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The Critical Period of Weed Control in Soybean (*Glycine max* (L.) Merr.) in North of Iran Conditions

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Abstract: A field study was conducted in 2006 at Sari Agricultural and Natural Resources University, in order to determine the best time for weed control in soybean promising line, 033. Experiment was arranged in randomized complete block design with 4 replications and two series of treatments. In the first series, weeds were kept in place until crop reached V2 (second trifoliolate), V4 (fourth trifoliolate), V6 (sixth trifoliolate), R1 (beginning bloom, first flower), R3 (beginning pod), R5 (beginning seed) and were then removed and the crop kept weed-free for the rest of the season. In the second series, crops were kept weed-free until the above growth stages after which weeds were allowed to grow in the plots for the rest of the season. Whole season weedy and weed-free plots were included in the experiment for yield comparison. The results showed that among studied traits, grain yield, pod numbers per plant and weed biomass were affected significantly by control and interference treatments. The highest number of pods per plant was obtained from plots which kept weed-free for whole season control. Results showed that weed control should be carried out between V2 (26 day after planting) to R1 (63 day after planting) stages of soybean to provide maximum grain yield. Thus, it is possible to optimize the timing of weed control, which can serve to reduce the costs and side effects of intensive chemical weed control.

Key words: Soybean, critical period, weeds interference, weeds control

INTRODUCTION

Soybean (*Glycine max* (L.) Merr.) is one of the protein and mineral sources for human food and livestock feed. Soybean production is expected as a result of the recent introduction of early maturing cultivars and an increasing demand for a new break crop to provide oil and protein (Lukiwatid and Simanungkalit, 2002). On the other hands, weeds compete for available resources, reduce soybean yield and increase production costs because of the added costs of weed management (Zimdahl, 1980). Weeds can be controlled in soybean; however, this requires good management practices in all phases of soybean production. Good soybean weed control involves utilizing all methods available and combining them in an integrated weed management system (Ferrell *et al*., 2006). The development of Integrated Weed Management (IWM) has become a major goal under the systems approach to sustainable agriculture (Swanton and Weise, 1991). IWM involves the reduction of weed interference through multi-disciplinary action, while acceptable crop yields and environmental, social and economic health are maintained (Swanton and Murphy, 1996). Knowledge of the critical period of weed competition in soybean helps growers implement effective and timely weed management practices. The definition of critical period can be broken down into two subunits: (i) the weed competition period and (ii) the weed free time requirement. The weed competition period defines the maximum period in which weeds can be allowed to compete with the crop not result in an unacceptable yield loss i.e., it defines the beginning of the critical period of weed control (Singh *et al*., 1996; Swanton and Weise, 1991; Zimdahl, 1988; Halford *et al*., 2001; Kenezevic *et al*., 2003). The weed-free time requirement describes the minimum amount of time a crop must be maintained free of weeds to prevent crop yield loss i.e., it defines the end of the critical period of weed control. Applying herbicides only during the critical period of weed control presents a potential way of reducing herbicide use under a no-till situation (Halford *et al*., 2001).

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One of the first studies to introduce the concept of a critical period of weed corn was conducted in Mexico by Nieto *et al.* (1968). They concluded that corn must be kept free of weeds from 10 days after crop emergence for maximum yields to be obtained. Zimdahl (1988) determined that a corn field should be weeded within the first four weeks after planting. However, Removing the weeds within the first two weeks after crop and weed emergence may not be necessary. In Ontario, research on the critical period of weed control for corn has been done using crop growth stages to define the critical period to account for environmental variation (Hall *et al.*, 1992; Knezevic *et al.*, 1994). Field studies showed that, for an acceptable yield loss of 2% the beginning of critical period defined by duration of weed interference in conventionally grown corn was highly variable ranging from the 3-14 leaf stages of crop development. However, The end of the critical period (defined by duration of weed-free maintenance) was less variable and ended at approximately the 14-leaf stage (Hall *et al.*, 1992). In a related study by Knezevic *et al.* (1994) it was found that if redroot pigweed (*Amaranthus retroflexus*) were not controlled in corn between the 4-leaf and 7-leaf stage of crop development yield was reduced by 5%. In soybean, Burnside (1979) showed that crops kept free of weeds from two to four weeks after planting did not display significant reductions in yield from later emerging weeds. Coble *et al.* (1981) found that when adequate moisture was available four weeks of weed-free maintenance was required to prevent soybean yield loss from common ragweed interference. However, only two weeks of weed free maintenance were required to prevent yield reduction during a dry season. In a study on common lambs quarters interference in soybean, Harrison (1990) reported that the crop could tolerate five weeks of interference at two lambs quarters plants per meter and seven weeks at one plant per meter.

