Weed interference on soybean performance by using integrated weed management and empirical model

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ABSTRACT: A field experiment was carried out to investigate the efficacy of various weed control methods and johnsongrass (Sorghum halepense L.) water extract (SHWE) spray on soybean (Glycine max L. Merrill) yield, some morphological and phenological traits and weed infestation in 2008. Two factors included SHWE spray at four levels as No-spray, spraying at 15 days after emergence (DAE), spraying at 15 and 30 DAE and spraying at 15, 30 and 40 DAE and current weed control methods at four levels as two hand-weeding, Trifluralin, Trifluralin plus two hand weeding and weedy check. The experiment was carried out as factorial based on randomized complete block design with three replications. All current weed control methods and SHWE spray treatments increased weed dry weight loss, and decreased days to flowering and maturity and so improved grain yield of soybean, significantly. Maximum number of leaves and branches per soybean plant observed in two hand weeding+Trifluralin plots. The SHWE spray at one, two and three times increased soybean grain yield by 21.2, 32.0 and 42.6% in comparison with control, respectively. Based on Cousens model the response of protein yield loss with weed density was hyperbolic, and increasing of weed density decreased protein yield in comparison with the grain and oil yield. Two foliar sprays of SHWE could substitute chemical herbicides and it can be integrated with physical method to produce efficient weed control in integrated weed management of soybean.

Keywords: Empirical Model; Integrated Weed Management; Morphology; Phenology; Water Extract; Yield.

INTRODUCTION

It is expected that world population will reach 9.3 billion person until 2050 year, so increasing food production is essential (Pritchards and Amthor, 2005), while under this condition, weeds are almost usual concomitant with crops (Reigosa et al., 2006). Yield loss due to weeds interference considered as a major limiting factor in soybean (Glycine max L. Merrill) production (Ferrell et al., 2008). Uncontrolled weeds can reduce soybean yield by 60-80% (Fundora et al., 1991). Allelopathy is an untapped resource for weed control in crops that could revolutionize organic crop production (Machado, 2007). Pure allelochemicals extracted and identified from some crop plants can also be used as bioherbicides (Batish et al., 2001) and have been receiving world-wide attention for its potential in integrated weed management (Wu et al., 2009). An equally promising way to use allelopathy in weed control is using extracts of allelopathic plants as herbicides (Dayan, 2002; Singh et al., 2005). The weed suppressive activity of Sorghum species can be utilized in integrated weed management and has the potential to be used as a natural herbicide (Macias et al., 2007; Gimsing et al., 2009). Anwar et al.,(2003) found that the weed control practices including hard weeding, chemical control and water extract of sorghum had significant effect on wheat phenology. One hand weeding (25 Days After Sowing)+ two sprays of sorghum water extract (45 and 64 DAS) exhibited suppressive effects on soybean height (Khaliq et al., 1999). Mesosulfuron methyl (Atlantis, 3 WG) at 6.25 g a.i. ha⁻¹ combined with sorghum water extract at 12 l.ha⁻¹ reduced total weed dry weight by 79.28% and increased grain yield by 18.65% over control (Sharif et al., 2005). Also the development of weed management systems requires accurate prediction of weed-crop competition, so empirical model of crop yield loss based on weed density is compared (Vitta and Fernandez Quintanilla, 1996). Much experimentation has been devoted to the study of the effects of weed density on yield;
the hyperbolic relationship described by Cousens (1985) generally achieving the best biological and statistical relationships. Estimates of the relative competitive ability of different weed species can be successfully based on yield loss/weed density relationships, as shown by Wilson and Wright (1990). Moreover, Lutman et al. (1996) used the regression models of crop yield loss and weed density to provide more reliable estimates of relative weed vigor, weed competition potential and crop yield. The objective of this study was to evaluate the some morphological, phonological traits and grain yield of soybean and weed dry weight loss in different integrated weed management systems. Also, the other point concentrated on predicting crop yield losses caused by weed interference using empirical model.

