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Growth Analysis of Dry Bean (*Phaseolus vulgaris* L.) in Different Weed Interference Situations

Hossein GHAMARI*, Goudarz AHMADVAND

*Bu-Ali Sina University, Faculty of Agriculture, Department of Agronomy and Plant Breeding, Janbazan Street, Hamedan, Iran; ghamari130@gmail.com (*corresponding author)*

Abstract

In production agriculture, weed plants play an important role in yield reduction. Analysis of crop growth can reveal underlying processes of yield loss under weed interference conditions. Therefore, an experiment was conducted in 2011 in order to assess the effect of weed competition on different aspects of dry bean growth. The experiment was a randomized complete block design with 3 replications. Treatments included weed-infested and weed-free periods until 0, 10, 20, 30, 40 and 50 days after crop emergence. Aboveground dry matter and leaf area were measured every two weeks. The functional approach to growth analysis was used to examine temporal patterns in crop growth in weed interference conditions. A negative relationship between weed biomass and dry bean growth indexes was observed. In all treatments, crop biomass had a similar trend and progressively increased over the crop cycle, then after reaching the maximum amount, gradually decreased. The lowest crop biomass (676.60 g m^{-2}) was observed in season-long weed-infested treatment, while the maximum one (1238.82 g m^{-2}) was recorded in season-long weed-free treatment. Relative growth rate (RGR) and net assimilation rate (NAR) had a declining trend during the growing season. Increase in weed-infested periods intensified decrease of them. Effect of weed competition on crop growth was trifle at the early of growing season. Since NAR and RGR represent photosynthesis potential and dry matter accumulation of the crop, their reduction can be the main cause of yield loss.

Keywords: biomass, functional approach, leaf area index, net assimilation rate, relative growth rate

Introduction

Production of pulse crops has steadily increased over the last two decades due to their rotational benefits and because they often provide greater economic return compared with cereals (Miller *et al*., 2002). Dry bean (*Phaseolus vulgaris* L.) is a predominantly self-pollinated crop plant mainly originated in Latin America, probably Central Mexico and Guatemala. From Latin America, Spanish and Portuguese spreaded it into Europe, Africa and other parts of the world (Gepts and Bliss, 1988). Nowadays, it is widely cultivated in the tropics, subtropics and temperate regions. Roughly 30% of dry bean production in the world comes from Latin American countries. Due to its nutritive components, it is one of the 10most important crops of the world (Kumar *et al*., 2008). In Iran, the area under common bean cultivation is 109355 ha and after pea, it is considered as the most important pulse crops.

Excluding environmental variables, yield losses in common bean are caused mainly by competition from weeds. The development of high efficacy herbicides in the 1940s did much to meet the challenge, but rapid evolution of herbicide resistant weeds, growing concerns over environmental and health issues and high costs associated with modern crop production have called for new approach to weed management (Rajcan and Swanton, 2001). Severity of weed competition and consequently detrimental effect of this phenomenon on growth and yield of the crop is related to some factors such as weed species, duration of infestation and climatic conditions. Weed interference can severely reduce final production, by affecting process of growing. Analysis of crop growth can provide a better understanding of competition mechanisms in yield reduction. It has been defined as the study of assimilation and dry matter accumulation of the crop during the growing season which give us valuable information about factors that affect final yield and development of the crop (Gardner *et al*., 1985). It uses simple primary data in the form of weights, areas and contents of crop components to investigate processes within and involving the whole plant (Hunt *et al*., 2002). Stagnari and Pisante (2011) reported that weed interference throughout the growing season caused a great reduction in growth and yield of French bean. Ni *et al*. (2000) informed that weed competition had a detrimental effect on biomass and relative growth rate (RGR) of rice. Crop growth indexes such as net assimilation rate (NAR) and leaf area index (LAI) can disclose the crop competency of competition. It is expected that species with higher growth have more competition ability compare to species with lower growth. Graham *et al*. (1988) stated that competition of pigweed (*Amaranthus retroflexus*) with sorghum considerably diminished the

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crop dry matter. Roush and Radosevich (1985) informed that crop biomass is the most simple and rapid measure of species competition. Spitters and Kramer (1986) suggested that since there is a direct relation between biomass and capture of the essential resources, therefore biomass can be used as an appropriate index for assessment of competition.

