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Wild Barley (*Hordeum spontaneum* Koch) Seed Germination as Affected by Dry Storage Periods, Temperature Regimes, and Glumellae Characteristics

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**ABSTRACT**

After dry storage, germination of newly harvested intact and naked seeds of wild barley (*Hordeum spontaneum* Koch) were determined at 20°C. Intact seeds did not germinate after 8 weeks whereas, naked seeds germinated and no significant differences between dry storage periods were observed for germination of these seeds. Cold stratification periods had no effect on germination percentages of non-dormant seeds of wild barley. The minimum, optimum, and maximum temperatures for germination of wild barley seeds were 5, 20, and 30 °C, respectively. Results showed that wild barley glumellae had either physical or chemical effects on seeds germination because, all naked seeds germinated but when intact seeds were rinsed in ethanol 70% and distilled water, the germination percentage were 0 and 54%, respectively, which was lower than that of naked and intact seeds.

**Keywords:** Cold stratification; *Hordeum spontaneum*; Wheat; Cardinal temperature; glumellae.

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INTRODUCTION

Seed dormancy is a major adaptive trait in weeds which facilitates the survival of them and provides for resistance to preharvest sprouting in members of Poaceae family (Benech-Arnold et al., 2000). In addition, the seeds of many weed species can remain viable in the soil seed bank because they possess some types of inherent dormancy (Fenner & Thompson, 2005). The dormancy can further reassure that the germination of seeds to occur only at an appropriate time and space (Benech-Arnold et al., 2000), and that is an important reason why most weeds are successful, though each individual will experience a differential success (Gutterman & Nevo, 1993).

There are several factors that have been found to trigger germination or break the seed dormancy including cold stratification, dry storage and/or exposure of dry seeds to elevated temperature, leaching, scarification and treatments with chemicals may be involved in breaking dormancy (Bradbeer, 1994). The conditions required to break dormancy often vary among species, but also vary within species or populations. (Alen & Meyer, 1998).

Wild barley (H. spontaneum Koch) such as wild wheat is one of the principal grain plants on which Neolithic food production in the Near East was founded. Wild barley is the progenitor of cultivated barley and this is indicated by its cross-compatibility, full fertility and sporadic spontaneous hybridization with other cultivars. The high genetic diversity of wild barley makes it as the best resources for improving the narrowing genetic base of the cultivated barleys (Nevo, 1997). Wild barley is an annual, brittle, two-row diploid (2n=14), and is predominantly self-pollinating (Brown et al., 1978). Wild barley is widespread in the Near East Fertile Crescent and its population involves abundant genetic variation against drought and salinity while its highest resistant genotype is significantly correlated with the high stress environment and with the highest genetic polymorphism (Nevo, 1992).

It has been founded that freshly harvested seeds of wild barley do not germinate in a range of temperatures, in light or darkness (Gutterman & Nevo, 1993; Gutterman et al., 1996). An important survival strategy of wild barley under unpredictable small amounts and infrequent winter rains in dry regions is after-ripening (Evenari, 1965; Gutterman, 1998). The need for after-ripening prevents germination of mature seeds after a late rain at the beginning of the long, dry summer (Evenari, 1965). The primary dormancy in wild barley seeds is a result of glumellae, the seed covering tissue. Such covering structures of the seed may limit the oxygen supply to the embryo (Gutterman, 1996) and thus inhibit germination. Gutterman et al., (1996) reported that the dormancy breaking of wild barley seeds occur during storage in dry conditions at 35 °C or in the natural habitat during summer. Gozlan & Gutterman, (1999) found that seeds of wild
barley ecotypes that originating from different regions, show different germination responses to dry storage temperatures and duration.

The aims of this investigation were to study (1) the effect of constant temperatures on seed germination, (2) after-ripening patterns of wild barley seeds, (3) effect of cold stratification on seed germination, and (4) physical and chemical effects of glumellae on seed germination of wild barley.

MATERIALS AND METHODS

All experiments were conducted in laboratory and germination tests were done in dark condition. Caryopses of wild barley were harvested on 15 May 2004 from the Experimental Station Farm of Shiraz University at Kushkak located 1650 meters above the average sea level with a longitude of 52° 34′ E and latitude of 30° 7′ N.

Experiment 1
Effect of Constant Temperatures on Wild Barley Non-Dormant Seed Germination

To determine the cardinal temperatures for the germination of wild barley seeds compared to wheat (*Triticum aestivum* cv. Pishtaz), surfaced-sterilized wild barley and wheat seeds were germinated in sterilized 9-cm Petri dishes containing two sheets of Whatman #2 filter papers moistened with 5 ml of distilled water. Petri dishes were then placed at 8 constant temperature regimes of 5, 10, 15, 20, 25, 30, 35, and 40 °C under dark condition. Germination counts were made after 3 and 7 days. Germination was considered to occur when radicle length was 1 mm or longer.

Experiments were conducted in a completely randomized design (CRD) with four replications. Twenty five seeds in each Petri dish were considered as a replicate. Data were subjected to analysis of variance procedure. Statistical analysis of data was conducted using MSTAT-C software.

Experiment 2
Effect of Dry Storage Periods on Germination of Wild Barley Seeds

Immediately after harvesting, the seeds were stored in fine-mesh bags at room temperature (25±3 °C) with relative humidity ranging from 15-20%. At 7-day intervals (for 14 weeks), two samples of 100 intact and hand dehulled (naked) seeds (four replicates of 25 seeds) were selected and germinated in a germinator set to constant temperature of 20±1 °C in the darkness (based on results of experiment 1). For each experiment, seeds were placed in 9-cm sterilized Petri dishes on two sheets of Whatman #2 filter paper and moistened with 5 ml of distilled water. Germination was considered to occur when radicle length was 1 mm or longer. Experimental design was split factorial in which the storage time was considered as main plot and seed type was considered as sub-plot.

Experiment 3
Effect of Cold Stratification on Dormant and Non-Dormant Seed Germination of Wild Barley
Wild barley dormant (freshly harvested) and non-dormant (from the previous year) seeds were placed in 9-cm sterilized Petri dishes on 2 sheets of Whatman # 2 filter paper and moistened with 5 ml distilled water and stored in an incubator at constant temperature of $2 \pm 1 \degree C$ for 4 weeks. At 7-day intervals, dishes were randomly selected and transferred to germinators and were kept at constant temperatures of 10, 20 and 40 $\degree C$ in the dark condition for 7 days. After 7 days the germinated seeds were counted. During cold stratification, the dishes were checked to make sure the seeds remain moist. Experiments were conducted using a split-plot design with four replicates. Twenty five seeds in each Petri dish were considered as a replicate. The main factor constituted three temperature levels (10, 20 and 40 $\degree C$) and the sub-factor constituted five stratification periods of 0, 1, 2, 3 and 4 weeks at $2 \pm 1 \degree C$. No germination was occurred when the dishes were incubated at $2 \pm 1 \degree C$.

Homogeneity were calculated for all of the experiments (as variance) and those data not linearly distributed were $\log_{10}$ transformed and detains formed data are present in the results. Data were subjected to analysis of variance, and mean separation was made using Duncan’s new multiple range test at the 0.05 level of significance.

Experiment 4

Effects of Glumellae Characteristics on Wild Barley and Wheat Seeds Germination

Germination of intact and dehulled wild barley and wheat seeds were examined under 13 conditions as described below:

1) Wild barley intact seeds (with glumellae) in order to reveal the physical effects of glumellae on germination;
2) Wild barley naked seeds along with the separated glumellae in the Petri dish to reveal the chemical effects of glumellae;
3) Wild barley intact seeds were rinsed in ethanol 70% for 5 min to remove any possible ethanol-soluble compound(s) from the glumellae (Chen et al., 2004);
4) Wild barley intact seeds were rinsed in distilled water for 5 min to remove any possible water-soluble compound(s) from the glumellae;
5) Wild barley naked seeds were rinsed in ethanol 70% for 5 min;
6) Wild barley naked seeds were rinsed in distilled water for 5 min;
7) Wild barley naked seeds alone;
8) Wild barley naked seeds and their separated glumellae were rinsed in ethanol 70% for 5 min and were then placed in the same Petri dishes;
9) Wheat seeds with wild barley glumellae (25:25 in each Petri dish);
10) Wheat seeds with wild barley naked seeds (25:25 in each Petri dish);
11) Wheat seeds with wild barley intact seeds (25:25 in each Petri dish);
12) Wheat seeds with wild barley glumellae that rinsed in 70% ethanol for 5 min (25:25 in each Petri dish);
13) Wheat seeds alone.

Following 7-days incubation at 25 ± 1 °C, seed germination, shoot and root length, and number of seminal roots for both plants were measured. Germination was considered to occur when radicle length was 1 mm or longer.

The experiment was conducted in a completely randomized design (CRD) with four replications. Homogeneity were calculated for all of the experiments (as variance) and those data not linearly distributed were log_{10} transformed and detransformed data are present in the results.

RESULTS AND DISCUSSION

Experiment 1

Effects of Constant Temperatures on Wild Barley Seeds Germination

Wild barley seeds required temperatures lower than 30 °C for germination. Maximum germination occurred at 20 °C (Figure 2). This optimum temperature for wild barley seeds germination was similar to that of reported by (Gutterman et al., 1996).

Wheat seeds germinated nearly 100% after 7 days at 25 °C or lower temperature, but declined to 24 and 0% at temperatures of 35 and 40 °C, respectively (Figure 3). The rate of germination for wild barley seeds was lower than that of wheat in both counting dates (Figures 2 & 3). The wheat also maintained a high germination percentage at high temperature. Compared to wheat, final germination values were lower for wild barley at all temperatures.

The results of this study indicated that lower temperatures (i.e. 5-10 °C) were more favorable for germination of wild barley seeds than higher ones (30-40 °C). These results agree with the results of (Egley & Duke, 1984) who reported that high temperatures may denature the enzymes and change lipid phase. However, the lack of germination of wild barley seeds at temperatures higher than 30 °C can be due to lower temperature requirements of this species for germination. However, (Gozlan & Gutterman, 1999) reported that after 20 months of storage of *H. spontaneum* seeds at 10-30 °C, a negligible percentage of seeds germinated at 30 °C.

Experiment 2

Effects of Dry Storage Periods on Wild Barley Seed Germination

No germination of intact seeds occurred until 8 weeks after storage (Figure 1). All these seeds were found to be dormant, as shown for *Aegilops cylindrica* (Fandrich & Mallory-Smith, 2005), *Tripsacum dactyloides* (Gibson et al., 2005) and *Phalaris sp.* (Matus-Cadiz & Hucl, 2005). The germination of intact seeds increased with dry storage durations. After 12 weeks, the germination of intact seeds reached its maximum rate (65%). This delay in germination, usually called after-ripening, is an important survival strategy for many Poacea family members such as *Lolium rigidum* (Steadman et al., 2003), weedy rice (*Oryza sativa*) (Gu et al., 2005), and *Alopecurus myosuroides* (Colbach & Durr, 2003) which may confront unpredictable rainfall in the summer (Evenari, 1965). On the contrary, no significant differences
between dry storage periods were observed for naked seeds germination (Figure 1). The dormancy of wild barley freshly harvested seeds results mainly from inhibitory action of glumellae which is reduced during dry storage (Figure 1).

It was suggested by (Lenior et al., 1986) that in wild and cultivated barley (*Hordeum vulgare* L.) glumellae prevents germination by placing the seed in hypoxia, because they fix oxygen. However, a good oxygen supply under the glumellae would be necessary only during the first hours of germination. In fact, after 30 hour, oxygen uptake by the glumellae is the same for dormant and non-dormant seeds. This oxygen absorption would be sufficient to prevent germination of freshly harvested seeds. But, after a long period of dry storage, seeds would not be subjected to this inhibition action because germination would have started at the beginning of imbibition, when the glumellae absorb very little oxygen. However, primary dormancy of *H. spontaneum* is much deeper than that of seeds of cultivated barley. According to (Baker, 1974), the success of a weed may depend in part on a delay in germination until conditions are suitable for plant growth therefore, high wild barley population density in wheat fields can be attributed to this phenomenon.

**Experiment 3**

**Effects of Stratification Periods on Wild Barley Dormant and Non-Dormant Seed Germination**

No significant differences were observed among stratification periods at all temperature regimes, whereas, the mean germination percentages varied significantly between temperature regimes. Overall, the highest germination percentage was occurred at 20°C (87%) followed by 10°C (65%) with no germination at 40°C (Table 1). None of the dormant seeds germinated after 4 weeks (data not shown), indicating those four weeks of cold stratification could not alleviate the dormancy of wild barley seeds. Baskin & Baskin, (1998) reported that cold stratification is not required for seed germination of all species, but is required for embryo growth in seeds with non-deep dormancy. Since, the dormancy of wild barley seeds is more likely to be related to glumellae characteristics (Figure 1) and not to embryo, this may explain why cold stratification is not effective for dormancy breaking.
Table 1. Effects of cold stratification periods on germination of wild barley non-dormant caryopses<sup>ab</sup>.

