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Research Article

MODELING OF PIGWEED INTERFERENTIAL EFFECTS IN BEAN FIELDS FOR SEMI ARID CLIMATICALLY CONDITIONS

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ABSTRACT
Two randomized complete block design experiments were conducted in Tabriz, Iran, to modeling of pigweed interferential effects in bean fields for semi arid climatically conditions. The treatments were weed-infested and weed-free plots at the periods of 2, 4, 6, 8, 10 and 14 weeks after bean emergence. Green bean biomass was affected by early-emergence of redroot pigweed, but biomass of green bean was not reduced when redroot pigweed emerged at 10 weeks after crop emergence, along with crop emergence, and grew with green bean until four weeks after bean emergence (WABE). Each 100 g m^{-2} of weed biomass produced resulted in a 1.4 kg ha^{-1} loss in green bean yield. When redroot pigweed interference lasted for four weeks or longer after green bean emergence, green bean yield was significantly reduced. Weeds, which grew in the field after green bean emergence for two weeks and thereafter they were controlled, did not significantly decrease crop productivity. The highest crop yield was obtained when weed emerged 14 WABE.

***Keywords**: Early-Emergence, Interference, Modeling, Weed-Infested*

INTRODUCTION
On a global basis, weeds are considered to be responsible for about 10% reduction of crop yield (Froud-Williams, 2002). Several species of *Amaranthus* are known to be important weeds that reduce crop yield. They constitute nearly 45-55% of the total weed flora of the region (Karimi, 2003). Green bean is an important pulse crop in this province and often grown in rotation with cereals. Critical period of weed control (CPWC) program depends on many factors such as cultivar (Seem *et al.*, 2003), climate, weed population density and dominant weeds in the region (Martin *et al.,* 2001; Seem *et al.,* 2003) and weed interference duration (Massinga *et al.,* 2001).
Weeds usually are very competitive, when they emerge before or along with the crop. When only two redroot pigweeds per meter row emerged with soybean [*Glycine max* (L.) Merr.], crop yield reduced by 12.3%, but weeds emergence at the second nodal stage of soybean did not cause significant effect on its yield (Dielman *et al.,* 1995). Redroot pigweed that emerges in June grew faster by 0.03 cm for each growing degree day than the plants emerged one month later (Horak and Loughin, 2000). Itulya *et al.,* (1997) reported that redroot pigweed at a density of 1,200 plants ha^{-1} reduced cowpea [*Vigna unguiculata* (L.) Walp.] yield by 56%. Full season competition of 120 ragweed plants per square meter with snap bean reduced crop yield 75% (Evanylo and Zehnder, 1989). In another experiment conducted by Aguyoh and Masiunas (2003), early emerging redroot pigweeds reduced snap bean yield 13 to 58% at densities of 0.5 to 8 plants m^{-1}, respectively. Green bean is a poor competitive plant and it's weeds control heavily relies on herbicides in Iran (Hosseini, 2006).
Limited use of herbicides, due to their adverse effects on sustainability of agricultural ecosystems in recent decades has been advocated (Burnside *et al.,* 1998). Critical period of weed control can help to determine the appropriate time of herbicide applications and reduce weed population impacts on the crop. It has also an important role in the development of alternative weed management strategies (Woolley *et al.,* 1993; Knezevic *et al.,* 2002; Miri and Ghadiri, 2006). CPWC is useful in defining the crop growth stages which are quite vulnerable to weed competition (Hall *et al.,* 1992; Van Acker *et al.,* 1993; Knezevic *et al.,* 1994). These research results reveal that early emerging weeds usually reduce crop yields. This means that late-emerging weeds may not reduce crop yields. The time interval between early

and late emergence is the critical period of weed control (Burnside *et al*., 1998; Miri and Ghadiri, 2006). Controlling weeds beyond this period may not be necessary for optimum crop yield (Swanton *et al.*, 1999). This period has been determined for many crops. In soybean it occurs between 9 to 38 days after planting (DAP) to control hemp sesbania [*Sesbania exaltata* (Rof) Cory.] (Van Acker *et al*., 1993). In cotton (*Gossypium hirsutum* L.) the period is less than 65 DAP (Bryson, 1990) and for safflower (*Carthamus tinctorius* L.) is up to flowering (Miri and Ghadiri, 2006). This period for dry bean (*Phaseolus vulgaris* L.) was 3 to 5 or 6 weeks after sowing (Burnside *et al*., 1998). There is no published information on weed interference and the critical period in green bean.
Determining CPWC and the potential weed impact on crop morphology may provide useful information upon which future weed control recommendations can be based. This study was aimed to modeling of pigweed interferential effects in bean fields for semi arid climatically conditions.

