *Cyperus difformis* (small flower). Fresh and dry weight m^{-2} for total weeds were used as reliable indicators for weed distribution in rice plots.

Fresh and dry weights of total weeds as influenced by rice genotypes, transplanting spaces, weed control treatments and their interactions at 35 DAT over the two seasons are shown in Table 1. The data indicated that, biomass of total weeds were significantly affected by allelopathic rice genotypes than that of Sakha 103. Gz 7955 and Gz 8565 recorded the lowest biomass in 2009 and 2010 seasons, except for total weed fresh weight in the second season, whereas Gz 8565 surpassed all other tested rice lines. On the other hand, Sakha 103 (check cultivar) recorded the highest values of fresh and dry weights for total weeds over the two seasons. The suppressive effects of selected rice lines on weeds may be attributed to the released alkaloids and other metabolites such as essential oils which can interact with germinated weed seeds. These findings are in agreement with those reported by Hassan *et al.* (1995) and Ko *et al.* (2005).

Fresh and dry weights of total weeds at 35 days after sowing were highly significant affected by transplanting spaces in both seasons. The closer space (15×20 cm) recorded the lowest fresh and dry weights of total weeds, followed by (20×20 cm) and (20×25 cm) in ascending order in both seasons. Chauhan and Johnson (2010) found that narrow row spacing led to decreased weed growth and germination, while the wider spaces had greater biomass and seedlings of weeds. These results are in harmony with those cited by Kim *et al.* (2006), Mussavi *et al.* (2009) and Hassan *et al.* (2010).

Concerning weed control treatments, data in Table 1 showed significant differences due to weed control treatments for fresh and dry weights of total weeds in 2009 and 2010 seasons. The herbicidal application of penoxsulam 24% sc at full dose showed its superiority in weed control, followed by half dose of the herbicide, while weedy check gave the highest values in these

Table 1: Fresh and dry weights of total weeds at 35 DAT, No. of panicles and grain yield as affected by rice genotypes, transplanting spaces and weed control in 2009 and 2010 seasons

	Fresh weight (g m^{-2})		Dry weight (g m^{-2})		No. of panicles (m^{-2})		Grain yield (tons fed^{-1})	
Factors	2009	2010	2009	2010	2009	2010	2009	2010
A-Rice genotypes								
Gz 6522	1924.74[b]	314.85[c]	437.03[b]	60.44[c]	514.82[b]	575.00[c]	2.66[d]	3.20[c]
Gz 5702	1077.50[d]	373.82[b]	314.20[d]	71.09[b]	563.67[a]	517.30[d]	3.12[b]	3.20[c]
Gz 7764	1666.37[c]	285.49[cd]	392.20[c]	63.26[c]	498.19[b]	480.52[e]	2.91[c]	3.37[b]
Gz 8565	611.92[e]	146.26[e]	119.28[e]	31.16[d]	581.10[a]	637.22[a]	3.85[a]	3.95[a]
Gz 7955	622.66[e]	239.27[d]	127.85[e]	55.66[cd]	591.44[a]	600.07[b]	3.81[a]	3.85[a]
Sakha 103	2646.25[a]	1089.22[a]	531.53[a]	266.72[a]	444.56[c]	441.41[f]	2.40[e]	2.72[d]
F test	**	**	**	**	**	**	**	**
B-Transplanting spaces								
15×20 cm	856.38[c]	184.07[c]	189.19[c]	45.54[c]	633.35[a]	625[a]	3.24[a]	3.71[a]
20×20 cm	1391.33[b]	328.88[b]	337.65[b]	69.78[b]	526.41[b]	527.44[b]	3.20[ab]	3.44[b]
25×20 cm	2027.01[a]	711.50[a]	434.21[a]	158.85[a]	437.11[c]	472.52[c]	2.93[b]	3.00[c]
F test	**	**	**	**	**	**	**	**
C-Weed control treatments								
Penoxsulam 24% sc. full dose	136.00[c]	7.78[c]	26.76[c]	3.79[c]	675.83[a]	676.09[a]	4.10[a]	4.19[a]
Penoxsulam 24% sc. Half dose	1090.69[b]	211.79[b]	216.21[b]	43.89[b]	560.80[b]	550.32[b]	3.29[b]	3.59[b]
Weedy check	3048.03[a]	1004.88[a]	718.07[a]	226.48[a]	360.24[c]	399.35[c]	1.99[c]	2.37[c]
F test	**	**	**	**	**	**	**	**
Interactions								
A×B	NS	NS	**	**	**	**	**	**
A×C	**	**	**	**	**	**	**	**
B×C	NS	NS	**	**	NS	NS	**	**
A×B×C	NS	NS	**	**	*	**	**	**

