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DENSITY DEPENDENT INTERACTIONS BETWEEN CLEAVERS (*Galium aparine*) AND WHEAT (*Triticum aestivum*) PLANTED AT DIFFERENT TIMES

Ahsan Aziz[1*], Asif Tanveer, Asghar Ali and Muhammad Yaseen[2]
[1]Department of Agronomy, University of Agriculture, Faisalabad, 38040
[2]Institute of Soil and Environmental Sciences, University of Agriculture, Faisalabad
Corresponding author's e-mail: drasiftanveeruaf@hotmail.com

Investigations regarding competitive effects of five *Galium aparine* density levels (0, 18, 36, 54 and 72 m^{-2}) on the yield and yield related traits of wheat planted at three sowing times were made in field trials conducted at the Agronomic Research Area, University of Agriculture, Faisalabad, Pakistan during winter 2005/06 and 2006/07. Maximum grain yield of 5480 and 5395 kg ha^{-1} was obtained in 2005/06 and 2006/07, respectively from weed free wheat. While *G. aparine* density of 18 plants m^{-2} did not cause significant yield reduction over control. Wheat growth and yield determinants like number of spike bearing tillers, grains per spike, 1000-grain weight and grain yield were significantly reduced by increasing *G. aparine* density above 18 m^{-2}. Wheat grain yield loss varied between 4 to 32% with weed density ranging from 18 to 72 plants m^{-2} in each year. Sowing of wheat on 7th November proved to be helpful in reducing crop yield losses due to *G. aparine* infestation. *G. aparine* per plant dry weight and seed production were suppressed with delayed sowing and increasing *G. aparine* densities in the presence of crop. On the basis of these results we can propose that wheat should be planted in early November to get bumper yields and the option of chemical herbicides to control *G. aparine* at its density beyond 18 plants m^{-2} should be exploited.

Keywords: *Galium aparine*, density, growth, yield, *Triticum aestivum,* response surface

INTRODUCTION

Evolution of short statured, fertilizer responsive, disease resistant and high yielding varieties have brought the real breakthrough in wheat production in Pakistan. However, there is still a wide yield gap between the potential yield (6 tons ha^{-1}) and the actual achieved yield at farmer's field i.e. 2.49 tons ha^{-1} (Anonymous, 2002). Among the factors responsible for obtaining higher yield, optimum planting time and weed control are of prime importance. Measures commonly used by wheat growers in controlling weeds include delayed planting and tillage. By delaying seeding, growers are able to control early emerging weeds via mechanical or chemical measures. Unfortunately, under lower weed densities, this practice may result in reduced yields and test weight (Humphreys *et al*., 1994).

Early sowing (Before 20th November) always produces greater yields than late sowing (After 20th November), mainly due to higher utilization of resources (Arain *et al*., 1999). A yield reduction of 33% and 31% was observed in wheat genotypes SD-1200/11 and SD-1200/51, respectively when sowing was delayed from 18th November to 11th December (Sial *et al*., 2005).

Weeds reduce crop yield either by competing for light, nutrients, water and carbon-dioxide (Anderson, 1983) or interfering with crops by releasing secondary substances in the rhizosphere of the crop (Rice,1984).

Wheat yield losses due to weeds in Pakistan were estimated to be in the range of 25-30% (Nayyar *et al*., 1994). Increased labour costs and limited energy resources have hampered the use of physical and mechanical methods, so chemical methods remains the only option for weed control as roughly 60% of wheat area is treated with herbicides in Pakistan. The economic threshold (ET), the density of pest at which the benefit of taking action is greater than the cost of taking action, is an important concept in integrated weed management (Daxl *et al.*,1994). Below the ETL, a certain amount of damage and the presence of weeds can be tolerated. In order to measure the ET of weeds in wheat we have to realize that bio-ecological relationships in weed crop-competition are complicated ones. In crop production our major concern is that a crop plant should be the dominant competitor. We need to understand weed crop ecology that will lead to more effective weed prevention, management and control based on critical weed density which seriously limit crop yield.