Due to high cost of herbicides, their potential adverse effects on the environment and the fact that most of the farmers in developing countries are illiterate, integrated weed management in these countries is mostly directed towards the use of nonchemical methods (Ngouajio *et al*., 1997). Obviously, this purpose is related to our knowledge on competition process which leads to a better understanding of crop-weed interactions as well as crop delicacies and capabilities towards weed interference. Therefore, the main aim of this study was to assess the variability of dry bean growth indexes in different weed infestation conditions.

Materials and methods

Field study was conducted at the Agricultural Research Station of Hamedan province, located in west of Iran, ON (34°52′ N latitude, 48°32′ W longitude and 1741.5 m above sea level). The soil type was a loam soil with 0.43% organic matter and pH of 8.08. 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 recommendation. An indeterminate dry bean cultivar (NAZ) was planted in 6 m rows with the depth of 5 cm on May 2011. The distance between rows was 50 cm and the distance between plants was 10 cm. Irrigation was done after sowing and repeated approximately each 7 days base on weather conditions.

The experimental layout was a randomized complete block design with three replications. Two series of weed removal treatments were included. In the first series, treatments of increasing duration of weed control were maintained weed-free until 10 (WF10), 20 (WF20), 30 (WF30), 40 (WF40) and 50 (WF50) days after crop emergence (DAE). The weeds were subsequently allowed to develop until final harvest when they were removed. In the second series, weed interference treatments of varying duration allowed weeds to compete with dry bean from crop emergence until 10 (WI10), 20 (WI20), 30 (WI30), 40 (WI40) and 50 (WI50) days; then the plots were weeded and kept weed-free until harvest. Control plots were kept free of weeds (WFT) or left weedy (WIT) throughout the growth period. Weeds were removed by hand pulling and hoeing.

To determine the effect of weed-crop competition on weed dry weight accumulation, weeds were sampled in two quadrate (1.0 m × 1.0 m) per plot at each weeding time in the weed interfered 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.

Crop sampling was started 14 days after emergence and repeated 6 times with a 14 days interval. In each sampling five dry bean plants per plot were cut at the soil surface in middle rows. Leaves were separated from stems and leaf area index of them was measured. Then plant biomass was determined by oven drying at 75°C for 48 hours. Dry bean leaf area index (LAI), biomass per unit area, relative growth rate (RGR) and net assimilation rate (NAR) as a function of time were determined for each subplot.

Specific procedures for our analysis were as follows. Primary crop data were first transformed to natural logarithms to stabilize variance. Following transformation, data were subjected to process of curve fitting to obtain the best functional description of relationships between primary measures and time (*t*, in days) using the REG procedure of SAS (SAS Institute, 1999). The relationship between time (*t*) and the transformed primary crop variables, dry matter [ln(DM)], leaf area index [ln(LAI)], relative growth rate (RGR) and net assimilation rate (NAR) can be expressed as presented in the following functions (Heggenstaller *et al*., 2009):

$$\ln(DM)=f_{DM}(t)$$
$$\ln(LAI)=f_{LAI}(t)$$
$$RGR=f'_{DM}(t)$$
$$NAR=f'_{DM}(t)\ \exp[f_{DM}(t)-f_{LAI}(t)]$$

For analysis of variance, ANOVA procedure was practiced in SAS software (SAS Institute, 1999).

Results and discussion

Lamb's Quarters (*Chenopodium album*), Red-root Amaranth (*Amaranthus retroflexus*), Prostrate Amaranth (*Amaranthus blitoides*) and Field Bindweed (*Convolvulus arvensis*) accounted for the majority of the weeds (Fig. 1) although Cockspur (*Echinocloa crus-galli*), Corn Sow Thistle (*Sonchus arvensis*) and Green Foxtail (*Setaria viridis*) were also present. Weed biomass had a significant difference in plots. Weed interference periods from 0 to 20 DAE do not have a significant effect on weed biomass accumulation (Tab. 1). After this period (20 DAE) weeds gathered more dry matter perhaps due to extension of their leaves as a photosynthetic area (Tab. 1). On the other hand, weed control more than 40 DAE, does not significantly affect weed biomass (Tab. 1). In fact, at this period

