WILD ONION (*Asphodelus tenuifolius*) COMPETITION IN RAINFED CHICKPEA-CHICKPEA CROPPING SYSTEM[1]

*Competição da Cebola Selvagem (**Asphodelus tenuifolius**) em Sistema de Cultivo de Grão-de-Bico em Sequeiro*

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ABSTRACT - Chickpea yield potential is limited by weed competition in typical chickpea growing areas of Pakistan where zero tillage crop grown on moisture conserved from rains received during the months of September and August. The objective of this work was to evaluate the growth and yield characteristics of chickpea grown in coexistence with increasing densities of wild onion (*Asphodelus tenuifolius*). The experiment was comprised of six density levels viz. zero, 20, 40, 80, 160 and 320 plants m^{-2} of *A. tenuifolius*. A decrease in chickpea primary and secondary branches per plant, pods per plant, seeds per pod, 100-seed weight and seed yield was observed due to more accumulation of dry matter per increasing densities of *A. tenuifolius*. The increase in *A. tenuifolius* density accelerated chickpea yield losses and reached the maximum values of 28, 35, 42, 50, 58 and 96% at 20, 40, 80, 160 and 320 *A. tenuifolius* plants m^{-2}, respectively. The yield loss estimation model showed that chickpea losses with infinite *A. tenuifolius* density were 60%. Yield reduction could be predicted by 2.52% with increase of one *A. tenuifolius* plant m^{-2}. It is concluded that *A. tenuifolius* has a strong influence on chickpea seed yield and showed a linear response at the range of densities studied.

Keywords: *Cicer arietinum*, weed density, yield components, grain yield.

*RESUMO - Grão de bico potencial de produção é limitada pela competição com plantas daninhas em áreas de cultivo de sementes do grão típico do Paquistão, onde o plantio direto de culturas cultivadas em umidade conservada de chuvas de monção de verão. O objetivo deste trabalho foi avaliar o crescimento ea produção de grão de bico personagens cultivadas em convivência com o aumento da densidade de cebola Silvestre (**Asphodelus tenuifolius**). O experimento foi composto de seis níveis de densidade viz. de zero, 20, 40, 80, 160 e 320 plantas m^{-2} de A. tenuifolius. Diminuição no primário de grão de bico e ramos secundários por planta, vagens por planta, de sementes por vagem, peso e rendimento de sementes de 100 sementes foi observada devido a uma maior acumulação de matéria seca por aumento da densidade de **A. tenuifolius**. Aumento da densidade de **A. tenuifolius** acelera as perdas de rendimento de grão de bico e atingindo os valores máximos de 28, 35, 42, 50, 58 e 96% em 20, 40, 80, 160 e 320 A. tenuifolius plantas m^{-2}, respectivamente. Modelo de estimativa de perda de rendimento mostrou que as perdas de grão de bico com infinita densidade **A. tenuifolius** eram 60%. A redução no rendimento pode ser previsto por 2,52% com um aumento de **A. tenuifolius** m^{-2}. Conclui-se que **A. tenuifolius** tem uma forte influência sobre o rendimento de sementes de grão de bico, mostrando uma resposta linear na faixa de densidades estudadas.*

Palavras-chave: *Cicer arietinum*, densidade de plantas daninhas, componentes de produção, produtividade de grãos.

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INTRODUCTION

Chickpea (*Cicer arietinun*) is a pulse grown throughout the world, mainly in dry areas. In Pakistan, it is an important winter crop in rainfed areas where the crop is sown on soil moisture preserved from the summer monsoon (July-September). Yield losses of 244-80% have been reported in chickpea due to weeds (Tiwari et al., 2001). Losses due to weeds depend upon the types and density of weeds, time of weed seed germination, duration of weed infestation, space available for growth, environmental factors and management practices which affect weed seeds germination and subsequent growth of seedlings. A common belief that has been supported by experiments is that there are more yield losses in chickpea as weed density increased (Tanveer et al., 1998; Whish et al., 2002).

Weed threshold density level is the point in weed infestation (number or weight) at which crop yield begins to reduce. To avoid or compensate yield losses, estimation of economic weed population (density) and its management by an effective method are very important in crop production (Deines et al., 2004). In weed management, the importance of weed threshold level is in open sight, because it is very helpful for farmers that use herbicides (Portugal & Vidal, 2009). Weed threshold density levels, reproduction and growth behaviors are different for different weed species (Onofri & Tei, 2006). Estimation of weed threshold level offers a deep insight for decisions about an appropriate and effective weed control method for a certain weed population in order to prevent economic losses (Fleck et al., 2002; Knezevic et al., 2002). Wild onion is a very harmful and noxious weed in chickpea, wheat, mustard, linseed and lentil in Pakistan and India (Nasir & Sultan, 2004) due to its high competitive ability, greater production of seeds and reproduction potential. It is found in almost 17 countries of the world (Holm et al., 1977). Although competitive effects of *A. tenuifolius* have been studied in wheat, lentil and mustard, no research has been conducted on its competitive effects on chickpea under rainfed chickpea-chickpea cropping system (Mishra et al., 2006). The main objectives of this study were to study the competitive effect of *A. tenuifolius* and to investigate the economic threshold level of *A. tenuifolius* in rainfed chickpea.