<table>
<thead>
<tr>
<th>Constant temperature (°C)</th>
<th>Weeks of stratification at 2 ± 1 °C</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>0 1 2 3 4 Means</td>
<td></td>
</tr>
<tr>
<td>66.00 a</td>
<td>66.00 a 65.00 a 64.00 a 66.00 a 65.40 B</td>
<td></td>
</tr>
<tr>
<td>87.00 a</td>
<td>86.00 a 88.00 a 87.00 a 87.00 a 87.00 A</td>
<td></td>
</tr>
<tr>
<td>0.00 a</td>
<td>0.00 a 0.00 a 0.00 a 0.00 a 0.00 C</td>
<td></td>
</tr>
<tr>
<td>Means</td>
<td>51.00 a 50.66 a 51.00 a 50.33 a 51.00 a</td>
<td></td>
</tr>
</tbody>
</table>

<sup>a</sup>Means within each row with the same letters (small letters) are not significantly different at the 5% level according to Duncan's new multiple range test.

<sup>b</sup>Means within each column with the same letters (capital letters) are not significantly different at the 5% level according to Duncan's new multiple range test.

---

Experiment 4

Effect of Glumellae Characteristics on Wild Barley and Wheat Seed Germination

The effects of different treatments on wild barley intact and naked seeds germination and the seedling growth are shown in Table 2. Only 59% of intact seeds were able to germinate within 7 days of incubation (T1). When the glumellae was removed, the naked seeds germinated up to 100% (T7). Naked seeds placed adjacent to glumellae germinated 95% (T2). Very similar results were obtained with naked seeds and detached glumellae that were inserted in ethanol 70% for 5 min (T8). Intact seeds treated with ethanol (T3) did not germinate but, those inserted in
distilled water (T4) had germinated as great as 54%. The germination percentages of naked seeds that were treated with ethanol (T5) or distilled water (T6) were 90 and 95%, respectively (Table 2).

Shoot length of intact seeds that were treated with distilled water (T4) were 54 mm and less than that showed no differences (T1), whereas, root length, and number of seminal roots were not affected by all treatments (Table 2). Wheat seed germination, root length, and number of seminal roots were not influenced by any of the treatments (Table 2), but the shoot length was increased as affected by wild barley glumellae.

The results presented above clearly show that glumellae had either physical and chemical effects on wild barley seed germination. When intact seeds were rinsed in ethanol 70% (T3) and distilled water (T4), their germination percentages were 0 and 54%, respectively. This was lower than that of naked (T7) and intact seeds (T1). This may be the main reason for chemical stimulating effects of glumellae on germination. The presence of some phenolic compounds in seeds of Gramineae family has been reported (Belderock, 1961; Glennie, 1981; Jayachandran-Neir & Sridhar, 1975). In nature and under high interference pressure, there are many known and unknown mechanisms that may be involved in enhancing the seed germination and plant seedling establishment. Results from this study show that ethanol- and/or water-soluble compound exist in glumellae and are desirable and suitable to enhance seed germination and seedling growth of its own plant. In this relation, absence of the glumellae chemical compound (T3 and T4) decreased germination of seeds (Table 2). Hamidi et al., (2006) reported that some extract concentrations made from the intact seeds of wild barley stimulated germination, shoot and root lengths, shoot and root dry weights of wheat and its own plant and this phenomenon could be considered as an ecological adaptation.
Table 2. Effects of physical and chemical characteristics of wild barley glumellae on wheat seed and its own seed germination, shoot and root length, and number of seminal roots $^{a,b}$.

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Germination (%)</th>
<th>Shoot length (mm)</th>
<th>Root length (mm)</th>
<th>Seminal roots (no.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wild barley</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$T_1$</td>
<td>59 b</td>
<td>94.43 ab</td>
<td>116.00 a</td>
<td>3.16 a</td>
</tr>
<tr>
<td>$T_2$</td>
<td>95 a</td>
<td>99.43 a</td>
<td>104.40 a</td>
<td>3.42 a</td>
</tr>
<tr>
<td>$T_3$</td>
<td>0 c</td>
<td>0 c</td>
<td>0 b</td>
<td>0 b</td>
</tr>
<tr>
<td>$T_4$</td>
<td>54 b</td>
<td>54.17 b</td>
<td>93.17 a</td>
<td>3.16 a</td>
</tr>
<tr>
<td>$T_5$</td>
<td>90 a</td>
<td>106.30 a</td>
<td>119.30 a</td>
<td>3.32 a</td>
</tr>
<tr>
<td>$T_6$</td>
<td>95 a</td>
<td>82.65 ab</td>
<td>113.60 a</td>
<td>3.10 a</td>
</tr>
<tr>
<td>$T_7$</td>
<td>100 a</td>
<td>85.87 ab</td>
<td>109.40 a</td>
<td>3.66 a</td>
</tr>
<tr>
<td>$T_8$</td>
<td>99 a</td>
<td>87.33 ab</td>
<td>111.00 a</td>
<td>3.33 a</td>
</tr>
<tr>
<td>Wheat</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$T_9$</td>
<td>100 a</td>
<td>129.50 a</td>
<td>123.70 a</td>
<td>5.81 a</td>
</tr>
<tr>
<td>$T_{10}$</td>
<td>99 a</td>
<td>108.20 b</td>
<td>114.00 a</td>
<td>5.71 a</td>
</tr>
<tr>
<td>$T_{11}$</td>
<td>99 a</td>
<td>106.50 b</td>
<td>123.40 a</td>
<td>5.63 a</td>
</tr>
<tr>
<td>$T_{12}$</td>
<td>100 a</td>
<td>121.70 a</td>
<td>129.40 a</td>
<td>5.22 a</td>
</tr>
<tr>
<td>$T_{13}$</td>
<td>100 a</td>
<td>112.70 b</td>
<td>126.30 a</td>
<td>5.07 a</td>
</tr>
</tbody>
</table>

For each species, means within each column with the same letters are not significantly different at the 5% level according to Duncan’s new multiple range test. $^{a}$T1: intact seeds; T2: naked seeds with the glumellae; T3: intact seeds treated with 70% ethanol; T4: intact seeds treated with distilled water; T5: naked seeds treated with 70% ethanol; T6: naked caryopse treated with distilled water; T7: naked seeds; T8: naked seeds with the gelumellae treated with 70% ethanol; T9: wheat seeds with wild barley gelumellae; T10: wheat seeds with naked seeds; T11: wheat seeds with intact seeds; T12: wheat seeds with gelumellae that treated with 70% ethanol; and T13: wheat seeds.

Figure 2. Effects of constant temperatures on wild barley seeds germination after 3 and 7 days.
Figure 3. Effects of constant temperatures on wheat seed germination after 3 and 7 days.

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چکیده

جوانه زنی گندم‌های تازه رسیده جو و جنگلی در دمای 20 درجه سانتی‌گراد تضعیف گردید. گندم‌های زنی دست نخوردند و در جوانه زنی 12 هفته به بیشترین مقادیر رسید. مواد زنی گندم‌های پوست کنده از هفته اول آغاز و در جوانه زنی آنها تفاوت معنی‌داری وجود نداشت. نتایج تشان دادن 6 خواب گندم‌های زنی دست نخورده از نوع پس رسمی بوده و پوسته‌های 6 مانع فیزیکی جوانه زنی می‌باشند. گندم‌های زنی برداشت شده و به انتهای کاهشی رسیده بودند در دمای 2 درجه سانتی‌گراد برابر چهار هفته تهیه شدند. میانگین درصد جوانه زنی در دمای‌های 10، 20 و 30 درجه سانتی‌گراد برابر گندم‌های زنی بدون خواب به ترتیب 85.6، 97.6 و 100 درصد بود. به همین دلیل، گونه تفاوت معنی‌داری بین درصد جوانه زنی گندم‌های هایی که 2 و 4 هفته در شرایط ادراری بودند، مشاهده نشد. همچنین کاهش گندم‌های زنی تازه برداشت شده در سانتی‌گراد اندک‌تر گردید. به‌طور کلی در دمای‌های بین 20 تا 30 درجه سانتی‌گراد رخ داد در حالی که در دمای‌های بین 25 تا 26 درجه سانتی‌گراد گردد یا کمتر جوانه زنید. گندم‌های زنی جوانه‌ای به‌طور کلی در دمای‌های بین 7 تا 8 روز در دمای بیش از 30 درجه سانتی‌گراد جوانه‌ای توانستند. مقایسه با گندم در سرتخت جوانه زنی کمتری می‌خورند، به‌طور کلی امکان پذیری ات فیزیکی و شیمیایی پوسته‌های گندم‌های زنی در محیط زیست و گسترش سپیده نیز محدود و رشد به انتهای به بیشتری افزایش یافته نبوده است. نتایج تحقیق دانش که پیشنهاد که حفاظت یک بار، گونه بی‌قراری افراد، جوانه زنی در دمای پاییز به گونه نتش فهمی داده‌اند.

کلمات کلیدی: فراشته، سرمایه، گندم، دمای پاییز، پوسته
Nitrification Inhibition Properties in Root Exudates of *Brachiaria humidicola* Plants

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**ABSTRACT**

Nitrification inhibition (NI) by climax ecosystems has been suggested for decades, and this inhibitory effect seems to be a feature of wild genotypes rather than commercial cultivars. Many plants particularly grasses were suggested to have NI activity, and recently *Brachiaria humidicola* (BH) was shown to have promising control on nitrification rates through root exudates. In this study effects of different treatments such as N form (NH\(_4^+\) vs NO\(_3^-\)) and N concentrations (1, 2 and 4 mM N), plant age, light intensity and different collecting mediums for root exudates on the NI activity of root washings were investigated. This was done using a series of nutrient solution experiments. The results showed that BH root exudates collected in distilled water, independent of light intensity, plant age, N-forms, N-concentrations and root exudates collection periods, had no significant inhibition on nitrification. However, root exudates collected in a 1 mM NH\(_4\)Cl medium had significant inhibition on nitrification process in a soil bioassay. This inhibition was more highlighted when plants were grown in presence of ammonium rather than nitrate. In comparison to drying with rotary evaporator, freezed dried root exudates indicated significant NI in root exudates of plants which were grown in NH\(_4^+\) under low light, while this effect was not seen under higher light intensity or nitrate nutrition. Measuring electric conductivity of solutions from root washing also showed higher conductivity when ammonium presented in root medium, particularly in root exudates collecting medium over extended time (24 instead 6 hours).

**Keywords:** root exudates, ammonium, nitrate, electric conductivity

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INTRODUCTION

Nitrogen management requires sufficient knowledge regarding spatial distribution of mineral nitrogen. Nitrification is the main cause of nitrogen losses in soil profile. This process can be retarded by different synthetic inhibitors. However, if plants could manage nitrification, it would offer important economic and environmental implications. Identification of such plants and related physiological and molecular traits can help to introduce such highly valuable properties from wild plants to crops. This consequently could lead to less application of fertilizers and higher N recovery rates (Subbarao et al., 2006). Plants are immobile in nature, but they have the ability to apply different strategies to cope with unfavourable conditions surrounding them, and to optimize unfriendly conditions for their growth and development. Despite physiological and morphological changes, exudation of primary and secondary metabolites by roots as well as emission of chemicals through leaves is a well known phenomena in this case (Liljeroth & Baath, 1988; Jones et al., 2004).

*Brachiaria humidicola* Napper plants are C₄ species and among the most important pastures widely adapted to grow in tropical and subtropical parts of South America, Africa & Asia (CIAT, 1983). Different *Brachiaria* species consist 85% of the total planted pasture area in South America (Nakamura et al., 2005), and commercially an important economic player in the tropics, particularly in Brazil. The genus *Brachiaria* contains a wide range of species, which are adapted to poor acid soils and tolerant to drought and harsh environments. Vast diversity in *Brachiaria* plants could be the main reason of their adaptation capacity to different edaphic and climatic conditions. In comparison to other plants, in such conditions, they have relatively higher biomass production due to the ability to uptake and use nutrients more efficiently in poor soils (Nakamura et al., 2005; Cazetta & Villela, 2004). There is no report of growing such plants in Iran, however they can be introduced to subtropical parts in Southern provinces.

Observations during field surveys have shown that soils of BH generally have low levels of N-NO₃⁻ (CIAT, 1985; Sylvester-Bradley et al., 1988). Recently experiments show that root exudates of *Brachiaria* plants specially BH (accession 26159) can efficiently suppress nitrification process in laboratory, soil and field conditions (Ishikawa et al., 2003; Wang et al., 2005; Subbarao et al., 2005 & 2008). They indicated that only BH particularly accession 26159 suppresses nitrification in soil, and this inhibition occurs under NH₄⁺ rather than NO₃⁻ nutrition. Nevertheless, it has been suggested that nitrification inhibition abilities are a plant's specific reaction to stress conditions, especially under low N level in the soil (Ishikawa et al., 2003; Subbarao et al., 2006).

(Subbarao et al., 2005, 2006 & 2007 a,b,c) mentioned strong inhibition of collected root exudates of BH on nitrification, which this inhibitory effect was lasting up to 70 days, which is more efficient than synthetic NIs such as N-Serve or DMPP (3,4-
dimethylpyrazol phosphate). Despite recent works, there is still not enough knowledge on nitrification inhibitory effect of plants root exudates. Therefore, the biological inhibition of nitrification by crop plants or pasture species particularly by BH plants is not well known, and still many questions are to be answered. In order to investigate whether the inhibitory effect of root exudates would change under different growth and physiological conditions (N-form, N-concentrations, different light intensities, plant age, differing collecting medium and collecting periods of root exudates), this study was conducted using BH plants under controlled condition in growth chamber.