*,**, NS: Indicates p<0.05, <0.01 and not significant, respectively, Means of each factor within each column, values followed by the same letters are not significantly different at 5% level, using Duncan's multiple range test, DAT: Days after herbicidal treatment

characters. Kogan *et al.* (2011) found that, using penoxsulam 24% sc application was sufficient to achieve broad-spectrum control: *Echinocloa* spp. (100% control) and *Cyperus difformis* (80-100% control). Mansur *et al.* (2010) reported that penoxsalum 24% sc were efficient in controlling *Echinocloa* spp. broad leaves and *Cyperus difformis* L. weeds. In general, using the full dose of penoxsulam achieve high weed control in rice fields, this may be a result of high efficiency on weed germination and growth. These results are in agreement with those reported by Abd El-Naby (2009), Ehsanullah *et al.* (2009), Ali *et al.* (2010) and Wazir *et al.* (2011).

Data recorded in Table 1 showed the effect of rice genotypes, transplanting spaces and weed control treatments on No. of panicles m^{-2} and grain yield (tons fad^{-1}).

It could be observed from the obtained data that, the allelopathic genotypes; Gz 7955, Gz 8565 and Gz 5702 gave significantly highest No. of panicles m^{-2} in 2009 season, with no significant differences between them, while Gz 8565 gave the highest value of the trait in view in 2010 season. On the other side, the allelopathic genotypes; Gz 8565 and Gz 7955 gave the significantly highest values for grain yield (ton fad^{-1}) in both seasons, with no significant differences between the two genotypes in this respect. However, the non-allelopathic genotype; Sakha 103 gave significantly lowest values for No. of panicles m^{-2} and grain yield in both seasons. These findings may be due

Table 2: Fresh and dry weights of total weeds at 35 DAT as affected by the interaction between rice genotypes and weed control in 2009 and 2010 seasons

		Fresh weight (g m^{-2})		Dry weight (g m^{-2})	
Rice genotype	Weed control	2009	2010	2009	2010
Gz 6522	HAFD	333.33^{h}	0.00^{g}	68.90^{fg}	0.00^{g}
	HAHD	1845.33^{e}	44.42^{g}	357.31^{e}	11.46^{fg}
	WC	3595.55^{b}	673.37^{d}	884.88^{b}	155.52^{d}
Gz 5702	HAFD	0.00^{j}	8.88^{g}	0.00^{h}	1.81^{g}
	HAHD	279.62^{hi}	170.00^{f}	59.57^{fg}	30.33^{f}
	WC	2952.88^{c}	942.55^{b}	883.04^{b}	181.11^{bc}
Gz 7764	HAFD	111.11^{ij}	0.00^{g}	17.77^{gh}	0.00^{g}
	HAHD	1475.55^{g}	70.22^{fg}	337.04^{e}	11.86^{fg}
	WC	3412.44^{b}	786.23^{c}	821.77^{c}	177.90^{c}
Gz 8565	HAFD	0.00^{j}	0.00^{g}	0.00^{h}	0.00^{g}
	HAHD	210.00^{hij}	44.44^{g}	42.24^{fgh}	4.52^{g}
	WC	1625.77^{fg}	394.33^{e}	315.62^{e}	88.96^{e}
Gz 7955	HAFD	0.00^{j}	0.00^{g}	0.00^{h}	0.00^{g}
	HAHD	80.88^{ij}	73.33^{fg}	31.11^{fgh}	6.62^{g}
	WC	1787.11^{ef}	871.22^{bc}	352.44^{e}	174.68^{cd}
Sakha 103	HAFD	371.55^{h}	37.77^{g}	73.91^{f}	20.92^{fg}
	HAHD	2652.75^{d}	868.31^{bc}	470.02^{d}	198.55^{b}
	WC	4914.44^{a}	2361.57^{a}	1050.66^{a}	580.69^{a}

Means within each column for every trait followed by the same letters are not significantly different at 5% level, using Duncan's multiple range test, DAT: Days after herbicidal treatment, HAFD, HAHD and WC reffered to herbicide at full dose, herbicide at half dose and weedy cheek, respectively

to the good weed control efficiency, sequently, a good vegetative growth due to minimizing the competition among weeds and rice plants as compared to nonallelopathic one (Sakha 103). These results are similar to those cited by Dilday *et al.* (2001), Shebl *et al.* (2007) and Moukoumbi *et al.* (2011).