MATERIALS AND METHODS

Field experiment was carried out at the Research Station of Faculty of Agriculture, University of Tabriz, Tabriz-Iran (Latitude 38°15’ N, Longitude 46°17’ E and Altitude 1360 m) in growing season of 2008. The treatments included SHWE (Sorghum halepense L. water extract) spray as first factor at four levels included no-spray, one spraying at 15 days after emergence (DAE), two sprays at 15 and 30 DAE and three sprays at 15, 30 and 40 DAE. The second factor with four levels included two hand-weeding (hand weeding 10-12 days after spraying with SHWE), Trifluralin [a, a-Trifluoro-2, 6-dinitro-N, N-dipropyl-p-toluidine] (1 l a.i. ha⁻¹, 48% a.i.) pre-planting application, Trifluralin plus two hand-weeding and weedy check. The soybean (Glycine max L. Merrill) cv. Williams, inoculated with Bradyrhizobium japonicum was planted with density of 60 plant.m⁻² in the last week of May, 2008. A basal dose of 30 kg N. ha⁻¹ (10 g net nitrogen in each row and below the seeds) was applied in the form of urea. Johnsongrass (Sorghum halepense L.) plants (leaves, stem, rhizome and roots) were collected in the vegetative growth stage (before floral initiation), then the plant materials were chopped into 2 cm lengths with fodder cutter. Plant materials were air-dried under shade at room temperature (25±4 °C) for a few days, and then were ground in a grinder into powder. The sorghum halepense water extract (SHWE) (1:10 W/V) were prepared by soaking 100 g of plant powder with 1000 ml of distilled water for 72 hr at room temperature and shook at 75 rpm for three time (Khaliq et al., 2002; Javaid et al., 2006; Cheema et al., 2008). The extract was filtered through four layers of cheesecloth to remove fiber debris. The SHWE sprayed at 400 l. ha⁻¹ related to the treatments. SHWE was sprayed on weeds with knap sack hand sprayer fitted with flat fan nozzle. The Trifluralin was incorporated with soil before planting, and hand- weeding was applied with hand hoe. Twelve soybean plants were selected randomly in each plot and the plant height, number of leaf and branch per plant were measured. Also phenology (days to flowering and maturity) during growing season was recorded. Soybean grain yield (adjusted to 15.5% moisture content) were determined by hand- harvesting in 3.6 m² for each plot. The grain protein and oil content were determined by a portable grain analyzer model Zx-50 (Zeltex Co.). Oil and protein yield per unit area were calculated through the grain yield. Grain, oil and protein yield loss percent were determined in comparison with controls. Densities and dry weights of weed species were recorded from one selected quadrat (100 cm x 100 cm) for each plot. Weeds were cut from ground surface and oven dried at 78 °C for 48 hours and dry weight was recorded. Weed dry weight loss calculated by comparing weed dry weight in controlled plots with non-controlled plot. Relationship between weed density and yield loss were based on the hyperbolic model of Cousins (1985), where:

\[
Y_L = \frac{I_d}{1 + I_d/A}
\]

In this model, \(Y_L\) = soybean yield loss\% , \(d\) = weed density (plant.m⁻²) , \(A\) = asymptotic yield loss, \(I\) = soybean yield loss % as weed density approaches zero. The grain, oil and protein yield loss were as dependent variables and weed density as independent variable. Data were subjected to analysis of variance as factorial experiment based on randomized complete block design by MSTAT-C and means were compared using Duncan multiple range test at 0.05 probability.

RESULTS AND DISCUSSION

Number of branches per plant, plant height, number of days to flowering and maturity and grain yield for soybean and weed dry weight loss were influenced by SHWE treatments and current weed control methods. Number of leaves per soybean plant was significantly affected by weed control methods. Interaction effect of SHWE*weed control method was significant for soybean plant height and weed dry weight loss (data not shown).

