Research Article

Competitive Ability of Wheat Crop against Different Densities of *Avena fatua* and *Silybum marianum*

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Abstract | A pot experiment was conducted to measure the competitive-ability of wheat (*Triticum aestivum* L.) against wild oat (*Avena fatua* L.) and milk thistle (*Silybum marianum* L. Gaertn), the two most troublesome weeds of the wheat crop in Pakistan. Four treatments viz. wheat, wheat + *S. marianum*, wheat + *A. fatua*, wheat + *S. marianum* and *A. fatua* were examined to check their effect on the growth dynamics of wheat, *A. fatua* and *S. marianum*. The experiment was carried out in 2018-2019 using Completely Randomized Design (CRD) and replicated thrice. The results showed that all the wheat growth parameters were significantly affected by the weeds competition in both the studied years. The maximum wheat plant height (38.1 and 39.4) was recorded in wheat, having no weeds competition during the year 2018 and 2019 respectively. Whereas, the minimum plant height (cm) 30.4 and 31.9 was recorded in wheat infested with *Avena fatua* and *Silybum marianum*. Due to the large leaf canopy of *S. marianum*, it is not possible for other species to sustain, because several broadleaf weeds are highly competitive and make a high canopy over the crop to get more light for photosynthesis and the morphological mimicry of *A. fatua* with wheat crop during the vegetative growth stage. It cannot be easily distinguished from wheat seedlings. Results showed that wheat in weed-free conditions had maximum biomass, and leaf area index in both the growing season as compared to weeds (*A. fatua* and *S. Marianum)* infested wheat. Therefore, management of these weeds i.e., *A. fatua* and *S. marianum* is highly desirable to avoid crop-weed competition and enhance crop production.

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Introduction

With increasing population growth, there is a growing interest in maximizing crop yield to fulfill food, feed, and fiber requirements. However, weeds represent a threat to secure this goal as they compete with crops for nutrients, moisture, space, and sunlight which result in the reduction of yield (Khan *et al*., 2004). In Pakistan, wheat contributes around 10.3% to agricultural production and 2.2 % to GDP and is planted on more than 9 million hectares and an annual production of more than 25 million tons (Anonymous, 2014, 2016). In the year 2000, wheat yield losses due to weed competition amount to more than Rs. 28 billion in the whole country and Rs. 2 billion in the province of Khyber Pakhtunkhwa (Hassan and Marwat, 2001).

Avena fatua L (wild oat) in Pakistan, is a summer annual grassy weed that represents a serious threat

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to spring wheat farmers across the world (Hassan and Marwat, 2001). Its competitive-ability and vigorous early growth suppress wheat emergence and growth. Also, *A. fatua* early seed maturity and efficient seed dispersal mechanisms further increase its noxiousness (Khan *et al*., 2012). *A. fatua* impact on wheat occur not only during the early growing period but may continue until the maturity of the crop up. However, the highest yield loses in wheat occurs before 45 to 50 days of wheat sowing (Khan *et al*., 2008, 2012) determined that the wheat yield is reduced exponentially when wild oat density increases from 0 to 30 plants m^{-2}. Similarly, wild oat reduced a number of tillers in various wheat cultivars (Khan *et al*., 2010). However, apart from density, the time of weed germination and emergence in the field is influenced by light, soil temperature, soil moisture, and soil atmosphere (Shaheen *et al*., 2016).

S. marianum L (Holy thistle) is one of the most troublesome weed species in the wheat in irrigated districts of North-West Pakistan (Darwent *et al*., 2006) determined that 15 to 20 shoots m^{-2} of *S. marianum* can reduce the wheat yields up to 36% . The conventional and reliable weed management strategies for Holy thistle cannot be executed without a clear understanding of inter-specific competition in *S. marianum* and primary winter crops (Khan and Marwat, 2006; Umm-E-Kulsoom *et al*., 2020).

Numerous works have been done to evaluate *A. fatua* and *S. marianum* competitive impact on wheat (O`Donovan *et al*., 2000; Korres *et al*., 2002; Khan *et al*., 2006; Lehnhoff *et al*., 2013). However, to our knowledge, no research has evaluated the combined effect of these two species on wheat. Large numbers of studies have been documented on weeds competition and density of wheat crop for improving growth and yields. Numerous works have been done on wild oat and holy thistle competition too, individually with the wheat crop. Though, there is no literature available on the combined effect of broadleaf and grassy (*Silybum marianum* L. and *Avena fatua* L.) weed competition with wheat. The purpose of this study will help to examine both the broadleaf and grassy weeds competition with the following objectives:

- To determine the effect of varying densities of *Silybum marianum* and *Avena fatua* on the wheat competition.
- To quantify the threshold density of these noxious weeds in wheat.
- To examines the effect of intra and inter-specific competition on the growth and development of wheat and the weeds.