The data presented in Table 1 showed that, both yield and its attribute were significantly affected by transplanting spaces of rice during the two seasons. The narrowest space (15×20 cm) recorded the highest No. of panicles unit area^{-1}, panicle weight in both seasons and grain yield in the two seasons followed by the medium space (20×20) and wider space (25×20 cm) in descending order in both seasons. These results are in harmony with those recorded by Hossain *et al.* (2003), Zayed *et al.* (2005), Sohel *et al.* (2009) and Uddin *et al.* (2011).

Regarding weed control treatments, it is observed from the data in Table 1 that, the use of penoxsulam 24% sc in full dose gave significantly the highest No. of panicles m^{-2} and grain yield ton fad^{-1} in both seasons, followed by half dose of herbicide and weedy cheek in descending order in both seasons. These findings are in the line with that reported by Cherati *et al.* (2011) and Khaliq *et al.* (2012).

Data in Table 2 showed significant effect of interaction between rice genotypes and weed control on total weeds studied characters at 35 DAT in both seasons.

It is clear from data that, penoxsulam 24% sc application at full dose for all allelopathic rice genotypes recorded the lowest fresh and dry weights of total weeds at 35 DAT in the second season, while in 2009 season, Gz 5702 and Gz 7955 genotypes at full dose of herbicides recorded the

Table 3: Dry weights of total weeds at 35 DAT as affected by the interaction between rice genotypes and transplanting spaces in 2009 and 2010 seasons

	Transplanting space (cm)					
	15×20		20×20		25×20	
Rice genotype	2009	2010	2009	2010	2009	2010
Gz 6522	257.43[f]	26.93[hi]	521.80[bc]	38.47[ghi]	531.86[b]	101.57[e]
Gz 5702	152.71[g]	18.82[ij]	315.91[e]	55.86[fg]	474.00[c]	138.56[gh]
Gz 7764	230.22[f]	26.91[hi]	406.31[h]	35.08[ghi]	540.06[b]	127.76[h]
Gz 8565	51.31[i]	0.00[j]	144.02[g]	35.71[ghi]	162.53[g]	57.77[fg]
Gz 7955	87.33[hi]	44.26[gh]	125.11[gh]	59.56[fg]	171.11[g]	77.47[f]
Sakha 103	356.13[e]	156.28[c]	494.26[bc]	193.94[b]	744.20[a]	449.93[a]

Means followed by a common letter within a season are not significantly different at 5% level, using Duncan's multiple range test, DAT: Days after herbicidal treatment

Table 4: Dry weights of total weeds at 35 DAT as affected by the interaction between transplanting spaces and weed control in 2009 and 2010 seasons

		Dry weight (g m^{-2})	
Transplanting space (cm)	Weed control	2009	2010
15×20	Herbicide at full dose	8.67[h]	0.00[g]
	Herbicide at half dose	85.26[f]	25.91[ef]
	Weedy check	473.63[c]	110.69[c]
20×20	Herbicide at full dose	23.11[gh]	0.00[g]
	Herbicide at half dose	234.33[e]	34.40[e]
	Weedy check	755.52[b]	174.92[b]
25×20	Herbicide at full dose	48.51[g]	11.36[fg]
	Herbicide at half dose	329.05[d]	71.36[d]
	Weedy check	925.06[a]	393.82[a]

Means within each column for every trait followed by the same letters are not significantly different at 5% level, using Duncan's multiple range test, DAT: Days after herbicidal treatment

significantly best weed control in the above mentioned traits. On the other hand, the highest values of all traits recorded by the nonallelopathic cultivar Sakha 103 under weedy check plots in both seasons.

Data on dry weight of total weeds g m^{-2} at 35 DAT as affected by the interaction between rice genotypes and transplanting spaces are cited in Table 3.

It is obvious from the data in Table 3 that dry weight of total weeds at this stage was greatly influenced by the above-mentioned interaction during 2009 and 2010 seasons. Gz 8565 rice line when interacted with 15×20 cm recorded the lowest values of dry weight of total weeds in the two seasons, while Sakha 103 (non-allelopathic one) under the wider space (25×20 cm) recorded the heaviest dry weight of total weeds in both seasons. These results show the effect of allelopathy in achieving a good weed management in rice fields. These results are confirmed those obtained by Mondal *et al*. (2013).