MATERIALS AND METHODS

Two field experiments were conducted on a sandy loam soil at the Agricultural Research Station of Islamic Azad University of Tabriz, Iran. The experimental fields had been in a bean-potato-barley rotation cycle for the last two years. Each year, the experimental area was ploughed in the fall and manured with 10 t ha^{-1}. Fields were cultivated, disked, furrowed and then plotted in spring before sowing the seeds. Fertilizers used, in spring and before sowing, were 150, 100 and 15 kg ha^{-1} of ammonium phosphate, potassium sulfate and urea, respectively. The size of plots was 3 by 3 m in both years. Each plot consisted of six green bean rows spaced 50 cm apart. The green bean hybrid '*Cantander*'[1], was inoculated with *Rhizobium phaseoli* and sown at four centimeter depth with a density of 100,000 plants ha^{-1} on 5th May, 2012, and 7th May, 2013. The treatments were weed-infested and weed-free in same periods. The last density of redroot pigweed was eight plants m^{-1} of bean row. Each year, for weed-infested plots, redroot pigweeds were hand removed after 2, 4, 6, 8, 10 and 14 weeks after bean emergence (WABE) and were kept weed free thereafter. For weed-free experiment, redroot pigweeds that were provided from transplanted seedlings in green bean rows were allowed to compete with green bean plants from 2, 4, 6, 8, 10 and 14 WABE thereafter. Also all plots were hand removed for other weed species in growing season. Plots were irrigated immediately after sowing to assure uniform emergence. No herbicide, neither before nor after sowing, was used to control weeds. At harvesting stages, the middle four green bean rows of each plot were hand harvested.
The experimental design in each year was a randomized complete block with three replications. All data were analyzed using the MSTAT-C software. Treatment means were separated using Fischer's Protected LSD at P= 0.05 level. Regression analysis was performed to describe the relationship between bean yield and duration of redroot pigweed interference using the REG PROCEDURE of SAS (SAS 2000).
A sigmoid model provided the best fit for the maximum weed-infested experiment. The model was as follows (Ghosheh *et al*., 1996):

$$Y= A + B * Exp (-CX^2)$$

where, Y: green bean yield (kg ha^{-1}), A + B: yield of redroot pigweed-free check plots, C: coefficient of redroot pigweed interference duration and X: weeks of redroot pigweed-infested period.
The relationship of green bean yield with weed-free period was best described by the polynomial equation as follows:

$$Y= a + b_1X + b_2X^2 + b_3X^3$$

where, Y: green bean yield (kg ha^{-1}), a, b_1, b_2 and b_3: coefficients of redroot pigweed interference duration and X: weeks of redroot pigweed-free period (Ghosheh *et al.*, 1996).
Predicted bean yield loss of 5% and 10% were chosen to determine maximum weed-infested and minimum weed-free periods.

[1]- Institute of Seed Improvement in Karaj, Iran.

RESULTS AND DISCUSSION

Green bean biomass was not affected by redroot pigweed after the first four weeks of interference; however a significant loss in crop biomass occurred thereafter in comparison with full-season weed-free plots. Number of stem branches of green bean in weedy check plots was reduced by 65% as compared with weed-free plots (Table 1). Redroot pigweed biomass was reduced when duration of interference decreased (Tables 1 and 2). The number of branches per green bean plant decreased, when the duration of weed interference increased. Comparison of stem height of green bean and redroot pigweed at different weed-infested durations was depicted in Table 3. Height of redroot pigweed at early interference durations was shorter than that of green bean in both years, while redroot pigweed suppressed height of green bean 8 WABE.