MATERIALS AND METHODS

Field experiments were conducted during chickpea growing season in 2008-09 and 2009-10 on sandy soil with pH of 8.2 in Bhakkar (31° N and 71° E), Pakistan. The experimental area has a chickpea-chickpea cropping system. Chickpea cultivar "Bittal-98" was sown in rows spaced 30 cm apart on October 25, 2008 and on October 22, 2009 with a tractor mounted drill using a seed rate of 60 kg ha^{-1}. The experiment was comprised of 0, 20, 40, 80, 160 and 320 *A. tenuifolius* plants m^{-2}. No land preparation was done before chickpea was sown in both years of experimentation, and the crop was sown on residual moisture of July-August rainfall. Crop rotation of chickpea-chickpea is common in the area covered by our study. Neither irrigation nor NPK fertilizer was applied to the crop. The crop was sown in the field where there was heavy infestation of *A. tenuifolius* in the previous year. All weeds other than *A. tenuifolius* (e.g *Chenopodium album*, *Convolvolus arvensis* and *Euphorbia dracunculoides*) were pulled out when they emerged. However, all weeds in control, including *A. tenuifolius*, were pulled out manually soon after their emergence (weed free plots). *Asphodelus tenuifolius* plants more than required were removed manually after every three days to maintain the required density in both years.

Statistical analysis

The experiment was arranged in a randomized complete block design (RCBD) with four replications. Data of both years were different so they could not be combined. Data underwent analysis of variance (ANOVA) with PROC GLM in SAS 9.0 (2002), and means were separated with Fisher's protected LSD at $P \leq 0.05$ level of probability (Steel et al., 1997).

A non-linear rectangular hyperbolic regression model (Cousens, 1985) was fitted to the chickpea yield and *A. tenuifolius* density data to analyze the relationship between chickpea yield (Y) and *A. tenuifolius* density (d). The model equation is expressed below.

$$Y = Y_{wf}\left[1 - \frac{i \times d}{100 \times \frac{i \times d}{A}}\right]$$

where Y is the observed wheat yield (kg ha^{-1}) in a particular weed density, Y_{wf} is the weed free crop yield, i is the percent of yield loss per unit of weed density (d) as $d \to 0$, d is weed density, A is the asymptotic value of the maximum yield loss (%), as $d \to \infty$. Parameter estimates were determined for the model using the nonlinear regression technique.

RESULTS AND DISCUSSION

Varying densities of *A. tenuifolius* had a significant effect on its dry weight (g m^{-2}) (Table 1). Data showed that *A. tenuifolius* dry weight was progressively increased as *A. tenuifolius* densities increased from 20 to 320 m^{-2}. Minimum (25.48 g m^{-2}) and maximum (188.97 g m^{-2}) dry weight of *A. tenuifolius* was recorded at its lowest (20 plants m^{-2}) and highest (320 plants m^{-2}) density level, respectively, during 2008-09 (Table 1). In 2009-10, the trend of *A. tenuifolius* dry weight was similar. Linear, quadratic and cubic responses of *A. tenuifolius* densities for dry weight were significant for both years (Table 1). Our data showed that with increasing *A. tenuifolius* densities, its dry weight (g m^{-2}) was increased significantly. This could be attributed to an increase in fresh weight; thus, our findings are comparable with those of Mishra et al. (2006). Those authors reported the highest dry weight of *A. tenuifolius* per unit area at its highest density. Similarly, Silva et al. (2008) and Rizzardi et al. (2004) recorded the highest dry matter production of different densities of *E. heterophylla*, *Digitaria horizontalis*, *Cyperus rotundus* and *Ipomoea nil* when competing with soybean.

