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Effects of removal time and Canary grass density on wheat yield and yield components

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ABSTRACT: An experiment was conducted in the split plot format using the randomized complete block design in three replications in Babol city Mazandaran province, Iran in the cropping year of 2011-2012. The two factors studied were removal time of canary grass (at wheat germination or 4, 8, 12, 16, 20 weeks later, and competition between wheat and weed plants until harvest time of wheat) and the density of the population of canary grass (0, 20, 40, 80, 160, and 320 plants/m^2). Wheat and canary grass seeds germinated at the same time. The evaluated characters included stem height, number of fertile tillers per square meter, number of seeds per spike, number of seeds per square meter, 1000-seed weight, seed yield, dry weight of stubble, and harvest index. Results of analysis of the variance showed that the effects of various treatments on all the studied characters were significant at the 99 percent level. The largest 1000-seed weight was that of the A1 treatment (removal of canary grass at germination of wheat seeds), and the 1000-seed weight and the seed yield of the treatment of weed removal 4 weeks after germination of wheat seeds came in second at 46.75 grams and 6980 kg.h, respectively. The maximum numbers of fertile tillers, of seeds/m^2, and of seeds per spike were obtained in the treatment of removing canary grass at germination of wheat seeds, and the minimum numbers of the mentioned characters were observed in the treatment of weed competition with wheat until wheat harvest time. The differences in the dry weights of stubble and in the harvest indices of all the treatments (except those of removal of the canary grass 4 and 8 weeks after germination of wheat seeds) were significantly lower than those of the A1 treatment. The largest seed yield, after that of the control treatment at 5960 kg.h, was that of the treatment with 20 canary grass plants/m^2. Differences in the seed yields of the other treatments were not significant. The reductions in the 1000-seed weights of the treatments of 40 and more canary grass plants/m^2 compared to the control treatment were significant, while differences in the dry weights of the stubble in the various density treatments were not. In this study, the time of removal of canary grass was more important than the density of its population with respect to negatively affecting seed yield.

***Keywords*:** Wheat, canary grass, time of removal, density, yield

INTRODUCTION

Common wheat grows in a wide range of weather conditions in the world. In fact, it is the most adaptable cereal species. Compared to other crop plants, large acreages of land all over the world are devoted to wheat cultivation because wheat is the main food of human beings who directly consume it (Noormohammadi, 2001). Although weeds constitute no more than one percent of plant species, they cause many problems: they interfere with food production, create health hazards, and endanger the economic stability and welfare of man. About 12 percent of reductions in crop plant yields are attributed to weeds (Hejazi, 2000). There is no definite and clear definition for weeds (Rahimian and Banayan, 1996). Agricultural fields, the so-called agricultural ecosystems, are ecosystems in which man plants the desired crops. In such systems, weeds are plants that grow where and when not wanted (Hadizadeh, 2000). Canary grass is an annual weed that poses problems for most autumn crops and that greatly affects their yield and quality. Although this weed can cause problems in the cultivation of several crop plant species and reduces their yields, its greatest destructive effects relate to autumn wheat. The reason for this is the great similarity between its morphological characters and growth needs and those of autumn wheat (Samunder, 1999). Canary grass is considered a common and troublesome annual weed in autumn cereal crops of areas such as the Mediterranean region and India (Afentouli and Eleftherohorinos, 1999), California and Arizona (Bell, 1992; Bulter, 1993), and Mazandaran (Research reports, 1992-1997). The main reasons for this are the similarity of its growth pattern and that of autumn cereals and its rapid seed dissemination, the high viability of its dormant seeds (which can remain dormant for several years), and the lack of effective herbicides to control it in cereals (Hartzeler and Bahler,1999). Cudney and Hill (1979) in the United States, Godinho, and Costa (1981) in Portugal, Montazeri (1993) in Iran, and Afentouli and Eleftherohorinos (1996) in Greece have studied the conspicuous effects of various densities of canary grass on wheat yield. Densities from 50 to 500 Phalaris plants per square meter reduce wheat yield by 8 to 50 percent (Mehra and Gill, 1988; Singh and Malik, 1994; Khera, 1995). Numerous studies have indicated that the species, the density, the time of germination, and the time of removal of this weed, and the species and cultivar and density of the crop plant and the environmental factors (Mehra and Gill, 1988; Cudney and Hill, 1979), influence competition between canary grass and autumn cereals. Cudney and Hill (1979) demonstrated that Canary grass densities of 108 and 915 plants per square meter reduced yield by 40 and 60 percent, respectively, while Afentouli and Eleftherohorinos reported that canary grass density of 350 plants per square meter reduced wheat yield in Portugal by 37 percent. Furthermore, Mehra and Gill (1988) conducted experiments in India and found that densities of 50 and 250 canary grass plants per square meter lowered wheat yield by 8 and 44 percent, respectively. In another experiment carried out by Afentouli and Eleftherohorinos (1999) concerning intervention of canary grass in wheat production, it was revealed that the density of 150 canary grass plants per square meter (if these plants were present until the early part of the first month of spring and were then removed) did not affect wheat yield. However, if this same density persisted until the end of the growing season, wheat yield declined by 26 percent. Balyan and Malik (1989) reported that the density of 20 canary grass plants per square meter had no significant effect on wheat yield in the Indian state of Haryana. However, if this density rose to 2000 plants per square meter wheat yield would be greatly damaged.