It has been observed that weed flora has also changed and some new weed species like *Galium aparine* (cleavers) are emerging as threats to wheat yields in the near future (Nayyar *et al*., 2001) as approximately 10% of wheat fields are infested with this weed in

Pakistan. Worldwide it has been reported as a weed affecting 19 crops in 31 countries (Holm *et al*., 1977). It is distributed in Pakistan from the plains to altitudes of 3658 meter but frequently found in the region known as "SOAN Valley" northern Punjab, sporadically found in patches in fertile and salt- affected soils of central irrigated Punjab (Nayyar *et al*., 2001).

Due to its highly competitive ability and reproductive potential, it is very important to know *G. aparine* threshold dynamics in wheat, so the focus of this research was the study of *G. aparine*-wheat interaction at different sowing times and weed densities.

MATERIALS AND METHODS

The study was conducted at the Agronomic Research Area (Latitude 1.26°N, Longitude 73.06°E and Altitude 184.4 m), Department of Agronomy, University of Agriculture, Faisalabad during 2005-06 and 2006-07.

Average precipitation recorded during the crop growth season of 2005-06 and 2006-07 was 59.8 and 156.2 mm, respectively.

The experiment was comprised of two factors namely *Galium aparine* density having five levels (0, 18, 36, 54 and 72 plants m^{-2}) and sowing date having three levels i.e 7th Nov., 15th Nov. and 23rd Nov.

Seeds of *G. aparine* were broadcast in all the plots except control at the time of wheat drilling. *G. aparine* density $plot^{-1}$ was maintained by hand pulling extra plants after emergence. Whereas, other weeds were removed by hand weeding through the crop season.

The experiment was organized as a split-plot factorial design keeping sowing dates of wheat in main plot and weed densities in sub-plots within a randomized complete block having four replications. The net plot size was 2 m x 1 m. Data regarding *G. aparine* per plant dry weight, seed production and wheat spike bearing tillers, number of grains per spike, 1000-grain weight and grain yield were recorded using the standard procedure.

Statistical analysis

Data were analyzed statistically using Fisher's Analysis of Variance technique on MSTAT Statistical Package (Russell and Eisensmith, 1993) on a computer. Years were analysed individually due to heteroscedascity and differences in environmental conditions in 2005-06 and 2006-07. The means of treatments were grouped on the basis of least significant difference at the 0.05 (5%) probability level (Steel *et al*., 1996).

RESULTS

Any agronomic practice that promotes the growth of wheat tends to diminish negative effects of weeds. Thus an experiment was conducted to record the effect of sowing dates and *G. aparine* densities on the growth and yield of wheat and weed.

Dry weight of *G. aparine* per plant

The significant differences were obtained among different weed density levels for per plant dry weight of *G. aparine* (Table 1). Dry weight of *G. aparine* per plant was decreased with an increase in its density during both years (2005-06 and 2006-07).

G. aparine dry weight ($P \leq 0.05$) at crop harvest was significantly reduced during both growing seasons with delayed sowing (23rd November).

The interaction between sowing dates and weed density levels was found to be significant in both years. Maximum dry weight of *G. aparine* was observed on 15th November (Table 1) sowing at weed density of 18 plants m^{-2} (D_2S_2) and was significantly differ from all other treatment combinations during 2005/06, while it was statistically at par with plots sown on 7th November at weed density of 36 plants m^{-2} (D_2S_1) during 2006/07. The lowest *G. aparine* dry weight was observed on 23rd November planting at weed density of 72 plants m^{-2} and was statistically at par with same density on 7th November planting (D_5S_1) and density level of 54 on 23rd November planting (D_4S_3) during 2005/06. Weed dry weight at the highest weed density declined as planting date was delayed.