Varying densities of *A. tenuifolius* had a significant effect on its height (Table 1). A progressive increase in *A. tenuifolius* height occured by increasing its density. The tallest *A. tenuifolius* plants (61 cm) were observed at its density level of 320 plants m^{-2} and the shortest *A. tenuifolius* plants were noted at its density level of 20 plants m^{-2} (54.25 cm). However, maximum height of *A. tenuifolius* was similar in plots where 80, 160 and 320 *A. tenuifolius* plants m^{-2} were maintained during 2008-09 (Table 1). Nevertheless, in 2009-10, the tallest (70 cm) *A. tenuifolius* plants were measured at a density level of 320 plants m^{-2}, which was similar (67 cm) to that of 160 *A. tenuifolius* plants m^{-2} only. Linear, quadratic and cubic responses for *A. tenuifolius* height were significant in 2008-09 and in 2009-10 (Table 1). Our results demonstrated that the tallest *A. tenuifolius* plants in plots with maximum density m^{-2} (320) were due to severe competition for light and, as a result, *A. tenuifolius* attained more height

Table 1 - Effect of *A. tenuifolius* densities on its different attributes

A. tenuifolius density (m^{-2})	Dry weight (g m^{-2})		Height (cm)		Shoots per plant		Capsules per plant		Seed weight per plant (g)	
	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10
0	0.00 f	0.00 f	0.00 c	0.00 d	0.00 c	0.00 d	0.00 c	0.00 d	0.00 d	0.00 d
20	25.48 e	19.83 e	54.25 b	59.00 c	5.00 a	5.75 a	380.00 a	385.00 a	14.75 a	15.00 a
40	48.08 d	52.07 d	54.50 b	59.00 c	4.75 ab	5.75 a	367.50 a	370.00 ab	13.50 a	13.50 b
80	76.44 c	75.96 c	59.25 a	64.00 b	4.75 ab	5.00 b	359.75 a	358.50 b	13.25 ab	13.00 b
160	118.18 b	126.76 b	59.75 a	67.00 ab	4.50 ab	4.50 b	317.50 b	323.00 c	11.50 bc	10.00 c
320	188.97 a	201.00 a	61.00 a	70.00 a	4.00 b	3.25 c	317.00 b	316.00 c	10.25 c	9.50 c
LSD	14.67	10.64	3.37	3.94	0.94	0.61	38.66	20.50	1.87	1.25
Trend comparison										
Linear	**	**	**	**	**	**	**	**	**	**
Quadratic	**	**	**	**	**	**	**	**	**	**
Cubic	*	**	**	**	**	**	**	**	**	**

Means not sharing same letter in a column were significantly different at 5% probability level. ** Indicates significance at $P \leq 0.01$ level of probability.

as compared with that of the lowest density m^{-2}. The results dissimilar with our findings were described by Khan et al. (2006) and Oad et al. (2007). They recorded a decrease in wheat height with increasing weed densities. Normally, weed/crop height is decreased with an increase in population because inter or intra-specific competition is increased with an increase in population.

The effect of different *A. tenuifolius* densities on shoot number per plant was shown in Table 1. *A. tenuifolius* shoots per plant were decreased with an increase in its density. A minimum number of 4.00 *A. tenuifolius* shoots was observed in plots with 320 *A. tenuifolius* m^{-2}, whereas at the lowest density level of *A. tenuifolius* (20 plants m^{-2}), the maximum number of shoots was 5.00 per plant in 2008-09. A similar trend in maximum and minimum number of *A. tenuifolius* shoots per plant was observed in 2009-10 (Table 1). Trend comparisons for *A. tenuifolius* shoots were significant in linear, quadratic and cubic responses in both years (Table 1). Our findings revealed that a decrease in the number of shoots of *A. tenuifolius* with an increase in its density was due to increased intraspecific and interspecific competition for resources like water, nutrients and light, etc. At highest densities, individual share of weed plants in utilizing resources is decreased markedly, which negatively affect their vegetative and reproductive growth. Similarly, Mishra et al. (2006) found a decrease in leaf and inflorescence numbers of *A. tenuifolius* competing with wheat crop plants.

Table 1 showed that varying *A. tenuifolius* densities had a negative effect on its number of capsules per plant. Increasing density of A*sphodelus tenuifolius* from 20 to 80 m^{-2} produced 380.00 to 359.75 capsules per plant in 2008-09. In contrast, in 2009-10, maximum (385) *A. tenuifolius* capsules were recorded at density level of 20 plants m^{-2} and were statistically similar with plots (367 capsules) having 40 *A. tenuifolius* m^{-2}. Minimum *A. tenuifolius* capsules per plant (317) were counted at 320 *A. tenuifolius* m^{-2}. Linear, quadratic and cubic responses for *A. tenuifolius* capsules per plant were significant in both years (Table 1). Data obtained in the study illustrated that an increase in *A. tenuifolius* densities from 20 to 320 plants m^{-2} caused a progressive decline in its number of capsules. It could be due to increased competition for resources (light, moisture and nutrients) with increasing *A. tenuifolius* density m^{-2}, which resulted in fewer *A. tenuifolius* shoots per plant. This ultimately decreased its inflorescences and produced fewer capsules per plant. Similarly to our findings, Sester et al. (2004) reported a decrease in flowers of beet weed when its density was increased.