Materials and Methods

A pot experiment was conducted at the Department of Weed Science, The University of Agriculture Peshawar-Pakistan in 2017-18 and 2018-19. The pots had a height of 18.79 cm and were 21.84 cm diameter each pot was filled with 5 kg of the soil just below the rim to accommodate the water for irrigation for seed germination and development. Atta-habib, a widely cultivated wheat variety was sown along with the *A. fatua* and *S. marianum* seeds in pots with equal distance and with the optimum soil depth for maximum germination. The experimental design was Completely Randomize Design (CRD) with three replications. All the pots were labeled as per treatment and were randomly rearranged every week to reduce any variation in sunlight and temperature. The number of total plants per pot was kept constant while the number of individual species varied according to the treatments as per the plan of work given below:

1. 4 plants of wheat per pot
2. 4 plants of *Avena fatua* per pot
3. 4 plants of *Silybum marinum* per pot
4. 2 plants of wheat and 2 *Avena fatua*
5. 2 plants of what and 2 *Silybum marinum*
6. 2 plants of *Avena fatua* and 2 *Silybum marinum*
7. 2 plant of wheat, 1 *Avena fatua* and 1 *Silybum marinum*.

No fertilizers were added to the pots and they were weekly checked to minimize the effect of microclimate and irrigation with an equal amount. The wheat and weeds were harvested after three months of sowing and the biomass of weeds and wheat was recorded separately. During the study the data was taken on the following variables:

Plant height (cm)

The plant height data was taken at physiological maturity. Plants height (cm.) of five random plants from the base to leaves tip was recorded in each pot and then the average was computed.

Biomass of wheat (gm)

Biomass of wheat was recorded by the following formula:

$$\text{Biomass of wheat} = \frac{\text{Weight of sample (g)}}{\text{Area harvested (pot)}}$$

Biomass of Avena fatua (gm)

Biomass of *Avena fatua* was recorded by the following formula:

$$\text{Biomass of } Avena\ fatua = \frac{\text{Weight of sample (g)}}{\text{Area harvested (pot)}}$$

Biomass of Silybum marianum (gm)

Biomass of *S. marianum* was recorded by the following formula:

$$\text{Biomass of } S. marianum = \frac{\text{Weight of sample (g)}}{\text{Area harvested (pot)}}$$

Leaf area index (LAI)

Leaf area index (LAI) is a dimensionless quantity that characterizes plant canopies. It is defined as the one-sided green leaf area per unit ground surface area (LAI = leaf area / ground area, m^2/ m^2) (Watson 1947).

The leaves sampling for determining leaf index was randomly collected from wheat plants in each pot and then average LAI was computed by using leaf area meter.

Relative growth rate ($g\ g^{-1}\ dwt\ day^{-1}$)

To record the relative growth rate, the same plants were cleaned and oven-dried at 70°C for 48 hours. Following formulae proposed by Gardner *et al.* (1985), the relative growth rate was calculated as:

$$\text{Relative Growth Rate} = \frac{\ln W2 - \ln W1}{T2 - T1}$$

Where;

W1= Dry weight of the first harvest; W2= Dry weight of the second harvest; ln= Natural logarithm; T2-T1=Time interval between two harvests.

Specific leaf area: (cm^2g^{-1}) was calculated according to Hunt (1990).

$$\text{Specific Leaf Area} = \frac{\text{Leaf Area per Plant m2 g 1}}{\text{Leaf weight per plant}}$$

Leaf area ratio: (cm^2g^{-1}). was calculated by as:

$$\text{Leaf Area Ratio} = \frac{\text{Leaf area per plant}}{\text{Weight per plant}} \text{(cm2 g 1)}$$

Results and Discussion

Plant height (cm)

Plant height is an important parameter that attributes to the yield of the crop. In this study, wheat height was negatively impacted by the infesting weeds (Table 1). In 2017-2018, the wheat crop grown in the absence of weeds achieved the maximum plant height (38.1 cm), while in competition with *A. fatua* and *S. marianum* its height was reduced to 30.4 cm. A similar trend was observed in 2018-2019, with wheat plants growing in similar conditions achieved the maximum plant height (39.4 cm) but competition with *A. fatua* or *S. marianum* resulted in shorter plants (31.9 cm). Overall, this two-year experiment showed that wheat height is negatively affected in the presence of either of the *A. fatua* or *S. Marianum* plants.