Yield loss of green bean due to redroot pigweed interference ranged from 3% in weed removal in 2 WABE to 68% in full-season weed-infested plots (Tables 1 and 2). Removal of redroot pigweed two WABE and interference of redroot pigweed at 10 WABE until harvesting provided a similar green bean yield to the season-long weed-free control. However, when redroot pigweed interference was lasted for four weeks or longer after green bean emergence, yield was reduced significantly. Redroot pigweed interference up to 10 WABE reduced green bean yield 67% compared with the weed-free check plots (Table 1). The CPWC using 5% yield loss was between 1.9 to 8.5 WABE (13 to 68 days after bean emergence). The CPWC for 10% yield loss, it was between 2.7 to 7.8 WABE (19 to 55 days after bean emergence) (Figure1).

Eftekhari *et al.,* (2006) reported that the number of side branches per plant in soybean decreased significantly when the period of weed interference increased. Weed interference duration of six WABE or more and weed-free period of less than eight weeks greatly reduced the number of pod bearing branches per plant (Table 1). Green bean biomass, as reported by Eftekhari *et al.,* (2006) on soybean, was also affected by early-emergence of redroot pigweed. However, its emergence at 10 WABE did not cause a substantial reduction in green bean biomass (Tables 1 and 2). This result might be due to the late emergence of redroot pigweed plants that grow slower and are weaker than green bean during growing season. Redroot pigweed biomass in check plots was 295.5 g m^{-2}, while it decreased 2.7 g m^{-2} per each day when its emergence was delayed (Table 2). These results are in agreement with those reported by Eftekhari *et al.,* (2006), who studied on interference of weeds with soybean. It has been also reported that with increasing of 100 g m^{-2} weeds biomass, bean yield decreased 1.4 kg ha^{-1} (Burnside *et al.*,, 1998).

Comparing stem height of green bean and redroot pigweed at different weed-infested durations (Table 3), it can be concluded that heights of redroot pigweed and green bean depending on weed emergence time would vary. Stem height of redroot pigweed at four weeks interference duration was shorter than green bean, but in later interference durations, redroot pigweed height increased as compared to green bean. This result could be attributed to relatively high temperature in region that has increased competitiveness of redroot pigweed in compared with green bean. Stem height is one of the important traits for light interception and higher ability of competition (Barnes *et al.,* 1990; Miri and Ghadiri, 2006). Percent yield loss of bean varied with redroot pigweed time of emergence. Green bean yield from season-long weed-free plots averaged over years was 6.18 t ha^{-1} (Table 1). Weeds, which emerged two weeks after green bean emergence, did not decrease crop productivity, significantly (Tables 1, 2).

Significant reduction in green bean yield with increasing of redroot pigweed interference duration indicates that redroot pigweed is highly competitive with bean, and it's competition beyond two WABE, results in greater yield loss of green bean (Table 1). As late emerging redroot pigweed was not as competitive as early emerging one, the yield reductions at $\geq$ 6 WABE based on weed-infested periods (Table 1) or < 8 WABE based on weed-free periods (Table 2) would not be acceptable to commercial growers. Similar results have been reported by Aguyoh and Masiunas (2003) and Evanylo and Zehnder (1989) on snap bean, Blackshaw (1991) on dry bean, Itulya *et al.,* (1997) on cowpea, Dielman *et al.,* (1995) and Eftekhari *et al.,* (2006) on soybean, and Wooley *et al.,* (1993) on white bean. A maximum of 10% acceptable yield loss could be considered to determine the CPWC for most crops. These results suggest that, when green bean hybrid '*Cantander*', is grown in 50 cm row spacing, to prevent such a loss in green bean, redroot pigweed should be removed from field at 1.9 WABE based on weed-infested period.

