IRANIAN WINTER WHEAT'S (*Triticum aestivum* L.) INTERFERENCE WITH WEEDS: I. GRAIN YIELD AND COMPETITIVE INDEX

Mohammad Ali Baghestani[1], Eskandar Zand and Saeid Soufizadeh

ABSTRACT

Competitive ability of Iranian winter wheat genotypes against weeds were studied in three separate experiments during 1999 to 2002 growing seasons at Plant Pest and Disease Research Institute, Karaj. All experiments were conducted in a randomized complete block design with factorial arrangement of treatments and four replications. In the first experiment, 12 wheat genotypes were studied under weed free and natural spectrum of weed infestation. In the second and third experiments, six genotypes of most and least competitive ability in the first experiment were selected and grown in the absence and presence of Avena ludoviciana (wild oat) at 80 plants m^{-2} and Goldbachia laevigata at 30 plants m^{-2}. Results of first experiment showed significant differences in weed suppressive ability among wheat genotypes. According to the results of this experiment 6618, M-75-15 and M-75-13 genotypes were selected as the most, and Alamout, Qafqaz and M-75-5 were selected as the least competitive genotypes. Grain yield of 6618 genotype not only did not decrease under weed infestation but also increased. On the other hand, this genotype caused the highest reduction in weed biomass compared with other genotypes, indicating that it may be considered as both a weed tolerant and a weed suppressive crop. In second and third experiments, 6618 and M-75-5 genotypes were also selected as the most and least competitive genotypes, respectively. Overall results of the three years of experiment show that the stability of CI in 6618 genotype was more than all the others and it can be introduced as a genotype having high competitive ability against weeds especially A. ludoviciana and G. laevigata. In contrast, competitive ability of M-75-5 genotype compared to other genotypes was the least but stable. The results of these experiments also revealed that wheat competitive ability depend heavily on the range of genotypes used and the magnitude of the environmental and genotype×environment variation.

Key words: Competitive ability, *Goldbachia laevigata*, wild oat.

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[1]Department of Weed Research, Plant Pest and Disease Research Institute, P.O. Box 19395-1454, Tehran, Iran. Corresponding author E-mail address: baghestani@hotmail.com (M.A. Baghestani)

INTRODUCTION

Yield loss due to weed competition in Iranian wheat fields has been reported to be about 21% (Montazeri *et al.* 2005). Over the last three decades wheat production in many parts of the world has relied heavily on herbicide as the primary method of weed management (Montazeri *et al.* 2005). But environmental safety concerns, increasing occurrence of herbicide resistance in weed species, and the need to reduce input costs have caused a growing awareness that intensive use of chemical weed control does not fit well in sustainable agriculture systems (Wyse, 1994). Pest tolerant improved crops would be a useful tool to reduce dependence on pesticides. Although insect- and disease-tolerant crops have long been selected and used in crop production systems, research efforts have only recently focused on crop tolerance to weeds (Ngouajio *et al.* 2001; Lemerle *et al.* 2001). If a crop cultivar can tolerate weeds, it may reduce the need for synthetic herbicide (Gealy *et al.* 2003), allow the use of less costly and more environmentally sound herbicides (Wicks *et al.* 1994; Pester, 1991), decrease the number of cultivations, or improve yield stability in weedy fields (Wyes 1994; Lindquist and Mortensen, 1998).