Weed dry weight loss

The lowest and highest dry weight loss of weeds related to control (weedy check) and two hand weeding treatments, respectively (Table 1). Mean weed dry weight loss for hand-weeding and hand-weeding plus chemical control at all SHWE application rates were not different, significantly. Integrated application of pre-planting herbicide and post-emergence SHWE spray at one SHWE spray+Trifluralin, two SHWE sprays+Trifluralin, and three SHWE sprays+Trifluralin treatments in comparison to application of only Trifluralin
herbicide (no-spray+Trifluralin) increased weed dry weight loss, significantly, and this shows the complementary effects of these two herbicides together. Application of SHWE increased significantly weed dry weight loss as compared to control, but there was no significant difference among SHWE application levels. Cheema et al., (2002) reported that sorghum water extract application reduced dry weight of weeds by 50% in wheat. Extracts of sorghum leaves at vegetative stage had maximum effects on Amaranthus sp. dry matter accumulation (Yarnia et al., 2009).

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Table 1. Means dry weight loss of weeds at different SHWE and weed control treatments.

<table>
<thead>
<tr>
<th>SHWE treatments</th>
<th>Weed control methods</th>
<th>Weed dry weight loss (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No-spray (weedy check)</td>
<td>Control</td>
<td>0% (Control)</td>
</tr>
<tr>
<td></td>
<td>2 hand weeding</td>
<td>95.74%</td>
</tr>
<tr>
<td></td>
<td>Trifluralin</td>
<td>4.54%</td>
</tr>
<tr>
<td></td>
<td>2 hand weeding + Trifluralin</td>
<td>98.17%</td>
</tr>
<tr>
<td></td>
<td>Control</td>
<td>0% (Control)</td>
</tr>
<tr>
<td>One SHWE spray (15 DAE)</td>
<td>2 hand weeding</td>
<td>94.14%</td>
</tr>
<tr>
<td></td>
<td>Trifluralin</td>
<td>14.64%</td>
</tr>
<tr>
<td></td>
<td>2 hand weeding + Trifluralin</td>
<td>98.41%</td>
</tr>
<tr>
<td></td>
<td>Control</td>
<td>0% (Control)</td>
</tr>
<tr>
<td>Two SHWE sprays (15+30 DAE)</td>
<td>2 hand weeding</td>
<td>94.75%</td>
</tr>
<tr>
<td></td>
<td>Trifluralin</td>
<td>10.85%</td>
</tr>
<tr>
<td></td>
<td>2 hand weeding + Trifluralin</td>
<td>98.71%</td>
</tr>
<tr>
<td></td>
<td>Control</td>
<td>0% (Control)</td>
</tr>
<tr>
<td>Three SHWE sprays (15+30+40 DAE)</td>
<td>2 hand weeding</td>
<td>97.31%</td>
</tr>
<tr>
<td></td>
<td>Trifluralin</td>
<td>35.17%</td>
</tr>
<tr>
<td></td>
<td>2 hand weeding + Trifluralin</td>
<td>98.99%</td>
</tr>
</tbody>
</table>

Different letters indicate differences at p<0.05 ; DAE: Days After Emergence.

The suppression in weed dry weight by sorghum water extract suggested the presence and also the effectiveness of allelochemicals in these materials (Mansoor et al., 2004). Integrated weed management is useful practical method in reduction of weed dry weight. Data pertaining to weed dry biomass recorded at 105 DAS in sunflower field, showed that sorghum water extract+pendimethalin (pre-emergence) reduced weed dry biomass significantly as compared to the weedy check (Awan et al., 2009). The results of this experiment is similar to Khaliq et al., (1999) who stated that one hand-weeding (25 DAS)+one sorgaab (Sorghum bicolor L. water extract) spray (45 DAS) and one hand weeding (25 DAS)+two sorgaab sprays (45 and 65 DAS) reduced weed dry weights by 43.97 and 67.53% at 45 DAS and 33.17 and 42.48% at 65 DAS, respectively. Mansoor et al., (2004) showed that integration of chemical weed control and hand weeding reduced weed dry weight in mungbean.