Data showed that variation of *A. tenuifolius* densities had a significant effect on its seed weight per plant (Table 1). In 2008-09, maximum seed weight of *A. tenuifolius* (14.75 g) was produced at 20 *A. tenuifolius* m^{-2}, which was statistically similar to the plots where 40 and 80 plants of *A. tenuifolius* were maintained (Table 1). Similarly, in 2009-10, maximum seed weight of *A. tenuifolius* per plant was 15 g at *A. tenuifolius* density of 20 m^{-2}, followed by those of 40 and 80 plants of *A. tenuifolius* m^{-2} (Table 1). The lowest seed weight (10.25 and 9.50 g per plant) was observed with 320 plants of *A. tenuifolius* m^{-2} in 2008-09 and 2009-10, respectively. Linear, quadratic and cubic trend comparisons for *A. tenuifolius* seed weight were significant in both years (Table 1). As *A. tenuifolius* shoots and capsules per plant were higher at 20, 40 and 80 *A. tenuifolius* plants m^{-2}, ultimately seed weight of these plants was higher. Our results are comparabe with those of (Aziz et al., 2009; Abbas et al., 2010), who revealed more seed weight of *Galium aparine* and *Emex australis* at their lowest densities in wheat. Similarly, Sester et al. (2004) also achieved a smaller number of beet weed seeds (per plant) when its density was decreased.

Data showed the evidence that chickpea primary branches per plant were significantly affected by varying *A. tenuifolius* density levels (m^{-2}). Maximum chickpea primary branches per plant (4.75 to 5.25) were recorded in *A. tenuifolius* free plots and minimum ones (2.25 to 2.50) were observed with 320 *A. tenuifolius* m^{-2} in 2008-09 and 2009-10 (Table 2). However, in 2008-09, chickpea plots where *A. tenuifolius* density increased from 0 to 40 plants m^{-2} did not affect primary branches of chickpea (per plant). Above this density

Table 2 - Effect of *A. tenuifolius* densities on yield and yield components of chickpea

A. tenuifolius density (m^{-2})	Primary branches per plant.		Secondary branches per plant		Pods per plant		Seeds per pod		100-seed weight (g)		Seed yield (kg ha^{-1})	
	2008-09	2009-10	2008-09	2009-10	2008-09	2008-09	2009-10	2009-10	2008-09	2009-10	2008-09	2009-10
0	4.75 a	5.25 a	20.00 a	19.00 a	63.25 a	66.00 a	2.25 a	2.25 a	21.00 a	21.15 a	2467 a	2579 a
20	4.50 a	4.75 a	18.00 a	16.00 b	58.00 b	59.50 b	2.00 ab	2.00 ab	20.74 a	20.61 ab	1879 b	1851 b
40	4.00 ab	4.00 b	14.25 b	14.00 bc	52.00 c	53.00 c	2.00 ab	2.00 ab	20.40 ab	20.25 ab	1638 c	1676 c
80	3.50 b	3.75 b	13.25 b	12.75 c	47.50 d	49.00 d	1.50 b	1.50 b	20.35 ab	20.25 ab	1491 d	1480 d
160	3.50 b	3.75 b	12.25 b	12.00 c	47.00 d	47.00 d	1.50 b	1.50 b	19.90 b	19.99 b	1340 e	1280 e
320	2.25 c	2.50 c	6.25 c	7.00 d	30.00 e	33.00 e	1.50 b	1.50 b	19.89 b	19.70 b	1118 f	1068 f
LSD	0.93	0.75	2.22	2.66	3.85	3.17	0.71	0.67	0.69	1.06	115	86
Trend comparison												
Linear	**	**	**	**	**	**	**	**	**	**	**	**
Quadratic	NS	NS	NS	NS	**	NS	NS	NS	NS	NS	**	**
Cubic	NS	NS	*	*	**	**	NS	NS	NS	NS	**	**

Means not sharing same letter in a column were significantly different at 5% probability level. [NS] and [**] indicate non-significant and significant at P ≤ 0.01 level of probability, respectively.

level, chickpea primary branches decreased with an increase in *A. tenuifolius* plants m^{-2}, and minimum chickpea primary branches were observed at 320 *A. tenuifolius* plants m^{-2} in 2008-09. In contrast, a significant reduction in primary branches per plant of chickpea was started from plots where 40 plants of *A. tenuifolius* were maintained in 2009-10 (Table 2). The trend comparison shown in Table 2 showed a significant linear response and non-significant quadratic and cubic responses in both years of study. Generally, with increasing *A. tenuifolius* densities m^{-2}, a decrease in primary branches of chickpea per plant was noted. This progressive reduction in primary branches is due to limitation of resource availability i.e., at higher *A. tenuifolius* densities, weed-crop competition was severe. Fast et al. (2009) reported a reduction in productive tillers of wheat with increasing weed densities.