This research was conducted with the following general purposes. First, to study competition between canary grass and wheat. Second, to investigate the effects of the densities and of the time of removal of canary grass on wheat yield. Third, to determine the best time of removal of canary grass, and the density of canary grass, at which cultural control of this weed must be carried out. Fourth, to study the interaction effects the time of removal of canary grass and its density have on wheat yield.

MATERIALS AND METHODS

This research was conducted in a farm in the city of Babol of the province of Mazandaran in the cropping year of 2011-2012. Babol has a longitude of 52° and 40´, and latitude of 36° and 33´. The soil had a clay loam texture and a pH of about 7.6. The experiment was conducted in the split plot format using the randomized complete block design. The main plot (the time of canary grass removal) had seven levels, and the sub plot (the density of canary grass) had six. The levels of the main plot were removal of weed at wheat germination and at 4, 8, 12, 16, 20, and 24 weeks after wheat germination. The sub plot had the six density levels of 0, 20, 40, 80, 160, and 320 canary grass plants/m^2. The wheat cultivar Shanghai was used, the seeds of which had been taken from the previous year's crop, and the canary seeds planted in the experimental field had been collected and dried from previous year's plants growing in the same region after they had produced seeds. The experiment was carried out in an area of about 750 m^2 that was plowed in the previous fall, prepared before planting by using a disk and a rotavator, and divided into 42 main plots and 126 sub plots. The sub plots in the replications were 30 cm apart and the distance between replications (blocks) was 50 cm. Wheat seeds were planted by hand after the completion of land leveling operation wheat seeds were planted three cm apart in shallow furrows and were covered by soil. Wheat and canary grass seeds were planted in alternate rows 10 cm apart. After germination of wheat seeds, the first treatment of weed removal was carried out to remove canary grass seedlings that had emerged at the same time as wheat seedlings. After that, thinning operation was carried out to obtain a uniform density of wheat plants in all of the plots (about 150 wheat plants/m^2). After the canary grass plants reached the desired stage (the two-leaf stage), they were also thinned to reach the density of the related treatment. The treatments are described in Table 1. During the growing season, pest, diseases, and other weeds were controlled using manual control operations.

Harvesting was performed by hand. Seven plants were selected from each plot and cut at ground level using a sickle. Wheat plants were counted at the same time the crop was harvested.

Table 1. Description of the treatments

Treatment No.	1	2	3	4	5	6	7	8	9	10	11	12	13
Abbreviation	A1	A2	A3	A4	A5	A6	A7	B1	B2	B3	B4	B5	B6
Notes	Weed removal at wheat germination	Weed removal 4 weeks after wheat germination	Weed removal 8 weeks after wheat germination	Weed removal 12 weeks after wheat germination	Weed removal 16 weeks after wheat germination	Weed removal 20 weeks after wheat germination	Competition until wheat harvest	No Weed present (control)	20 weed plants per square meter	40 weed plants per square meter	80 weed plants per square meter	160 weed plants per square meter	320 weed plants per square meter