Planting a more competitive wheat cultivar has been suggested as a cultural practice to suppress weed growth (Ogg and Seefeldt, 1999). Researchers have shown that differences in weed competitiveness of crop cultivars are the rule rather than the exception (Callaway, 1992). There are many crops with examples of cultivar tolerance to weed, including soybean (Burnside, 1972; Bussan *et al.* 1997), rice (Gealy *et al.* 2003; Gibson *et al.* 2003; Ni *et al.* 2000), canola (Zand and Beckie, 2002), cotton (Bridge and Chandier, 1988), tomato (Ngouajio *et al.* 2001) and wheat (Callaway, 1992; Baghestani *et al.* 1999; Lemerle *et al.* 2001; Ogg and Seefeldt, 1999; Zand *et al.* 2001). The competitive ability of a crop can be measured either as suppression of weed growth and seed production by the crop (competitive index), or as crop yield loss, which is the ability of the crop to tolerate weed presence and maintain grain yield, 'crop tolerance' (Goldberg, 1990; Jordan, 1993). Jordan (1993) stated that a competitive cultivar should maintain its yield when competing with weeds (low weed interference) and at the same time, reduce the growth and seed production of the weeds against which it is competing. In the study conducted by Challaiah *et al.* (1986), the most competitive winter wheat cultivar (Turkey) had the smallest percent yield reduction when competing against downy brome (*Bromus tectorum* L.) and reduced the biomass of the downy brome more than other less competitive cultivars. Lemrele *et al.* (2001) have determined that crop competitive ability may be negatively associated with its yield, particularly under weed-free environment. In UK, wheat varieties that produced the greatest grain yield in weed free plots were the most severely affected by weed competition (De Lucas and Froud-Williams, 1976). In contrast, in Australia no relationship was observed between weed free yield and percent yield loss (Lemerle *et al.* 1996a, 2000; Cousens and Mokhtari, 1998; Gill and Coleman, 1999; 2000). But although there have been previous studies of varietal differences in competitiveness of wheat, including attempts to correlate morphology with crop yield reduction (Moss, 1985; Challaiah *et al.* 1986; Wicks *et al.* 1986; Lemerle *et al.* 1996a), these have examined only a small part of the available gene pool.

Few studies have been conducted to determine the competitiveness of Iranian winter wheat cultivars against weeds. Our objectives were to investigate the interference between Iranian winter wheat cultivars and weeds.

MATERIALS AND METHODS

A three year experiment (one preliminary and two supplementary) was conducted during 1999 to 2002 growing seasons, at Plant Pest and Disease Research Institute, Karaj (35° 59′ N 52° 60′ E, 1160 masl), Iran on a sandy clay soil. Each year the experimental area was plowed and followed by two disking in the fall to prepare the seedbed for planting. The mean annual rainfall is 250mm and the climate is arid. Long term mean, maximum and minimum annual temperatures are 13.7, 41 and –21.7°C, respectively. All the experimental fields were fallowed during previous year.

1. Preliminary experiment (1999-2000 growing season)

The experiment was laid out in a randomized complete block design with a factorial arrangement and replicated four times. Treatments consisted of 12 wheat genotypes (Navid, Qafqaz, Niknejad, Mahdavi, Marvdasht, Alamout, M-75-17, M-75-5, M-75-13, 6517, and 6618), each kept under weedy and weed free conditions. Naturally occurring weed populations were used in the experiment. Weed species in order of dominance were wild oat (*A. ludoviciana*), *G. laevigata*, brome grass (*Bromus* sp.), wild rye (*Secale cereale*), and ryegrass (*Lolium rigidum*). But, *A. ludoviciana* and *G. laevigata* comprised about 90 percent of the total weed population. Ammonium phosphate and urea were applied at rates of 150 and 100 kg ha^{-1} based on soil analysis, respectively, prior to seeding. Top dress of urea was applied at tillering and heading stages at rate of 50 kg ha^{-1} at both stages.

The wheat genotypes seeds were obtained from Cereal Research Section of Iranian Seed and Plant Improvement Institute, Karaj, Iran. Wheat was sawn at a density of 400 viable seed m^{-2}. Each plot consisted of four rows, 9m in length with a 0.60m inter row spacing, and each planted to two rows of wheat on Oct 22, 1999. A full irrigation, and pest and disease program were employed so that at no time during growing season these factors appear to constrain yield.