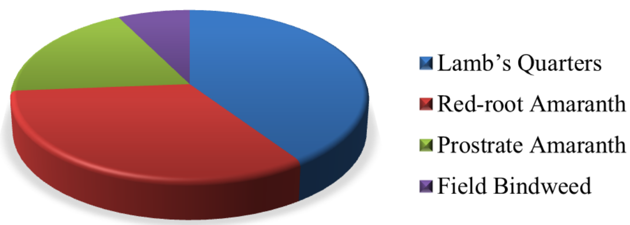

Fig. 1. Biomass of major weeds at dry bean harvest time in season-long weed-infested treatment

Tab. 1. Means comparison for weed biomass at different treatments of weed interference and weed free periods using LSD test

	Day after crop emergence					
	0	10	20	30	40	50
	Weed biomass (g m^{-2})					
Weed Infested	0.00f	7.70f	38.57f	160.47cd	214.34bc	252.27b
Weed Free	337.40a	290.56ab	217.48bc	153.21cd	127.17de	54.76ef

Means followed by the same letter(s) are not significantly different at the p=0.05 level using LSD test

of time, dry bean can suppress the weeds because of its expanded canopy.

Leaf area and leaf photosynthetic efficiency represent two fundamental factors driving crop growth (Hunt, 1982). For all crops, LAI generally increased to a maximum point and then declined until harvest. Maximum LAI was approximately achieved 80 days after emergence for all treatments (Fig. 2). As the crop kept weed-free from the emergence LAI trend was increased. Conversely, weed inference reduced LAI trend over time (Fig. 2). However, this reduction was not conspicuous at the early of growing season, conceivably because of low density of weeds at this time. Williams and Lindquist (2007) reported that in sweet corn, growth in LAI was strongly affected by weed interference. Hall *et al.* (1992) and Stagnari and Pisante (2011) observed similar leaf area reductions due to weed interference.

Growth in biomass was affected by weed interference (Fig. 3). Maximum of crop biomass was approximately observed at 80 DAE which corresponds with maximum LAI that obtained at this time (Fig. 2 and Fig. 3). Eighty days after emergence, weed interference reduced crop biomass from 1238.82 g m^{-2} in WF to 676.60 g m^{-2} in WI (Fig. 3). Similar to LAI, detrimental effects of weed competition on crop biomass was more severe in the middle of growing season than first days of emergence. LAI reduction which leads to a poor photosynthesis can be the main result of biomass decline. Confirming these results Papamichail *et al.* (2002) observed a decrease in total crop biomass due

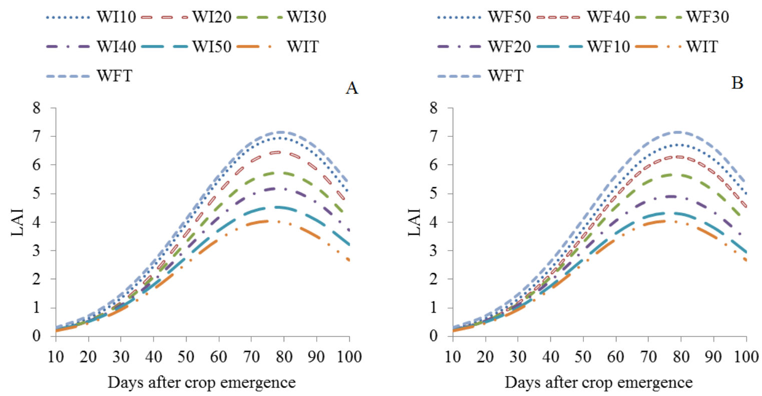

Fig. 2. Dry bean leaf area index (LAI) trend over time at different treatments of weed interference (A) and weed free (B) periods. WI10, WI20, WI30, WI40 and WI50: weed infested periods until 10, 20, 30, 40 and 50 days after crop emergence, respectively; WF10, WF20, WF30, WF40 and WF50: weed free periods until 10, 20, 30, 40 and 50 days after crop emergence, respectively; WIT and WFT: weed competition and weed control throughout growing season, respectively