Number of *G. aparine* seeds per plant

G. aparine seed production per plant decreased with delay in sowing significantly (Table 2) during both years. Different densities also significantly affected *G. aparine* seed production during both years of study. Weed seed production was maximum at density of 36 plants m^{-2} while minimum number of seeds was recorded in plots where density was maximum (72 plants m^{-2}). Interactive effects of both these factors were also significant. During 2005/06, minimum number of weed seeds were recorded in plots where sowing was done on 23rd November at weed density of 72 plants m^{-2} which was statistically at par with other sowing dates at the same density level. *G. aparine* plants sown on 7th November at population density of 36 plants m^{-2} produced the highest (381.0) number of seeds which did not differ statistically from those sown on 15th November at density of 18 plants m^{-2}. Generally, fewer seeds $plant^{-1}$ was produced in delayed sowing at higher density levels of 36, 54 and 72 plants m^{-2}. In the second year of study a similar trend was observed with seed number but overall seed production per plant was higher. It was most probably due to 161.2% more rainfall during 2006/07 compared to 2005/06 which contributed for better growth and reproduction of *G. aparine*.

Table 1. Effect of sowing dates and densities of *G. aparine* on its dry weight (g) per plant

Weed Density (m^{-2})		Sowing Dates							
		7^{th} Nov. (S_1)		15^{th} Nov. (S_2)		23^{rd} Nov. (S_3)		Mean	
		2005/06	2006/07	2005/06	2006/07	2005/06	2006/07	2005/06	2006/07
D_1	0	-	-	-	-	-	-	-	-
D_2	18	2.84 c	2.93 bc	3.67 a	3.39 a	2.93 c	2.95 bc	3.15 A	3.09 A
D_3	36	3.12 b	3.18 ab	2.66 d	2.80 bc	1.83 f	2.03 d	2.54 B	2.67 B
D_4	54	2.26 e	2.61 c	1.64 g	1.84 de	1.30 i	1.27 f	1.73 C	1.91 C
D_5	72	1.47 h	1.63 ef	1.43 h	1.47 ef	1.22 i	1.32 f	1.37 D	1.47 D
Mean		2.42 A	2.58 A	2.35 A	2.37 A	1.82 B	1.89 B		

LSD 5% (2005-06) Sowing date = 0.098 Weed density =0.108 Interaction =0.187
LSD 5% (2006-07) Sowing date =0.205 Weed density = 0.233 Interaction =0.403

Table 2. Effect of sowing dates and densities of *G. aparine* on its number of seeds per plant

Weed Density (m^{-2})		Sowing Dates							
		7^{th} Nov. (S_1)		15^{th} Nov. (S_2)		23^{rd} Nov. (S_3)		Mean	
		2005/06	2006/07	2005/06	2006/07	2005/06	2006/07	2005/06	2006/07
D_1	0	-	-	-	-	-	-	-	-
D_2	18	239.8 c	291.0 c	380.5 a	391.3 a	350.8 b	367.5 b	323.7 A	349.9 A
D_3	36	381.0 a	399.8 a	134.0 d	289.3 c	118.8 d-f	242.0 d	211.3 B	310.3 B
D_4	54	127.3 d	188.5 e	124.5 de	176.0 e	106.8 d-f	170.0 e	119.5 C	178.2 C
D_5	72	106.0 e-g	141.8 f	101.0 fg	144.8 f	90.50 g	131.3 f	99.2 D	139.3 D
Mean		213.5 A	255.2 A	185.0 B	250.3 A	166.7 C	227.7 B		

LSD 5% (2005-06) Sowing date = 12.17 Weed density =10.80 Interaction =18.71
LSD 5% (2006-07) Sowing date = 16.09 Weed density =12.14 Interaction =21.03
Values followed by the same letter do not differ significantly at 5 % probability level
LSD = Least significant difference NS = Non-significant

Spike bearing tillers of wheat

Grain yield of wheat is mainly a function of the number of spike bearing tillers per unit area at harvest. Data pertaining to spike bearing tillers given in Table 3 revealed that these were affected significantly at different densities of weed and sowing dates of wheat. The interactive effect of weed densities and crop sowing dates in respect of spike bearing tillers was also significant during both years of study. In 2005/06, maximum (505.0) number of spike bearing tillers per