Notes: A: Removal time; B: Weed density (number of weed plants per square meter)

Seven plants were selected and harvested from each plot to measure the studied characters. The height of the main stem of each plant was measured from the ground level up to the spike (the spike node) using a tape measure. The average height of the seven main stems was considered as the height of the main stems of the plants in the plot. The number of tillers in these seven plants were counted and divided by seven to determine the number of tillers per plant in the plot. The number of seeds per plant was counted and divided by the number of spikes in the plant to find the number of seeds per spike. Four 100-seed samples were taken and weighed and the average weight was multiplied by 10 and considered the average 1000-seed weight. The samples were then taken to the laboratory and dried for 24 hours in an oven at 90 degrees to determine the other characters (such as the seed yield, the dry weight of the stubble, and the harvest index). Duncan's multiple range test was used for analysis of the variance, the SAS software for the correlations between the characters, the MSTAT-C software for the determination of the interaction effects of the characters, and the SlideWrite software for drawing the Figures and the figures.

RESULTS AND DISCUSSION

The tables of analysis of the variance, comparison of the means, and comparison of the means of interaction effects were used to analyze the characters studied including stem height, number of fertile tillers/m^2, number of seeds/m^2, 1000-seed weight, seed yield, dry weight of stubble, and harvest index. The obtained results are presented in the related tables.

Stem height

According to the table of analysis of the variance, wheat stem height is influenced by the time of removal of the weed and by its density at the one percent level of probability (Table 2). On this basis, the tallest stems (108.06 cm) belong to the A1treatment (weed removal at wheat germination), and the shortest (91.38 cm) to the A7 treatment (competition until wheat harvest) (Table 3).

The table of comparison of the means of the effects of the weed density on the character of stem height indicates the tallest wheat plants (104.07 cm) are those of the B6 treatment (320 weed plants/m^2), and the shortest (100.39 cm) to the B6 treatment (40 weed plants/m^2). Furthermore, the results in this table reveal that, with respect to wheat stem height, the various densities of the weed (up to 160 weed plants/m^2) exhibit no statistical differences with the control treatment (lack of weeds). It is only in the B7 treatment (320 weed plants/m^2) that wheat stem height somewhat increases and shows differences with that of the plants in the control treatment (Table 4).

Table 2. Analysis of the variance of the morphological characters and yield components at physiological maturity

Mean Squares

Sources of variation	DF	Stem height (cm)	No. of tillers/m^2	No. of Seeds/m^2	No. of seeds per spike	1000-seed weight (g)	Seed yield (g.m^2)	Dry weight of stubble (g.m^2)	Harvest Index (%)
Block	2	12.13	1234.02	3064246.54	10.4	0.38	3501.14	16842.85	1.74
Time of weed removal	6	506.39**	39676.59**	64143434.06**	57.97**	15.9**	207582.54**	226682.56**	77.1**
Block × time of weed	12	18.71	1034.25	1803821.16	21.71**	3.55	5212.71	20739.73**	10.21
removal	5	39.56**	22372.6**	39946264.99**	35.97**	14.4*	72243.75**	22496.69**	74.26**
Weed density	30	18.56	2832.73**	3205246.31	1.93	11.05**	7524.66**	24896.01**	24.83**
Time of weed removal × weed density	10	25.13*	1089.25	2404787.23	7.57	6.03	6834.99	5812.7	6.99
Block × weed density									
Coefficient of Variation (%)		3.46	4.49	13.05	14.1	4.45	11.49	12.39	7.94

The symbols * and ** indicate significance at the 5 and 1 percent probability levels, respectively

Table 3. Comparison of the means of the simple effect of weed removal time on the measured characters