**Number of leaves and branches per plant**

Maximum number of leaves per plant (18) observed in two hand weeding +Trifluralin plots, while no-significant difference was observed between hand-weeding treatments (Table 2). Also, there was no significant difference between Trifluralin and weedy check. Based on Adelusi et al., (2006) there was no significant difference in number of leaflets of soybean under different interference treatments with Euphorbia heterophylla L.. In the studies by Rajcan et al., (2002) and Tollenaar (1999) on Maize, the number of leaves was not affected by Amaranthus sp. interference.

Table 2. Number of leaves and branches per plant, number of days to flowering and maturity and grain yield of soybean at different SHWE application treatments and current weed control methods.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Number of leaves per plant</th>
<th>Number of branches per plant</th>
<th>Days to flowering</th>
<th>Days to maturity</th>
<th>Grain yield (kg.ha⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SHWE treatments</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No-spray (weedy check)</td>
<td>13.2a</td>
<td>1.3c</td>
<td>74.1a</td>
<td>160.3a</td>
<td>1176b</td>
</tr>
<tr>
<td>One SHWE spray (15 DAE)</td>
<td>14.1a</td>
<td>2.1ic</td>
<td>70.7a</td>
<td>158.6ac</td>
<td>1425bc (21.2%)</td>
</tr>
<tr>
<td>Two SHWE sprays (15+30 DAE)</td>
<td>13.7a</td>
<td>1.7bcd</td>
<td>69.5b</td>
<td>155.6bcd</td>
<td>1552ace (32.0%)</td>
</tr>
<tr>
<td>Three SHWE sprays (15+30+40 DAE)</td>
<td>15.5a</td>
<td>2.7c</td>
<td>69c</td>
<td>152.3ac</td>
<td>1676bc (42.6%)</td>
</tr>
<tr>
<td>Current weed control methods</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control (weedy check)</td>
<td>9.5b</td>
<td>0.8d</td>
<td>76.1a</td>
<td>165.6a</td>
<td>656.2d</td>
</tr>
<tr>
<td>Two hand weeding</td>
<td>17.5a</td>
<td>2.7a</td>
<td>70.6a</td>
<td>155.2a</td>
<td>1926b (193.5%)</td>
</tr>
<tr>
<td>Trifluralin</td>
<td>11.3a</td>
<td>1.4a</td>
<td>80.0a</td>
<td>158.5a</td>
<td>1008b (53.7%)</td>
</tr>
<tr>
<td>Two hand weeding +Trifluralin</td>
<td>18.0a</td>
<td>2.8a</td>
<td>65.6a</td>
<td>147.5c</td>
<td>2239c (241.2%)</td>
</tr>
</tbody>
</table>

Different letters indicate differences at p<0.05 , *The number in parenthesis indicate increasing percentage compared to control ; DAE: Days After Emergence, SHWE: Johnsongrass (Sorghum halepense) water extract.
The results of this experiment showed that by increasing the weed control efficiency (especially with hand weeding), the number of leaves per plant increased. A significant positive influence on leaf area in mungbean was observed by three sorghum sprays (20+30+40 DAS), chemical control and hand weeding (30 DAS) as compared to weedy check (Cheema et al., 2001). The results are in agreement with the Angiras et al., (1987) who stated that no suppressive effect was observed on leaf establishment of soybean by Sorghum halepense. Three sprays of SHWE increased number of branches per plant compared to other spray treatments, significantly (Table 2).

Comparison of weed control methods revealed that maximum branches per plant (2.8) was achieved by two hand-weeding+Trifluralin which was similar to two hand-weeding (2.7) treatment. It can be concluded that by decreasing dry weight of weeds per unit area, the space and nutrients were being available to the soybean and then the number of branches per plant was increased. Chivinge et al., (1996) demonstrated that reduction in the number of branches in soybean due to competition from Upright starburl L. resulted in fewer nodes and consequently a reduction in grain yield. The results of this experiment are in accordance with Abdelhamid and El-Metwally (2008) who reported that the number of branch in soybean increased by two hand weeding.