The obtained data in Table 4 indicated that transplanting spaces x weed control interaction was significantly affected dry weight of total weed g m^{-2} at 35 DAT. Herbicide application at full dose under 15×20 cm space in 2009 season and under all spaces in 2010 season were the best treatments

Table 5: Dry weight of total weeds at 35 DAT as influenced by the interaction among rice genotypes, transplanting spaces and weed control in 2009 and 2010 seasons

		Weed control					
		2009			2010		
Rice genotype	Transplanting space (cm)	Herbicide at full dose	Herbicide at half dose	Weedy check	Herbicide at full dose	Herbicide at half dose	Weedy check
Gz 6522	15×20	52.03^{nr}	110.90^{mp}	609.33^{fg}	0.00^{m}	0.00^{m}	80.80^{jk}
	20×20	53.33^{nr}	485.40^{hi}	1026.66^{c}	0.00^{m}	0.00^{m}	115.43^{i}
	25×20	101.33^{mq}	475.60^{hi}	1018.66^{cd}	0.00^{m}	34.40^{lm}	270.33^{e}
Gz 5702	15×20	0.00^{r}	36.26^{or}	421.86^{ij}	0.00^{m}	0.00^{m}	56.46^{kl}
	20×20	0.00^{r}	10.86^{qr}	936.86^{d}	0.00^{m}	10.20^{m}	157.40^{gh}
	25×20	0.00^{r}	131.60^{mno}	1291.40^{b}	5.43^{m}	80.80^{jk}	329.46^{cd}
Gz 7764	15×20	0.00^{r}	42.66^{nr}	648.00^{f}	0.00^{m}	0.00^{m}	80.73^{jk}
	20×20	0.00^{r}	432.26^{ij}	786.66^{e}	0.00^{m}	2.13^{m}	103.13^{ij}
	25×20	53.33^{nr}	536.20^{gh}	1030.66^{c}	0.00^{m}	33.47^{lm}	349.83^{c}
Gz 8565	15×20	0.00^{r}	0.00^{r}	153.93^{m}	0.00^{m}	0.00^{m}	0.00^{m}
	20×20	0.00^{r}	26.66^{pqr}	460.93^{hij}	0.00^{m}	5.56^{m}	101.56^{ij}
	25×20	0.00^{r}	100.06^{mq}	332.00^{kl}	0.00^{m}	8.00^{m}	165.33^{gh}
Gz 7955	15×20	0.00^{r}	0.00^{r}	262.00^{L}	0.00^{m}	0.00^{m}	132.80^{hi}
	20×20	0.00^{r}	0.00^{r}	375.33^{jk}	0.00^{m}	13.66^{m}	165.03^{gh}
	25×20	0.00^{r}	93.33^{mr}	420.00^{ij}	0.00^{m}	6.20^{m}	226.23^{f}
Sakha 103	15×20	0.00^{r}	321.73^{kl}	746.66^{e}	0.00^{m}	155.50^{gh}	313.36^{d}
	20×20	85.33^{mr}	450.80^{hij}	946.66^{cd}	0.00^{m}	174.86^{g}	406.96^{b}
	25×20	136.40^{mn}	637.53^{f}	1458.66^{a}	62.76^{kl}	265.30^{e}	1021.13^{a}

Means followed by a common letter within a season are not significantly different at 5% level, using Duncan's multiple range test, DAT: Days after herbicidal treatment

in controlling weeds as compared to weedy check. While weedy check under the largest space 25×20 cm recorded the highest values of dry weight of total weeds in the two seasons.

From the data listed in Table 5, dry weight g m^{-2} of total weeds at 35 DAT was significantly influenced by the second order interaction among rice genotypes, transplanting spaces and weed control treatments during the two seasons.

The use of penoxsulam 24% sc at full dose with all transplanting spaces and all allelopathic genotypes recorded the significantly lowest dry weight of total weeds at 35 DAT in both seasons, with one exception i.e., the genotype; Gz 6522 under the wider space (25×20 cm) in 2009 season, where its values was significantly differed.

On the other hand, Sakha 103 recorded the highest dry weight of total weeds under the largest space 25×20 cm in weedy check plots in 2009 and 2010 seasons. These results may reflect the effect of integration among allelopathy and cultural practices with reduced herbicide rates in controlling weeds in rice fields with high efficacy. These results are confirmed those obtained by Kolo and Umaru (2012) and Harding and Jalloh (2011).