MATERIALS AND METHODS

Plant Culture

This study was conducted during 2005-2007 in the Institute of Plant Nutrition, University of Hohenheim, Stuttgart-Germany. Seeds of Brachiaria humidicola (Rendle) accession 26159 germinated at 25 ºC in fine sand (0.02-0.5 mm) for the first experiment. For the next experiments, due to long germination period (4 weeks), heterogeneous germination, as well as low germination rate (15%), vegetative new tillers from older plants were used as new seedlings. Seedlings more than 10 cm (3-4 leaves) were cut and transferred to treatment condition in nutrient solution (2.5 litres in black plastic pots). The composition of nutrient solution was 10 µM H$_3$BO$_3$, 0.5 µM MnSO$_4$, 0.5 µM ZnSO$_4$, 0.1 µM CuSO$_4$, 0.01 µM Mo$_7$O$_{24}$(NH$_4$)$_6$, 83 µM Fe-EDTA, 0.7 mM K$_2$SO$_4$, 0.5 mM KH$_2$PO$_4$, 1.2 mM MgSO$_4$, 1.2mM KCl. For ammonium treatments 1 mM CaCl$_2$ was used (Souri, 2008). Treatments were N-form (NH$_4^+$ or NO$_3^-$) in form of (NH$_4$)$_2$SO$_4$ or Ca(NO$_3$)$_2$, with 1, 2, and 4 mM N, depending on experimental set up. However, normal N concentration was 2 mM N as ammonium sulphate or calcium nitrate. Each treatment consisted of four replicates. Ammonium treatment was applied either at the beginning of transferring the seedlings to nutrient solution or for short periods, after being pretreated in nitrate (2 mM N-NO$_3^-$ as pre-culture) for two weeks (Prof. Dr. Volker Römheld, personal communication).

In addition to N status, the effect of different variable factors such as light intensity and plant age (young three-weeks-old vs seven-weeks-old plants) on production and release of NIs were tested.

Different light intensity conditions were applied using the same growth chamber, in which for high light intensity (400 µmol/m$^2$s$^{-1}$), plants were placed at the centre of the table in the growth chamber with constant light intensity. For intermediate light intensity plants were placed at the corner of the growth chamber, where light intensity was 240 µmol/m$^2$s$^{-1}$. Low light intensity was achieved in the same growth chamber by locating plants inside a box and under different layers of plastic, where they received 180 µmol/m$^2$s$^{-1}$ light intensity. Plants were grown under a light/dark regime of 16/8, and a temperature of 28/25 ºC in nutrient solution culture. Nutrient solutions were renewed thoroughly every 3 days. In treatments with pH control, a solution of 3 mM
Morpholinoethanesulfonic acid (MES) and double daily pH checking and adjusting with KOH, Ca(OH)\(_2\) and H\(_2\)SO\(_4\) were performed.

**Collection of Root Exudates**

Root exudates were collected 2 hours after starting the light period, either for 6 hours from 10 am to 4 pm, or for 24 hours from 10 am to 10 am in the next day. Before collection, plant roots were washed for 1-2 minutes in distilled water. Collecting medium generally was 500 ml distilled water, however, a solution of 1mM NH\(_4\)Cl was also used as the collection medium. After collection, root exudates were concentrated at 35 °C using rotary evaporator to a volume of 15 ml, from which 2.5 ml was applied per replicate in soil incubation bioassay for rapid detection of potential nitrification (Kandeler, 1993). Four samples (replicates) for incubation as well as two samples which were kept under freezing conditions for original NO\(_2^-\) concentrations were used to determine potential nitrification inhibitory of root exudates. In this study we used two controls in our bioassay; first water control in which distilled water was applied instead of root exudates in soil nitrification bioassay, and second 3,4 dimethylpyrazol phosphate (DMPP) control as a standard synthetic nitrification inhibitor which was used in 10 times of its normal concentration (1% of N-NH\(_4^+\)) in all incubations during this study. Plants were exposed to 6 or 24 hours root exudates collection in 1 mM NH\(_4\)Cl, and the electric conductivity (µS/m) of root washings after 3 hours collection was determined.

Excel and SPSS soft wares were used to draw and analysis the data. Comparison of means was performed at P= 0.05 using Duncan test. In figures data are presented as average of four replicates ± SD.

**RESULTS**

A) Collecting Root Exudates in Distilled Water

Root exudates of plants which were grown in nutrient solution under NO\(_3^-\) and NH\(_4^+\) or under NH\(_4^+\) but with buffered pH 6 (Figure 1), and were collected after a 24 hours period in distilled water, showed no significant nitrification inhibition (NI) compared to control. Significant changes in the pH of nutrient solution were occurred for both ammonium and nitrate grown plants within only 24 hours where a pH of 2 has been also recorded (data not presented). Similarly, different effects of plant age (Figure 2); collecting periods (Figure 3); nitrogen concentrations (Figure 4); different light intensities (Figure 5), when collected in distilled water, showed no significant nitrification inhibition compared to water or DMPP control. DMPP, as a standard synthetic nitrification inhibitor, always resulted in very low amounts of produced nitrite in all nitrification incubation tests, indicating high efficiency regarding control of nitrification (Figures 1-7).

Collected root exudates in distilled water when dried in freeze drier and extracted with methanol and further with DMSO (Figure 6), showed significant NI activity only in NH\(_4^+\) grown plants under low light intensity but not in nitrate or higher light intensities. Nevertheless, there was a
The general trend of nitrification reduction was observed with younger plants rather than older plants, as well as lower concentrations of nitrogen in nutrient solution.

**Figure 1.** Nitrification inhibition effect of root exudates collected in 0.5 l distilled water for 24 hours period. Plants were grown with NH$_4^+$, NO$_3^-$ or buffered-NH$_4^+$, with the concentration of 2 mM N. PH of collected root exudates was ~ 3.5 for NH$_4^+$ and ~ 7 for NO$_3^-$ grown plants. Data are average of four replicates ± SD.

**Figure 2.** Nitrification inhibition effect of root exudates of 3-weeks old (A) and 7-weeks old (B) plants grown under 2 mM N-NO$_3^-$ or NH$_4^+$. The pH of nutrient solution for both ammonium and nitrate medium was adjusted to 5 using MES and H$_2$SO$_4$ or KOH. PH of medium after collection was ~ 3.5 for NH$_4^+$ and ~ 7 for NO$_3^-$ treated plants. Data are average of four replicates ± SD.
Figure 3. Nitrification inhibition effect of root exudates collected in distilled water for 6 or 24 hours. Plants were grown in nutrient solution with ammonium or nitrate (without pH adjustment during growing period). PH of medium after collection was ~ 3.5 for NH₄⁺ and ~ 7 for NO₃⁻ plants. Data are the average of four replicates ± SD.

Figure 4. Nitrification inhibition of root exudates collected for 24 hours in distilled water. Plants were grown with different N concentrations as NO₃⁻ or NH₄⁺. PH of collected root exudates was ~ 3.5 for NH₄⁺ and ~ 7 for NO₃⁻ plants. Data are average of four replicates ± SD.
Figure 5. Nitrification inhibition of root exudates collected in distilled water of 6 hours period (A) or 24 hours period (B). Plants were grown in low (LL), middle (ML) and high (HL) light intensities with NH$_4^+$ (2 mM N), compared to NO$_3^-$ (2 mM N) grown plants in high light intensity. Data are average of four replicates ± SD.

Figure 6. Nitrification inhibitory effects of freeze dried root exudates (collected in distilled water) of plants pre-treated with NH$_4^+$ or NO$_3^-$ in high or low light intensity, which have been extracted finally with 0.6% DMSO (on basis of final volume). Data are average of four replicates ±SD. Duncan test was conducted for mean values at P= 0.05.
B) Collecting Root Exudates in NH$_4$Cl Medium

Effects of collected root exudates in 500 ml of 1 mM NH$_4$Cl solution for plants grown in NH$_4^+$ or NO$_3^-$ under different collecting periods are presented in (Figure 7). Significant inhibition of nitrification compared to control was seen for NH$_4^+$ grown plants, although this was for the 24 hours collection period rather than the 6 hours collection period. There was no significant inhibitory effect for nitrate grown plants. However, root exudates of nitrate grown plants showed considerable inhibition after the 24 hours collection period, which was not statically significant. Electric conductivity (EC) of root washings (Figure 8) showed higher conductivity when ammonium is presents particularly in the collecting medium. Ammonium grown plants showed higher conductivity rather than nitrate grown plants.

Discussion

It is almost three decades that the role of phytosidrophores has been well established mainly in iron uptake of plants. Their collection procedure is still used for collecting root exudates for different purposes. In these experiments, plant roots were transferred 2 hours after the light period to a distilled water medium for collection of root exudates (Römheld & Marschner 1986). In contrast to (Subbarao et al., 2005, 2006a & 2007a) which collected root exudates only in 1 mM NH$_4$Cl or KNO$_3$, in this study we used both 1 mM NH$_4$Cl (or KNO$_3$), and distilled water as the collecting medium for root exudates. In Figures 1-6, root exudates collected in distilled water from plants grown under different N forms, N concentrations in nutrient solution, plant age, light intensities, as well as collecting periods showed no significant inhibitory effect on nitrification. However, root exudates of ammonium grown plants under low light intensity which were collected in distilled water and dried using freeze drier instead of rotary evaporator, showed significance differences compared to control (Figure 6). This might be due to avoiding some degradation of NI compounds during routine concentration procedure via rotary evaporator. This, in turn, indicates that the release procedure of natural nitrification inhibitors (NNIs) may not be an active process, since collecting in distilled water due to the osmotic effect, results in higher exudation (Neumann & Römheld, 2000). Exposure of plant roots to external solutions of very low ionic strength is likely to increase exudation rates due to an increased transmembrane concentration gradient of solutes (Neumann & Römheld, 2000). The highest inhibitory effect occurred when 1 mM NH$_4$Cl was used in the collecting medium (Figure 7). This inhibition was a function of the collection period and N-form. Similar results were obtained by others (Subbarao et al., 2005-2008; Ishikawa et al., 1999; 2003; Gopalakrishnan et al., 2007).

In the current study there was always a negative correlation between nitrogen concentrations in nutrient solution and NI activity of root exudates or shoot homogenates independent of N-forms (data
not presented). However, Subbarao et al., (2005-2008) showed that amount of NNI production and release is a function of nitrogen status of plant, as well as NH$_4^+$ rather than NO$_3^-$ nutrition, in which higher nitrogen content of plants leads to more production of NI compounds. In contrast, our data support the idea that nitrogen stress (deficiency) could be the main factor behind the evolution of NNIs as an adaptive mechanism, and they are expressed under N limitation (Ishikawa et al., 2003; Lata et al., 2004; Subbarao et al., 2007b). Subbarao et al., (2007c) released a patent indicating some isomers of unsaturated linolenic and linoleic fatty acids show strong NI activity. Nevertheless, active exudation of fatty acids specially unsaturated long chain isomers of linolenic acid is not possible (Neumann & Römheld, 2000). This could be possible only through root damage or passive exclusion of root debris. In addition, no significant NI activity was indicated when root exudates were collected in distilled water, while significant inhibition effects when collected in ammonium chloride, indicates no active release of NNIs. This is further supported by low pH as an indirect effect of NH$_4^+$ uptake in collecting medium, which can damage the root cells membrane, and consequently leaching of NNIs could occur as a passive phenomenon (Figure 8).

The inhibitory effect of exudates when collected in 1mM NH$_4$Cl, might be a secondary response of BH to salt or osmotic conditions in collection medium. Mergulhao et al., (2002) showed that BH is relatively sensitive to salinity particularly to chloride in growth medium, with a succulent effect on leaves and roots which is more pronounced on roots (Mergulhao et al., 2002; Cazetta and Villela, 2004). The same succulent effect was observed in our pot plants in greenhouse (data not presented). Therefore, the presence of Cl in collecting medium may trigger release of phytoalexins which could have an inhibitory effect on nitrification, which further studies are necessary in order to be clarified. Based on their capabilities, plants can change their biochemical, physiological and morphological characteristics in response to environmental variations. The nature of these changes usually determines a species ability to succeed under temporary or permanent environmental stress. It is quite important that interactions among stress factors that occur parallel in infertile acidic soils must always be considered (Wenzl et al., 2003). Nevertheless, the ability of plants to inhibit nitrification is also presented in this work (Figure 7), and as our results showed, under specific conditions plants can have NI activity in their root exudates. However, our findings can not support the idea that BH plants release controlled root exudates which strongly and efficiently suppress nitrification.

**Conclusion**

There was no detection of NI in root washings, independent of plant age, light intensity, collection period, N-form and N concentrations, except for the ammonium chloride collecting medium. Therefore,
under proper collection conditions for root exudates, (avoiding membrane damage and potential degradation or chemical modification of exudates compounds due to extended collection times in distilled water), there was no evidence for a controlled release of NI compounds from *Brachiaria* roots, independent of plant age, amount and form of N supply, pH of the growth medium and light intensity during the culture period.

However, NI activity was detectable in root washings when plants were exposed to extended collection times (24 h) in combination with NH$_4^+$ supply (Figure 7), but not with NO$_3^-$ in the collection solution or after short-term collection (6 h). This observation is consistent with the findings of (Subbarao *et al.*, 2005, 2006, 2007 & 2008) but also strongly suggests that the observed release of NI compounds was rather a consequence of membrane damage due to inadequate collection conditions (Figure 8), rather than mediated by controlled exudation from undamaged roots. Supplying only ammonium (1 mM) in distilled water as root washing medium over extended time periods (24 h) will lead to rapid ammonium uptake and medium acidification associated with the risk of K$^+$ and Ca$^{2+}$-leaching, as an important element required for membrane stabilisation. Accordingly, (Cakmak & Marschner, 1988) reported detrimental effects on membrane stability in roots of cotton seedlings due to the lack of Ca$^{2+}$ in the washing medium of roots, which was detectable already after an incubation period of only six hours.