Table 3. Effect of sowing dates and densities of *G. aparine* on number of spike bearing tillers (m^{-2}) of wheat

Weed Density (m^{-2})		Sowing Dates							
		7^{th} Nov. (S_1)		15^{th} Nov. (S_2)		23^{rd} Nov. (S_3)		Mean	
		2005/06	2006/07	2005/06	2006/07	2005/06	2006/07	2005/06	2006/07
D_1	0	505.0 a	490.0 a	495.8 ab	480.8 ab	413.8 d	399.3 de	471.5 A	456.7 A
D_2	18	496.8 ab	484.3 a	482.8 ab	470.8 ab	399.5 de	390.0 ef	459.7 AB	448.3 A
D_3	36	478.0 ab	465.3 ab	472.0 ab	452.3 a-c	379.8 d-f	347.0 fg	443.3 BC	421.8 B
D_4	54	464.8 ab	451.5 a-c	458.5 bc	436.5 b-d	362.8 ef	328.0 g	428.7 C	405.3 B
D_5	72	417.8 cd	408.3 c-e	415.3 cd	404.0 de	346.5 f	319.5 g	393.2 D	377.3 C
Mean		472.5 A	459.9 A	464.9 A	448.9 A	380.5 B	356.9 B		

LSD 5%(2005-06) Sowing date = 29.20 Weed density =25.24 Interaction =43.71
LSD 5%(2006-07) Sowing date = 27.90 Weed density =26.16 Interaction =45.32

square meter was recorded in weed free plots where crop was planted on 7th November (D_1S_1) and it was statistically similar to weed density level of 18, 36 and 54 with 7th and 15th November planting. Spike bearing tillers per unit area were statistically minimum where sowing was done on 23rd November in combination with any density level (D_5S_3, D_4S_3, D_3S_3 and D_2S_3). A very similar trend was noted in the year 2006/07.

Number of grains per spike

Data pertaining to number of grains per spike presented in Table 4 indicated that it was influenced significantly by weed densities, crop sowing dates and their interaction during 2005/06 and 2006/07. Grain number per spike was significantly higher in case of 7th November and 15th November sowing time as compared to 23rd November planting during both the years. A progressive decrease in number of grains per spike was observed with successive increase in weed density m^{-2} in both years.

Generally the plots where wheat was sown on either 7th November, 15th November or 23rd November at zero weed density produced the highest number of grains per spike but were not significantly different from those where weed density of 18 and 36 plants m^{-2} was maintained. However, the minimum number of grains per spike was recorded at *G. aparine* density of 72 plants m^{-2} with 23rd November planting (D_5S_3). Remaining treatment combinations were intermediate with respect to number of grains per spike. A similar trend was observed in the 2nd year of study (2006/07).

1000-grain weight

The development of individual grain is reflected by 1000-grain weight. Data presented in Table 5 indicate a linear decrease in 1000-grain weight with increase in density of *G. aparine* whereas, the effect of sowing dates was non-significant during both years.

Sowing date x seed density interaction for 1000-grain weight was significant for both growing seasons. During 2005/06 maximum 1000-grain weight was obtained in weed free plots at all sowing dates which was statistically at par with weed density 18 m^{-2} at 7th November and 15th November planting dates. Minimum 1000-grain weight (34.07g) was observed at weed density level of 72 when sowing was done on 23rd November which was statistically similar to plots where weed density was 18, 36 and 52 plants m^{-2} at the same sowing date. The interactive effect of 7th November and 15th November planting on 1000-grain weight of wheat was also not significant at weed density levels of 18, 36 and 54. During 2006/07, wheat in weed free plots gave the maximum 1000-grain weight at all observed sowing dates. It was statistically similar ($P \leq 0.05$) to plots with 18 weed plants sown on 7th November. Sowing date of 15th November with weed density of 72 plants m^{-2} gave the minimum 1000-grain weight (33.83 g) but it did not differ statistically from other sowing dates at weed density of 54 and 72.