Data presented in Table 6 clearly indicated that, panicles No. m^{-2} was significantly affected by the interaction between rice genotypes and transplanting spaces in the two seasons. The highest panicles number was produced by Gz 8565 and Gz 7955 rice genotypes under the space of 15×20 cm with no significant differences in the first season, while in the second one, Gz 8565 gave the highest value for the trait in question. In contrast, Sakha 103 rice cultivar under the largest space 25×20 cm recorded the lowest No. of panicles m^{-2} during 2009 and 2010 seasons. These

Table 6: No. of panicles m^{-2} as affected by the interaction between genotypes and transplanting spaces in 2009 and 2010 seasons

		No. of panicles (m^{-2})	
Rice genotype	Transplanting space (cm)	2009	2010
Gz 6522	15×20	617.11^{bc}	709.77^{ab}
	20×20	544.33^{de}	570.22^{de}
	25×20	383.00^{g}	445.00^{g}
Gz 5702	15×20	638.22^{b}	601.33^{cd}
	20×20	589.77^{cd}	505.66^{f}
	25×20	463.00^{f}	444.88^{g}
Gz 7764	15×20	586.22^{cd}	508.22^{f}
	20×20	445.22^{f}	504.55^{f}
	25×20	463.11^{f}	428.77^{gh}
Gz 8565	15×20	722.44^{a}	725.88^{a}
	20×20	569.00^{de}	615.55^{c}
	25×20	451.77^{f}	570.22^{de}
Gz 7955	15×20	689.88^{a}	676.22^{b}
	20×20	546.55^{de}	569.33^{de}
	25×20	537.88^{e}	554.66^{e}
Sakha 103	15×20	546.22^{de}	533.33^{ef}
	20×20	463.55^{f}	399.33^{hi}
	25×20	323.88^{h}	391.55^{i}

Means within each column for every trait followed by the same letters are not significantly different at 5% level, using Duncan's multiple range test, DAT: Days after herbicidal treatment

results may be referred to the productivity of more active tillers and heavier panicle weight by the rice genotype Gz 8565 especially under the space of 15×20 cm. These results are in harmony with those obtained by Okasha *et al*. (2009) and Mondal *et al*. (2013).

Number of panicles m^{-2} as influenced by the interaction between rice genotypes and weed control treatments in 2009 and 2010 seasons are cited in Table 7. Except, for panicles m^{-2} in the first season, Gz 8565 with the herbicidal application at full dose significantly recorded the highest values for panicles No. unit area^{-1} and grain yield in both seasons. The highest panicles m^{-2} in 2009 season was registered by Gz 7955 rice genotype under penoxsulam 24% sc at full dose during 2009 season. On the opposite, weedy check plots cultivated by rice cultivar Sakha 103 recorded the lowest values for panicles m^{-2} during 2009 and 2010 seasons and grain yield in the first season, while Gz 5702 genotype recorded the lowest grain yield under weedy check plots during the second season. These findings are confirmed with those reported by Shebl *et al*. (2007) and Harding and Jalloh (2011).

Number of rice panicles m^{-2} as influenced by the second order interaction of genotypes×transplanting spaces×weed control treatments during 2009 and 2010 seasons are presented in Table 8.

The obtained data cleared that, panicles No. m^{-2} recorded the highest values by the application of penoxsulam 24% sc at full dose under both of Gz 8565 and Gz 7955 rice genotypes in plots transplanted with the space of 15×20 cm in 2009 and 2010 seasons. On the other hand, Sakha 103 rice cultivar under the wider transplanting space of 25×20 cm in the untreated plots recorded the lowest No. of panicles in the two seasons. The superiority of Gz 7955 genotypes when integrated with 15×20 cm transplanting spaces and the use of penoxsulam 24% sc

Table 7: No. of panicles and grain yield as affected by the interaction between genotypes and weed control in 2009 and 2010 seasons