![Figure 7. Nitrification inhibition effect of root exudates collected in distilled water containing 1 mM NH$_4$Cl (6 hours versus 24 hours collection). Plants were grown in nutrient solution with 2mM N-NH$_4^+$ or NO$_3^-$. The pH value for ammonium was ~4 and ~3 for 6 and 24 hours, and pH value for nitrate was ~5 and ~4 respectively. Data are average of four replicates ± SD. Duncan test was conducted for mean values at P= 0.05.](image-url)
Figure 8. Electric conductivity (µS/m) of root washings collected for the 3 hours period in distilled water, just after collection of their root exudates for 6 or 24 hours period in 1 mM NH₄Cl. Plants were grown with ammonium, (NH₄)₂SO₄ or with nitrate, Ca(NO₃)₂. Data are average of four replicates ± SD. Duncan test was conducted for mean values at P= 0.05.

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چکیده

ممانعت از تیترفیکاسیون در آکوسیستم‌های طبیعی چندین دهنده است که مطرح می‌باشد. این اثرات ممانعت کندگی یک ویژگی زنوتپیژه‌ای و حسی می‌باشد. این اثر ارتقام نیازمند یک گیاهان مخصوصاً گرانه‌نشین داده شده است. اذ که نیازمند حسی و اذکار برخی Brachiaria humidicola مخصوصاً یک خوراکی Brachiaria توجه زیادی را به سپر نشان آن در کاهش میزان تیترفیکاسیون در خاک از طریق ترشحات رشته‌ای گیاه محدود است. این مطالعه نشان می‌دهد که هیئت ترشحات ریشه‌ای این گیاه در آب مقطور جمع آوری گردیده، جدای از میوه و غلظت ترکیزی، شدت تور، سن گیاه و طول مدت جمع آوری ترشحات ریشه، ترشحات رشته‌ای این گیاه همچنین منفعت بر فرازند تیترفیکاسیون نداشته، به هر حال وقتی ترشحات ریشه در محیطی هاوی یک میلی مول کلدکم آمونیم جمع آوری گردیده، آن به طور منفعت از تیترفیکاسیون ممانعت نمود و این اثر ممانعت کندگی در گیاهان رشد یافته با آمونیم بیشتر از گیاهان رشد یافته با ترکیبات آمونیم نموده‌های جمع آوری شده ترشحات ریشه وقتی هجیز شدند، عصاره استخراج شده ترشحات ریشه ای گیاهان رشدیه با آمونیم و آن هم تنا تخت شرط شدند. شدت نور کم (و یا نور متوسط با زاید) ممانعت از تیترفیکاسیون را باعث گردید. ابزاره‌گیری هیدایت الکتریکی ترشحات ریشه در آب مقطور (بعد از جمع اوری ترشحات ریشه در محلول یک میلی مول کلدکم آمونیم) بیان کننده هیدایت الکتریکی بیشتر تحت شرایط جمع آوری میوه در محیط ریشه مخصوصاً بر مرحله جمع آوری ترشحات ریشه ای برای مدت طولانی (۲۲ ساعت بجای ۶ ساعت) وجود داشت.

کلمات کلیدی: Brachiaria humidicola، ترشحات ریشه، آمونیم، نیترات، هیدایت الکتریکی
Mouse barley germination environmental factors influencing germination of mouse barley (Hordeum murinum L.) in South Khorasan Province, Iran

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ABSTRACT

Mouse barley (Hordeum murinum), from the poaceae family, is an abundant annual grass weed in wheat fields of South Khorasan province. Determining the ecological factors of this grass weed will contribute to development of its control programs. Effects of environmental factors on germination and emergence of mouse barley was investigated in the laboratory. Although mouse barley germination was greater than 85% at salinity level of 160 mM, further increase of salinity caused a remarkable decrease in its germination, following a 3% decrease in germination at salinity level of 320mM. Increasing osmotic potential from 0 to -0.8 MPa, resulted in an 80% decrease in its germination. Mouse barley germination was not affected by the pH and in a pH range of 4 to 10 remained approximately 90%. Emergence depth test showed that the maximum emergence of mouse barley occurred for seeds placed on the soil surface (86%) and no seedlings emerged from the seeds buried at 10cm depth. High germination ability of mouse barley under diverse environmental conditions may greatly contribute to it as a problematic weed species in the wheat fields of the region.

Keywords: Salinity, osmotic potential, emergence depth, acidity.

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INTRODUCTION

Mouse barley, also referred to as barley grass or wild barley, is a winter annual grass that grows in non-cropland and croplands of Southern Khorasan. Its native range extends from central Europe, south to northern Africa and east to western Asia and the Caucasus (USDA, ARS 2005). Mouse barley grows well in warm and dry areas, while cold and moist conditions hinder its growth (Davison, 1977). It propagates by seeds which are produced in large number (Halloran & Pennell 1981). It is a successful invader species, in disturbed and soil high in nutrient levels and nitrogen (Dean, 1990). Mouse barley establishes easily on land subjected to regular grazing and becomes dominant with increasing intensity of grazing (Groves et al., 2003). After flowering in the spring, the grass matures rapidly to produce a large number of seeds. The majority of mouse barley seeds remain dormant during the summer till autumn. Seed dormancy is an important mean of avoiding the catastrophes that weeds encounter (Baker, 1974) and the ability of a seed to persist in the soil is favorable in disturbed habitats where synchronous germination could result in the mortality of all plants (Cohen, 1966; Westoby, 1981). The high level of dormancy is usually a general characteristic of annual weeds that results in large, persistent seed banks (Anderson, 1990). An appropriate seed dormancy strategy will enable winter weed species to germinate under favorable conditions of late autumn and winter and also prevents germination after summer rains, which are invariably followed by a period of drought (Dunbabin & Cocks, 1999).

The success of mouse barley as an invader species throughout the world has been attributed to its early germination and rapid growth rate, seed dormancy, high seed production and efficient dispersal mechanisms. It has a short life cycle and 19 to 29 seeds are produced per head (Dean, 1990).

Various environmental factors, such as temperature, osmotic potential, pH, light quality, management practices and seed location in the soil seed bank as well as soil texture have been known to influence weed seed germination and emergence (Norsworthy & Oliveira, 2006). To understand why mouse barley is so troublesome, it is important to gain a better understanding of how its seeds germinate in response to different environmental factors such as light, temperature, osmotic potential, pH, and burial depth (Chachalis & Reddy, 2000; Chauhan & Johnson, 2008). A better understanding of mouse barley germination could aid strategies to manage this weed. Develop offing models helps to predict germination and emergence or the influence of tillage and burial on the two mentioned processes. Longevity is influenced by several factors, including the physiological status of seeds, the chemical and physical environment where seeds reside, and the position of seeds relative to the soil surface (Baskin & Baskin, 1998).

Although mouse barley is a problematic weed species in Southern Khorasan cereal
farms (Tareghian, 2002), little information on effects of environmental factors on its germination biology exists. Knowledge about mouse barley germination would help estimating the potential of its spread to new croplands. Therefore, this study was conducted in order to understand the influence of different environmental factors on the seed germination and seedling emergence of mouse barley.

**MATERIALS AND METHODS**

**Site and Seed Description**

Mature mouse barley seeds were collected in June 2007, from several wheat fields at the Amirabaad Campus, Birjand, in Southern Khorasan (latitude = 32º 56´N, longitude = 59º 13´E and 1480 m altitude). Seeds from 500 plants were separated from the inflorescence and pooled to obtain seed samples. 3 months after maturity, the seeds were stored in paper bags at a constant temperature (4 ± 1°C). An 1,000-seed weight of mouse barley was 4.2 ± 0.01 g.

**General Protocol for Germination Tests**

Four 25-seeds of mouse barley were placed in 9-cm petri dishes lined with 2 discs of filter paper, moistened with either 5mL deionized water or treatment solution when required. The petri dishes were sealed with parafilm to minimize evaporation and placed directly in the germinator or wrapped in two layers of aluminum foil to exclude light prior to placing them in the germinator. Germination tests were conducted for 14 days at a day/night temperature of 25 °C/15°C (12h/12h). Seeds were considered to have germinated when the radicle emerged. The number of germinated seeds was counted at the end of the germination test. In preliminary testing, freshly harvested seeds placed in petri dishes did not germinate under normal laboratory conditions.

**Temperature and Light**

Experiments were conducted to determine the effects of various fluctuating day/night temperatures (15/6, 20/10, 25/15, 30/15 & 35/20 °C) on seed germination (3 months after maturity) under light/dark and continuous dark regimes. This temperature regime was chosen to simulate the late summer and autumn temperatures in Southern Khorasan.

**Salinity**

Sodium chloride solutions of 0, 10, 20, 40, 80, 160, 320 and 640 mM were prepared in deionized water. These salinity concentrations were chosen to cover variations in the level of salinity in South Khorasan soils. Petri dishes were incubated as described in the general protocol under light/dark regime.

**Solution Osmotic Potential**

Mouse barley seeds were germinated in the light/dark in aqueous solutions of polyethylene glycol 6000 with osmotic potentials of 0, -0.1, -0.2, -0.4, -0.6, -0.8, and -1.0 MPa, prepared by dissolving appropriate amounts of PEG 6000 in deionized water (Michel, 1983).

**PH**

The effect of pH on germination was studied using buffer solutions of pH = 4 to 10 according to the method described by Chachalis & Reddy (2000). A 2 mM potassium hydrogen phthalate buffer solution was adjusted to pH 4 with 1 N HCl. A 2 mM solution of MES [2-(N-morpholino) ethanesulfonic acid] was
adjusted to pH 5 and pH of 6 with 1 N NaOH. A 2-mM solution of HEPES [N-(2-hydroxymethyl)piperazine-N-(2-ethanesulfonic acid)] was adjusted to pH 7 and pH 8 with 1 N NaOH. Buffer solutions of pH 9 and pH 10 were prepared with 2-mM tricine [N-Tris(hydroxymethyl)methylglycine] and adjusted with 1 N NaOH. Petri dishes were incubated at 25/15 °C day/night temperature as described in the general protocol.

**Emergence Depth**

The effect of different planting depths on seedling emergence of mouse barley was investigated in a growth chamber. Seeds were placed at five different depths (0 cm or surface, 2.5, 5, 7.5, and 10 cm) in 15-cm-diam plastic pots. Control pots, where seeds were not added, indicated that there was no background seed bank of mouse barley in the study soil. Moist soil was placed over sown seeds to the appropriate depth and gently compacted. For each burial depth, four pots (replicates), with 50 seeds per pot were set up (total of 20 pots). Soil used for this experiment was a loamy soil comprised of 43% sand, 32% silt and 25% clay with 0.44% total organic matter and a pH of 7.4. The temperature of the growth cabinet was set to 25/15 °C (day/night). The photoperiod was set to 12 hours with fluorescent lamps used to produce a light intensity of 140 µmol m⁻² s⁻¹. The pots were watered as needed to maintain adequate soil moisture. Seedlings were counted as they emerged through the soil and the experiment was run till 45 days after burial. Mean emergence time (MET) was calculated using the following formula

\[
MET = \frac{\sum (n \times g)}{N}
\]

in which, \(n\) is the number of seedlings emerging per day, \(g\) is the number of days needed for emergence, and \(N\) is the total number of emerged seeds. At the end of the experiment, seeds buried at 10 cm depth were recovered to determine the fate of non-germinated seeds. The soil was filtered using a 1 mm mesh metal sieve to recover intact (dormant) seeds as well as seedlings that were rotted due to failure of emergence after germination. This procedure made it possible to distinguish between seeds that remained dormant and germinated seeds that failed to emerge due to excessive depth of burial.

**Data Analysis**

All experiments were carried out twice (except the emergence depth study) as a completely randomized design with four replicates per treatment. The data of the experiments were pooled for analysis, as there was no time-by-treatment interaction. A functional three parameter logistic model (Chauhan et al., 2006a) as expressed below:

\[
G (%) = G_{\text{max}} \left[1 + \left(\frac{x}{x_{50}}\right)^{Grate}\right]
\]

was fitted to the germination values (%) obtained at different concentrations of NaCl or osmotic potential using SigmaPlot³ (version 11.0). In this equation, \(G\) represents the total germination (%) at NaCl concentration or osmotic potential \(x\), \(G_{\text{max}}\) is the maximum germination (%), \(x_{50}\) is the NaCl concentration or osmotic potential for 50% inhibition of the maximum germination, and \(Grate\) indicates the slope. The seedling emergence values...
(%) obtained at different burial depths were fitted to a sigmoidal decay curve (Norsworthy and Oliveira, 2006) in the form of:

\[
E(\%) = \frac{E_{\text{max}}}{1 + \exp\left(-\frac{x-x_{50}}{E_{\text{rate}}}\right)}
\]

where \( E \) represents the seedling emergence (\%) at burial depth \( x \), \( E_{\text{max}} \) is the maximum seedling emergence, \( x_{50} \) represents the depth at which emergence is reduced by 50%, and \( E_{\text{rate}} \) indicates the slope. Transformation of data did not improve homogeneity; therefore, ANOVA and regression analysis were performed on non-transformed percentage of germination (Genstat, version 9.2). Means were separated using either LSD test at \( P = 0.05 \) or standard error bars.