Character/weed removal time	Stem height (cm)	Number of Tillers/m^2	Number of seeds/m^2	Number of seeds per spike	1000-seed weight (g)	Seed yield (g/m^2)	Dry weight of stubble (g/m^2)	Harvest Index (%)
At wheat seed germination	108.063 a	787.5 a	16297.9 a	22.647.a	46.75 a	704.87 a	958.41 a	43.887 a
4 weeks later	105.926 a	717.35 b	14397.6 b	21.686 ab	46.16 ab	698.9 a	904.8 a	43.45 ab
8 weeks later	102.260 a	713.53 bc	13322.2 c	20.264	45.7 bc	565.36 b	863.73 ab	41.993 abc
12 weeks later	101.388 b	690.47 cd	128126.5 c	abc	45.45 bc	548.66 b	783.61 bc	41.03bcd
16 weeks later	100.477 b	671.43 d	12713.5 c	20.094	45.35 bc	542.09 b	738.17 cd	40.096 cd
20 weeks later	100.004 b	667.49 d	114972.6 d	abc	45.16 c	440.84 c	696.75 cd	39.083 d
Competition until wheat harvest (Weeds not removed)	91.381 c	644.05 e	1052.2 e	19.965 abc 18.356 bcd 17.407 cd	45.04 d	439.96 c	656.23 d	38.547 d

Figures in the same column having common letters are not significantly different (statistically) at the five percent probability level

Table 4. Comparison of the means of the simple effect of weed density on the characters measures

Character/ weed density	Stem height (cm)	Number of Tillers/m^2	Number of seeds/m^2	Number of seeds per spike	1000-seed weight (g)	Seed yield (g/m^2)	Dry weight of stubble (g/m^2)	Harvest Index (%)
Control (no weeds)	101.034 b	752.55 a	15113.3 a	21.76 a	47.56 a	670.05 a	842.45 a	44.16 a
20 weed plants/m^2	101.265 b	710.581 b	14241.3 a	21.15 a	46.88 ab	596.77 b	832.93 a	42.71 ab
40 weed plants/m^2	100.393.b	697.522 bc	12879.6 b	20.34 ab	46.07 bc	543.95 c	805.1 a	40.71 bc
80 weed plants/m^2	100.476 b	696.937 bc	12786.1 b	19.92 ab	46 bc	538.48 c	788.98 a	40.21 c
160 weed plants/m^2	100.898 b	681.108 c	12102.3 bc	18.69 b	45.72 bc	518.42 c	768.44 ab	39.72 c
320 weed plants/m^2	104.076 a	654.293 d	11363.7 c	18.48 b	45.27 c	509.7 c	763.57 ab	39.4 c

Figures in each column having common letters are not significantly different (statistically) at the five percent probability level.

As can be seen in the table of correlation between the characters (Table 5), wheat stem height is correlated with characters such as seed yield, number of seeds per spike, number of seeds/m^2, and number of tillers per plant. The strongest correlation is observed between wheat stem height and seed yield. This relates to the fact that the taller wheat plants are in their competition with weeds, the more successful they will be in producing an acceptable yield. The weakest correlation exists between wheat stem height and the number of tillers per plant because, under conditions of competition with weeds, wheat plants cannot both increase their stem height and raise the number of their tillers. Therefore, the number of tillers declines (compared to conditions where there is no competition with weeds) with a rise in stem height. This weak correlation could also be due to changes in the quality of the incident light (i.e., it could result from a reduction in the ratio of the red light to the far red light. This ratio is the effective factor in increasing cell size, but not cell number, and is considered one of the mechanisms plants use to escape from shade (Rohris and Stunzel, 2001).

Table 5. Correlations of characters measured

Character	Stem height (cm)	Number of Tillers/m^2	Number of seeds/m^2	Number of seeds per spike	1000-seed weight (g)	Seed yield (g/m^2)	Dry weight of stubble (g/m^2)	Harvest Index (%)
Harvest index (%)	0.12	0.11	0.32**	0.3**	0.07	0.56**	-0.2**	1
Dry weight of stubble(grams per	0.55**	0.55**	0.63**	0.53**	0.14	0.67**	1	
square meter)	0.54**	0.56**	0.78**	0.67**	0.15	1		
Seed yield (grams per square meter)	0.1	0.005	0.14	0.12	1			
1000-seed weight (grams)	0.42**	0.35**	0.61**	1				
Number of seeds per spike	0.47**	0.51**	1					
Number of seeds per square meter	0.18	1						
Number of tillers per square meter	1							
Stem height (centimeters)								

The symbols * and ** indicate significance at the level of probability of one and five percent, respectively

Number of fertile tillers

The table of analysis of the variance reveals that the number of fertile wheat tillers/m^2 is affected by the time of removal of the weed and by its density, and by the interaction effects of the treatments (at the probability level of one percent error) (Table 2). The largest number of tillers produced (787.5 tillers/m^2) belonged to the A1 treatment (removal of weeds at wheat seed germination), and the smallest (644.05 tillers/m^2) to the A7 treatment (competition until wheat harvest) (Table 3).

