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Weed Interference Effects on Leaves, Internode and Harvest Index of Dry Bean (*Phaseolus vulgaris* L.)

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Abstract

The development of appropriate weed management strategies and efficient use of herbicides relies upon understanding weed-crop interactions. A field study was carried out to assess the effect of weed interference on leaves, internode and harvest index of dry bean (*Phaseolus vulgaris* L.). The experiment was established under a randomized complete block design with two types of weed interference treatments: plots with weeds and plots without weeds at different time intervals (0, 10, 20, 30, 40 and 50 days after crop emergence). The sigmoid Boltzmann model was used to quantify the crop traits as influenced by weed interference. Prolonged delays in weed removal reduced gradually the number of leaves of the crop. Weed interference decreased dry weight of leaves as well, so that the lowest value of it (33.49 g plant^{-1}) was observed in full season during weed-infested treatment. Infestation of weeds affected the length of the crop internodes. While the weed interference duration increased, the length of the internodes decreased. Harvest index was also sensitive to weed competition. As the crop was kept weed-infested from the emergence for increasing periods of time, harvest index decreased to a value of 28.01%. A significant negative correlation between total biomass of weeds and dry bean traits (number of leaves, leaves dry weight, internode length and harvest index) was observed. Therefore, weeds are able to adversely affect dry bean growth through constraining environmental resources and impairing leaves as the photosynthetic areas.

Keywords: *Chenopodium album*, competition, dry matter, internode, regression

Introduction

Dry bean (*P. vulgaris* L.) is a predominantly self-pollinated crop plant originated mainly form Latin America, Central Mexico and Guatemala. From Latin America, Spanish and Portuguese spread it into Europe, Africa and other parts of the world (Zeven, 1997). In addition to have a broad distribution as a crop worldwide, dry bean is indispensable for the diet of many countries. Nutritionally, the importance of dry bean as human food is due to its good protein content and digestibility and as a source of important nutritional factors such as flavonoids, iron, zinc, phosphorus and calcium (Bazel and Anderson, 1994; Hempel and Bohm, 1996).

The growth and yield of dry bean are substantially reduced by weed interference. Thus, weed management is one of the most important problems that bean growers can face. Weeds compete with dry bean for light, moisture and nutrients and can drastically reduce dry bean quality and yield (Bauer *et al.*, 1995; Urwin *et al.*, 1996). The presence of certain weeds at harvest time interferes with harvesting efficiency and can stain the beans, which lowers marketability (Arnold *et al.*, 1993; Bauer *et al.*, 1995). Severity of weed competition and detrimental effects of this phenomenon on growth and crop yield are related to the following factors: weed species, duration of infestation and climatic conditions. Weed interference can severely reduce final production, by affecting growing processes and impairing some growth related attributes of the crops such as leaf number, height and biomass. Qasem *et al.* (1995) reported that dry bean yield was significantly reduced by weed interference. Without weed control during all the cycle, a reduction of 82.9% in cotton yield was observed (Cardosoa *et al.*, 2011). Since competition for solar irradiation is one of the major crop-weed interactions, weeds can also harm photosynthesis and light absorption of the crops through imposing detrimental impacts on crop leaves (Kropff and Van Laar, 1993). Stagnari and Pisante (2011) highlighted that the increase of the duration of weed interference may considerably impair leaves of French bean. Harvest index (HI) represents the amount of dry matter which is related to the crop economical part (i.e. seeds in legumes). Weeds are able to affect HI through influencing dry matter production and also allocation of it to different parts of the crop (Blackshaw, 1991). Considering the destructive effects of weeds on crops, weed management is an intrinsic part of crop production. Today, the application of pre-emergence herbicides is quite common for weed control and it is often associated with post-emergence herbicide treatments. Alternatively, dry bean growers rely on machine hoeing techniques, especially in organic farming systems. These techniques are often expensive, time consuming but they are not often successful or cost effective (Ngouajio *et al.*, 1997). Since weed control represents major production costs and herbicides have a potential adverse effect on the environment, the use of integrated weed management systems

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(IWMS) is recommended (Hall *et al.*, 1992; Swanton and Weise, 1991) to develop optimum weed control strategies and efficient use of herbicides. Obviously, the development of such systems is closely related to our knowledge on crop-weed interactions and competition processes. Therefore, the main of this study was to evaluate weed interference effects on leaf number, leaves dry matter, internode length and harvest index of dry bean.