Table 4. Effect of sowing dates and densities of *G. aparine* on number of grains per spike

Weed Density (m^{-2})		Sowing Dates							
		7th Nov. (S_1)		15th Nov. (S_2)		23rd Nov. (S_3)		Mean	
		2005/06	2006/07	2005/06	2006/07	2005/06	2006/07	2005/06	2006/07
D_1	0	50.25 a	48.25 a	50.13 a	47.50 a	48.50 a-c	46.25 ab	49.63 A	47.67 A
D_2	18	49.06 ab	48.00 a	47.49 a-c	46.25 ab	46.38 a-d	44.50 ab	47.64 A	46.58 AB
D_3	36	47.59 a-c	45.00 ab	47.00 a-c	45.06 ab	46.50 a-d	43.00 a-c	47.03 AB	44.69 BC
D_4	54	46.69 a-d	44.25 a-c	44.50 b-d	44.25 a-c	42.00 de	41.75 b-d	44.40 B	43.75 C
D_5	72	43.66 cd	40.00 de	41.75 de	40.00 c-e	38.50 e	37.28 e	41.30 C	38.76 D
Mean		47.45 A	45.10 A	46.17 AB	44.61 A	44.38 B	42.55 B		

LSD 5%(2005-06) Sowing date =2.806 Weed density =2.884 Interaction =4.995
LSD 5Values followed by the same letter do not differ significantly at 5 % probability level
LSD = Least significant difference NS = Non-significant

Grain yield

It is evident from the data given in Table 6 that sowing dates and various density levels of weed affected the grain yield during both the years. Maximum grain yield of 5480 kg ha^{-1} and 5395 kg ha^{-1} was obtained in weed free (D_1) plots for the year 2005/06 and 2006/07, respectively which was statistically similar to grain yield at weed density level of 18 m^{-2}. Grain yield loss due to the presence of 18 weed plants m^{-2} was non-significant, suggesting that suppressive effects of this density level might have been negated by wheat and most of its yield components remained unaffected.

During 2005/06 the sowing date of 7th November and 15th November produced statistically similar but significantly higher grain yield than 23rd November planting. However, yield across all planting dates

Table 5. Effect of sowing dates and densities of *G. aparine* on 1000-grain weight (g) of wheat

Weed Density (m^{-2})		Sowing Dates							
		7th Nov. (S_1)		15th Nov. (S_2)		23rd Nov. (S_3)		Mean	
		2005/06	2006/07	2005/06	2006/07	2005/06	2006/07	2005/06	2006/07
D_1	0	43.13 a	41.86 a	43.08 a	41.40 a	42.03 ab	40.17 a	42.75 A	41.14 A
D_2	18	42.68 a	40.01 a	40.93 a-c	35.54 bc	36.50 cd	35.75 bc	40.04 B	37.10 B
D_3	36	37.88 b-d	36.58 b	36.68 cd	34.15 bc	35.59 d	34.99 bc	36.72 C	35.24 C
D_4	54	36.85 cd	35.76 bc	35.68 d	34.07 bc	35.00 d	34.98 bc	35.85 C	34.94 C
D_5	72	35.51 d	34.21 bc	35.20 d	33.83 c	34.07 d	34.75 bc	34.93 C	34.26 C
Mean		39.10	37.68	38.32	35.80	36.64	36.13		

LSD 5%(2005-06) Sowing date = NS Weed density = 2.601 Interaction = 4.505
LSD 5%(2006-07) Sowing date = NS Weed density =1.472 Interaction =2.550

Table 6. Effect of sowing dates and densities of *G. aparine* on grain yield (kg ha^{-1}) of wheat