Plant height

Among hand weeding treatments, application of two SHWE sprays had significant difference with no-spray. Also among Trifluralin treatments, by increasing the consumption of SHWE, the plant height was reduced (Fig. 1). Between hand weeding+Trifluralin treatments, there was no significant difference among no-spray, one-spray and two-sprays treatments, but three-sprays +hand weeding had lowest plant height, and founds significant difference with others. Soybean height advantage over the weed probably enabled it to capture more photoactive radiation in addition to other consumable resources for flower development and seed set (Chiving et al., 1996). Plant height was higher in soybean plants in which Euphorbia heterophylla L. were introduced at the onset of the canopy development for competition with water and mineral nutrients (Adelusi et al., 2006). The reduction of soybean height at three-sprays of Trifluralin+hand weeding treatment, might be attributed to weed competition.

![Soybean height in different SHWE treatments and weed control methods (hand weeding and Trifluralin). a: no-spray (weedy check), a: one SHWE spray (15 DAE), a: two SHWE sprays (15+30 DAE), a: three SHWE sprays (15+30+40 DAE), SHWE: Johnson grass (Sorghum halepense) water extract, DAE: Days After Emergence.](image)

Figure 1. Soybean height in different SHWE treatments and weed control methods. a: no-spray (weedy check), a: one SHWE spray (15 DAE), a: two SHWE sprays (15+30 DAE), a: three SHWE sprays (15+30+40 DAE), SHWE: Johnson grass (Sorghum halepense) water extract, DAE: Days After Emergence.

However, by increasing the weed control and application of integrated weed management, soybean height was decreased. Chemical control of weeds led to the greatest height for wheat in comparison with sorghum water extract and hand weeding (Cheema and Khaliq, 2000). Application of isoproturon increased height of wheat, significantly, as compared to weedy check (Cheema et al., 2002). One hand weeding (25 DAS) + two sorghum water extract sprays (45+65 DAS) decreased soybean height in comparison with control (weedy check) (Khaliq et al., 1999). Sarif et al., (2005) reported that application of aqueous extract of sorghum combined with chemical herbicides did not affected wheat height.

Number of days to flowering and maturity

Among SHWE treatments, three SHWE sprays showed highest reduction in days to flowering (69) and days to maturity (152.3), but it had no significant difference with two and one SHWE sprays in days to flowering and two sprays in days to maturity (Table 2). Also two hand-weeding+Trifluralin had the lowest number of days to flowering (65.6) and days to maturity (147.5) and were followed by two hand-weeding and Trifluralin.
treatments. Longer duration of weeds interference with mungbean resulted in delayed flowering time (Naeeem and Ahmad, 1999). The results indicated that increasing the competition period in maize field caused delaying in floral initiation (Swanton, 2002).

Weed management strategies such as sorghum water extract spray, hand weeding and chemical herbicide decreased weed dry weight, significantly and accelerated the flowering and maturity. Similar results were reported by Anwar et al., (2003) that different weed management treatments cause to changes in phenology and a significant decrease in days to maturity of wheat in comparison with the control.