The number of fertile tillers/m^2 is correlated with characters such as stem height, seed yield, number of seeds/m^2, number of seeds/spike, and dry weight of stubble (Table 5). Among these correlations, the significant one is that between the number of tillers/plant and the seed yield, which shows the important point that the larger the number of fertile tillers/plant is the greater the correspondent rise in seed yield will be. One of the notable features observed in this table is the strong correlation of the number of tillers/plant and the dry weight of stubble. In fact, the number of tillers per plant is a morphological character, and an increase in morphological characters causes a rise in crop plant biomass. As for the effects of weed density on the number of fertile wheat tillers per plant shown in the table, it can be seen that the maximum number of tillers/ plant belongs to the B1 treatment (no weed present in the field), and the minimum to the B6 treatment (320 weed plants/m^2) (Table 4).

Wheat is one of the plants that produce more tillers if they have more space available, and the less the space available to them is the fewer tillers they produce (either because of their competition with weeds or due to the excessive number of wheat plants/m^2) (Iqball and Wright, 1999).

Number of seeds per spike

The table of analysis of the variance shows that differences in the time of weed removal and in the density of weeds were significant with respect to the number of seeds per spike at the probability level of one percent error (Table 2). The largest number of seeds (22.64 seeds per spike) was that of the treatment of weed removal at wheat seed germination (A1), and the smallest (17.407 seeds per spike) that of the treatment of competition until wheat harvest (A7) (Table 3). Results of this table indicate that this character depends more on the genetic features of the crop plant and that environmental factors have little effect on it. The evidence for this is that the trend of the decline in the number of seeds per spike at different times of the canary grass weed removal (up to 16 weeks after wheat emergence) did not become significant, and only weed removal in the final weeks after wheat emergence caused a significant decline in this character.

The table of comparison of the means (Table 4) revealed that the maximum number of seeds per spike (21.76) was that of the treatment without any weed, and the minimum (18.69) that of the treatment of 320 weed plants/m^2. The numbers of seeds per spike for six weed densities are shown in Digram1. Cousens (1988b) reported that high densities of downy brome (*Bromus tectorum*) greatly affect the number of wheat seeds per spike.

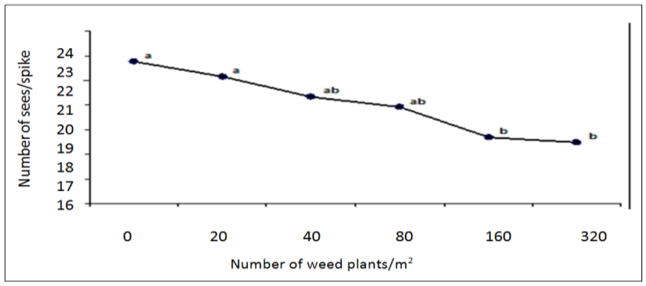

Figure 1. The effects of canary grass densities on the number of wheat seeds per spike

Number of seeds/m²

This character was influenced by weed removal time and by weed density (at the probability level of one percent) (Table 2).The largest number of seeds/m^2 (16297.9) belonged to the treatment of weed removal at wheat seed germination, and the smallest (10526.2) to the treatment of competition until wheat harvest (Table 3). The rise in this character with weed removal at wheat seed germination can be attributed to the increase in the number of wheat seeds per spike. As can also be observed in Table 5, there is a strong correlation (r = 0.61) between the characters of the number of seeds/m^2 and the number of seeds per spike, which confirms what was said above.