The crop and weed were harvested on 5 June 2000. Harvested area in each plot was 2.4 m^2 (2m of the 4 center rows). Harvested materials were separated into weed and wheat, and weed biomass, wheat biomass and grain yield were determined. Percent wheat grain yield reduction was also calculated as the proportion of wheat grain yield under weedy condition to the same amount under weed free condition, minus one and multiply by 100. Competitive ability of the wheat cultivars with weeds were calculated from the following equation (Challaiah *et al.* 1986; Zand *et al.* 2001):

$$CI = \frac{Var_i}{Var_{mean}} / \frac{Weed_i}{Weed_{mean}}$$

Where Var_i is the yield of genotype *i* in the presence of weed, Var_{mean} is the mean yield of all genotypes in the presence of weed, $Weed_i$ is the weed biomass related to genotype *i* and $Weed_{mean}$ is the mean weed biomass at mixture with all genotypes.

Finally, three genotypes with high competitive ability and three genotypes with low competitive ability were selected and used for the supplementary experiments.

2. Supplementary experiments (2000-2001 and 2001-2002 growing seasons)

Due to the results from the preliminary experiment, M-75-15, M-75-13 and 6618 were selected as genotypes with high competitive ability and Alamout, Qafqaz and M-75-5 were selected as low competitive ability genotypes, and were applied for the supplementary experiments.

Plots were fertilized with 150 kg ha^{-1} ammonium phosphate and 50 kg ha^{-1} potassium sulfate prior to seeding. Nitrogen fertilizer was applied as urea at the same times and rates as the preliminary experiment. Wheat seeding procedure, rate and planting pattern were similar to that of the preliminary experiment. *A.ludoviciana* and *G. laevigata* (the two dominant weed species in the preliminary experiment) seeds were sown simultaneously with wheat and later thinned to 50 and 30 plants per m^2. It should be mentioned that seed viability of *A. ludoviciana* and *G. laevigata* were 32 and 80%, respectively. Planting dates were September 8 in 2000, and September 5 in 2001. During the growing season, all weed species except *G. laevigata* and *A. ludoviciana* were hand weeded.

The experiments were conducted using a factorial arrangement in a randomized complete block design replicated four times. Experimental treatments consisted of 6 wheat cultivars and 2 levels of weed species (*Goldbachia laevigata* and *Avena ludoviciana*). Moreover, two additional plots of pure stands of wheat, *G. laevigata*, and *A. ludoviciana* were included in the experimental treatments.

Final harvest was performed on June 7 and June 22 in 2001 and 2002, respectively. Harvest area was 2.4m^2 (1m long of 2nd and 3rd rows). Harvested plants were separated into wheat and weed, oven-dried at 75°C for 48 hours to obtain uniformity in moisture and weighed. Grain yield was also measured. In these experiments the same methodology was used for measuring weed biomass, grain yield, wheat biomass and competition index as the preliminary experiment.

All data were analyzed using PROC GLM procedure in SAS software (SAS Institute, 1996). Means separation test was performed using Duncan multiple range test (DMRT). Since the interaction between experimental treatments and year of experiment was significant in the supplementary experiment, data were analyzed separately for each location.