Weed Density (m^{-2})		Sowing Dates									
		7th Nov. (S_1)		15th Nov. (S_2)		23rd Nov. (S_3)		Mean		Reduction over control (%)	
		2005/06	2006/07	2005/06	2006/07	2005/06	2006/07	2005/06	2006/07	2005/06	2006/07
D_1	0	5844 a	5780 a	5691 a	5539 a	4904 bc	4868 b-d	5480 A	5395 A	-	-
D_2	18	5690 a	5708 a	5397 ab	5223 ab	4621 cd	4571 c-e	5236 A	5167 A	4.5	4.2
D_3	36	4924 bc	4910 bc	4878 bc	4784 b-d	4135 d-f	4087 e-g	4645 B	4594 B	15.2	14.8
D_4	54	4323 c-e	4324 d-f	4266 de	4175 e-g	3955 ef	3744 gh	4181 C	4081 C	23.7	24.4
D_5	72	3830 ef	3762 f-h	3725 ef	3700 gh	3618 f	3510 h	3724 D	3657 D	32.0	32.2
Mean		4922 A	4897 A	4791 A	4684 B	4247 B	4156 C				

LSD 5% (2005-06) Sowing date = 220 Weed density =349 Interaction =604
LSD 5% (2006-07) Sowing date = 137.7 Weed density =325.1 Interaction =563.1
Values followed by the same letter do not differ significantly at 5 % probability level
LSD = Least significant difference NS= Non-significant

differed significantly during 2006/07. In 2005/06 and 2006/07, grain yield for third planting date was much lower. The interaction for grain yield (kg ha^{-1}) between sowing dates and *G. aparine* density was significant in both years. During 2005/06 the highest grain yield was recorded in wheat plots sown on 7th and 15th November at zero weed density (D_1S_1, D_1S_2) and were statistically similar to plots having 18 weed plants m^{-2} for these sowing dates. Grain yield was minimum (3618 kg ha^{-1}) in plots where sowing was done on 23rd November and weed density was 72 plants m^{-2}. It was statistically similar to other planting dates at same weed density. Furthermore, *G. aparine* density levels of 36, 54 and 72 m^{-2} were also statistically at par with each other in case of 23rd November sowing with respect to grain yield ha^{-1}. Trend of grain yield to sowing date x *G. aparine* densities in 2006/07 was same as in 2005/06.

The percentage loss of wheat grain yield over weed free control shown in Table 6 indicate that it varied between 4 to 32% with weed density ranging from 18 to 72 plants m^{-2} during both years.

DISCUSSION

This observed reduction in dry weight of *G. aparine* with delayed sowing could be due to stronger competitive effect of wheat at the earlier planting date. These results are in agreement with the findings of Burnett *et al.* (2006) who reported reduction in dry matter yield of rye grass with late sowing.

Significantly more dry weight on 15th November planting at lowest weed density might be due to early emergence of weed because of favourable temperature and more branching compared with other sowing dates and weed density levels. These results are according to the findings of Mishra *et al*. (2006) who reported that the dry weight $plant^{-1}$ for wild onion was decreased by increasing density. Mishra *et al*. (2006) had also reported reduction in number of seeds per plant for wild onion with increasing density. Sester *et al*. (2004) found that increasing beet (weed) density resulted in decrease in flowering and seed production per beet plant while Westra *et al*. (1996) reported that delayed planting of jointed goatgrass reduced its seed production by 83% or more. Hartzler (2003) observed that waterhemp, lambsquarter and foxtail seed production was reduced with delayed emergence. In contrast, research findings of Khan *et al.* (2007) mentioned that wild oat seed production was not influenced by increasing its density. Hanf (1970) found 300 to 400 seeds per plant of *G. aparine* which is in agreement with our results.

In general, spike bearing tillers decreased with increasing weed densities. This was attributed to the resource competition stress caused by proximity of associated weeds. Decline in the number of spike bearing tillers with increase in *A. fatua, A. myosuroides* and *S. media* density from 2 to 160 plants m^{-2} was also reported by Farahbakhsh *et al*. (1987). Likewise Tessema *et al*. (1996a, b) demonstrated that fertile spikes per unit area were negatively affected by weed competition due to increase in weed density.

Higher number of spike bearing tillers during 2005/06 could be due to favourable soil fertility and environmental conditions which resulted in better growth and development of the crop plants. Work by Seavers and Wright (1999) demonstrated that reduction in wheat tillers due to high density of *G. aparine* was more in 1995-96 as compared to 1996-97. Similarly, Seefldt *et al*. (1999) and Roberts *et al*. (2001) proposed that environmental conditions may play an important role in wheat growth and development.