**Grain yield**

Soybean grain yield was affected by weed interference. All current weed control methods and SHWE spray treatments increased soybean grain yield significantly. SHWE sprays at 15, 15+30 and 15+30+40 DAE increased soybean grain yield by 21.2, 32 and 42.6% in comparison with control, respectively (Table 2). The greatest increase in grain yield (241.2%) occurred in two hand weeding + Trifluralin plots, while minimum increasing (53.7%) was observed in Trifluralin application compared to control. Grain yield increase may be due to better removing of weeds and greater pod number per plant, grain per plant and grain weight. Ali et al., (2004) and Mansoor et al., (2004) resulted that sorghum water extract application increased the grain yield of wheat and mungbean. Cheema and Khaliq (2000) reported a 22% increase in wheat yield due to three sorghaab sprays (1:10 ratio). Two sprays of sorghaab at 25 and 45 DAS increased soybean grain yield by 8.28% (Khaliq et al., 1999). Probably increasing the availability of nutrients in low weed infested plots stimulated vegetative growth which resulted in greater pod number, grains per pod (data weren't mentioned) and finally higher grain yield. Increasing in weed dry weight can strongly limit the use of environmental resources by soybean. This can potentially reduce photosynthesis and consequently grain yield, because of competition (Millar et al., 2007).

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Grain yield loss %</th>
<th>Oil yield loss %</th>
<th>Protein yield loss %</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>96.96</td>
<td>95.724</td>
<td>98.55</td>
</tr>
<tr>
<td>I</td>
<td>0.561</td>
<td>0.569</td>
<td>0.581</td>
</tr>
<tr>
<td>R²</td>
<td>0.703</td>
<td>0.685</td>
<td>0.714</td>
</tr>
<tr>
<td>S.E.,I</td>
<td>0.161</td>
<td>0.166</td>
<td>0.167</td>
</tr>
</tbody>
</table>

Also it can be concluded that, by increasing weed management efficiency and decreasing weed competition, the space for soybean growth and the opportunity for oil and protein synthesis increases and this cause to promoting in oil and protein yield. High value in $R^2$ (adj coefficient) indicates it’s accuracy in predicting of yield loss, so the highest accuracy was achieved from the protein yield loss simulation (Table 3). The susceptibility of crops to compete with weeds increases by promoting in A parameter (Amini et al., 2009). Mahmoodi et al., (2004) showed that the lowest I parameter estimated the lowest yield loss and caused to linear model. It is obvious from the table 3 that protein yield had the highest sensitivity to the weed density in comparison with oil and grain yield. Also the presence of weeds and their competition with soybean for assimilating of nitrogen in soil decrease protein yield. Based on Cousens hyperbolic function, the crop yield decreases by increasing density of weeds (Cousens, 1985). Also, the corn yield was declined to non-linear shape by increasing the Chenopodium album L. density (Beckett et al., 1988). The grain, oil and protein yield loss have been increased in the weed density response curves (Fig. 2, 3 and 4). Considering the curve prominent gradient in Fig 4 it can be inferred that the high weed density cause to high protein yield loss than grain and oil yield and these results confirm the results of Table 3. This supports the findings of Randhawa et al., (2009) who suggested a reduction in grain protein content in response to higher density of Trianthema portulacastrum L. possibly due to reduced crop growth and hence poor grain protein content.

Integrated weed management by different weed control techniques has the important role in weed management (Monjardino et al., 2004). Sharif et al. (2005) stated that sorghum water extract-chemical herbicide led to increase in wheat grain yield in comparison with control. Also hand weeding-chemical herbicide (pre-emergence) increased grain yield of wheat, significantly (Anwar et al., 2003). Among different weed management, hand weeding was the best treatment for promoting soybean seed yields (Saudy and El-Metwally, 2009). This increase in grain yield by hand weeding may be due to better weed management, greater leaf area, more pod number, more and heavier grains (Cheema et al., 2001). It is resulted that SHWE sprays, hand weeding and herbicide, reduced competition of weeds with soybean and stimulated vegetative growth which resulted in morphology and therefore in growth duration of soybean (days to flowering and maturity), that finally increased
the grain yield. The information about yield loss related to weed density based on Cousens model can be used to determine the acceptable yield loss and weed economic damage threshold. Application of sorghum water extract as environment friendly method and the reduction in herbicide dose may also decrease the production cost and strengthen efforts on sustainable agriculture. So it could be concluded that sorghum water extract spray can be integrated with physical (hand weeding) and chemical methods to provide an efficient weed control in soybean by using integrated weed management strategies.

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