As for the effects of the treatments of weed densities on this character, the highest number of wheat seeds/m^2 (15113.3) was that of the treatment of no weed present (B1) , and the lowest (11363.7) to the treatment with the highest weed density (B6) (Table 4). The correlation between the number of wheat seeds/m^2 and the number of wheat seeds per spike (61 %) was greater than that between the number of seeds/m^2 and the number of tillers/m^2 (51 %). Weed control and prevention of competition between wheat and weed plants could substantially increase the number of seeds/m^2 compared to lack of weed control and competition between wheat and weed plants (Table 5).

One-thousand seed weight

According to the table of analysis of the variance (Table 2), 1000-seed weight was affected by the treatments of the time of weed removal, weed densities, and by their interaction effects as well. The table of the comparison of the means shows that the largest 1000-seed weight (46.75 g) belonged to the treatment of weed removal at wheat seed germination, and the smallest (45.04 g) to the treatment of competition until wheat harvest (Table 3). Moreover, the maximum 1000-seed weight as affected by weed density was observed in the control treatment (no weed plants) with 47.56 g, and the minimum in the treatment of 320 weed plants/m^2 with 45.27 g (Table 3).These results are in agreement with those found by Mirshekari 2006).

Seed yield

This character was influenced by the time of weed removal, the density of weeds, and their interaction effects at the probability level of one percent (Table 2). The largest seed yield (704.86 g/m^2) was that of the treatment of weed removal at the time of wheat seed germination, and the smallest (493.96 g/m^2) that of the treatment of not removing the weed plants (competition until wheat harvest) (Table 3). It is reasonable for the seed yield to reach its maximum in the treatments in which the number of fertile tillers/m^2, the number of seeds per spike, and the number of seeds/m^2 are statistically at their maximum values (Table 5). This suggests a reduction in the competition of weed plants with the main crop, and indicates the optimal use of plant nutrients and light by the crop plant as well. In other words, the sooner the weeds are removed at the early stages of the growth of the crop plant, the more the crop plant can optimally use the resources available in the environment, and the more easily it is able to compensate for the reduction in its yield resulting from the competition of the weeds. The longer this weed removal is delayed, the more pronounced the reduction in yield will be, and the harder it will be (it may even be impossible) for the crop plant to compensate for the damage caused by the competition of the weeds. The reduction in seed yield did not become significant up to the maximum of four weeks after wheat seed germination, suggesting that canary weeds have to be removed no later than four weeks after wheat seed germination to achieve a suitable yield (because from four weeks after wheat seed germination on, failure to remove canary plants will reduce yield).

The table of correlation of the characters (Table 5) clearly indicates the correlation between yield and yield components. As can be seen in the table, seed yield shows the strongest correlation with the characters of the number of fertile tillers/m^2, the number of seeds per spike, and the number of seeds/m^2. The mentioned characters are yield components and a reduction or an increase in them will directly influence yield. As for the effect of weed density on seed yield, the highest seed yield (670.05 g/m^2) was that of the treatment with no weeds, and the lowest (509.7 g/m^2) that of competition until wheat harvest (Table 4). These results reveal that reductions in yield happen because of increases in the densities of canary grass up to 40 weed plants/m^2, and that reductions in yield caused by densities from 40 to 320 weed plants/m^2 are not significantly different. This demonstrates that canary grass density must be kept at its lowest level because increases in its density will limit the space, light, and water available to the crop plant.

The tables of comparison of the means of the times of removal of canary grass and of the densities of this weed (Tables 3 and 4) indicate that wheat yield is more affected by the time of removal of canary grass than by its density. That is, in this research, the time of removal of canary grass influenced wheat yield more than its density. In Figure 2, the effect of the time of removal of canary grass on wheat yield is shown. Afentouli and Eleftherohorinos (1999) found that the density of 150 canary grass plants/m^2, if present until the early part of the first month of spring and then eliminated, will not influence wheat yield but that, if this same density is present until the end of the growing season, wheat yield will decline by 26 percent.