Less rainfall (59.8mm) and high temperature during 2005/06 growing season probably resulted in wheat being more competitive compared with 2006/07, when comparatively more rainfall (156.2mm) favored *G. aparine* growth. Mennan and Zandstra (2005) also reported similar results in different growing seasons as *G. aparine* is more sensitive to moisture stress as compared to wheat (Ivany *et al*., 1993). At higher densities, *G. aparine* competition with wheat reduced the number of grains per spike by disturbing wheat growth at grain formation stage. These results are similar to those of Peters (1984) and Khan *et al*. (2007) who found that grain number per spike was reduced with increasing weed density.

Decrease in 1000-grain weight of wheat with increase in weed density has also been reported by many previous workers (Farahbakhsh, 1987; Khan *et al*., 2005; Khan *et al*., 2007). Non-significant effect of sowing dates on 1000-grain weight of wheat was probably due to small gap between sowing dates. Similar findings has also been reported by Akhtar *et al*. (2002) who concluded that sowing date of Ist, 15th and 30th November and 15th December did not have any effect on 1000-grain weight of wheat but it was affected negatively when sowing was delayed upto 30th December.

Lower grain yield for third planting date was perhaps because the crop had a shorter growing period than early planting dates. These results are in agreement to those of Mahdi *et al*. (1998) and Akhtar *et al*. (2002) who suggested that late sowing could result in yield penalties while Williams (1969) mentioned that early sowing of wheat lessened the loss from *Agropyron repens* competition and gave greater grain yield. Competitive effects in terms of wheat grain yield loss from *G. aparine* (ranging from 18 to 72 plants m^{-2}) were greater in 2006/07, the year with the best early growth and development of *G. aparine* under better soil moisture conditions due to 161.2% more rainfall as compared to 2005/06. This is also in conformity with Taylor (1999) who reported that *G. aparine* thrives in damp to fairly wet soils.

Reduction in grain yield due to increase in weed density and late sowing is explained by the observed decrease in yield contributing components like ear number per unit area, grains per spike and 1000-grain weight. Reduction in yield by different densities of weeds has been reported by several workers. Padro (1977) reported a 13 to 30% reduction in wheat yield at a density of 9-16 *A. fatua* plants m^{-2}. While with a density of less than 8 plants m^{-2} there was non-significant reduction in yield. Carlson *et al*. (1981) stated that wheat yield was reduced up to 65% at a wild oat density of 300 plants m^{-2}. Mahdi *et al.* (1998) obtained the highest grain yield from the Ist November planting than 15th November, Ist December or 15th December planting.

Subhan and Khan (2004) reported that wheat grain yield was depressed with delay in sowing after mid-November. Reduction in wheat yield, using weed density as a variable factor has been demonstrated by many researchers (Dew, 1972; Tessema and Tanner, 1997; Tessema *et al*., 1996a, b). The increase in crop yield loss due to increase in *G. aparine* density might be due to competitive exclusion of wheat plants by higher weed density as weeds may prevent the use of an area's resources by crop plants. A similar report (Zimdahl, 2004) confirm that at low weed densities, there is no or little effect on crop yield, and as weed density continues to increase, crop yield drops quickly but never goes completely to zero. Our result with *G. aparine* are consistent with previous report of Mennan (1998) who found that 10 *G. aparine* plants m^{-2} reduced wheat grain yield by 18%. Mehra and Gill (1998) have found that population pressure of a weed had great influence on grain yield of wheat and on the basis of their research trials they reported that increase in *Phalaris minor* population from 50 to 200 plants m^{-2} resulted in 7.6 to 44.2% reduction in grain yield of wheat. Various models showing decline in grain yield of wheat due to increase in weed density have been reviewed (Zimdhal, 1980; Cousens, 1985).

CONCLUSION

There is a potential for reducing herbicide use within the context of a weed management system when *G. aparine* infestation is below 18 plants m^{-2}.

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