RESULTS AND DISCUSSION

Temperature and Light

Although light and fluctuating temperatures can be important in stimulating germination of many agricultural weeds, the impact of temperature and light on mouse barley germination was insignificant (data not shown). There was no interaction between temperature and light. Mouse barley showed high germination (>90%) at all tested temperatures under both light/dark and continuous dark regimes. Results showed that mouse barley could germinate over a wide range of temperature regimes from 15/6 to 35/20 \( ^{\circ} \text{C} \) alternating day/night temperatures. Studies in Australia similarly showed that germination of mouse barley occurred at constant temperatures ranging from 7 to 32 \( ^{\circ} \text{C} \), with optimum temperatures between 18 and 24 \( ^{\circ} \text{C} \) (Groves et al., 2003). The effect of large diurnal temperature swings on the germination was insignificant (Cocks & Donald, 1973, Piggin et al., 1973, Popay, 1981). The ability of mouse barley to germinate over a wide range of temperatures supports the extended period of its emergence in the field throughout most autumn and winter months in south Khorasan.

This study also indicated that mouse barley does not require light for germination (non-photoblastic). Exposure to light breaks dormancy in many weed species, but there are species in which light has no effect or may even inhibit germination. Grime and Jarvis (1976) also found that mouse barley seeds maintained under high or low light intensity or in darkness, germinated completely in all conditions.

Baskin and Baskin (1998) summarized that among 54 grass species, germination of 28 was promoted by light, 13 were unaffected by light or dark conditions, and 13 were inhibited by light. Milberg et al., (1996) tested 44 species, mostly agricultural weeds, and found that germination improved in 24 species after a 5-s exposure to light. In the remaining 20 species, there were no effects. Buhler, (1997) found that germination percentage of annual grasses like Echinochloa crus-galli L., Alopecurus myosuroides Huds., and Setaria glauca L. were similar under presence or absence of light. Seed germination of Atriplex stocksii Boiss. (Khan & Rizvi, 1994) and Suaeda fruticosa Forssk.(Khan & Ungar, 1998) were not inhibited by the absence of light. Germination of Aegilops cylindrica host has also been shown to be insensitive to
light and dark conditions (Baskin & Baskin, 1998). In situations where light promotes germination, it has been associated with small, rather than large seed masses (Milberg et al., 2000; Schutz et al., 2002).

**Salinity**

The three-parameter logistic model \( G(\%) = \frac{98.6}{[1 + (x/207.9)^{8.6}]} \), \( r^2 = 0.99 \) provided a satisfactory fit for the data of mouse barley seed germination obtained at different concentrations of NaCl (Figure 1). Germination was greater than 95% up to 80 mM NaCl and also high at 160 mM NaCl (> 85%). Increasing NaCl concentration to 320 mM sharply decreased mouse barley germination (<3%). The parameter \( x_{50} \) (Equation 1) that represents the NaCl concentration for 50% inhibition of the maximum germination, was 207.9 mM NaCl, indicating a moderately salt tolerance in this species at germination stage. The results show that mouse barley would be able to germinate even at saline soil types which are common in Southern Khorasan (Forooghifar & Shahidi, 1999).

![Figure 1](image)

**Figure 1.** Effect of NaCl concentration on germination of mouse barley seed incubated at 25/15 °C day/night temperature with a 12-hour photoperiod for 2 weeks.

**Solution Osmotic Potential**

Increased solution osmotic potentials reduced mouse barley germination (Figure 2). Increasing osmotic potential from 0 to –0.6 MPa caused an 80% reduction in mouse barley germination.
Mouse Barley Germination Environmental Factors …

The three-parameter logistic model \( G(\%) = \frac{98.9}{1 + (x/0.40)^{4.21}}, \quad r^2 = 0.99 \) provided a satisfactory fit for the data of mouse barley seed germination obtained at different osmotic potentials. As osmotic potential decreased from 0 to -0.6 MPa, mouse barley seed germination decreased from 98 to 20%. No germination occurred when the osmotic potential was -0.8 and -1.0 MPa.

The osmotic potential required for 50% inhibition of maximum germination \((x_{50})\), determined from the fitted model (Equation 1) was -0.40 MPa. Although at lower incidence, mouse barley can still germinate under moderate water-stress conditions. Germination over a broad range of osmotic potentials indicates that mouse barley could pose a weed threat under both adequate and moderate moisture-stress soil conditions.

**PH**

Mouse barley seeds germinated greater than 90% over a pH range from 4 to 10 (data not shown) while most soils of South Khorasan fall in the neutral to alkaline range (Forooghifard & Shahidi, 1999). These results suggest that pH should not be a limiting factor for germination of this weed species in most soils. Similar to mouse barley, other weed species, including annual sowthistle \((Sonchus oleraceus\) L. \(\text{SONOL}\)) (Chauhan et al., 2006a) horseweed \((Conyza canadensis\) L. Cronq. \(\text{ERICA}\)) (Nandula et al., 2006) texasweed \([Caperonia palustris\) (L.) St. Hil.\]) (Koger et al., 2004), and giant sensitiveplant \((Mimosa invisa\) Mart. ex Colla \(\text{MIMIN}\)) (Chauhan & Johnson, 2008), germinated in a wide range of pH. High germination of mouse barley over a broad range of pH has implications for a widespread distribution and infestation in South Khorasan.

**Emergence Depth**

Depth of burial strongly influences seedling emergence. Germination was noted the 9\(^{\text{th}}\) day after establishing the experiment for seeds placed on the soil surface (27%) and for seeds sown at 2.5 cm (21%) (data not shown). Mouse barley emergence was influenced by seeding depth \((P < 0.001)\). Increasing the seeding
depth decreased emergence percentage and also delayed the emergence time (Figure 3). The greatest mouse barley emergence occurred for seeds placed on the soil surface (86%) and no seedlings emerged from burial depth 10 cm. The sigmoidal decline model \( E(\%) = \frac{84.2}{1 + \exp(-\frac{(x-4.7)}{-1.2})}, \quad r^2 = 0.97 \) was best fitted to the data of mouse barley emergence in relation to seeding depth (Figure 4). According to the model, the seeding depth that decreased mouse barley emergence by 50% was 4.5 cm. Popay and Sanders (1975) also reported that mouse barley seedlings from seed sown on the soil surface emerged well but the seed was slow in germination. They also found that seed sown at 2 mm below the surface or at 2.5 cm deep emerged well but with seed sown at 5, 7.5, and 10 cm emergence was gradually declined.

Figure 3. Effect of seeding depth on seedling emergence (as percentage of soil surface germination) and mean emergence time (MET) of mouse barley seedlings. Vertical bars represent standard errors.

Emergence of weeds is affected by the amount of food reserves in seeds and the depth of seed burial in the soil. Decreased emergence due to increased planting depth has been reported in several weed species, including horseweed (Conyza canadensis L.) (Nandula et al., 2006), sicklepod (Senna obtusifolia L.) (Norsworthy & Oliveira, 2006), and African mustard (Brassica tournefortii L.) (Chauhan et al., 2006b). Roberts, (1986) found that mouse barley seeds sown in a 7.5 cm layer of soil in cylinders sunk in the field, emerged mainly in the year of sowing with less than 1% of seedlings emerging in year 2 and none thereafter. Recovery of nongerminated seeds showed that failure to emerge was almost entirely the result of fatal germination (95%), rather than re-induction of dormancy. Similarly (Popay & Sanders, 1975) found that the mouse barley seeds sown deeper than 10 cm did germinate but failed to emerge. Therefore, it is thought to be unlikely that mouse barley would build up a large seedbank in the soil. As mouse barley does not form long seed bank duration (Popay & Sanders, 1975), burial of seed by deep summer
tillage may prevent germination in the following autumn. Emergence from depth of 7.5 cm could allow mouse barley to escape control with pre-emergence herbicides.

Our data suggest that mouse barley is able to germinate under a broad range of environmental conditions. Light, temperature and solution pH levels used in this study had little impact on mouse barley germination. On the contrary, water stress, salinity and depth of burial affected seed germination of this weed. Deep tillage may prevent emergence of this troublesome weed species and can be adopted as an effective tool for its control as it showed fatal germination at deep burial depths.

**REFERENCES**


چکیده

جواموشی، علی‌هایی یک‌ساله از خانواده گندمیان، در مزارع گندم استان خراسان جنوبی به وفور یافت شده و گزارش شده است. شناخت اکولوژی جوانه‌زنی این علی‌های به توسیع برنامه‌های کنترل آن کمک خواهد کرد. اثرات عوامل محیطی مختلف بر جوانه‌زنی و سیز شدن جواموشی در آزمایشگاه مورد تحقیق قرار گرفت. اکر چه در شرایط معادل 160 میلی‌میلر کلرور سدیم، یک میزان جوانه‌زنی بیش از 85 درصد به دست آمد. افزایش سطح شوری از آن به بعد منجر به کاهش قابل ملاحظه‌ای در جوانه‌زنی گردید. به طوری که در شرایط 230 میلی‌میلر، یک میزان جوانه‌زنی به 3 درصد کاهش یافت. افزایش یکسالی اسمزی از صفر به 8/80 درصد فاکتور، منجر به کاهش جوانه‌زنی به میزان 80 درصد گردید. جوانه‌زنی جواموشی به وسیله pH تحت تأثیر قرار نگرفت و در دامنه pH تا 4، 10 در حدود 90 درصد باقی ماند. آزمایش عمق سیز شدن نشان داد که حداکثر سیز شدن این علی‌های جواموشی تحت شرایط محیطی متفاوت ممکن است تا حد زیادی در موقعیت این علی‌هایه که علت سیز شدن یک جوانه‌زنی سیز شدن گونه مشکل‌ساز در مزارع گندم منطقه سهیم باید.

کلمات کلیدی: شوری، یکسالی اسمزی، عمق رویش، اسیدیتی
Corn and Soybean Intercropping Canopy Structure as Affected by Competition from Redroot Pigweed (*Amaranthus retroflexus* L.) and Jimson Weed (*Datura stramonium* L.)

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**ABSTRACT**

In order to determine the role of plant leaf area in radiation distribution within the canopy and a better understanding of how crops and weeds intercept light a study of the complexity of plants is necessary. The effect of intercropping on leaf area distribution and dry matter accumulation in corn, soybean and weeds canopy was studied in a field experiment at a research field of Tehran University (Karaj campus), during 2007 growing season. Treatments were arranged in a factorial experiment based on randomized complete blocks with three replications. The treatments were five different mixing ratios of corn (*Zea mays* L.) and soybean (*Glycine max* L.) including 100/0, 75/25, 50/50, 25/75 and 0/100 (corn/soybean). Crops were planted at four levels of weed infestations, including weed free, infested to redroot pigweed (*Amaranthus retroflexus* L., AMRET), infested to jimsonweed (*Datura stramonium* L., DASTR) and mixed stands of both weeds species (DASTR+AMRET). Results showed that in weed free corn pure stand, 30.36% of the maximum leaf area was distributed in 90-120 cm layer, but when corn was grown with jimsonweed or infested with both weed species (DASTR+AMRET), the maximum leaf area were established in the upper layer. Soybean weed free monoculture produced 34.66% of its total biomass in the layer of 30-60 cm, but contaminated soybean with DASTR+AMRET, allocated 32.97% of its biomass in the 60-90 cm layer. In this treatment DASTR had also its maximum biomass (49.54%) in the 120-150 cm layer. Soybean canopy in monoculture couldn’t compete with weeds and was suppressed, but intercropped soybean with the corn especially in 50%: 50% mixing ratio, suppressed the weeds successfully. Therefore we can concluded that complementarily effect of corn/soybean intercropping created better condition for optimum utilization of solar radiation to successfully suppress weeds and maintain crop production.

**Key words:** canopy structure, leaf area distribution, legume/cereal intercropping
INTRODUCTION

Amount and vertical distribution of leaf area are essential for estimating interception and utilization of solar radiation of crop canopies and, consequently dry matter accumulation (Sivakumar & Virmani, 1984; Valentini & Tollenaar, 2006). Vertical distribution of leaf area is leaf areas per horizontal layers, based on height (Boedhram et al., 2001). The presence of weeds intensifies competition for light, with the effect being determined by plant height, position of the branches, and location of the maximum leaf area (Holt, 1995).

The effect of leaf area distribution on light competition can be illustrated by dividing the canopy into horizontal layers (Wiles & Willkerson, 1991). Evaluating the interference of common cocklebur (Xanthium strumarium) and entire leaf of morning glory (Ipomoea hederacea) on soybean indicated that the crop LAI within a given canopy stratum was smaller in multi-species plots than those of soybeans grown alone or with single weed species and soybean plants also developed a large proportion of their leaf area in the upper portion of the canopy (Mosier & Oliver, 1995). Growth assessment of corn (Zea mays L.) in monoculture and in competition with Datura stramonium L. showed faster growth of corn leaf area and height reduced the photosynthetically active radiation (PAR) received by the weed. Corn had 70% and Datura stramonium had 95% of its leaf area in the upper half portion of the plant while weed competition did not affect the canopy architecture of corn (Cavero et al., 1999). In the study of (Massinga et al., 2003), palmer amaranth (Amaranthus palmeri) LAI increased with increasing its density from 0.5 to 8 plants.m\(^{-1}\). While at low plant densities, 60% of palmer amaranth’s leaf area occurred between 0.5 and 1.5 m. As plant density increased, 80% of the leaf area was concentrated above 1 m.