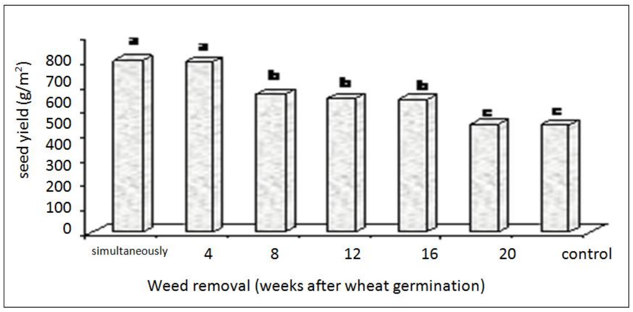

Figure 2. The effect of removal time of canary grass on wheat seed yield

Dry weight of stubble

This character, which is a component of the biological yield of crop plants, is influenced by the effects of the treatments of weed removal and weed density, and by their interaction effects as well, at the one percent level of probability of error (Table 2).

According to the table of the comparison of the means, the maximum dry weight of stubble (958.41 g/m^2) belonged to the treatment of weed removal at wheat seed germination, and the minimum (656.23 g/m^2) to the treatment in which weeds were not removed (Table 3). It seems that if germination of weed seeds is delayed, the time when resources become limited will be postponed and the intensity of the resulting limitation will be reduced as well. As for the effect of the densities of the weed on the dry weight of stubble, the largest dry weight of stubble (842.45 g/m^2) was that of the treatment without weeds (B1), and the smallest (763.57 g/m^2) that of the treatment with 320 weed plants/m^2. It must be added that all of the figures obtained showing the effects of the various weed densities could be placed in one statistical group, meaning that there were no significant differences between them (Table 4). We can infer from the results that the time of eliminating the weeds has a greater influence than weed density on the dry weight of stubble, and that the combined effects of weed intensity and duration of competition between weeds and plants cause considerable decreases in the biomass of the crop plant. As can be seen in Table 5, there is a negative correlation between the dry weight of stubble and the harvest index: with increases in plant biomass, less dry matter is allocated to the main sink (the seeds). Dry weight of stubble has strong correlations with height of plants and with the number of tillers (Table 5). This indicates that the greater the magnitudes and quantities of morphological characters of the crop plant are, the more its biomass will increase (Figure 3). Percentage light absorption and the quantities of dry matter produced in the control treatments in which sorghum grew without the presence of weeds were higher than the corresponding values of treatments in which sorghum grew in the presence of weeds (Irawati, 2003).

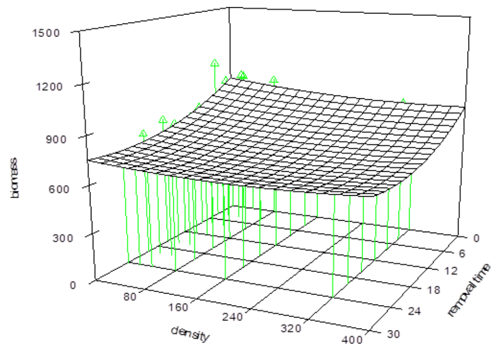

Figure 3. The interaction effects of removal time of canary grass and of its density on wheat biomass

Harvest index

Table of analysis of the variance indicates that harvest index was influenced by removal time of weed, by weed density, and by their interaction effects, and that these effects were significant at the one percent error level (Table 2). The table of comparison of the means reveals that the highest harvest index (43.88 percent) was observed in the treatment of removing weeds at wheat seed germination, and the lowest (38.54 percent) in the treatment of competition until wheat harvest. The increase in the harvest index in the treatment of removing the weeds at germination of wheat seeds can be attributed to the increase in economic yield (Table 3). At low weed plant densities the harvest index rose due to decreased competition (which led to increases in seed yield), and with rises in the number of weed plants/m^2, competition increased leading to decreases in seed yield (which resulted in lower harvest indices). When the number of weed plants/m^2 rises, the crop plant allocates more photosynthates to its vegetative organs so it can increase its competitive power. That is, the crop plant tries to increase its height and the number of its tillers to compete more successfully with weed plants. Therefore, the biological yield of the crop plant increases compared to its economic yield, which will lead to a decline in the harvest index of the crop plant. In our experiment, the largest harvest index was obtained in the treatment in which no weed plants were present, and the smallest in the treatment in which there were 320 weed plants/m^2 (Table 4).