Rice genotype (tons fed^{-1})	Weed control	No. of panicles (m^{-2})		Grain yield	
		2009	2009	2009	2010
Gz 6522	Herbicide at full dose	651.88^{c}	677.77^{b}	3.46^{d}	3.91^{d}
	Herbicide at half dose	563.44^{e}	594.55^{ef}	2.93^{fg}	3.29^{f}
	Weedy check	329.11^{h}	452.66^{i}	1.59^{k}	2.41^{i}
Gz 5702	Herbicide at full dose	702.00^{b}	645.88^{c}	4.10^{b}	4.08^{c}
	Herbicide at half dose	581.33^{de}	534.00^{g}	3.18^{e}	3.37^{f}
	Weedy check	407.66^{g}	372.00^{j}	2.07^{i}	2.14^{j}
Gz 7764	Herbicide at full dose	646.55^{c}	608.55^{de}	3.91^{c}	4.32^{b}
	Herbicide at half dose	516.77^{f}	504.66^{h}	3.05^{ef}	3.70^{e}
	Weedy check	331.22^{h}	328.33^{k}	1.76^{j}	2.08^{j}
Gz 8565	Herbicide at full dose	720.44^{b}	778.55^{a}	4.85^{a}	4.52^{a}
	Herbicide at half dose	597.88^{de}	624.88^{cd}	3.88^{c}	4.19^{bc}
	Weedy check	424.88^{g}	508.22^{h}	2.79^{gh}	3.12^{g}
Gz 7955	Herbicide at full dose	750.22^{a}	768.88^{a}	4.71^{a}	4.49^{a}
	Herbicide at half dose	611.88^{cd}	577.77^{f}	3.98^{bc}	4.13^{c}
	Weedy check	412.22^{g}	453.55^{i}	2.74^{h}	2.93^{h}
Sakha 103	Herbicide at full dose	583.88^{de}	576.88^{f}	3.52^{d}	3.82^{de}
	Herbicide at half dose	493.44^{f}	466.00^{i}	2.71^{h}	2.85^{h}
	Weedy check	256.33^{i}	281.33^{l}	0.96^{L}	1.49^{k}

Means within each column for every trait followed by the same letters are not significantly different at 5% level, using Duncan's multiple range test, DAT: Days after herbicidal treatment

Table 8: No. of panicles m^{-2} as influenced by the interaction among genotypes, transplanting spaces and weed control in 2009 and 2010 seasons

Rice genotype	Transplanting space (cm)	Weed control					
		2009			2010		
		Herbicide at full dose	Herbicide at half dose	Weedy check	Herbicide at full dose	Herbicide at half dose	Weedy check
Gz 6522	15×20	802.33^{b}	656.33^{cg}	392.66^{pu}	838.66^{a}	742.66^{b}	548.00^{gh}
	20×20	666.66^{cg}	613.66^{fj}	352.66^{rw}	661.00^{cd}	594.33^{fg}	455.33^{mp}
	25×20	486.66^{kn}	420.33^{nr}	242.00^{y}	533.66^{hij}	446.66^{mq}	354.66^{tu}
Gz 5702	15×20	832.00^{b}	647.00^{dg}	435.66^{nq}	737.00^{b}	629.66^{cf}	437.33^{nq}
	20×20	680.66^{cf}	619.33^{ei}	469.33^{mp}	669.33^{c}	492.33^{im}	355.33^{tu}
	25×20	593.33^{gj}	477.66^{ko}	318.00^{ux}	531.33^{hij}	480.00^{kn}	323.33^{uv}
Gz 7764	15×20	715.33^{cd}	630.00^{ei}	413.33^{ns}	635.33^{cf}	513.00^{hk}	376.33^{rst}
	20×20	633.00^{fh}	433.33^{nqd}	269.33^{xy}	652.66^{cde}	539.00^{hi}	322.00^{uv}
	25×20	591.33^{gj}	487.00^{kn}	311.00^{vy}	537.66^{hi}	462.00^{lo}	286.66^{vw}
Gz 8565	15×20	913.66^{a}	719.33^{cd}	534.33^{jm}	828.33^{a}	735.00^{b}	614.33^{def}
	20×20	694.33^{cde}	610.00^{fj}	402.066^{ot}	749.66^{b}	611.00^{ef}	486.00^{jn}
	25×20	553.33^{hl}	464.33^{mp}	337.66^{sx}	757.66^{b}	528.66^{hk}	424.33^{or}
Gz 7955	15×20	854.00^{ab}	731.66^{c}	484.00^{kn}	844.00^{a}	645.66^{cde}	539.00^{hi}
	20×20	714.00^{cd}	553.00^{hl}	372.66^{qv}	736.00^{b}	550.00^{gh}	422.00^{or}
	25×20	682.66^{cf}	551.00^{il}	380.00^{qv}	726.66^{b}	537.66^{hi}	399.66^{qt}
Sakha 103	15×20	722.66^{cd}	596.66^{gj}	319.33^{ux}	676.33^{c}	552.33^{gh}	371.33st
	20×20	555.66^{hk}	550.00^{il}	285.00^{wxy}	544.33^{h}	439.00^{nq}	214.66^{x}
	25×20	473.33^{lo}	333.66^{tx}	164.66^{z}	510.00^{hl}	406.66^{ps}	258.00^{wx}