The effect of different *A. tenuifolius* densities on secondary branches of chickpea per plant is shown in Table 2. Chickpea secondary branches were significantly decreased with an increase in *A. tenuifolius* densities (m^{-2}). In 2008-09, maximum chickpea secondary branches (18-20 per plant) were produced at 0 or 20 *A. tenuifolius* m^{-2}. At 40 *A. tenuifolius* m^{-2}, chickpea secondary branches significantly decreased when compared with 0 or 20 plants of *A. tenuifolius* m^{-2} and after this level, there was no significant decrease in chickpea secondary branches with an increase in *A. tenuifolius* density upto 160 plants of *A. tenuifolius* m^{-2}. Minimum chickpea secondary branches were recorded at 320 plants of *A. tenuifolius* m^{-2}, whereas in 2009-10, chickpea secondary branches were significantly decreased with an increase in *A. tenuifolius* density from 20 to 320 when compared with the control. At the highest density level (320 plants m^{-2}), only 7.00 chickpea secondary branches were recorded (Table 2). Trend comparisons regarding chickpea secondary branches were significant for linear and cubic responses; however, they were non-significant for quadratic response in 2008-09 and 2009-10 (Table 2).With an increase in *A. tenuifolius* density m^{-2} from 0 to 320, a decreased response in chickpea secondary branches was observed in both years due to resource competition and fewer primary branches. Maximum chickpea secondary branches at zero *A. tenuifolius* m^{-2} may be due to ample availability of resources and more primary branches in these plots, and the reverse is true with 320 *A. tenuifolius* m^{-2}. In *A. tenuifolius* free plots, chickpea produced more above ground biomass (primary and secondary branches) as compared to plots where highest *A. tenuifolius* density was maintained from 20 to 320 m^{-2}. Similar results were reported by Singh & Tewari (1992), who concluded that more light was intercepted, which produced a good canopy in weed free plots in pigeon pea.

Table 2 showed evidence that varying *A. tenuifolius* densities m^{-2} significantly affected chickpea pods per plant. The highest *A. tenuifolius* density level (320 plants m^{-2}) resulted in the lowest chickpea pods per plant which were 30.00 and 33.00 in 2008-09 and 2009-10, respectively, and chickpea pods were increased with a decrease in *A. tenuifolius* density m^{-2}. *Asphodelus tenuifolius* free plots resulted in maximum chickpea pods per plant (63.25 and 66.00) in 2008-09 and 2009-10 (Table 2). In trend comparisons, linear and cubic responses were significant in both years. However, quadratic response for chickpea pods per plant was significant in 2008-09 and non-significant in 2009-10 (Table 2). Our findings showed that an increase in *A. tenuifolius* densities (from 0 to 320 plants m^{-2}) resulted in decreased chickpea pods per plant (from 66.00 to 30.00). Our findings are consistent with those of (Aslam et al., 2007). They reported the highest chickpea pods per plant in weed free plots. Khan et al. (2005) revealed that *Silybum marianum* densities above three plants m^{-2} resulted in reduction in yield parameters of wheat. Similarly, Khan et al. (2007) reported that 30 plants m^{-2} of *Avena fatua* significantly decreased wheat yield and yield components.

Effect of *A. tenuifolius* densities on chickpea seeds per pod is shown in Table 2. Minimum chickpea seeds per pod (1.50) were recorded at *A. tenuifolius* density level of 80, 160 or 320 plants m^{-2} in both years (Table 2). *Asphodelus tenuifolius* free plots resulted in the highest (2.25) chickpea seeds per pod which was at par with those of 20 and 40 *A. tenuifolius* plants m^{-2}. Among trend comparisons, linear response was significant and quadratic and cubic responses were non-significant for chickpea seeds per pod in both years (Table 2). Our findings concluded that with an increase in *A. tenuifolius* density m^{-2} (from 0 to 320), a significant decrease was recorded in chickpea seeds per pod. This decrease in seeds per pod was due to an increase in competition for nutrients and moisture with an increase in *A. tenuifolius* m^{-2}, as *A. tenuifolius* population shared the available resources, which ultimately resulted in less photosynthate production and transfer towards pods to produce more seeds per pod. Similar to our findings, Aslam et al. (2007) found a higher number of seeds in chickpea in weed free plots.