Van Acker *et al.* (1993a) described the critical period of weed control using crop growth stages for conventionally grown soybean in Ontario. Their results showed that with an acceptable yield loss of 2.5%, the beginning of the critical period was highly variable ranging from the second node growth stage V2 or 9 Days After Emergence (DAE) to the beginning pod stage (R3 or 38 DAE). However, the end of the critical period consistently occurred at the fourth node stage (V4 or 25 DAE). It was concluded that weed should be removed before the onset of the soybean reproductive growth stages (R1 or 30 DAE), after which rapid soybean yield loss occurred (Halford *et al.*, 2001). Because of the competitive ability of crops and weeds is heavily dependent on the environmental conditions (Knezevic *et al.*, 2002). Because of critical period for weed control is a part of IWM and influenced by the cropping practices such as nitrogen (N) fertilizer (Knezevic *et al.*, 2003; Evans *et al.*, 2003; Evans and Knezevic, 2000) and crop row spacing (Knezevic *et al.*, 2002), therefore this paper describes the results of a field study conducted in north of Iran to identify critical period of weeds in soybean (promising line of 033) to the development of an IWM strategy for farmers in the region.

MATERIALS AND METHODS

A field study was conducted at Sari Agricultural and Natural Resources University (53°4′ E, 36°39′ N) during 2006. The soybean cultivar (033 promising line) sown in May 20. Plot size was 2×4 m and consisted of 4 rows. The experimental design was a randomized complete block with 14 treatments and four replications. The treatments were weed removal at different soybean growth stages. To represent increasing duration of weed interference, weeds were allowed to interfere with soybean from emergence until soybean reached: 1) V2 (second trifoliolate), 2) V4 (fourth trifoliolate), 3) V6 (sixth trifoliolate), 4) R1 (beginning bloom, first flower), 5) R3 (beginning pod), 6) R5 (beginning seed). At these stages weeds were removed and plots were then maintained weed free for the remainder of the season. Another set of treatments designed to represent increasing duration of weed control in which some plots were maintained weed-free until soybean reached the above mentioned stages after which weeds were allowed to grow for the remainder of the season. In addition, each trial had season-long weed infested and weed free checks. In all cases, weeds were controlled by hand weeding. To measure yield and yield components, soybean plants were hand harvested from the central 3 m of the two middle rows in each plot on 152 days after planting. The dominant weeds observed at field were velvetleaf (*Abotilon theophrasti* L.), Johnson grass (*Sorghum halepense* L.) and redroot amaranth (*Amaranthus retroflexus* L.). Using SAS (1996) data were analyzed and the significantly differences between different treatments were determined. Using ANOVA method and Duncan Multiple Range Test (DMRT) the means were compared.

RESULTS AND DISCUSSION

Results of analysis variance showed that there were significant differences for grain yield, number of pods per plant and weed dry matter in weed-free ($p<0.05$) and weed infested period ($p<0.01$) (Table 1). The number of pods per plant significantly increased with increasing length of weed-free period and decreased with increasing length of

Table 1: Results of the variance analysis of studied traits in control and interference treatments

SOV	df	Weed dry matter (g m^{-2})	Seeds per pod (No.)	Pods per plant (No.)	1000-seed weight (g)	Yield (t ha^{-1})
Control						
Replication	3	10.07ns	0.01ns	40.94ns	595.71ns	0.29ns
Treatment	6	239.00**	0.07ns	660.96**	118.40ns	4.75**
Error	18	7.05	0.03	16.96	84.59	0.26
CV (%)		31.37	7.89	10.59	5.91	13.41
Interference						
Replication	3	7.55ns	0.02ns	154.88*	73.34ns	0.19ns
Treatment	6	145.11**	0.05ns	335.93**	79.81ns	6.88**
Error	18	5.16	0.03	40.61	85.99	0.12
CV (%)		15.54	8.56	19.44	5.97	13.52

ns = Not significant, *, **: Significant at the 5 and 1% levels of probability, respectively

Table 2: Mean comparison of studied traits in control and interference treatments

Treatments	Yield (t ha^{-1})	1000-seed weight (g)	Pods per plant (No.)	Seeds per pod (No.)	Weed dry matter (g m^{-2})
Control					
V2	2.10^{f}	145.70^{b}	22.87^{e}	2.00^{b}	476.28^{a}
V4	2.8b^{c}	153.64^{ab}	25.87^{e}	2.10^{b}	233.18^{b}
V6	3.12^{b}	155.39^{ab}	33.50^{d}	2.25^{ab}	118.12^{c}
R1	4.57^{a}	154.08^{ab}	39.37^{cd}	2.15^{ab}	51.05^{cd}
R3	4.62^{a}	159.05^{ab}	43.75^{bc}	2.17^{ab}	17.25^{de}
R5	4.65^{a}	160.42^{ab}	46.87^{b}	2.35^{a}	00.00^{e}
H	4.70^{a}	161.81^{a}	60.00^{a}	2.37^{a}	00.00^{e}
Infested					
V2	4.34^{a}	160.46^{a}	44.25^{a}	2.25^{ab}	50.16^{d}
V4	4.06^{a}	156.82^{a}	41.25^{a}	2.05^{b}	82.75^{cd}
V6	3.20^{b}	159.58^{a}	38.12^{a}	2.37^{a}	126.24^{bc}
R1	2.30^{c}	154.12^{a}	38.25^{a}	2.25^{ab}	170.85^{b}
R3	1.67^{d}	156.36^{a}	25.50^{b}	2.10^{ab}	383.72^{a}
R5	1.33^{de}	150.32^{a}	24.00^{b}	2.12^{ab}	434.55^{a}
H	1.09^{e}	148.56^{a}	21.12^{b}	2.07^{ab}	436.63^{a}