Table 1: *Wheat plant height (cm) as affected by weeds competition.*

Treatments	2017-18	2018-19
Wheat	38.1a	39.4a
Wheat + *Silybum marianum*	33.0b	34.5b
Wheat + *Avena fatua*	33.3b	34.6b
Wheat +*Avena fatua* and *Silybum marianum*	30.4c	31.9c
$LSD_{0.05}$	2.03	1.96

In the absence of weed competition, wheat plants were able to take full advantage of the available resources such as nutrients, light, moisture, and space. The combined effect of *A. fatua* and *S. marianum* was larger than the individual impact of each of these two weed species. Both these weed species are highly efficient competitors, (Umm-E-Kulsoom *et al.*, 2020) which resulted in reduced wheat growth, biomass, and yield underscoring the need to develop efficient weed management strategies to secure the required crop yield. This study also provides further information about the interactive competitive effects of *A. fatua* and *S. marianum* on yield losses in wheat crops. According to Khan *et al.* (2008), *A. fatua* density and competition have a significant effect on the plant height of the wheat crop. Bogale *et al.* (2011) also observed a reduction in plant height of wheat due to weeds competition. Similarly, Nassab and Farshad (2012) and Woldesenbet *et al.* (2016) observed a decreasing trend in the height of wheat plants when weeds were not properly managed.

Wheat biomass

Weed competition severely affected the biomass production of wheat during the two years of study. Under no competition, the mean data presented in Table 2 reported that wheat biomass was 153.3g for the year 2018-19, and 143.0 g for 2017-18. A significant decrease in wheat biomass was observed for both years i.e. (133.7 and 144.2 g), during wheat grown in the combination with *S. marianum* and *A. fatua*. Wheat is an important crop in Pakistan and weeds represent the major constraint in yield and biomass production as it is highly sensitive to weed competition at early growth stages (Weisany *et al*., 2016). The results showed that wheat biomass is highly sensitive to competition with weeds. The decrease in wheat biomass may be due to high weed pressure and competition for resources which causes a reduction in biomass. This research study is in line with Nassab and Farshad (2012) who reported that treatment of weed decreased the biomass of wheat. Bogale *et al*. (2011) investigated that weed affected the biomass of wheat. Umm-e-Kulsoom and Khan (2015) studied that weed decreased the biomass of wheat. Woldesenbet *et al*. (2016) reported that the biomass of wheat is affected by weed.

Table 2: *Wheat biomass (gm) as affected by intra- or inter-specific competition.*

Treatments	Year	
	2017-18	2018-19
Wheat	143.0a	153.3a
Wheat + *Silybum marianum*	137.0ab	148.1ab
Wheat + *Avena fatua*	137.3b	148.6ab
Wheat +*Avena fatua* and *Silybum marianum*	133.7c	144.2b
LSD $_{0.05}$	5.59	NS

Biomass of Avena fatua

Data in Table 3 reveal that that inter-and intra-specific competition severely affected *A. fatua* biomass. Results indicated that *A. fatua* when grown in monoculture, had the highest *biomass* production for 2018-19 (77.5g) and 2017-18 (73.7g). The results also demonstrated the relative importance of intra- and inter-specific competition in determining *A. fatua* biomass. Specifically, the lowest biomass (26.7g and 30.3g) was observed when *A. fatua* has grown in combination with wheat and *S. marianum* for both years, respectively. The results are similar to Abbas *et al*. (2010) who reported that increasing the density of wild oat, the biomass increased. Because a greater number of plants produce more tillers and thus captures more resources which ultimately reflects in biomass accumulation. Singh *et al*. (2013) have shown the competitive ability of weed with wheat was density-dependent probably due to the biomass of weeds. Thus, growth could be different under different climates (Scott *et al*., 2016) and temperatures (Shaheen *et al*., 2016). The same results were also reported by (Blanco *et al*., 2014).