Above-ground biomass is one of the central traits in functional plant ecology and growth analysis. It is a key parameter in many allometric relationships (West et al., 1999; Niklas & Enquist, 2002). The vertical biomass distribution is considered to be a main determinant determine of competitive strength in plant species (Schwinning & Weiner, 1998; Tackenberg, 2007). Many vegetation and yield variables are potentially influenced by the competition of the plant with a second crop in an intercrop system and by competition with other plants of the same species in monocrop systems, all being affected by changes of plant population density (PPD) (Fortin et al., 1994). In monocrop systems, soybean plants are more sparsely branched at greater densities than at lower densities. Soybean height, LAI and light interception increased with increasing PPD (Boquet, 1990, Parvez et al., 1989; Foroutan-pour et al., 1999).

Although yield variability in corn and soybean intercrop systems has been the focus of much research work (e.g. Hayder et al., 2003; Egbo et al., 2004), there is little information on vertical distribution of leaf area and biomass in weed-crop components of an intercropping system (e.g. in corn-soybean mixed cropping).
Therefore, in this research we concentrate on leaf area and biomass changes in the mentioned crops and weeds.

**MATERIALS AND METHODS**

The experiment was conducted at research field of Tehran University (Karaj campus), during the growing season of 2007. Soil characteristics were clay-loam with 1.67% organic matter, 0.093% total N, 46.67 ppm P and 393.33 ppm K. Seedbed preparations were a deep tillage in previous autumn and two vertical diska and leveller in spring. Fertilization was done separately for each crop, in such a manner 400 kg.ha\(^{-1}\) urea and 250 kg.ha\(^{-1}\) ammonium phosphate for the corn row, applied in two stages, first split (200 kg) of urea and whole phosphorus fertilizer, and the second split of urea was applied at 6-8 leave stages. For soybean 150 kg.ha\(^{-1}\) ammonium phosphates with 50 kg.ha\(^{-1}\) urea were applied at early growing season. No diseases and insect were observed.

Treatments were established in factorial arrangement based on randomized complete blocks design with three replications. The treatments were five different mixing ratios of corn (Ze a m ays L.) and soybean (Glycine max L.) including(corn/soybean): 100/0 (P\(_1\)), 75/25 (P\(_2\)), 50/50 (P\(_3\)), 25/75 (P\(_4\)) and 0/100 (P\(_5\)). Which were planted at four levels of weed infestations: weed free (W\(_1\)), infested to redroot pigweed (Amaranthus retroflexus L. AMRET) at 25 plant m\(^{-2}\) (W\(_2\)), infested to jimsonweed (Datura stramonium L., DASTR) at 25 plant m\(^{-2}\) (W\(_3\)) and mixed stands of redroot pigweed and jimsonweed at total density of 25 plant m\(^{-2}\) (W\(_4\)). Each plot had 6 rows with 60 cm inter row space and 6.5 m length. Corn (cv. K.SC. 500) and soybean (cv. Williams) were planted on June 5th with arrangement of 20 * 60 cm and 25*60 cm for corn and soybean respectively. The weed seeds which were collected last year from the research farm were kept at 4º C before sowing, then simultaneously sown 15 cm apart from crop rows at either two sides. Weed seedlings were thinned to 15 plants per row meter at two-leaf stage. All weed species except of our target species were thinned in two stages until 8 leaves of corn. Field was irrigated with a seven days interval.

At corn canopy closure (50% silking), a vertical card board frame marked in 30-cm increments was used in the field as a guide to cut standing plants (both crops and weeds) into 30-cm strata increments with hedge shears (Mosier & Oliver, 1995). All samples were transferred to the laboratory, leaves and stem were separated and for every sample the area of green leaves was measured with a leaf area meter LICOR-3000 A (LI-COR, Lincoln, NE, USA). Afterwards all samples were oven-dried at 80 ºC for 72 hours and weighted. Both leaf area and biomass were calculated as percentage (%) in relation to whole plant.

At the end of growing season, all plants in 2 meters of 4 rows were harvested in each plot, to evaluate the crop yield. The land equivalent ratio (LER) gives an accurate assessment of the greater biological efficiency of the intercropping situation and was calculated as equation (1):
Equation

(1): $\text{LER} = (\frac{Y_{ab}}{Y_{aa}}) + (\frac{Y_{ba}}{Y_{bb}})$

$\text{LER} = R_{Yc} + R_{Ys}$

Where $Y_{aa}$ and $Y_{bb}$ are yields of sole crops and $Y_{ab}$ and $Y_{ba}$ are yields of intercrops. We considered $R_{Yc}$ and $R_{Ys}$ as relative yield of corn and soybean respectively. LER values greater than 1 were considered advantageous.

RESULTS AND DISCUSSION

Corn Monoculture

In monoculture of corn the maximum leaf area was 30.36% in weed free, while when grown in presence of one or two weed species, this index was higher (Figure 1 a, b, c & d). Similar to other studies corn allocated more leaf area to the upper layer in presence of weeds. (Rajcan & Swanton, 2001 & Cavero et al., 1999). In sever competitiveness (intra & inter specific competition) there was no leaf area in layer 0-30 cm since plant ability to allocate green shoot in upper layer is one of the main traits therefore changing canopy architecture is very important in competition (Aerts, 1999). In corn infested to DASTR, and DASTR + AMRET the maximum leaf area of weeds was in layer 120-150 cm (Figure 1 f & g), while in corn infested to AMRET, the maximum leaf area (67.79%) was in layer 90-120 cm (Figure 1 e).

![Figure 1. LAI profiles of corn A. retroflexus and D. stramonium in 100% corn: 0% soybean.](image-url)
The maximum amount of corn biomass (42.7 & 42.96%) in weed free and in competition condition with AMRET were established in layer 90-120 cm, but in corn infested with DASTR and DASTR + AMRET the maximum amount of corn biomass (45.19 & 46.63%) was in layer 120-150 cm (Figure 2 a, b, c & d), which could be for the reason of ear formation in this layer.

Profiles of weeds biomass distribution in these treatments showed that, when corn competed with DASTR this weed also had translocated the most percentage of biomass to the highest layer (Figure 2 e).

This rate of biomass was for the reason of formation of the most part of leaf area in this layer. The main characteristics that allowed this weed to compete against a strong competitor such as corn was its height plasticity, canopy architecture, concentrated leaves in the upper part of the plant, and higher light extinction coefficient. An important feature is its indeterminate growth habit, which allows continuous increase in height (Stoller & Wolley, 1985). This condition also, was in both weed contamination (Figure 2 g). This distribution pattern of biomass seems to be for more radiation capturing.

**Figure 2.** Biomass profiles of corn [red], soybean [brown], *A. retroflexus* [blue] and *D. stramonium* [green] in 100% corn: 0% soybean.
**50% Corn: 50% Soybean Ratio**

In weed free canopy of corn the greatest leaf area (28.56%) was found in layer 90-120 cm followed by layer 60-90 cm which had less leaf area (27.75%) than the above layer (Figure 3 a). which could be concluded that in the absence of weed, corn contributes its leaf area in lower layers. When corn was grown with **AMRET, DASTR** and both weed species, more leaf area was established between 120-150 cm. In such conditions weeds can not compete for light with crops.

Soybean in weed free unit had maximum leaf area (43.68%) in layer 30-60 cm. When grown with weed the maximum leaf area were formed in layers 60-90, 90-120, 90-120 cm in plots which were infested to **AMRET, DASTR and AMRET+DASTR** (50.96, 37.57 and 37.30%) respectively. Soybean plants developed a large proportion of their leaf area in the upper portion of the canopy, indicating their competition for available light in the canopy (Mosier & Oliver, 1995). In this ratio, crops in weed infested treatments expanded their leaf area and suppressed weeds for radiation capture. Therefore it is concluded that intercropping can be used as a tool to improve competitive ability of a canopy with good suppressive characteristics. Planting patterns would also provide better light distribution to obtain higher biomass accumulation rates and higher yields.

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**Figure 3. LAI profiles of corn, soybean, A. retroflexus and D. stramonium** in 50% corn: 50% soybean.
In 50% corn: 50% soybean ratio, both crops reach to a higher height to compete with weeds (Figure 4 a, b, c & d) while weeds could not compete well with crops, because maximum biomass of DASTR and AMRET in this treatment was formed in layer 90-120 cm (Figure 4 e, f & g). A faster growth of leaf area and height in crops reduced the photosynthetically active radiation (PAR) received by the weed and consequently reduced weeds growth rate (Cavero et al., 1999). Intercropped systems are reported to use resources higher and more efficiency than monocrop systems, thus decrease the availability of resources for weed production (Caruuthers et al., 1998). In this ratio, crops can conquer weeds and have good growth, with or without weeds.

Figure 4. Biomass profiles of corn, soybean, A. retroflexus and D. stramonium in 50% corn: 50% soybean.

**Soybean Monoculture:**

Soybean in the weed free treatment, expanded leaf area throughout the whole canopy, but in weed infested plots it allocated its leaf area to upper layers due to inter specific competition (Figure 5 a, b, c, & d). Soybean plants infested to DASTR allocated its leaf area to layer 60-90 cm (47.05 %) (Figure 4 c), which was lower than the weed which shows that the weed is a better competitor than soybean specially when soybean grows by both weeds species (Figure 5 c & d).

Soybean infested to AMRET had higher leaf area in a lower layer than the weed (A. retroflexus) meaning that when the soybean grows in monoculture, it could not suppress the weed and thus fewer yields, but when it grown with corn, it could suppress weeds due to the similar ability in
corn. Therefore in intercropping systems crop partners use resource and grow probably better than in monosulture condition. For this reason they can suppress weeds. The advantage that weeds have over crops for light interception is their height which is one of the best predictions of competitive success in light competition (Holt & Orcutt, 1991). Graham et al., (1988) also observed that by absorbing light in the upper canopy, Palmer amaranth (*Amaranthus palmeri*) and smooth pigweed (*A. hybridus* L.) reduced light penetration into the sorghum canopy. Effects of weed height on light penetration through the crop canopy were reported in competition studies between velvetleaf (*Abutilun theophrasti* Medikus) and soybean (Akey et al., 1990). although Mosier & Oliver, (1995) reported that soybeans grown alone/ monoculture of soybean or with *Ipomoea hederacea*, developed similar canopies and had similar strata LAI values because *Ipomoea hederacea* never acquired enough leaf area or size to affect the soybean canopy with irrigation.

In weed free soybean biomass amounts of upper layers of canopy were decreased due to increasing height. This decrement in 30% upper layer was obvious. In non competition condition, soybean tried to have more branching which was caused in lower layers of canopy therefore dry matter accumulation was less in the upper layer. Lack of weed interference for light interception can be considered as an acceptable reason for this event (Figure 10)

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**Figure 5.** LAI profiles of soybean [A. retroflexus](#) and *D. stramonium* in 0% corn: 100% soybean.
a). Investigation of biomass profiles of soybean in competition with DASTR, AMRET and DASTR+AMRET showed that soybean changed biomass distribution pattern (Figure 6 b, c & d) in such a manner that higher amounts of biomass were allocated to the upper layers (Figure 6 a, b, c & d). McLachlan et al., (1993) suggested that lack of branching in high density may lead to decreasing light spectral quality as R/FR ratio. High plant density decreased light penetration into the canopy which can restrict stem branching and lateral growth.

Changing the biomass profile in a crop canopy is an important trait in the result of competition and final crop yield. In three way competition between soybean, DASTR and AMRET, jimsonweed had maximum biomass (38.29%) in 120-150 cm which was due to increased height and more branching in the upper layers, while redroot pigweed founded its maximum biomass (45.17%) in layer 90-120 cm (Figure 10 g).

The intensity of aboveground competition experienced by soybean was expected to increase from monoculture to intercropping. The architecture of plant affected the asymmetry of light competition. Corn effectively suppresses its neighbours with creating a deep shade on them. But weeds interference may be reduced by a combination of crop species occupying two or more niches in the field. Intercrops are more effective than sole crops in conquering resources from weeds, resulting to greater crop yield and less weed growth.

![Figure 6. Biomass profiles of soybean A. retroflexus and D. stramonium in 0% corn: 100% soybean.](image)
Corn Yield

Corn/soybean mixing ratio and weed infestation significantly affected corn grain yield (P<0.001). The interaction effects was also significant (P<0.01). The highest amount of corn grain yield (9627.8 Kg ha⁻¹) was obtained in P₃W₁ treatment and lowest amount (3916.5 kg ha⁻¹) in P₃W₄ (Table 1 & Figure 1). Presence of both weed species had the highest effect on corn yield loss. Yield reduction in treatments of low density corn (P₄) has been contributed to low number of plants and increased weed competition ability for radiation reception and probably higher efficiency of weed roots for water and nutrient uptake.

In many intercropping experiments, consisting legume and grass, intercropping had higher yield compare to monocropping (Morris & Garrity, 1993). In a legume/cereal intercropping, the nitrogen of the associated crop may be improved by direct nitrogen transfer from the legume to cereal (Banik et al., 2006). Legumes, with their adaptability to different cropping patterns and their ability to fix nitrogen, may offer opportunities to sustain increased productivity (Jeyabal & Kuppuswamy, 2001). Normally, productivity is potentially enhanced by the inclusion of a legume in a cropping system (Maingi et al., 2001). Legume intercrops are also potential sources of plant nutrients that complement inorganic fertilizers (Banik & Bagchi, 1994; Banik et al., 2006). Li et al., (2001) showed that yield and nutrient uptake by intercropped wheat, maize and soybean were all significantly greater than monocultures of wheat, maize and soybean with the exception of potassium uptake by maize. Intercropping advantages in yield were 40-70% for wheat intercropped with maize and 28-30% for wheat intercropped with soybean.