Table 2 showed the effect of varying *A. tenuifolius* densities m^{-2} on 100-seed weight of chickpea. *Asphodelus tenuifolius* free plots resulted in maximum 100-seed weight of chickpea which was at par with 100-seed weight of chickpea from *A. tenuifolius* density of 20 m^{-2} up to 80 m^{-2} in both years (Table 2). The tallest *A. tenuifolius* plants (320 m^{-2}) resulted in the lowest 100-seed weight of chickpea (19.89 and 19.70 g in 2008-09 and 2009-10, respectively), and this was statistically similar where 160 *A. tenuifolius* plants m^{-2} were maintained. Linear response of chickpea for 100-seed weight was significant, and quadratic and cubic responses were non-significant in both years (Table 2). Our findings pertaining to chickpea 100-seed weight showed that *A. tenuifolius* at the highest densities resulted in the lowest 100-seed weight of chickpea. However, a density level up to 80 did not reduce 100-seed weight of chickpea compared with the control (*A. tenuifolius* free plots). Thus, the observed decrease in 100-seed weight of chickpea with the increase in *A. tenuifolius* densities were most probably due to limited availability of light, moisture, space and nutrient in highly infested *A. tenuifolius* plots, and this resulted in the lowest chickpea seed weight gain. Our findings are in accordance with the reports of Aslam et al. (2007), who recorded maximum chickpea 100-seed weight in weed free plots and the lowest seed weight in plots highly infested with weeds. Similar to our findings, Oad et al. (2007) revealed that with increasing weed densities, 1000-seed weight was decreased in wheat. Similarly, Silva et al. (2008) observed the lowest 1000-seed weight of soybean in plots highly infested with weeds.

Varying the density of *A. tenuifolius* significantly affected chickpea seed yield in both years (Table 2). Maximum seed yield of chickpea was achieved in *A. tenuifolius* free plots in 2008-09 (2467 kg ha^{-1}) and 2009-10 (2579 kg ha^{-1}). An increase in *A. tenuifolius* density m^{-2} progressively reduced chickpea seed yield. Yield loss started in plots where 20 plants m^{-2} were maintained (Table 2). Minimum seed yield was 1118 and

1068 kg ha^{-1} in 2008-09 and 2009-10, respectively (Table 2). The highest (320) *A. tenuifolius* density m^{-2} resulted in the highest chickpea seed yield reduction, which was 1349 and 1511 kg ha^{-1} (Table 2) with a percent yield reduction of 54.62 and 58.55% over *A. tenuifolius* free plots in both years, respectively. Trend comparisons for chickpea seed yield are given in Table 2, which showed that chickpea yield was significantly different from linear, quadratic and cubic response in both years.

Chickpea seed yield is governed by its yield parameters (number of pods, seeds per pod and 100-seed weight). With increasing *A. tenuifolius* densities m^{-2}, chickpea yield parameters like pods per plant, seeds per pod and 100-seed weight decreased gradually. Above trend in crop yield reduction with anincrease in weed densities m^{-2} is reported by many researchers in many field crops. (Mishra et al., 2006) revealed linear yield reduction in chickpea and lentil with an increase in *A. tenuifolius* density up to 800 plants m^{-2}. Similarly, Whish et al. (2002) observed that with increasing weed density, chickpea yield losses were also increased. Yield reduction was high (50%) even with lower weed densities (< 10 weed plants m^{-2}) and yield losses were increased as row spacing became wider. Our results are further supported by Zimdal et al. (2004), who recorded low yield at higher weed densities. They further reported that yield can never drop to zero with weed infestation. Similarly, previous work showed that yield of other leguminous crops (cowpea and soybean) were significantly reduced with increasing *E. heterophylla* density (Carvalho et al., 2010). Cowpea growth, yield and yield components also reduced with increasing density of *E. heterophylla* (Olorunmaiye & Ogunfolaji, 2002). An increase in *E. geniculata* density from 10 to 120 plants m^{-2} reduced the seed yield of soybean by 12-30% and chickpea by 18-53% in soybean-chickpea cropping system, indicating that at the same density, chickpea was more susceptible to *E. geniculate* than soybean (Mishra & Singh, 2003; Mohammadi et al., 2005).