RESULTS AND DISCUSSION

1. Preliminary experiment (1999-2000 growing season)

Weed biomass was significantly affected by wheat genotypes (Table-1). Maximum weed biomass was obtained from the plots in which M-75-5 genotype was planted. In contrast, the plot planted by 6618 genotype produced the least weed biomass but was not significantly different with those of M-75-13, Mahdavi and Niknejad genotypes (Table-1). Also, significant differences existed among wheat cultivars under weed free and weedy conditions (Table-1). Under weed-free condition, the genotypes Alamout and Qafqaz produced the highest and lowest grain yields, respectively. But under competition with weeds, Alamout ranked amongst the lowest yielding wheat genotypes, indicating that this genotype is not a good competitor of weeds. The highest yielding genotype under weed infested condition was 6517, which was significantly different with all other genotypes. Our finding is in agreement with those of De Lucas and Froud-Williams (1976) in UK who found that wheat varieties produced the highest grain yield in weed free plots were the most severely affected by weed competition. Nonetheless, Lemerle et al. (2001) stated that the degree of association between wheat competitive ability and weed free yield depend heavily on the range of genotypes used and the magnitude of the environmental and genotype×environment variation. Percent grain yield reduction was the highest in Alamout (21%) compared to other cultivars (Table 1). This shows that Alamout is not a weed tolerant genotype. Van Heemst (1985) reported that mean wheat yield loss from weeds was 25%. In his investigation on the competitive ability of 10 wheat cultivars, Challaiah *et al.* (1986) reported that yield losses between the varieties ranged from 9 to 21% at one site to 20-41% at the other. Surprisingly, grain yield of 6618, 6517, M-75-13, M-75-15, and Niknejad genotypes not only did not decrease under weed competition but also increased in this condition (Table-1). This is perhaps because under weed-free condition, sufficient availability of resources like light and nutrients cause wheat to produce more tillers resulting in a consequent source limitation in reproductive stage, an increase in tiller infertility and poor grain filling (Hay and Walker, 1989). But all other cultivars showed lower grain yield under weed infested condition, the highest reduction belonged to Alamout cultivar. But under weedy condition and due to the interplant competition, although fewer tillers are produced but the plant is capable to fully develop their tillers.

Significant differences were observed among CI of different wheat genotypes (Table-1). The genotype 6618 had the highest CI significantly different from all other genotypes. This can be attributed to the high grain yield of this genotype under competition with weeds. This is accompanied by very low weed biomass in the presence of this genotype, which shows the genotype capability to suppress weeds successfully. In the study conducted by Challaiah *et al.* (1986), the most competitive winter wheat cultivar (Turkey) had the smallest percent yield reduction when competing against downy brome (*Bromus tectorum* L.) and reduced the biomass of the downy brome more than other less competitive cultivars. Goldberg (1990) has stated that a competitive crop can be defined as either a crop that maintains its yield well in the presence of weeds (tolerance to weed pressure) or as one that is able to reduce weed growth significantly (weed suppressive ability). As a result this genotype may be considered as both a weed tolerant and a weed suppressive crop. The genotypes M-75-5, Qafqaz, 6517, Navid and Alamout had the lowest CI, respectively, and there were no significant differences among these genotypes in this respect (Table-1). In fact, these genotypes could not reduce weed biomass considerably, indicating their poor suppressive ability. As observed, although the genotype 6517 had a yield increase under weed infested condition (weed tolerant crop) but it was not able to reduce weed biomass compared to other genotypes which is consistent with findings of De Lucas and Froud-Williams (1976). Totally, wheat genotypes used in the preliminary experiment were ranked according to their CI into four groups: (*i*) genotypes with high grain yield and high weed biomass (6517, Marvdasht, Navid); (*ii*) genotypes with high grain yield but low weed biomass (M-75-13, 6618, M-75-15); (*iii*) genotypes with low grain yield but high weed biomass (M-75-15, Qafqaz, Alamout); and (*iv*) genotypes with low grain yield and low weed biomass (M-75-17, Mahdavi, Niknejad).

Table-1. Weed biomass, wheat grain yield under weedy and weed free conditions, percent grain yield reduction and competitive index in the preliminary experiment (1999-2000).

Treatments	Weed biomass ($g\ m^{-2}$)	Grain yield weed free ($kg\ ha^{-1}$)	Grain yield infested ($kg\ ha^{-1}$)	Grain yield reduction (%)	CI
Alamout	664d*	5337a	4178e	-21.70	0.77ef
Marvdasht	576d	5113b	4859c	-4.96	1.02de
Navid	806c	5112b	4801c	-6.09	0.74ef
M-75-13	314ef	4992bc	5332b	+6.79	2.18b
M-75-15	380e	4925cd	5153b	+4.62	1.68c
6517	1044b	4921cd	5582a	+13.42	0.66ef
M-75-5	1258a	4852cde	4471d	-7.85	0.43f
Niknejad	287ef	4746de	4905c	+3.34	2.10bc
Mahdavi	289ef	4723ef	4697cd	-0.56	2bc
6618	197f	4671ef	5349b	+14.5	3.36a
M-75-17	430e	4557f	4486d	-1.56	1.32d
Qafqaz	916bc	4072g	3992e	-1.97	0.54f

*In each column, means followed by same letter(s) do not differ significantly by DMRT at $\alpha_{0.05}$.