Table 3: *Biomass (g) of A. fatua as affected by intra- or inter-specific competition.*

Treatments	Year	
	2017-2018	2018-2019
Avena fatua	73.7a	77.5a
Wheat + *Avena fatua*	45.3b	48.7b
Wheat + *Silybum marianum* and *Avena fatua*	26.7b	30.2c
Silybum marianum and *Avena fatua*	40.3b	43.7b
LSD $_{0.05}$	19.57	19.30

Biomass of S. marianum

Data in Table 4 show that in 2017-18 and 2018-19, *S. marianum* biomass was differently impacted by intra- and interspecific competition. For both years, the maximum biomass was observed when *S. marianum* was grown in monospecific conditions (32.3 g and 36.0 g, respectively) and the lowest biomass was observed when it grew in combination with wheat and *A. fatua* (8.7 g and 11.9 g, respectively). Biomass is the basic parameter and showed the adaptation strategy of any plant in their environment. Biomass is the phenotypic characteristics of plants and showed the healthy status of plants and vice versa. This result showed that due to inter and intraspecific competition, the biomass production of *S. marianum* was also significantly affected and also showed that *S. marianum* in competition loss its status as compared to alone. Previous work has also evaluated the relative importance of intra- and inter-specific competition in determining weed biomass. Our results are similar to Khan *et al*. (2008) that reported that weed biomass reduced with combination with wheat. Similarly, Abdullah *et al*. (2008) reported that agronomic traits of maize (*Zea mays*) significantly affected weed biomass. Marwat *et al*. (2011) studied that wheat affected the biomass of weed. Fakhari *et al.* (2018) studied that the combination of wheat and rye affects the biomass of weed.

Table 4: *Biomass (g) of S. marianum as affected by intra- and interspecific competition.*

Treatments	Year	
	2017-2018	2018-2019
Silybum marianum	32.3a	36.0a
Wheat + *Silybum marianum.*	16.0b	19.5b
Wheat + *Silybum marianum* and *Avena fatua*	8.7c	11.9c
Avena fatua + *Silybum marianum*	15.0b	19.0b
LSD $_{0.05}$	12.37	12.47

Table 5: *Leaf area index of wheat crop as affected by density of weeds.*

Treatments	Year	
	2017-2018	2018-2019
Wheat	3.1a	3.2a
Wheat + *Silybum marianum*	2.6b	2.7b
Wheat + *Avena fatua*	2.6b	2.7b
Wheat + *Silybum marianum* and *Avena fatua*	2.3c	2.4c
LSD $_{0.05}$	0.20	0.20

Leaf area index (cm)

Data in Table 5 showed that weed competition significantly affected the leaf area index. Specifically, when growing in monocultures, the maximum leaf area was recorded (3.1 and 3.2 for 2017-18 and 2018-19, respectively) and the minimum leaf area index was recorded when the wheat is grown in combination with *A. fatua and S. marianum* (2.3 and 2.4, respectively). Our results suggest that the reduction in leaf area of wheat crop may be due to competition it is experienced when growing in combination with *S. marianum* and *A. fatua*. Several broadleaf weeds are highly competitive and make a high canopy over the crop to get more light for photosynthesis (Khaliq *et al.*, 2012). The effect of broadleaf weed is more pronounced in affecting the leaf area index and in the absence of broadleaf weed increase the survival and competition potential of crop achieved more leaf area index that reached to 3.2. Our research is in line with Khan *et al.* (2005) who determined that the leaf area index showed significant results. Khan *et al.* (2008) studied that the leaf area index of wheat was significantly affected by weeds. Nassab and Farshad (2012) revealed that weed affected the leaf area index of wheat. Ziaf *et al.* (2009) also investigated the leaf area index of wheat was affected by weed.

Relative growth rate (g g^{-1}dwt day^{-1})

Data in Table 6 reveal that *S. marianum* and *A. fatua* had significantly affected Relative growth rate. This study indicated that the relative growth rate of wheat was similarly impacted by inter and intra specific competition during both years of 2017-18 and 2018-19. The results showed that growth in monocultures wheat relative growth was statistically at par for both the consecutive years 2017-18 and 2018-19. Therefore, this study indicates that wheat's relative growth rate is not sensitive to different competitive conditions. Some authors have reported a significant response of wheat to different densities (Khan *et al.*, 2005; Kumar *et al.*, 2012; Zaif *et al.*, 2009).