Table 1: Influence of weed-infested periods on some traits of green bean and redroot pigweed

Weed-infested periods (WABE)	Number of branches per green bean plant	Green bean biomass (kg ha^{-1})	Redroot pigweed biomass (g m^{-2})	Green bean yield (kg ha^{-1})
2	12.5	665	69.2	6010
4	11.9	643	84.5	5722
6	8.6	575	180.2	4220
8	7.3	532	237.7	2523
10	6.6	493	282.6	2059
14	4.5	443	292.3	2016
Weed free check	13.0	674	0	6175
LSD (0.05)	1.2	34	3.9	123

Each value averaged over two years of experiment
WABE means weeks after bean emergence

Table 2: Influence of weed-free periods on some traits of green bean and redroot pigweed

Weed-free periods (WABE)	Number of branches per green bean plant	Green bean biomass (kg ha^{-1})	Redroot pigweed biomass (g m^{-2})	Green bean Yield (kg ha^{-1})
2	5.5	464	295.5	2124
4	6.5	495	270.0	3386
6	8.9	576	211.0	4849
8	10.8	616	171.0	5792
10	12.0	645	70.0	5966
14	12.5	674	35.1	6175
Weedy check	5.0	443	295.5	2016
LSD (0.05)	1.4	25	28.6	217

Each value averaged over two years of experiment
WABE means weeks after bean emergence

Table 3: Stem height of green bean and redroot pigweed at different periods after emergence

Year	WABE	Green bean height (cm)	Redroot pigweed height (cm)	Differential height
2012	0	-	-	-
	2	8	6	-2
	4	15	11	-4
	6	19	19	0
	8	24	32	+8
	10	30	40	+10
	14	31	83	+52
LSD (5%)		3.25	7.33	-
2013	0	-	-	-
	2	8	5	-3
	4	15	11	-4
	6	20	20	0
	8	25	35	+10
	10	31	45	+14
	14	34	93	+59
LSD (5%)		3.89	9.00	-

WABE means weeks after bean emergence

A green bean crop should be grown without redroot pigweed for 7.8 WABE, so that yield losses will not exceed that of 10% (Figure 1). We concluded that if growers use pre-plant incorporated or pre-emergence herbicides, they should use those with enough soil residual activity to control weeds until eight WABE.

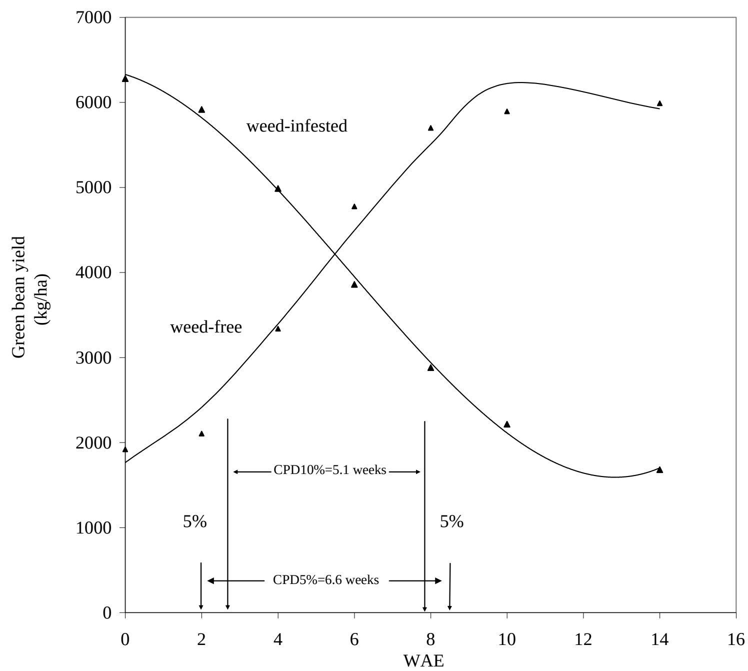

Figure 1: Relationship between green bean yield and weed-infested and / or weed-free period
Predicted yield values for weed-infested duration were obtained by the equation:
Y = 1654.72+ 4816.33* Exp (-0.02 X^2), R^2= 0.96.
Predicted yield values for weed-free duration were obtained by the equation:
Y = 1845.31 + 187.75 X + 70.29 X^2 – 4.43 X^3, R^2=0.98.
CPD means critical period duration at 5% or 10% yield loss; and WABE means weeks after bean emergence.

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