2. Supplementary experiments (2000-2001 and 2001-2002 growing season)

Genotype 6618 yielded the most under weed free condition in both years of experiment (Table-2). Significant differences existed between this genotype and the others in this respect in 2000-2001. However, there were not any significant differences in grain yield between this genotype, and Alamout, M-75-13 and M-75-15 in 2001-2002. The lowest grain yield under weed free condition belonged to Qafqaz in both years (Table-2). In 2000-2001, genotype 6618 also produced the highest grain yield in competition with *G. laevigata* and *A. ludoviciana* (Table-2). However, the difference was only significant with M-75-15 and M-75-5 in case of *G. laevigata*, and with M-75-5 only under *A. ludoviciana* competition. In 2001-2002, the results were a little different. Alamout and M-75-15 yielded the most in competition with *G. laevigata* and *A.*

ludoviciana, respectively, although they did not significantly differ with 6618 genotype (Table-2). Under weed infested condition, M-75-5 and Qafqaz produced the lowest grain yield in 2000-2001 and 2001-2002, respectively. As it is observed, genotype 6618 acted well in the supplementary experiments as in the preliminary experiment. This indicates that this genotype could show a good and stable performance in all experimental years in this respect. Similarly, genotype Qafqaz which ranked the last in the preliminary experiment also showed a weak performance in the supplementary experiments, indicating its poor competitive ability. Our findings are in agreement with Australian data, which showed a strong positive correlation between weed free grain yield and weedy yield (Cousens and Mokhtari, 1998; Gill and Coleman, 1999; Lemerle *et al.* 2001). A general comparison among wheat varieties used in this experiment reveals that there is genetic variability for competitiveness in Iranian winter wheat genotypes which can be considered as a good genetic pool to increase competitive ability of less competitive genotypes.

In 2000-2001, Alamout's CI in the presence of both weed species was the highest and significantly differed with those of all other genotypes except M-75-13 and 6618 in *A. ludoviciana* and *G. laevigata* infestation, respectively (Table-3). Although being lower than Alamout, 6618 also had an acceptable CI in this year. But in 2001-2002, 6618 genotype possessed the highest CI, although not significantly different from M-75-15 and Alamout under *A. ludoviciana* infestation (Table-3). As observed, Alamout was ranked third after 6618 and M-75-15 in the presence of *G. laevigata*. While being high, the stability of 6618 CI in the presence of this weed was more than that of Alamout and M-75-15, a more desirable case in selecting highly competitive genotypes. Slafer and Kernich (1996) stated that yield stability is an important objective of agricultural progress, should be considered in researches. The lowest CI in the supplementary experiments belonged to M-75-5 except in the presence of *A. ludoviciana* in 2000-2001 under which M-75-15 had the lowest CI (Table-3). This result agrees with the results of the preliminary experiment in which M-75-5 and Qafqaz possessed the lowest CI (Table 1). Like the present study, many other researchers have documented differential competitive ability against weeds among existing wheat varieties in the experiments (Challaiah *et al.* 1986; Blachshaw, 1994; Lemerle *et al.* 1996a; Olesen *et al.* 2004).

According to the above results and like the preliminary experiment, genotype 6618 which yielded high both under weed-free and weed infested conditions, had low *A. ludoviciana* and *G. laevigata* biomass, and high CI can be introduced as a highly competitive genotype. This genotype maintained its high CI both in the preliminary and supplementary experiments. On the other hand, although Alamout showed low yield under weed infested condition, high weed biomass and low CI in the preliminary experiment (Table 1), but it acted better in the supplementary experiments (Tables 2, 3) and possessed high CI in the presence of both weed species. Overall results of the three years of experiment (Tables 1, 3) show that the stability of CI in 6618 genotype was more than all the others and it can be introduced as a genotype having high competitive ability against weeds especially *A. ludoviciana* and *G. laevigata*. These findings may indicate that 6618 genotype has more adaptation to the environmental conditions of the experimental location than Alamout. Lemerle *et al.* (2001) has strongly emphasized on the importance of the genotype×environment interaction on wheat and local adaptation to optimize wheat competitive ability. The reason may be attributed some extent to the more adaptability of 6618 compared to Alamout. The genotype M-75-5 almost maintained its low CI in all experimental years (Table-3).