Materials and methods

Site description

The experiment was conducted in the year 2011 in the experimental farm of Agricultural Research Station of Hamadan (34° 52' N latitude, 48° 32' W longitude and 1741.5 m a.s.l.) which is located in western Iran. The soil type was a loam soil consisting of 35% sand, 40.6% silt and 24.4% clay with a pH of 8.08 and an organic matter content of 0.43%. The climate is moderate with an average annual precipitation of 335 mm. Cultural practices such as moldboard ploughing to a 25 cm depth, disking and land levelling were done according to local practices for dry bean production. Field received a broadcast application of granular fertilizer including 100 kg ha^{-1} urea and 100 kg ha^{-1} super phosphate triple base on the soil laboratory recommendations. An indeterminate dry bean cultivar (NAZ) was planted in experimental plots with the depth of 5 cm in May 2011. Each experimental plot was 6.0 m long with 5 rows. The distance between rows was 50 cm and the distance between seeds on rows was 10 cm. Sprinkle irrigation was applied to the plot area throughout the dry bean growing season.

Experimental design

The experiment consisted of two set of treatments established on a randomized complete block design with three replications. A set of treatments consisted of leaving weedy for 0, 10, 20, 30, 40 and 50 days after dry bean emergence (DAE). In other set of treatments, plots were kept weed-free for 0, 10, 20, 30, 40 and 50 DAE by hand pulling and hoeing.

Sampling and data analysis

Naturally occurring weed populations were utilized in all plots. Weeds were sampled using a 1.0 m × 1.0 m quadrate at each weeding time in the weed-infested plots and at the end of the growing cycle in the weed-free plots. Weeds were cut at the soil level and dried at 75 °C to a constant weight. To determine the number of leaves and dry weight of them, five crops were harvested at 70 DAE and their leaves were separated, counted and oven dried. At the crop maturity, in each plot an area of 2.0 m long corresponding to the central area in the middle of two rows was harvested by hand and then internodes length of the main stem, biological yield (total biomass) and economical yield (seed yield) was determined, then harvest index was calculated as follows:

$$HI = \frac{\text{Economical Yield}}{\text{Biological Yield}} \times 100 \qquad (1)$$

The sigmoid Boltzmann model was used to describe weeds and dry bean traits as a function of weed-free and weed-infested periods (Cardosoa *et al.*, 2011):

$$Y = A_2 + \frac{A1 - A2}{1 + \exp[(x - x_0)/dx]} \qquad (2)$$

where Y = a quantitative trait of the plant; A1 = maximum value of the trait; A2 = minimum value of the trait; x = period of time in the treatment kept the longest weedy or weed free; x_0 = weedy period of time in which the trait had the average value between the highest and the lowest value of them; dx = calculated value to fit the equation corresponding to the tangent of the curve in the point x_0. The model was fitted to the data using PROC NLIN within SAS (SAS Institute, 2002). In addition, to evaluate the relationship between crop traits and weed biomass data were submitted to analise the regression using PROC REG (SAS Institute, 2002) and also Pearson's correlation coefficients were calculated using PROC CORR (SAS Institute, 2002) to measure the association between them.

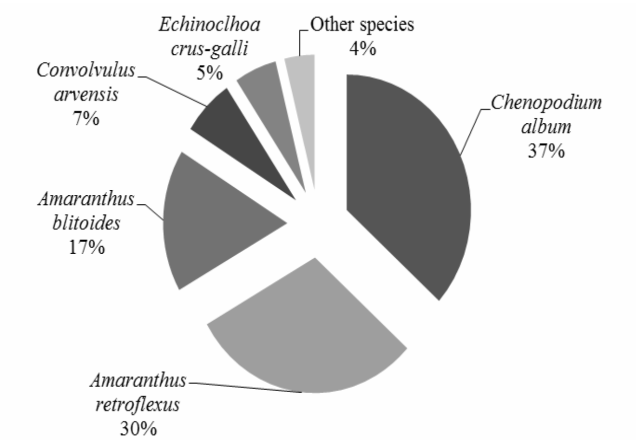

Fig. 1. Weed composition and percentage of their dry weight in full season weed-infested treatment at the crop harvest

Results and discussions

Weed biomass

Weeds began emerging shortly after crop emergence and then infested the plots during the crop cycle. Common species