Many researchers revealed that Leaf area and vertical leaf area profile influence the interception and utilization of solar radiation of corn canopy and consequently,
corn dry matter accumulation and grain yield (Valentinuz & Tollenaar, 2006).

**Soybean Yield**

Both simple and interaction effects of mixing ratios of corn/soybean and weed infestation on soybean grain yield were statistically significant (P<0.001). Results indicated that in all weed infested treatments, soybean monoculture had higher yield than intercropped one (Table 2) mainly due to higher plant density. Similarly in intercropped treatments yield loss could be attributed to inter specific competition. Indeed decrement of soybean ratio in intercropping decreased soybean grain yield because of intensified competition.

Results showed that soybean has less competitive ability than corn in intercropping systems. According to soybean growth nature, it used to allocate part of its resources to symbiosis. Redroot pigweed and jimsonweed infestations caused greatest soybean yield loss in different ratios of intercropping. Simultaneous infestation of AMRET and DASTR have more competitive ability with soybean than one species infestation and caused restricted number of pod per plant, grain number per pod, 1000 grain weigh, and finally caused yield reduction. Banik et al., (2006) confirm that higher grain yield of monocropped wheat and chickpea relative to intercropping treatments may be due to the fewer disturbances in the habitat in homogeneous environment of monocropping systems. The Highest amount of soybean grain yield (5050.0 kg ha$^{-1}$) was produced in P$_3$W$_1$ treatment while the lowest amount (365.67 kg ha$^{-1}$) was observed in P$_2$W$_4$ (Table 2 & Figure 2).

![Figure 2](image)

**Figure 2.** Interaction effect of mixing ratios to weed infestation on soybean yield. (W1): weed free, (W2):infested to redroot pigweed, (W3): infested to jimson weed and (W4): infested to both weed species.

It seems the weed compensated low irradiance by increasing the specific leaf area and partitioning more dry matter initially to stems and later on to leaves which increased the amount of photosynthetically active area in proportion to above – ground biomass, as found when competing with soybean (Regnier et al., 1988).
Conclusion

According to our investigations from corn and soybean grain yield at their monocultures and intercrop, the highest amount of Land Equivalent Ratio (LER) (1.37) was observed in $P_3W_1$, which had the lowest weed leaf area and biomass, consequently suppressing weeds successfully. Occupied different niches in uptake of resources and reduced competition mechanism resulted in advantage for corn and soybean yield. Neighboring of $C_4$ (corn) and $C_3$ (soybean) species in all parts of growth stages not only decreased competition, but also increased facilitative mechanism (Table 1).

It is concluded that intercropping can be used as a tool to improve competitive ability of a canopy with good weed suppressive characteristics. Studies using species with growth forms similar to soybean are therefore needed because since this study suggests that the outcome of intercropping is influenced by the architectural and therefore size response of intercropped species.

Table 1 - Land Equivalent Ratio of corn and soybean intercropping.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>RYc</th>
<th>RYS</th>
<th>LER</th>
</tr>
</thead>
<tbody>
<tr>
<td>$P_2W_1$</td>
<td>1.12</td>
<td>0.221</td>
<td>1.33</td>
</tr>
<tr>
<td>$P_2W_2$</td>
<td>1.029</td>
<td>0.203</td>
<td>1.23</td>
</tr>
<tr>
<td>$P_2W_3$</td>
<td>1.033</td>
<td>0.208</td>
<td>1.24</td>
</tr>
<tr>
<td>$P_2W_4$</td>
<td>0.928</td>
<td>0.192</td>
<td>1.12</td>
</tr>
<tr>
<td>$P_3W_1$</td>
<td>0.865</td>
<td>0.501</td>
<td>1.37</td>
</tr>
<tr>
<td>$P_3W_2$</td>
<td>0.662</td>
<td>0.458</td>
<td>1.12</td>
</tr>
<tr>
<td>$P_3W_3$</td>
<td>0.787</td>
<td>0.387</td>
<td>1.17</td>
</tr>
<tr>
<td>$P_3W_4$</td>
<td>0.775</td>
<td>0.365</td>
<td>1.14</td>
</tr>
<tr>
<td>$P_4W_1$</td>
<td>0.577</td>
<td>0.721</td>
<td>1.30</td>
</tr>
<tr>
<td>$P_4W_2$</td>
<td>0.477</td>
<td>0.712</td>
<td>1.19</td>
</tr>
<tr>
<td>$P_4W_3$</td>
<td>0.522</td>
<td>0.770</td>
<td>1.29</td>
</tr>
<tr>
<td>$P_4W_4$</td>
<td>0.425</td>
<td>0.762</td>
<td>1.19</td>
</tr>
</tbody>
</table>

REFERENCES


چکیده

با توجه به نقش تعیین کننده نرخ انرژی سطح برق در توزیع نور در داخل کانونی، تشکیل گیاهان زراعی و علف‌های هرز، مستلزم مطالعه ساختار کانونی می‌باشد. به منظور بررسی اثر کشت مخلوط بر توزیع سطح برق و ماده خشک گیاهی در برفیل کانونی در سال ۱۳۸۶ در زمین روزه‌ای داشته‌ایم. نتایج این کار نشان داد که در کشت مخلوط سیاه‌پاکی، نسبت اختلاف به رضایت زراعی کاهش یافت.

علف‌های هرز، آزمایش در سال ۱۳۸۶ در مزرعه روزه‌ای داشته‌ایم. نتایج این کار نشان داد که در کشت مخلوط سیاه‌پاکی، نسبت اختلاف به رضایت زراعی کاهش یافت.

گل‌های کانالی: ساختار کانونی، توزیع سطح برق، کشت مخلوط علف و کناره‌اله.
Floristic Composition of Weed Community in Turfgrass Fields of Bajgah, Iran

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ABSTRACT

A weed survey of turfgrass fields was conducted at Bajgah during 2008-2009. The turfgrass fields had been covered with Sport turf. Quantitative measurements viz frequency (F), field uniformity (FU), mean field density (MFD), mean occurrence field density (MOFD) and relative abundance (RA) were recorded. Fourteen species of weeds of 9 families were recorded. Most of them were included in Asteraceae, Fabaceae, Poaceae, and Plantaginaceae. The most important broad leaved and narrow leaved weeds were Taraxacum officinale L. and Cynodon dactylon [L.] Pers., respectively. Results indicated that the highest frequency (F) (100%), field uniformity (FU) (89.28%), mean field density (MFD) (58.43 m⁻²) and mean occurrence field density (MOFD) (58.43 m⁻²) belongs to T. officinale L. of the year 2008. Results were almost the same at year 2009. Taraxacum officinale L. showed the highest relative abundance in both years.

Key words: Lawn, population, survey, Taraxacum officinale L., weeds.

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INTRODUCTION

Turfgrass has been widely used by humans as soil covers for more than ten centuries (Beard, 1994). Lawn and turfgrasses are important for functional, recreational and ornamental uses (Beard, 1998). In turf area, weeds are the major problem, which can be often the result of improper and inappropriate management (Uddin et al., 2009). Weeds compete with turfgrasses for light, soil nutrients, available water and physical space. They are also hosts for pests such as plant pathogens, nematodes and insects. Certain weeds are also irritants to humans as allergic reactions of pollen or chemicals. Turfgrasses have attractive green color, texture, density and uniformity (Emmons, 2000). Turf weeds may be grasses, grass-like plants (rushes or sedges), or broadleaf plants with annual, biennial, and/or perennial life cycles (Bennet, 2004). Therefore, to enrich aesthetic quality of turf, weeds must be eliminated from turfgrass area. However, in any place a plant community is rarely homogenous as to the species and distribution (Kim & Moody, 1980).

Whenever weeds appear in a turfgrass community, proper identification of the weed species is essential before economical and effective management practices (Dernoeden, 1999). Therefore, weed surveys are useful for determining the occurrence and importance of weed species in any production systems as well as turf area (Thomas, 1985; McCully et al., 1991; Frick & Thomas, 1992; McClosky et al., 1998). The objective of this study was to determinate density, frequency, and uniformity of weeds and weed prevailing species in climatic condition of Bajgah, Shiraz. There are many weed species with similar morphology to turfgrass, therefore, it is important to identify the species correctly and decide upon the practical weed control methods.

MATERIALS AND METHODS

A survey study was conducted in turfgrass fields of the Shiraz College of Agriculture, Shiraz University, Iran, located at Bajgah (1810 m above the mean sea level, 52° 32' E and 29° 36' N). Average maximum and minimum temperatures are 38 °C and –9 °C, respectively with the annual rainfall of 400 mm (Salehi & Khosh-Khui, 2004). The turf fields had been covered with sport turf (25% Lolium perenne 'Esquire', 30% Lolium perenne 'Keystone', 10%, Festuca rubra 'Maxima 1', 15% Poa pratensis 'Balin' and 20% P. pratensis 'Sobra'). Seven fields were selected randomly and samplings were performed in 0.5×0.5 m² plots (Figure 1), four samples from each plot. All weeds in each plot were identified, counted and recorded. Data were summarized using five quantitative measurements as outlined by Thomas (1985); frequency (F), field uniformity (FU), density (D), Mean field density (MFD), Mean occurrence field density (MOFD) and relative abundance (RA). Frequency (F) was calculated as the percentage of the total number of fields surveyed in which a species occurred in at least one quadrat.
where \( F_k \) = frequency value for species k
\( Y_i \) = presence (1) or absence (0) of species k in field i
n = number of fields surveyed.

Field uniformity was calculated as the percentage of the total number of quadrates sampled in which a species occurred.

\[
FU_k = \frac{\sum_{i=1}^{n} X_{ij}}{\sum_{i=1}^{n} X_{ij}} \times 100
\]

where \( FU_k \) = field uniformity value for species k
\( X_{ij} \) = presence (1) or absence (0) of species k in quadrate j in field i
n = number of fields surveyed.

The field density (D) of each species in a field which was calculated as:

\[
D_{ki} = \frac{\sum_{i=1}^{n} Z_i}{A_i}
\]

where \( D_{ki} \) = density (in numbers m\(^{-2}\)) value of species k in field i
\( Z_i \) = number of plants of a species in quadrate j (0.25 m\(^2\))
\( A_i \) = area i (m\(^2\)) of 20 quadrates in field i.

Mean field density (MFD):

\[
MFD_k = \frac{\sum_{i=1}^{n} D_{ki}}{n}
\]

where \( MFD_k \) = mean field density of species k
\( D_{ki} \) = density (in numbers m\(^{-2}\)) of species k in field i
n = number of fields surveyed.

Mean occurrence field density (MOFD):

\[
MOFD_k = \frac{\sum_{i=1}^{n} D_{ki}}{n - a}
\]

where \( MOFD_k \) = mean occurrence density of species k
Relative frequency for species k (\(RF_k\)):
\[
RF_k = \frac{\text{Frequency value of species } k}{\text{Sum of frequency values for all species}} \times 100
\]

Relative field uniformity for species k (\(RFU_k\)):
\[
RFU_k = \frac{\text{Field uniformity value of species } k}{\text{Sum of field uniformity values for all species}} \times 100
\]

Relative mean field density for species k (\(RMFD_k\)):
\[
RMFD_k = \frac{\text{Mean field density value of species } k \times 100}{\text{Sum of mean field density values for all species}}
\]

The relative abundance of species k (\(RA_k\)) was calculated as the sum of relative frequency, relative field uniformity and relative mean field density for that species;

\[RA_k = RF_k + RFU_k + RMFD_k\]

Relative abundance is an index that was calculated using a combination of frequency, field uniformity and field density for each species, as described by Thomas (1985).

**RESULTS AND DISCUSSION**

In the present survey on weed communities of turf fields in the College of Agriculture, Shiraz University, 14 weed species from 9 plant families were identified. Most of the weed species were included in the Fabaceae family (Table 1). However, Asteraceae had the most frequency (F), uniformity (UF), mean field density (MFD) and mean occurrence density (MFOD) (Tables 1, 2, 3). In our study, 21.42% of observed weeds were classified as annuals, and 78.57% as perennials (Table 1).
Table 1. Distribution of observed weed species based on family and life cycle.