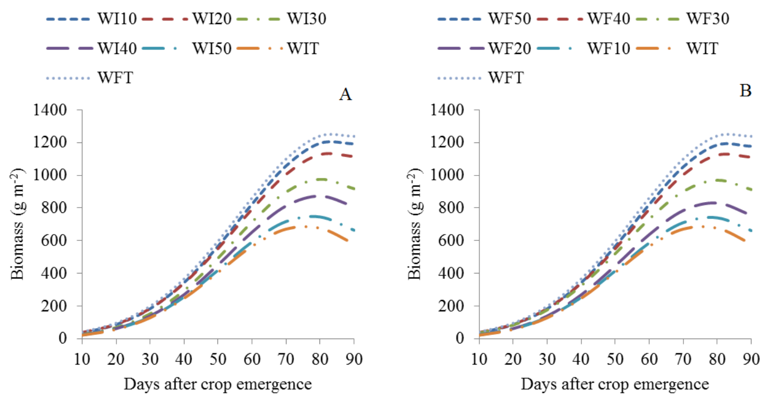

Fig. 3. Dry bean biomass trend over time at different treatments of weed interference (A) and weed free (B) periods. WI10, WI20, WI30, WI40 and WI50: weed infested periods until 10, 20, 30, 40 and 50 days after crop emergence, respectively; WF10, WF20, WF30, WF40 and WF50: weed free periods until 10, 20, 30, 40 and 50 days after crop emergence, respectively; WIT and WFT: weed competition and weed control throughout growing season, respectively

to weed interference. Bukun (2004) reported the same results on biomass and plant height of cotton.

Relative growth rate (RGR) describes dry matter which is produced by current crop biomass. In all treatments RGR trend was similar and gradually decreased over time (Fig. 4). This is corroborates findings of Buttery (1988) who stated that RGR had a linear reduction trend in soybean during the growing season. Intensity of RGR decline was more acute in WI compared to other treatments (Fig. 4). As the crop was kept weed-free from the emergence for increasing periods of time, an increase in RGR was observed (Fig. 4). Similar results are reported by Traore *et al.* (2003) in sorghum.

Net assimilation rate (NAR) explains amount of dry matter which is made by leaf area. NAR is closely related to absorption of sun light. Therefore, when all leaves receive sun light more than light compensation point (LCP) NAR can be at the maximum amount. Results showed a similar trend of NAR in all crops so that NAR gradually decreased from emergence up to harvest (Fig. 5). At the early of growing season due to an undeveloped canopy, sun light can easily pass through the crop canopy. Thus, underneath leaves can receive more photosynthetic photon flux density (PPFD) for doing photosynthesis and consequently NAR would be at the highest point. As the crop develops, underneath leaves receives less PPFD which lead to a reduction of NAR. Weed interference adversely affected NAR and intensified decline of this trait over time (Fig. 5). However, at the early of growing season the effect of weed-infested treatments was trifle so that in 10 DAE, the highest NAR was observed in WI10 (Fig. 5). Velayati *et al.* (2010) reported the same result on cotton.

Natural weed biomass was found to have an effect on leaf area index, plant biomass, RGR and NAR. As weeds accumulated more biomass, further decline in these crop traits was observed (Fig. 6). When weeds increased their biomass from 0 to 200 g m^{-2} NAR had a positive value (Fig. 6). However, accumulation of more than 200 g m^{-2} decreased NAR to a negative value (Fig. 6) which indicates a severe effect of weeds on crop assimilation. Moreover, RGR trend in relation to weed biomass was almost similar to NAR (Fig. 6). These results confirm findings of Qasem (1995) who stated that crop growth was adversely affected by weed biomass accumulation. Same results reported by Covero *et al.* (1999).

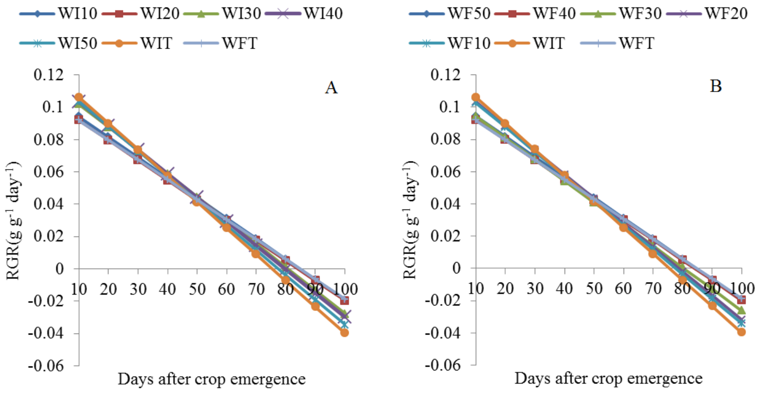

Fig. 4. Dry bean relative growth rate (RGR) trend over time at different treatments of weed interference (A) and weed free (B) periods. WI10, WI20, WI30, WI40 and WI50: weed infested periods until 10, 20, 30, 40 and 50 days after crop emergence, respectively; WF10, WF20, WF30, WF40 and WF50: weed free periods until 10, 20, 30, 40 and 50 days after crop emergence, respectively; WIT and WFT: weed competition and weed control throughout growing season, respectively