Table 1. Boltzmann equations for weed dry weight accumulation in weedy and weed-free plots depending on days after emergence (X)

Weedy	Weed free
$Y = 337.4 + [-337.4/1 + e^{x-30/9.7553}]$, $r^2 = 0.97$	$Y = 337.4/1 + e^{x-30/13.3787}$, $r^2 = 0.98$

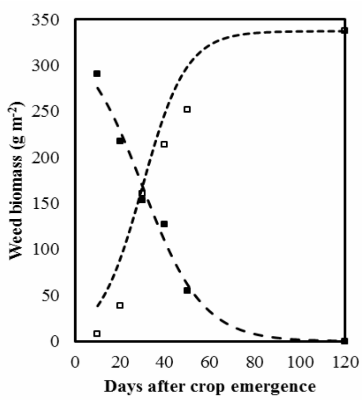

Fig. 2. The effects of duration increase of weed-infested (empty squares) and weed-free (squares) periods on weed biomass. Equations for fitted curves are given in Table 1

and their percentage of dry weight are presented in Fig. 1. *Chenopodium album* and *Amaranthus retroflexus* gathered more biomass than the other weed species (Fig. 1). These species has been identified as the most dominant weeds in western Iran (Ahmadvand *et al.*, 2009). Total biomass of weeds progressively increased as the duration of weed-infested period increased (Fig. 2; Table 1). Weeds produced 337.4 g m-2 biomass in full season weed-infested treatment (Fig. 2; Table 1). More biomass accumulation represents more consumption of growth resources (i.e. light, water and nutrients). Since in agro-ecosystems these resources are often limited therefore biomass production of weeds can severely affect the crop growth through restricting environmental factors.

Leaf number

The number of the leaves was severely influenced by weed interference. Prolonged delays in weed removal progressively reduced the number of the leaves of dry bean. The number of leaves increased as the duration of weed control increased (Fig. 3; Table 2). A 31.22% reduction in number of leaves was observed in full season weed-infested treatment compared to full season weed-free treatment (Fig. 3; Table 2). These results are in agreement with Hall *et al.* (1992) and Evans *et al.* (2003) findings. Also Stagnari and Pisante (2011) point out that weed competition can prejudice the crop leaves. Growth deficiency resources, under weed interference conditions impair crop photosynthesis and assimilation (Kropff and Van Laar, 1993). Thus, the current study shows that crop incapability in order to provide sufficient nutrition and dry matter for development of the leaves led to leaf reduction. Such conditions accelerate abscission of the old leaves and impede the young leaves to grow.

Leaf dry weight

Leaf dry weight was very sensitive to weed interference and decreased as the duration of weed interference increased

Table 2. Boltzmann equations for leaf number, leaf dry weight, internode length and harvest index of dry bean in weedy and weed-free plots depending on the days after emergence (X)

Crop trait	equation	r^2
	Weedy	
Leaf number	$Y = 25.77+[11.7/1+e^{x-30/8.39}]$	0.99
Leaf dry weight	$Y = 33.49+[14.02/1+e^{x-30/12.4533}]$	0.99
Internode length	$Y = 8.45+[3.08/1+e^{x-35/8.1286}]$	0.99
Harvest index	$Y = 28.01+[14.19/1+e^{x-35/9.7647}]$	0.97
	Weed-free	
Leaf number	$Y = 37.47+[-11.7/1+e^{x-30/8.9996}]$	0.93
Leaf dry weight	$Y = 47.51+[-14.02/1+e^{x-30/9.9612}]$	0.99
Internode length	$Y = 12.25+[-3.08/1+e^{x-40/13.2377}]$	0.99
Harvest index	$Y = 42.2+[-14.19/1+e^{x-15/13.3587}]$	0.99