*: Means with similar letter(s) in each column are not significantly different at 5% probability level according to DMRT

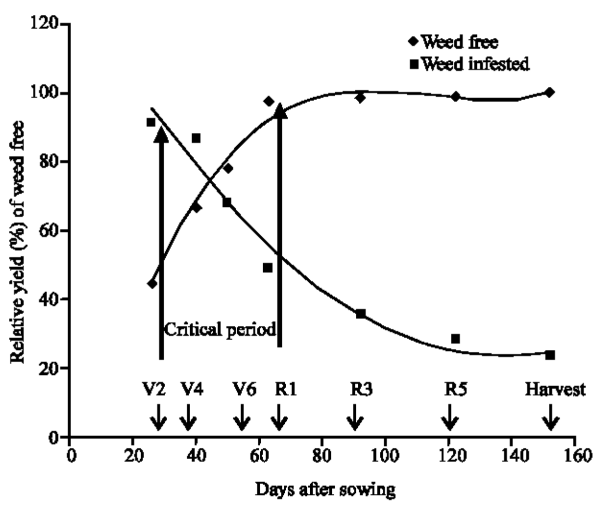

Fig. 1: Soybean yield response to increasing length of weed-free period or duration of weed infestation in days after sowing of the crop. The development stages of the crop, indicated by the arrows, were 2nd leaf (V2), 4th leaf (V4), 6th leaf (V6), beginning bloom (R1), beginning pod (R3), beginning seed (R5)

weed-infested period (Table 2). By contrast, the number of seed per pods and 1000 seed weight were not significantly affected by weed interference. In interference treatments, the highest yield was belonged to V2 treatment and this amount significantly decreased until R5 and whole season weed infested treatment that had the minimum yield compare with other growth stages. According to Table 2, decrease of weed dry weight in control treatments was observed. Dry weight of all weeds in interference treatments increased gradually until late growth stages of soybean (Table 2). The results showed that longer weedy period lead to increase weed dry weight, that maybe because of weeds potential to compete with soybean for water, nutrients and light. Adversely, in interference treatments, decrease of weed dry weight may be result of inter and intra specific competition of weeds and also leaves yellowing and falling at last season. The beginning of the critical period (based on 10% yield loss) was at early V2 stage (26 days after planting). The end of the critical period was at the R1 stage or 63 days after planting (Fig. 1).

Pod number per plant is the first yield component to be determined in the reproductive phase followed by seed per pod and seed weight (Woolley *et al*., 1993). Findings of present study showed that grain yield and number of pods per plant were affected by weeds interference. Hagood *et al*. (1980) reported that 1.4-40 density of

Abutilon theophrasti plant in square meter decreased number of pods in plant. Present results are similar to Woolley *et al*. (1993) findings that revealed number of seeds per pod was not influenced by weed competition. Cousens (1988) suggested the Gompertz equation to describe the relationship between the lengths of the weed control and yield. Hall *et al*. (1992) also suggested Logistic equation to represent the influence of increasing of duration of weed interference on yield. The crop development stage at which weed interference occurs is an important factor in determining potential yield losses. Expressing data as days after planting could indicate more variation between locations and years due to different planting dates and different environments. Strahan *et al.* (2000) reported that with increasing period of interference, weed dry weight increase and with increasing control period that's decrease. From the results of this study it can be concluded that a weed-free duration (5-6 weeks) starting from the 2-leaf stage of soybean is enough to provide acceptable yield, as Van Acker *et al.* (1993b) and Knezevic *et al*. (2003) also suggested. With the aid of critical period of weed control it is possible to avoid unnecessary control measurements, to give up the use of long persistent soil herbicides and to use post-emergence herbicides more consciously, even with lower doses than recommended (Knezevic *et al*., 2002). Present results indicated that the seed number per pod was not significantly affected by interference or control treatments. Generally imposing interference or control treatments decrease the pod number per plant but these pods established the same seed number as well as the check treatment. This finding is similar to Woolley *et al.* (1993) that reported the seed number per pod was not affected by weed competition. On the other hands, in interference treatments because of decreasing the pod number per plant assimilates were distributed within lower pods and thus 1000 grain weight had not difference compared with control treatments which the pod number per plant was increased because of favorable conditions, therefore assimilates were distribute within higher pods. In general, movement towards the use of POST herbicides with little or no residual activity has resulted in renewed interested in determining the most appropriate timing and periodicity of weed control in soybean cultural system in the north of Iran.

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