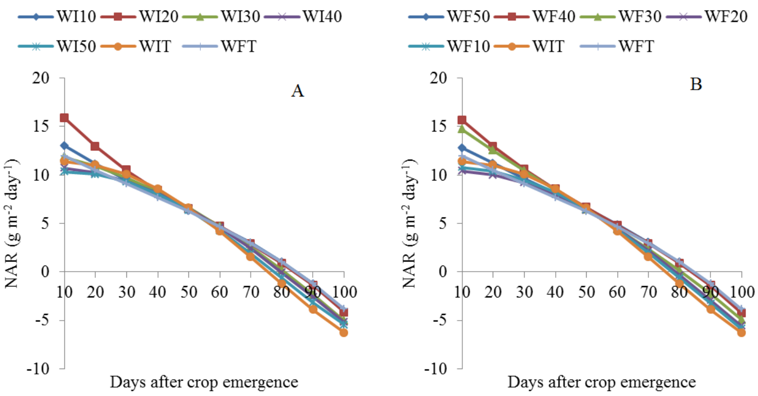

Fig. 5. Dry bean net assimilation rate (NAR) trend over time at different treatments of weed interference (A) and weed free (B) periods. WI10, WI20, WI30, WI40 and WI50: weed infested periods until 10, 20, 30, 40 and 50 days after crop emergence, respectively; WF10, WF20, WF30, WF40 and WF50: weed free periods until 10, 20, 30, 40 and 50 days after crop emergence, respectively; WIT and WFT: weed competition and weed control throughout growing season, respectively

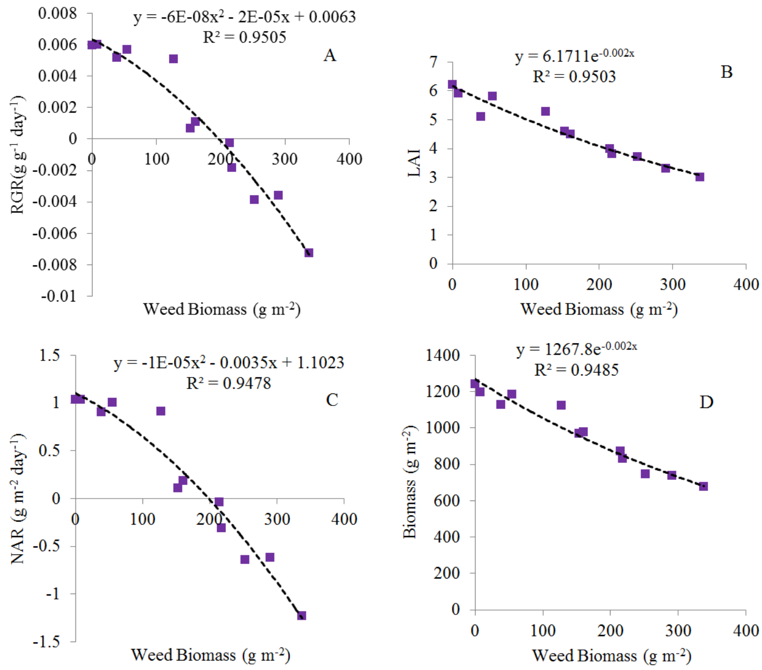

Fig. 6. Relationship between weed biomass and dry bean RGR (A), LAI (B), NAR (C) and biomass (D)

Conclusions

Results indicate that dry bean can be strongly affected by weed interference. Crop biomass was severely reduced by increasing duration of weed-infested periods. This phenomenon can be explained by detrimental effect of weed competition on leaf area index. In all treatments relative growth rate gradually decreased over time. Therefore, it can be concluded that crop ability of dry matter production declines from emergence to harvest. Weed competition caused a conspicuous reduction in net assimilation rate. However, at the early of growing season, this phenomenon was trifle. Thus, adverse effect of weed interference on photosynthesis at the initial stage of dry bean growth is trivial.

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