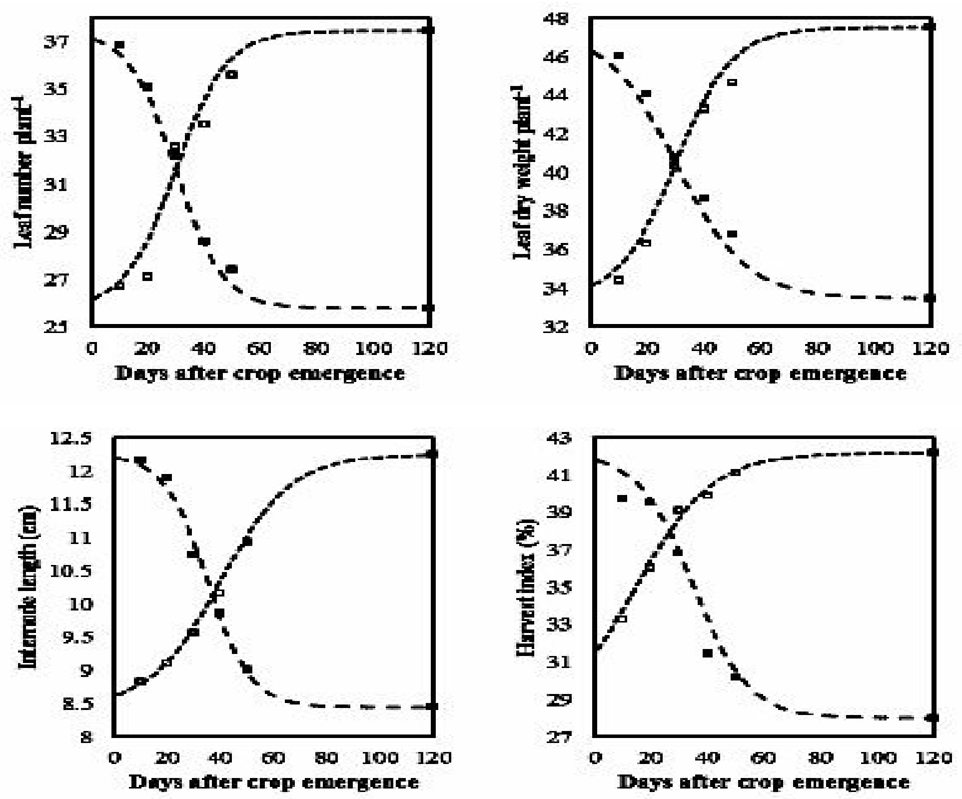

Fig. 3. The effects of duration increase of weed-infested (squares) and weed-free (empty squares) periods on different traits of dry bean using the sigmoid Boltzmann model. Equations for fitted curves are given in Table 2

(Fig. 3; Table 2). The highest value of leaf dry weight (47.51 g plant-1) was observed in full season weed-free treatment, while the lowest value of it (33.49 g plant-1) was registered in full season weed-infested plot (Fig. 3; Table 2). Since *C. album* and *A. retroflexus* were the most dominant weeds and formed the main biomass due to their size (Fig. 1), the leaf dry weight declined possibly due to the high competition of dry bean with these species.

Internode length

Infestation of weeds affected the length of the crop internodes. As far as the duration of weed interference was increasing, the internode length of dry bean decreased (Fig. 3; Table 2). Unless the crop was kept weed-free from the emergence for increasing periods of time, internode length increased up to values of 12.25 cm (Fig. 3; Table 2). This is in line with the findings of Amador-Ramirez *et al.* (2005) who reported that weed interference remarkably reduced internode length of the chili pepper. Plant height is correlated with internode length. In the current study weed infestation reduced the dry bean height as well (data not shown). It has been determined that some crops become taller due to the enlargement of longitudinal axis or etiolation phenomena (Morales-Payan *et al.*, 2003) with no induction of leaf extension, when the leaves of the plants are exposed to barriers that block light absorption or weed competition mainly for light than crop plants with no competition (Amador-Ramirez *et al.*, 2005). Response of crop height and internode length to weed interference depends on crop and weed type and density (Kavurmaci *et al.*, 2010; Williams and Lindquist, 2007). In the present experiment, the decrease in crop internode length may be the result of the decrease in essential resources, which consequently might have been caused a reduction in cell division and subsequently had affected the internode length of the crop.

Harvest index

Harvest index was influenced by weed interference and it started to decrease with prolonged delays in weed removal especially after twenty days of weed interference (Fig. 3; Table 2). The effect of weed-free treatments was contradictory. The harvest index increased during the treatments (Fig. 3; Table 2). About a 33 % reduction in dry bean harvest index was caused by the increasing period of weed interference, which was observed in comparison to the crop harvest index without interference (Fig. 3; Table 2). This confirms the findings of Blackshaw (1991) who reported that the increase of duration of weed infestation, significantly reducee dry bean harvest index. Cavero *et al.* (1999) stated that the reproductive parts of crops are more susceptible to the deficiency of environmental resources than vegetative parts. Therefore stressful conditions can lower the harvest index of crops. In addition, genetic factors have an important influence on this trait (Beatty *et al.*, 1982; Mariorana *et al.*, 1990). Thus, in the present experiment, a reduction in harvest index could be the result of the vulnerability of dry bean reproductive phase to weed interference, in contrast to its vegetative phase. However, specific response of the cultivar to weed competition must be considered.