Estimation of chickpea yield and yield losses

A model of density-yield (Cousens, 1985) was used to characterize chickpea yield across *A. tenuifolius* density. The models estimated that the yields of weed free chickpea (Y_{wf}) were 2458 kg ha^{-1} (95% CI [2376, 2541]) and 2563 kg ha^{-1} (95% CI [2484, 2641]) in 2007-08 and 2008-09, respectively. The estimated percentage yield loss per unit of weed density (i) was 1.88 (95% CI [1.40, 2.35]) in 2008-10 and 2.13 (95% CI [1.67, 2.59]) in 2008-10. In contrast, the asymptotic values of the maximum yield loss of chickpea (A) were 56.87 (95% CI [52.97, 60.76]) and 60.68 (95% CI [57.20, 64.15]) kg ha^{-1} in 2007-08 and 2008-09, respectively (Table 3). In 2008-09, maximum chickpea yield losses with one unit of *A. tenuifolius* and its infinite densities m^{-2} were 2.18 and 60.73 %, respectively. In 2009-10, maximum chickpea yield losses with one unit of *A. tenuifolius* and its infinite densities m^{-2} were 1.29 and 56.89%, respectively (Table 3). Similarly, Coelho et al. (2009) found that the presence of *Ageratum conyzoides, Digitaria nuda, Eleusine indica* and *Lepidium virginium* caused 94% yield reduction of carrot. The chickpea yield loss estimation

Table 3 - Model estimate of chickpea yield (kg ha^{-1}) and yield losses (%) in 2008-09 and 2009-10

Parameter		Estimate		Std. Error		95%LCI		95%UCI	
		2008-09	2009-10	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10
Chickpea yield	Y_{wf}	2458	2563	42.00	40.23	2376	2484	2541	2641
	i	1.88	2.13	0.24	0.23	1.40	1.67	2.35	2.59
	A	56.87	60.68	1.99	1.77	52.97	57.20	60.76	64.15
Yield loss	i	2.18	1.90	0.172	0.197	1.84	1.51	2.52	2.29
	A	60.73	56.89	1.54	1.97	57.71	53.02	63.75	60.76

Y_{wf} = yield of weed free plot, i = chickpea yield loss per unit of *A. tenuifolius,* A = chickpea yield loss at infinite *A. tenuifolius* density, LCI = lower confidence interval and UCI = upper confidence interval.

model showed that maximum yield losses of chickpea occurred with infinite *A. tenuifolius* densities in both years.

An increase in *A. tenuifolius* density m^{-2} progressively reduced chickpea seed yield. The model estimate showed that *A. tenuifolius* density at infinity may cause 56-60% chickpea yield losses. Measures should be taken to control *A. tenuifolius* in chickpea field at 20 plants m^{-2}.

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LITERATURE CITED

ABBAS, R. N. et al. Simulating the effect of *Emex australis* densities and sowing dates on agronomic traits of wheat. **Pak. J. Agric. Sci.**, v. 47, n. 2, p. 104-110, 2010.

PAKISTAN. Ministry of Food and Agriculture**. Agriculture statistics of Pakistan.** (Planning unit). Islamabad: 2010/ 2011. 21 p.

ASLAM, M. et al. Effect of sowing methods and weed control techniques on yield and yield components of chickpea (*Cicer arietinum* L.). **Pak. J. Weed Sci. Res.**, v. 13, n. 1-2, p. 49-61, 2007.

AZIZ, A. A.; TANVEER, A. A.; YASIN, M. Density dependent interactions between Cleavers (*Galium aparine*) and wheat (*Triticum aestivum*) planted at different times. **Pak. J. Agri. Sci.**, v. 46, n. 4, p. 258-265, 2008.

CARVALHO, L. B.; BIANCO, S.; GUZZO, C. D. Inteference of *Euphorbia heterophylla* in the growth and macronutirent accumulation of soybean. **Planta Daninha**, v. 28, n. 1, p. 33-39, 2010.

COELHO, M.; BIANCO, S.; CARVALHO, L. B. Weed interference on carrot crop (*Daucus carrota*). **Planta Daninha**, v. 27, p. 913-920, 2009. (Número Especial).

COUSENS, R. A simple model relating yield loss to weed density. **Ann. Appl. Biol.**, v. 107, n. 2. p. 239-252. 1985.

DEINES, S.R.; DILLE, J. A.; BLINKA,E.L.; REGHER, D. L.; STAGGENBORG, S. A. Common sunflower (*Helianthus annuus*) and shattercane (*Sorghum bicolor*) interference in corn. **Weed Sci.**, v. 52, n. 6, p. 976-983, 2004.

FAST, B. J.; MEDLIN. C, R.; MURRAY, D. S. Five cool-season annual grass weeds reduce hard red winter wheat grain yield and price. **Weed Technol.**, v. 23, n. 2, p. 206-213, 2009.

