Allelopathic effects of redroot pigweed (*Amaranthus retroflexus* L.) root exudates on common bean seedling growth

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**Abstract**

The study was conducted to evaluate the allelopathic effects of redroot pigweed (*Amaranthus retroflexus* L.) root exudates on seedling growth of common bean (*Phaseolus vulgaris* L.) cultivars. The study was arranged in a factorial experiment based on randomized completely block design (RCBD) with four replications. The factors were three common bean cultivars including Akhtar, Daneshkade and Khoemun, redroot pigweed densities at 0, 4, 8, 16, 24 and 32 pre-germinated seeds in each beaker and redroot pigweed growing time at 3, 6, 9 and 12 days. Results indicated that the effects of common bean cultivar, redroot pigweed seed density and growing time were significant on common bean root and shoot length. The redroot pigweed growing time of 6 days and densities of 16 and 24 plants per beaker had the greatest inhibitory effect on common bean root and shoot length. Also the redroot pigweed had the greatest inhibitory effect on seedling growth of cv. Daneshkadeh.

**Keywords:** Allelopathy, common bean, growing time, redroot pigweed, root exudates

**Introduction**

Allelopathy occurs through the release of chemicals from one plant species affecting other species growing in its vicinity, usually to their detriment (Pratley, 1996). This phenomenon is due to inhibitory substances that are released directly from living plant into the environment through root exudation, leaching and volatilization, and through the decomposition of plant residues (Rice, 1984). Allelopathic materials prevented the growth and development of plants and decrease their yield in field (Putnam, 1986).

Common bean (*Phaseolus vulgaris*) is the main source of protein in many developing countries throughout the world (FAO, 2009). Redroot pigweed (*Amaranthus retroflexus* L.) is one of the most important weeds of common bean in Iran (Shimi and Termeh, 2004). Redroot pigweed is a C₄ weed that has been spread at many agricultural areas and is the third dicotyledon prevalence weed in the world (Ronald and Smith, 2000). Stebbing et al. (2000) showed that *A. retroflexus* at densities of 1 plant per 2 and 3 m of row, reduced sugar beet yield by 12%, and by 31%, respectively. Redroot pigweed at a density of 1200 plants m⁻² reduced cowpea (*Vigna unguiculata* L. Walp.) yield by 56% (Itulya et al., 1997). Two redroot pigweed plants per meter emerging with soybean (*Glycine max* (L.) Merr.) Reduced crop yield 12.3% (Dielman et al., 1995). *Amaranthus* extract influenced germination, seeding dry weight and growth of rapeseed (*Brassica napus*) by producing allelochemicals (Rezaei et al., 2008). The palmer amaranth (*Amaranthus palmeri*) residue was incorporated in to the soil had allelopathic effects on grain sorghum seedling growth (Thilsted and Murray, 1980). Menges (1988) also found that *Amaranthus* spp. root and shoot growth was equally sensitive to the allelopathic effect of palmer amaranth residue.
Allelopathy is a two-way interaction; therefore, redroot pigweed allelopathic effect on common bean may be through release of allelochemicals and thereby affecting the common bean growth and establishment. In this research the Equal-Compartment-Agar Method (ECAM), developed by Wu et al. (2000) was used to assess the effects of redroot pigweed root exudates on common bean. The main objective of this study was to evaluate the allelopathic effects of redroot pigweed root exudates at different densities and growing times on seedling growth of three common bean cultivars.

Materials and Methods

The experiment was conducted during 2011 in Faculty of Agriculture, Tabriz University. The redroot pigweed seeds were collected from research farm of Faculty of Agriculture, Tabriz University. The common bean seeds were germinated at 25°C during 3 days and redroot pigweed were germinated at 30°C during 2 days, in Petri dish. Pre-germinated seed of redroot pigweed were uniformly selected and transplanted on the agar surface in an embryo-upward state, so that one-half of agar surface was allotted to them. Each glass beaker (600 ml) was prefilled with 40 ml of 3% water agar. The beakers were placed in a controlled growth cabinet preparing a daily light/dark cycle of 13/11 h and a temperature cycle at 27 °C /17 °C. The studied factors of this experiment were three common bean cultivars including Akhtar, Daneshkade and Khomein, redroot pigweed pre-germinated seed densities and growing times. After transplanting the pigweed pre-germinated seeds at different densities (0, 4, 8, 16, 24 and 32 pre-germinated seeds per each beaker) they were allowed to grow for different times (3, 6, 9 and 12 days) an then 8 common bean pre-germinated seeds were added to growth medium and had co-growth for more 10 days. At end of the growth period, the total root length and shoot length of common bean were measured as growth criteria.

The study was arranged in factorial experiments based on randomized completely block design (RCBD) with four replications. Experimental data were subjected to analysis of variance using SAS and SPSS software. Comparisons of treatments were performed using the LSD test at $P < 0.05$.