Crop-weed relationships

The relationship between weed biomass and calculated crop traits (leaf number per plant, leaf dry weight, internode length and harvest index) was better described by linear models; these models were a consistent reflection of how weed biomass influenced dry bean different characteristics (Fig. 4).

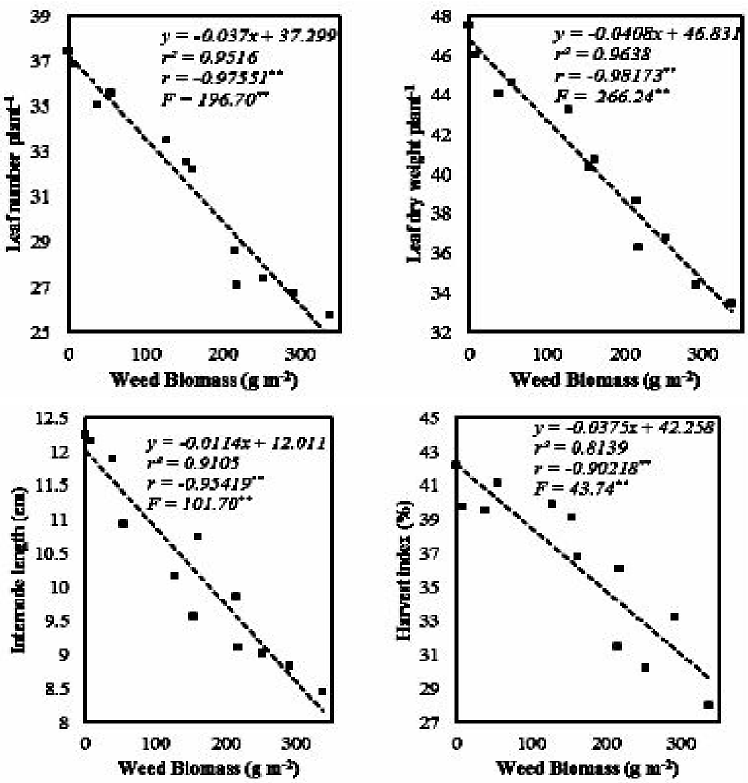

Fig. 4. Relationships between weed biomass and different traits of dry bean; **: significance at 1%

The curves fitting the crop traits against the weed biomass had high coefficients of determination and were significance at 1% (Fig. 4). Natural weed biomass was found to have a significantly negative correlation with the number of the leaves, dry weight of the leaves, internode length and harvest index of dry bean (Fig. 4). Weed dry matter (≈200 g m-2) showed with treatments under increasing periods with weed interference, was enough to reduce crop leaves to 24 %. It has been previously determined that crop yield and growth tend to be reduced as weed dry weight increases accounting for an inverse relationship (Amador-Ramirez *et al*., 2005). Long life cycle of the crops allows weeds to become well established reducing crop growth and yield, which can be avoided by reducing the time of weed establishment (Amador-Ramirez *et al*., 2005). Dry bean requires a period of up to 48 days of weed-free maintenance to avoid losses above 5%. Given the lack of effective registered herbicides for the crop, mechanical and hand hoeing control are the only simple options to manage weeds and minimize yield loss (Amador-Ramirez *et al*., 2005). However, in the last decades some other methods such as biological control have been shown to be effective.

Conclusions

This study revealed that *C. album* and *A. retroflexus* produce more biomass than the other species. Therefore, they can impose more competitive effects on dry bean. Weed interference severely reduced the leaf number and leaf dry weight of the crop. These results reveal detrimental effects of weed competition on the crop photosynthesis which can subsequently lead to dysfunctional growth and yield reduction. Increasing weed-infested periods, decreased the crop harvest index. This phenomenon identifies that dry bean reproductive parts are more susceptible to weed competition than vegetative parts. Herbicides have a potential adverse effect on the environment and developing methods for efficient applications of them is related to our knowledge on weed-crop interactions.

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