The table of the correlation of characters (Table 5) indicates that there are positive correlations between the harvest index and the number of seeds/m^2, the number of seeds per spike, and the seed yield, and that there is a negative correlation between the harvest index and the biomass. These results are logical and expected because harvest index has positive correlations with characters that increase yield and negative correlations with characters that decrease yield. Rises in the ratio of yield to biomass increase the harvest index, and decreases in this ratio lower the harvest index.

REFERENCES

Afentouli GC and Eleftherohorinos IG. 1996. Littleseed canarygrass (*Phalaris minor*) and short spiked canarygrass (*Phalaris brachystachys*) interference in wheat and barley. Weed Sci. 44: 560-565.

Afentouli GC and Eleftherohorinos IG. 1999. Competition between wheat and canarygrass (*P. minor*) biotypes and their response to herbicides. Weed Sci. 47: 55-61.

Balyan RS and Malik RK. 1989. Influence of nitrogen on competition of wild canarygrass (*Phalaris minor* Ritz.) in wheat pestology. 13: 5-6.

Bell CE. 1992. Little seed canarygrass control in cereal grains. Res. Prog. Rep. West. Soc. Weed Sci. pp. 232-233.

Cousens R, Firbank LG, Mortimer AM and Smith RGR. 1988$_b$. Variability in the relationship between crop yield and weed density for winter wheat and *Bromus sterilis*. J. Applied Ecology, 25:1033-1044.

Cudney DW and Hill JE. 1979. The response of wheat grown with three population levels of canarygrass to various herbicide treatments. Prog. West. Soc. Weed Sci. 32: 55-56.

Godinho I and Costa JCA. 1981. Competition of *Phalaris minor* in wheat. 1st Congress Portuguese de Fitiatria e de Fitofarmacologia e III Simposio Nacional de Herbologia, 3: 237-243.

Hartzler B and Bahler DD. 1999. Initial dates of weed emergence. Iowa State University. Department of Agronomy. Weed Sci online.

Hejazi A, Rahimian Mashhadi H, Torkamani A and Shahroodi M. 2000. Determination of critical periods for controlling weeds in sunflower, Proceeding 6th Congress on Agronomic Sciences and Plant Breeding of Iran, Babolsar University.

Iqbal J and Wright D. 1999. Effects of weed competition on flag leaf photosynthesis and grain yield of spring wheat. J. Agric. Sci. 132:23-30.

Irawati C, Acram T and Robin J. 2003. Weed interference in soybean (*Glycine max* L.). Proc. Of 11th Aust. Agro. Conf., Gee long.

Khera KL, Sandhu BS, Aujla TS, Singh CB and Kumar K. 1995. Performance of wheat (*Triticum aestivum*) in relation to small canarygrass (*Phalaris minor*) under different levels of irrigation, nitrogen and weed population. Indian J. Agric. Sci. 65: 717-722.

Mehra SP and Gill HS. 1988. Effect of temperature on germination of *Phalaris minor* retz and it's competition in wheat. Punjab agric univ. Res. J. 25: 529-533.

Mirshekari B, Javanshir A, Dabbagh Mohammadi Nasab A, Noormohammadi GH and Rahimian Mashhadi H. 2006. Ecophysiological study of interference of *Amaranthus retroflexus* L. with three sunflower cultivars, PhD. Thesis, the Sciences and Research Unit of the Islamic Azad University.

Montazeri M. 1993. Evaluation of a few wheat selective grass herbicides at two times of application on canarygrass (*Phalaris minor*) and wild oat (*Avena sterilis*). Proc. Indian Society of weed science Int. Symp. On Integrated weed management for sustainable Agriculture, Hisar, India, vol. 2, 18-20 November, pp. 166-167.

Rahimian H and Banayan M. 1996. Biological control of weeds, translation, Ferdowsi University of Mashhad Publications.

Rohris M and Stunzel H. 2001. Canopy development of *Chenopodium album* in pure and mixed stands. Weed Res. 41: 111-128.

Samunder S, Kirkwood RC and Marshall G. 1999. Biology and control of *Phalaris minor* Retz. (littleseed canarygrass) in wheat. A Review Article. P. 1.

Singh S and Malik RK. 1994. Effect of application methods of chlorotoluron on the control of *Phalaris minor* in wheat (*Triticum aestivum*). Indian J. Agron. 39: 23-26.