Means followed by a common letter within a season are not significantly different at 5% level, using Duncan's multiple range test, DAT: Days after herbicidal treatment

Table 9: Grain yield as affected by the interaction between genotypes and transplanting spaces in 2009 and 2010 seasons

	Transplanting space (cm)					
	15×20		20×20		25×20	
Rice genotype	2009	2010	2009	2010	2009	2010
Gz 6522	3.17^{d}	3.59^{de}	2.61^{g}	3.05^{g}	2.20^{g}	2.96^{g}
Gz 5702	2.88^{f}	3.62^{cde}	3.39^{c}	3.31^{f}	3.09^{de}	2.65^{i}
Gz 7764	3.06^{de}	3.76^{bcd}	2.98^{ef}	3.63^{cde}	2.68^{g}	2.71^{hi}
Gz 8565	3.81^{a}	4.16^{a}	3.93^{a}	3.86^{b}	3.79^{a}	3.82^{bc}
Gz 7955	3.89^{a}	4.24^{a}	3.89^{a}	3.88^{b}	3.64^{b}	3.43^{ef}
Sakha 103	2.65^{g}	2.87^{gh}	2.38^{h}	2.88^{gh}	2.17^{i}	2.42^{j}

Means within each column for every trait followed by the same letters are not significantly different at 5% level, using Duncan's multiple range test, DAT: Days after herbicidal treatment

Table 10: Rice grain yield ton fad^{-1} as affected by the interaction between transplanting spaces and weed control in 2009 and 2010 seasons

	Weed control					
	Herbicide at full dose		Herbicide at half dose		Weedy check	
Transplanting space (cm)	2009	2010	2009	2010	2009	2010
15×20	4.31^{a}	4.44^{a}	3.38^{d}	3.86^{c}	2.04^{f}	2.83^{f}
20×20	4.13^{b}	4.30^{b}	3.41^{d}	3.64^{d}	2.05^{f}	2.37^{g}
25×20	3.84^{c}	3.84^{c}	3.08^{e}	3.27^{e}	1.87^{g}	1.89^{h}

Means followed by a common letter within a season are not significantly different at 5% level, using Duncan's multiple range test, DAT: Days after herbicidal treatment

at recommended dose 35 mL fed^{-1} may be due to the higher weed inhibition and good conditions for rice vegetative growth, consequently, good yield components as mentioned by Ali *et al.* (2010) and Singh *et al.* (2012).

Grain yield of rice tons fed^{-1} was greatly affected by the genotypes×transplanting spaces interaction in the two seasons as shown in Table 9.

Regarding to rice grain yield tons fed^{-1}, both of Gz 8565 and Gz 7955 under the narrowest space 15×20 cm recorded the highest grain yield during the two seasons with insignificant differences between them. However, the genotypes; Gz 8565 and Gz 7955 gave the highest values of grain yield under all transplanting spaces in 2009 season, except Gz 7955 at the wider space. On the other hand, Sakha 103 rice cultivar recorded the lowest grain yield under the transplanting space of 25×20 cm during the two seasons. The high yielding potentiality of Gz 8565 and Gz 7955 rice lines under 15×20 cm and 20×20 cm transplanting spaces might be referred to the optimum rice density per unit area which produced heavier grains and panicles m^{-2} resulted in higher yield of rice as mentioned by Okasha *et al.* (2009) and Mondal *et al.* (2013).

Rice grain yield was greatly affected by the interaction between transplanting spaces and weed control treatments in the two seasons of study as cleared from Table 10.

The application of herbicide at full dose recorded the highest grain yield under the space of 15×20 cm in 2009 and 2010 seasons, followed by the same herbicidal application under the medium space 20×20 cm. Weedy check plots under the largest transplanting space 25×20 cm ranked the latest during the two seasons. These findings are confirmed with those obtained by Jacob and Syriac (2005) and Khaliq *et al.* (2012).