Table 6: *Relative growth rate of the wheat crop as affected by density of weeds.*

Treatments	Year	
	2017-2018	2018-2019
Wheat	0.02a	0.036a
Wheat + *Silybum marianum*	0.019a	0.035a
Wheat + *Avena fatua*	0.019a	0.036a
Wheat + *Silybum marianum* and *Avena fatua*	0.019a	0.034a
LSD $_{0.05}$	NS	NS

Specific leaf area (cm^2 g^{-1})

Data regarding specific leaf area in Table 7 indicated that wheat growing in monospecific conditions recorded maximum specific leaf area (279.3 and 280.5, for 2017-18 and 2018-19, respectively) as compared with wheat growing in combination with *A. fatua* and *S. marianum*. Specifically, wheat in competition with *S. marianum and A. fatua* reduced the specific leaf area and recorded a minimum leaf area in both years. The specific leaf area was slightly greater in the year 2018-19 than the specific leaf area of 2017-18 which might be due to environmental fluctuations. These results revealed that a specific leaf area is a sensitive parameter to the competition. Both weeds have a highly competitive ability against wheat causing in a reduction of specific leaf areas. These results are in confirmation with Zaif *et al.* (2009) who reported that specific leaf area was reduced when different treatments were applied.

Table 7: *Specific leaf area of the wheat crop as affected by density of weeds.*

Treatments	Year	
	2017-2018	2018-2019
Wheat	279.3a	280.5a
Wheat +*S. Marianum*	244.1b	245.1b
Wheat + *A. fatua*	239.9b	241.0b
Wheat + *S. marianum* and *A. fatua*	225.4c	226.4c
LSD $_{0.05}$	12.04	11.99

Leaf area ratio (cm^2 g^{-1})

Data regarding leaf area ratio presented in the Table 8 exhibit that competition of *A. fatua* and *S. Marianum* with wheat had a significant effect on leaf area ratio. Statistical analysis revealed that interspecific competition with *A. fatua* and *S. Marianum* resulted in a reduction in the leaf area ratio of wheat. The maximum leaf area ratio (216 and 218, for 2017-18 and 2018-19, respectively) when wheat crop was grown in monospecific conditions. However, a decline in leaf area ratio was observed when wheat grew in combination with both *A. fatua* and *S. marianum,* and recorded minimum values (174.3 and 176.3, for 2017-18 and 2018-19, respectively). These results suggest that decreased weed crop competition increased leaf size is an attempt to maximize the light interception and increase the wheat economy for gaining of resources needed for growth and development. These results are in confirmation with Zaif *et al.* (2009) who observed that leaf area ratio was significantly reduced under different treatment. Our research is in contrast with Amanullah *et al.* (2007) LAR improved to a maximum with increasing plant density. Medek *et al.* (2007) observed that leaf area ratio was positively correlated with the relative growth rate.

Table 8: *Leaf area ratio of the wheat crop as affected by density of weeds.*

Treatments	Year	
	2017-2018	2018-2019
Wheat	216.0a	218.0a
Wheat + *Silybum marianum*	189.5b	191.3b
Wheat + *Avena fatua*	188.7b	190.8b
Wheat + *Silybum marianum* and *Avena fatua*	174.3c	176.3c
LSD $_{0.05}$	8.75	8.62

Conclusions and Recommendations

Results showed that wheat in weed-free condition had maximum plant height, biomass, and leaf area index in both the growing season as compared to weeds (*A. fatua* and *S. Marianum)* infested wheat. Reducing weed interference had a positive impact on biomass, and other growth parameters. The study indicated that *S. marianum* is a stronger competitor than *A. fatua*. Due to the large leaf canopy of *S. marianum* it is not possible for other species to sustain and the morphological mimicry of *A. fatua* with wheat crop during the vegetative growth stage, it cannot be easily distinguished from wheat seedlings. Hence it is recommended for farmers that timely management of both these noxious weeds specially *S. marianum* is very important to enhance the wheat yield.

Novelty Statement

In the past five decades the excessive use of herbicides is an alarming threat to the biodiversity and human health hazard. The present study describes weed suppression through enhancing crop density. This approach is an effective and eco-friendly weed management strategy to reduce the intended use of herbicides.

Author's Contribution

Ijaz Ahmad: Did research, collected data, analysis and wrote draft of the manuscript.
Bakhtiar Gul: Major supervisor who provided technical guidelines and supervised the whole Ph.D study.

Conflict of interest

The authors have declared no conflict of interest.

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