FLECK, N. G.; RIZZARDI. M. A.; AGOSTINETTO, D. Threshold level as a criteria for arrowleaf sida control decision in soybeans. **Planta Daninha**, v. 20, n. 3, p. 421-429, 2002.

HOLM, R. et al. **World weeds, natural histories and distribution**. New York: John Wiley and Sons, 1977.

KHAN, I. J. et al. Effect of wild oats (*Avena fatua*) densities and proportions on yield and yield components of wheat. **Agric. Biol. Sci.**, v.1, n. 1, p. 26-31, 2007.

KHAN, M. A.; MARWAT, K. B.; HASSAN, G. Grain yield of wheat at various seed rates under Holy thistle (*Silybum marianum*) densities. **Herbologia**, v. 6, n. 3, p. 13-17, 2005.

KHAN, M. A.; MARWAT, K. B. Impact of crop and weed densities on competition between wheat and *Silybum marianum* Gaertn. **Pak. J. Bot.**, v. 38, n. 4, p. 1205-1215, 2006.

KNEZEVIC, S. Z. et al. Critical period for weed control. The concept and data analysis. **Weed Sci.**, v. 50, p. 773-786, 2002.

MISHRA, J. S.; SINGH, V. P. Interference of *Euphorbia geniculata* in soybean-chickpea cropping system. **Indian J. Weed Sci.**, v. 35, n. 3/4, p. 225-227, 2003.

MISHRA, J. S.; SINGH, V. P.; YADURAJU, N. T. Wild onion (*Asphodelus tenuifolius* Cav.) interference in lentil and chickpea crops and its management through competitive cropping. **Weed Biol. Manag.**, v. 6, n. 3, p. 151-156, 2006.

MOHAMMADI, G. et al. Critical period of weed interference in chickpea. **Weed Res.**, v. 45, n. 1, p. 57-63, 2005.

NASIR, Z. A.; SULTAN, S. Survey of weeds in mustard fields of district Chakwal, Pakistan. **Pak. J. Biol. Sci.**, v. 7, n. 2, p. 279-286, 2004.

OAD, F.; SIDDIQUI, M.; BURIRO, U. Growth and yield losses in wheat due to different weed densities. **Asian J. Plant Sci.**, v. 6, n. 1, p. 6173-6176, 2007.

OLORUNMAIYE, K. S.; OGUNFOLAJI, R. T. Effect of density and duration of *Euphorbia heteropylla* (L.) on the performance of cowpea (*Vigna unguiculata*) (Walp). **NISEB J.**, v. 2, n. 1, p. 17-22, 2012.

ONOFRI, A.; TEI, F. Competitive ability and threshold levels of three broad leaf weed species in sunflower**. Weed Res.**, v. 34, n. 6, p. 471-479, 2006.

PORTUGAL, J. M.; VIDAL, R. A. Economic levels of weed injury on crops: Concepts, definitions and calculation models. **Planta Daninha**, v. 27, n. 4, p. 869-877, 2009.

RIZZARDI, M. A. et al. Interference of populations of *Euphorbia heterophylla* and *Ipomoea ramosissima* isolated or in mixture in soybean crop. **Planta Daninha**, v. 22, n. 1, p. 29-34, 2004.

SESTER, M. et al. Crop and density effects on weed beet growth and reproduction. **Weed Res.**, v. 44, n. 1, p. 50-59, 2004.

SILVA, A. F. et al. Effect of weed densities and control periods on soybean yield components. **Planta Daninha**, v. 26, n. 1, p. 65-71, 2008.

SINGH, K. K.; TEWARI, A. N. Weed management in inter-cropped pigeonpea. **Indian J. Weed Sci.**, v. 24, n. 3-4, p. 21-25, 1992.

STEEL, R. G. D. et al. **Principles and Procedures of Statistics. Multiple comparisons**. 3.ed. McGraw Hill Book Co., New York, USA. p. 178-198, 1997.

TANVEER, A. et al. Effect of different levels of weed management on weed growth and grain yield of gram (*Cicer arietinum* L.). **Pak. J. Sci.**, v. 50, n. 3-4, p. 60-62, 1998.

TIWARI, A. N. et al. Crop-weed competition studies in chickpea having *Asphodelus tenuifolius* dominated weed community under rain fed condition**. Indian J. Weed Sci.** v. 33, n. 3-4, p. 198-199, 2001.

WHISH, J. P. M. et al. **The development of a wild oat simulation model for APSIM.** Victoria Park: Plant Protection Society of Western Australia, 2002.

ZIMDAHL, R .L. **Weed crop competition. Blakwell publication**. Canada, 2004. 22 p.