Results and discussion

The results of analysis of variance showed significant difference among bean cultivars, growing times and redroot pigweed densities. The interaction effects of redroot pigweed density and growth time, common bean cultivar and growth time, and common bean cultivar and redroot pigweed density on common bean root and shoot length were significant (data not shown). At low densities of redroot pigweed the difference among redroot pigweed growing times was lower, but at high densities, the inhibitory activity of redroot pigweed increased and differences among growing times were significant (Figure 1, A and B). The greatest inhibition effect on common bean root and shoot length observed at high densities and 6 day old seedlings of redroot pigweed (Figure 1, A and B). There was negligible difference between 3 and 12 and also 6 and 9 days, whereas difference between them was noticeable, especially at high densities of redroot pigweed. When redroot pigweed grew for 12 days the inhibition effect was reduced in comparison with 6 and 9 days, probably because of degradation of root exudates. It is resulted that 6 and 9 days old seedlings of redroot pigweed produced more root exudates and exerted more allelopathic effects on common bean seedlings. Control treatment was without redroot pigweed and there was not any significant difference between them. Redroot pigweed seedlings grown in agar medium reduced the root and shoot length of common bean and this effect was intensified by increasing the redroot pigweed density beyond 24 plants /beaker. Qasem (1994) observed that the shoot and root extracts of redroot pigweed, prostrate amaranth (Amaranthus blitoides S. Wats), and slender amaranth (Amaranthus gracilis Desf.) reduced the shoot and root length and root dry matter of wheat (Triticum durum L.). Ismail and Chonge (2002) found that allelochemicals may have negative or positive effects on target plants in low concentrations, but at high concentrations have inhibitory activity. The reduction in inhibition effect of redroot pigweed at high densities may be attributed to autotoxicity effects of redroot pigweed seedlings. Also in farm experiment the autotoxicity effect of root exudates on wheat (Triticum aestivum L.) root growth have been reported (Wu et al., 2007). Generally at all common bean cultivars, when the redroot pigweed grew for 6 days, it had the greatest inhibition effect on redroot pigweed growth. The reduction in inhibition effect of redroot pigweed at growth time greater 9 days could be explained by degradation of redroot pigweed root exudates. Huang et al. (2003) also observed that concentration of allelochemicals had the greatest amount between 6-8 growing days and after this time their concentration declined. One reason could be the limited half-life of allelopathic compounds in agar medium. For example, DIMBOA has a half-life of 5.3 hr and
decomposes to the more stable MBOA that has lesser inhibitory activity (Macias et al., 2002). The root exudates of annual ryegrass (*Lolium rigidum*) in agar medium reduced the wheat root length by up to 50% related to the control (Amini et al., 2009). They also observed that by increasing the growing days, the inhibition effect of annual ryegrass was decreased.

![Figure 1](image1.png)

**Figure 1.** The effect of redroot pigweed growth time and density on common bean root (A) and shoot length (B) (LSD = 6.4 and 0.55, *P* < 0.05).

Assessment of redroot pigweed density effect on root length of common bean cultivars indicated that increasing redroot pigweed density from 0 to 24 plants increased the inhibition effect of redroot pigweed on root growth of common bean cultivars. Increasing the redroot pigweed density from 24 up to 32 plants had not significant effect on common bean root length. The cv. Akhtar and Khomein showed similar response regard to root length to redroot pigweed density and the redroot pigweed had the lowest inhibition effect on root length of cv. Khomein (Figure 2). The cv. Daneshkadeh showed the greatest susceptibility to increasing the redroot pigweed density (Figure 2, A and B).

![Figure 2](image2.png)

**Figure 2.** The effect of redroot pigweed density on root (A) and shoot (B) length of three common bean cultivars (LSD = 5.5 and 0.5, *P* < 0.05).

Common bean cultivars showed different response to allelopathic potential of redroot pigweed. The effect of redroot pigweed density on common bean root length was significantly different at all redroot pigweed densities, whereas the effect of redroot pigweed density on common bean shoot length was different at high densities of redroot pigweed. Totally results indicated that redroot pigweed had the greatest and lowest inhibition
effect on cv. Daneshkade and Khomein, respectively. The different responses to allelopathic effects were reported at different cultivars of crops (Duke, 1987). Amini et al. (2011) also observed that the seedling growth of wheat cultivars had different responses to root exudates of annual ryegrass. The inhibition effect of redroot pigweed on cv. Akhtar and Daneshkade was not significantly different at all redroot pigweed densities.

We observed that there is genetic diversity in common bean cultivars in response to the allelopathic challenge of redroot pigweed and thus more common bean cultivars need to be evaluated for their responses. Previous studies have indicated that allelopathy can be used in integrated weed management (Roth et al., 2000; Inderjit and Duke, 2003). Given the increasing public concern about the use of synthetic herbicides, there is great need for new approaches to weed management (Bertin et al., 2007). The use of common bean cultivars with elevated tolerance to allelopathic activity of redroot pigweed could reduce the need for commercial herbicides in early season application, with late season weed control provided by the crop competitiveness. Common bean is a crop with low competitive ability especially at early growth stages (Mesbah et al., 2004), therefore selection of common bean cultivars with high tolerance to redroot pigweed allelopathic activity can suppress the redroot pigweed early growth and competitive ability. These cultivars should therefore grow better and common bean yield should be increased in presence of redroot pigweed. Therefore the identification of common bean cultivars with low susceptibility to redroot pigweed allelopathic activity may contribute to the development of effective and more environmentally friendly weed management strategies.

References