Table 11: Rice grain yield as influenced by the interaction among genotypes, transplanting spaces and weed control in 2009 and 2010 seasons

		Weed control					
		2009			2010		
Rice genotype	Transplanting space (cm)	Herbicide at full dose	Herbicide at half dose	Weedy check	Herbicide at full dose	Herbicide at half dose	Weedy check
Gz 6522	15×20	4.09^{def}	3.54^{ijk}	1.87^{t}	4.13^{fi}	3.69^{lm}	2.69^{pq}
	20×20	3.46^{jkl}	2.85^{opq}	1.50^{uv}	3.74^{klm}	2.91^{pq}	2.49^{s}
	25×20	2.82^{pq}	2.41^{s}	1.39^{vw}	3.84^{il}	3.27^{no}	1.77^{tu}
Gz 5702	15×20	3.86^{fgh}	2.92^{nop}	1.87^{t}	4.39^{bg}	3.58^{lm}	2.91^{pq}
	20×20	4.20^{cde}	3.50^{il}	2.46^{rs}	4.40^{bg}	3.55^{lmn}	1.99^{t}
	25×20	4.27^{cd}	3.13^{mno}	1.87^{t}	3.45^{mn}	2.97^{pq}	1.54^{uv}
Gz 7764	15×20	4.16^{cf}	3.15^{mn}	1.87^{t}	4.62^{abc}	4.10^{gj}	2.57^{rs}
	20×20	3.93^{eh}	3.29^{klm}	1.72^{tu}	4.34^{cg}	4.16^{dh}	2.39^{s}
	25×20	3.64^{hij}	2.71^{pqr}	1.69^{tu}	4.00^{hk}	2.84^{qr}	1.30^{v}
Gz 8565	15×20	5.06^{a}	3.69^{hij}	2.68^{ps}	4.68^{ab}	4.33^{cg}	3.46^{mn}
	20×20	4.83^{ab}	4.04^{dg}	2.91^{nop}	4.47^{ad}	4.12^{fj}	2.99^{pq}
	25×20	4.68^{b}	3.92^{e-h}	2.79^{pq}	4.43^{af}	4.13^{fj}	2.91^{pq}
Gz 7955	15×20	4.84^{ab}	4.10^{def}	2.73^{pqr}	4.71^{a}	4.45^{ae}	3.56^{lmn}
	20×20	4.92^{ab}	4.04^{dg}	2.73^{pqr}	4.62^{abc}	4.11^{fj}	2.92^{pq}
	25×20	4.39^{c}	3.78^{ghi}	2.75^{pqr}	4.15^{eh}	3.83^{jkl}	2.32^{s}
Sakha 103	15×20	3.87^{fgh}	2.87^{nop}	1.20^{wx}	4.09^{gj}	2.98^{pq}	1.54^{uv}
	20×20	3.47^{jkl}	2.70^{pqr}	0.98^{x}	4.23^{dh}	2.97^{pq}	1.44^{v}
	25×20	3.23^{lm}	2.56^{qrs}	0.71^{y}	3.16^{op}	2.60^{rs}	1.49^{uv}

Means followed by a common letter within a season are not significantly different at 5% level, using Duncan's multiple range test. DAT: Days after herbicidal treatment

Data in Table 11 revealed the effect of the second order interaction of genotypes×transplanting spaces×weed control treatments on rice grain yield during 2009 and 2010 seasons. The data indicated that application of penoxsulam 24% sc at recommended dose gave the highest values of rice grain yield under the narrow space 15×20 cm in plots cultivated by Gz 8565 or Gz 7955 in 2009 and 2010 seasons, respectively. On the opposite, the lowest grain yield of rice was recorded by the largest transplanting space (25×20 cm) under weedy check plots cultivated with Sakha 103 rice cultivar and Gz 7764 rice genotype during 2009 and 2010 seasons, respectively. The highest grain yield a result of second order interaction mentioned above might be referred to the high efficiency of used suppression under such condition which allowed producing more panicles m^{-2}, heavier grains per panicle and the other yield components as reported by Harding *et al.* (2012) and Singh *et al.* (2012).

CONCLUSION

However, it could be concluded that, allelopathic genotypes reduced weeds as compared with non-allelopathic one (Sakha 103). The allelopathic genotypes; Gz 8565 and Gz 7955 were the best genotypes in the aspect of weed control and recorded the highest yield. The narrow transplanting space of 15×20 cm was the best in controlling weed and recorded the highest yield. The herbicidical treatment i.e., penoxsulam 24% sc at full dose had high efficiency in weed control in comparison to other treatments. The best combination for the best weed management and recorded high yield under the high infested fields by weeds is transplanted at the space of 15×20 cm and the application of penoxsulam 24% sc at full dose with cultivated the allelopathic genotypes of Gz 7955 or Gz 8565.

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