The genotypes M-75-15 and M-75-13 that were selected as genotypes having high competitive ability in the preliminary experiment, acted instable against *A. ludoviciana* and *G. laevigata* in the supplementary experiments and showed variations in their grain yield and CI under weed infestation. According to these results, a correct conclusion cannot be made for these genotypes. This also shows the great effect of season on wheat competitive ability against weeds. Cousens and Mokhtari (1998) reported that genetic variation in wheat competitive ability is often confounded with effects of site and season, and therefore ranking of current varieties is inconsistent between environments.

Qafqaz was introduced as a genotype with low competitive ability in the preliminary experiment. This genotype along with M-75-5 maintained this characteristic in the supplementary experiments too and always ranked the lowest CI against the two studied weed species. Results obtained in the supplementary experiments showed that Qafqaz had a higher yield in the presence of *A. ludoviciana* than its weed-free treatment (Table-2), while M-75-5 had always lower yield in *A. ludoviciana* and *G. laevigata* infested treatments than its weed-free condition. In other words, the latter genotype better maintained its low competitive ability through the experiments

In total, the genotype 6618 can be introduced as the most competitive genotype in this study. In contrast, competitive ability of M-75-5 genotype compared to other genotypes was the least but stable. It is noteworthy to mention that differences in wheat competitive ability existed in the present study, but ranking for competitive ability is often confounded with environmental factors, making recommendations for farmers unreliable. To achieve better result, better understanding about morphological and physiological traits contributing wheat competitive ability is of most help.

Table-2. Grain yield of wheat genotypes under weed free *A. ludoviciana* and *G. laevigata* infested conditions in supplementary experiments.

Treatments	2000-2001			2001-2002		
	Weed free ($kg\ ha^{-1}$)	With *A. ludoviciana* ($kg\ ha^{-1}$)	With *G. laevigata* ($kg\ ha^{-1}$)	Weed free ($kg\ ha^{-1}$)	With *A. ludoviciana* ($kg\ ha^{-1}$)	ith *G. laevigata* ($kg\ ha^{-1}$)
6618	4270a*	3381a	3489a	4896a	3888a	4654a
Alamout	3782b	3310a	3079ab	4258ab	4168a	4041ab
Qafqaz	2969d	3377a	3216ab	3457c	2715b	3457b
M-75-13	3339c	3372a	3464a	4300ab	3704a	3752b
M-75-15	3629bc	2944b	3175ab	4389ab	3834a	4746a
M-75-5	3503bc	2885b	2927b	3972bc	2743b	3483b

*In each column, means followed by the same letter do not differ significantly by DMRT at $\alpha_{0.05}$.

Table-3. Competitive index of wheat genotypes in the presence of *A. ludoviciana* and *G. laevigata* in the supplementary experiments.

Genotypes	2000-2001		2001-2002	
	With *A. ludoviciana*	With *G. laevigata*	With *A. ludoviciana*	With *G. laevigata*
6618	1.58b*	1.31ab	1 52a	7.9a
Alamout	2.09a	1.67a	1.28a	1.1cd
Qafqaz	0 79d	0.82cd	0.82b	0 55d
M 75-13	1.86ab	1.05bc	0.81b	2.2b
M-75-15	0 42e	1.01c	1.29a	1 6bc
M-75-5	1.22c	0.67d	0.77b	0.43d

*In each column, means followed with same letter do not differ significantly by DMRT at $\alpha_{0.05}$

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