<table>
<thead>
<tr>
<th>Family</th>
<th>Scientific name</th>
<th>Common name</th>
<th>Life cycle</th>
</tr>
</thead>
<tbody>
<tr>
<td>Poaceae</td>
<td><em>Cynodon dactylon</em> [L.] Pers.</td>
<td>Common bermudagrass</td>
<td>Perennial</td>
</tr>
<tr>
<td></td>
<td><em>Lactuca scariola</em> L.</td>
<td>Prickly weld lettuce</td>
<td>Annual</td>
</tr>
<tr>
<td></td>
<td><em>Taraxacum officinale</em> L.</td>
<td>Common dandelion</td>
<td>Perennial</td>
</tr>
<tr>
<td></td>
<td><em>Medicago sativa</em> L.</td>
<td>Alfalfa</td>
<td>Perennial</td>
</tr>
<tr>
<td>Asteraceae</td>
<td><em>Medicago lupulina</em> L.</td>
<td>Black medic</td>
<td>Annual/Perennial</td>
</tr>
<tr>
<td></td>
<td><em>Trifolium repens</em> L.</td>
<td>Red clover</td>
<td>Perennial</td>
</tr>
<tr>
<td>Fabaceae</td>
<td><em>Malva neglecta</em> Wallroth</td>
<td>Common mallow</td>
<td>Biennial/Perennial</td>
</tr>
<tr>
<td></td>
<td><em>Plantago lanceolata</em> L.</td>
<td>Buckhorn plantain</td>
<td>perennial</td>
</tr>
<tr>
<td>Plantaginaceae</td>
<td><em>Plantago major</em> L.</td>
<td>Common plantain</td>
<td>Herbaceous</td>
</tr>
<tr>
<td>Chenopodiaceae</td>
<td><em>Chenopodium album</em> L.</td>
<td>Common lambsquater</td>
<td>Annual</td>
</tr>
<tr>
<td>Convolvulaceae</td>
<td><em>Dichondra repens</em> L.</td>
<td>Kidney grass</td>
<td>Perennial</td>
</tr>
<tr>
<td></td>
<td><em>Convolvulus arvensis</em> L.</td>
<td>Field bin weed</td>
<td>Perennial</td>
</tr>
<tr>
<td>Rubiaceae</td>
<td><em>Galium aparine</em> L.</td>
<td>Cleavers</td>
<td>Herbaceous annual</td>
</tr>
<tr>
<td>Ulmaceae</td>
<td><em>Ulmus minor</em> Mill.</td>
<td>Elm</td>
<td>Perennial</td>
</tr>
</tbody>
</table>

In both years, the highest frequency belonged to *Taraxacum officinale* from the Asteraceae family (Tables 2 & 3). *T. officinale* is clearly the most important and abundant weed in turfgrass fields, known as a perennial plant that has deep roots if propagated via seeds. *T. officinale* seeds disperse by wind. The growth of weed species in different areas is influenced by several factors. For example, Xing et al., (2000) reported 74 weed species belonging to 24 families in turfgrass lands in Hangzhou, China. In a floristic survey in Brazil on *Paspalum notatum* Flugge cultures under sun light and shadow of tree canopy, 45 weed species belonging to 15 families were observed, among which Asteraceae, Poaceae, Cyperaceae, Euphorbiaceae and Fabaceae had the major species (Maciel et al., 2008). However, in our investigated fields the most weed species belonged to Fabaceae, Asteraceae, Convolvulaceae and Plantaginaceae. In the present survey number of perennial weed species was higher than annual weeds. Similarly, Al-Gohary (2008) reported that perennial weeds were more than annual weeds in eleven lands of Gebel Elba districts in Egypt.
Table 2- Frequency (F), field uniformity (FU), mean field density (MFD), and mean occurrence field density (MOFD) of weeds in turfgrass fields in the first year.

<table>
<thead>
<tr>
<th>Scientific name</th>
<th>F (%)</th>
<th>FU (%)</th>
<th>MFD (m$^{-2}$)</th>
<th>MOFD (m$^{-2}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Taraxacum officinale</em> L.</td>
<td>100.00</td>
<td>89.28</td>
<td>58.43</td>
<td>58.43</td>
</tr>
<tr>
<td><em>Medicago sativa</em> L.</td>
<td>71.43</td>
<td>35.71</td>
<td>6.71</td>
<td>11.75</td>
</tr>
<tr>
<td><em>Medicago lupulina</em> L.</td>
<td>57.14</td>
<td>28.57</td>
<td>8.428</td>
<td>14.75</td>
</tr>
<tr>
<td><em>Ulmus minor</em> Mill.</td>
<td>42.86</td>
<td>17.86</td>
<td>3.14</td>
<td>7.33</td>
</tr>
<tr>
<td><em>Trifolium repens</em> L.</td>
<td>71.43</td>
<td>28.57</td>
<td>13.85</td>
<td>22.00</td>
</tr>
<tr>
<td><em>Malva neglecta</em> Wallroth</td>
<td>14.28</td>
<td>3.57</td>
<td>0.14</td>
<td>1.00</td>
</tr>
<tr>
<td><em>Plantago lanceolata</em> L.</td>
<td>57.14</td>
<td>25.00</td>
<td>1.71</td>
<td>2.40</td>
</tr>
<tr>
<td><em>Plantago major</em> L.</td>
<td>71.43</td>
<td>35.71</td>
<td>1.71</td>
<td>2.40</td>
</tr>
<tr>
<td><em>Chenopodium album</em> L.</td>
<td>14.28</td>
<td>3.57</td>
<td>0.14</td>
<td>1.00</td>
</tr>
<tr>
<td><em>Lactuca scariola</em> L.</td>
<td>14.28</td>
<td>3.57</td>
<td>0.43</td>
<td>3.00</td>
</tr>
<tr>
<td><em>Dichondra repens</em> L.</td>
<td>28.57</td>
<td>10.71</td>
<td>8.00</td>
<td>28.00</td>
</tr>
<tr>
<td><em>Convolvulus arvensis</em> L.</td>
<td>28.57</td>
<td>7.14</td>
<td>0.71</td>
<td>2.50</td>
</tr>
<tr>
<td><em>Galium aparine</em> L.</td>
<td>28.57</td>
<td>10.71</td>
<td>2.43</td>
<td>8.50</td>
</tr>
<tr>
<td><em>Cynodon dactylon</em> [L.] Pers.</td>
<td>71.43</td>
<td>35.71</td>
<td>18.14</td>
<td>25.40</td>
</tr>
</tbody>
</table>

Uniformity is a quantitative measure of the spread of a weed species within a given field. For example, *T. officinale*, *Medicago sativa*, *Plantago major*, *Cynodon dactylon*, *M. lupulina*, *Trifolium repens*, and *P. lanceolata* were uniformly distributed throughout the fields (Table 2). In the first year, *T. officinale* was the most abundant weed with a density of 58.43 plants m$^{-2}$. In the second year, *T. officinale* and *T. repens* were the most abundant weeds with 86.8 and 54.86 plants m$^{-2}$, respectively.

Results of the experiment is similar to the report by Ghorsi-Anbaran et al., (2006) who observed that the highest frequency belonged to Asteraceae in grasslands of Mashhad.

Table 3. Frequency (F), field uniformity (FU), field density (MFD), and mean occurrence field density (MOFD) of weeds in turfgrass fields in the second year.

<table>
<thead>
<tr>
<th>Scientific name</th>
<th>F (%)</th>
<th>FU (%)</th>
<th>MFD (m$^{-2}$)</th>
<th>MOFD (m$^{-2}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Taraxacum officinale</em> L.</td>
<td>100.00</td>
<td>82.14</td>
<td>86.86</td>
<td>80.57</td>
</tr>
<tr>
<td><em>Medicago sativa</em> L.</td>
<td>57.14</td>
<td>42.86</td>
<td>17.57</td>
<td>30.75</td>
</tr>
<tr>
<td><em>Medicago lupulina</em> L.</td>
<td>85.71</td>
<td>42.86</td>
<td>6.57</td>
<td>11.50</td>
</tr>
<tr>
<td><em>Ulmus minor</em> (Mill.)</td>
<td>57.14</td>
<td>28.57</td>
<td>6.14</td>
<td>10.75</td>
</tr>
<tr>
<td><em>Trifolium repens</em> L.</td>
<td>71.43</td>
<td>42.86</td>
<td>54.86</td>
<td>76.80</td>
</tr>
<tr>
<td><em>Malva neglecta</em> Wallroth</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><em>Plantago lanceolata</em> L.</td>
<td>57.14</td>
<td>14.28</td>
<td>0.71</td>
<td>1.25</td>
</tr>
<tr>
<td><em>plantago major</em> L.</td>
<td>57.14</td>
<td>35.71</td>
<td>1.71</td>
<td>3.00</td>
</tr>
<tr>
<td><em>Chenopodium album</em> L.</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><em>Lactuca scariola</em> L.</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><em>Dichondra repens</em> L.</td>
<td>28.57</td>
<td>7.14</td>
<td>5.00</td>
<td>17.50</td>
</tr>
<tr>
<td><em>Convolvulus arvensis</em> L.</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><em>Galium aparine</em> L.</td>
<td>28.57</td>
<td>14.28</td>
<td>4.71</td>
<td>16.50</td>
</tr>
<tr>
<td><em>Cynodon dactylon</em> [L.] Pers.</td>
<td>71.43</td>
<td>39.28</td>
<td>19.43</td>
<td>27.20</td>
</tr>
</tbody>
</table>
Younesabadi et al., (2006) observed that Poaceae, Brassicaceae and Fabaceae had the highest Relative abundance (RA) in Golestan province and showed that 82% of the observed weeds were annual and the remaining were perennial. Furthermore, 87% of weeds were dicotyledonous and 13% were monocotyledonous. *Phalaris minor* Retz., *Melilitus officinalis* (L.) Lam., *Avena ludoviciana* Durieu., *Veronica persica* Poir., *Brassica* sp., *Polygonum aviculare* L. and *Sinapis arvensis* L. had the highest abundance in Golestan province. In our study, the highest RA belonged to weed species including: *T. officinale*, *C. dactylon*, *M. lupulina*, *T. repens*, and *M. sativa*. The RA values for these weed species were 99.39, 41.17, 39.31, 35.01, and 26.72, respectively (Table 2). The RA values of *T. officinale* were the highest in both years reflecting its respective highest values of frequency (F), field uniformity (FU) and mean field density (MFD) (Tables 2, 3, 4, 5).

**Table 4.** Relative abundance (RA) of weeds that occurred in seven fields in the first year.

<table>
<thead>
<tr>
<th>Scientific name</th>
<th>RA</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Taraxacum officinale</em> L.</td>
<td>99.39</td>
</tr>
<tr>
<td><em>Medicago sativa</em> L.</td>
<td>26.72</td>
</tr>
<tr>
<td><em>Medicago lupulina</em> L.</td>
<td>39.31</td>
</tr>
<tr>
<td><em>Ulmus minor</em> Mill.</td>
<td>16.94</td>
</tr>
<tr>
<td><em>Trifolium repens</em> L.</td>
<td>35.01</td>
</tr>
<tr>
<td><em>Malva neglecta</em> Wallroth</td>
<td>4.03</td>
</tr>
<tr>
<td><em>Plantago lanceolata</em> L.</td>
<td>20.46</td>
</tr>
<tr>
<td><em>Plantago major</em> L.</td>
<td>12.77</td>
</tr>
<tr>
<td><em>Chenopodium album</em> L.</td>
<td>4.03</td>
</tr>
<tr>
<td><em>Lactuca scariola</em> L.</td>
<td>4.27</td>
</tr>
<tr>
<td><em>Convolvulus arvensis</em> L.</td>
<td>8.42</td>
</tr>
<tr>
<td><em>Galium aparine</em> L.</td>
<td>11.14</td>
</tr>
<tr>
<td><em>Cynodon dactylon</em> [L.] Pers.</td>
<td>41.17</td>
</tr>
</tbody>
</table>

**Table 5.** Relative abundance (RA) of weeds that occurred in seven fields in the second year.

<table>
<thead>
<tr>
<th>Scientific name</th>
<th>RA</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Taraxacum officinale</em> L.</td>
<td>82.41</td>
</tr>
<tr>
<td><em>Medicago sativa</em> L.</td>
<td>30.18</td>
</tr>
<tr>
<td><em>Medicago lupulina</em> L.</td>
<td>29.43</td>
</tr>
<tr>
<td><em>Ulmus minor</em> Mill.</td>
<td>20.48</td>
</tr>
<tr>
<td><em>Trifolium repens</em> L.</td>
<td>50.82</td>
</tr>
<tr>
<td><em>Malva neglecta</em> Wallroth</td>
<td>-</td>
</tr>
<tr>
<td><em>Plantago lanceolata</em> L.</td>
<td>20.35</td>
</tr>
<tr>
<td><em>Plantago major</em> L.</td>
<td>20.35</td>
</tr>
<tr>
<td><em>Chenopodium album</em> L.</td>
<td>-</td>
</tr>
<tr>
<td><em>Lactuca scariola</em> L.</td>
<td>-</td>
</tr>
<tr>
<td><em>Dichondra repens</em> L.</td>
<td>9.15</td>
</tr>
<tr>
<td><em>Convolvulus arvensis</em> L.</td>
<td>-</td>
</tr>
<tr>
<td><em>Galium aparine</em> L.</td>
<td>11.05</td>
</tr>
<tr>
<td><em>Cynodon dactylon</em> [L.] Pers.</td>
<td>32.39</td>
</tr>
</tbody>
</table>
Uddin et al., (2009) stated that *Cyperus aromaticus* (Ridley) Mattf & Kuk and *Fimbristylis dichotoma* (L.) Vahl are the most important two sedges in turfgrass areas. Two grass *Ischaemum indicum* (Houtt.) Merr., *Chrysopogon aciculatus* (Retz.) Trin. and two broadleaves *Desmodium triflorum* (L.) DC. and *Borreria repens* DC. were equally important and abundant species containing frequency ≥50% and RA value ≥12.

Diversity of weed species depended on different factors such as soil structure, pH, nutrients and water, crop type, weed control methods and field history especially in local geographical variation (Kim et al., 1983). Furthermore, diversity of weed communities will determine the nature of weed management strategies required and changes in diversity may be indicative of potential weed management problems (Derksen et al., 1995).

Relative abundance provides an indication of the overall weed problem posed by an species (Uddin et al., 2009). Overall, the weed species of turf are those that are adapted in some way to the continuous defoliation experienced in a turf field and well-adequate in that environment. However, the ranking of weed species differed in the lists based on frequency (F), field uniformity (FU) and mean field density (MFD) but, within the weed type (Uddin et al., 2009).

Generally, *T. officinale* belonging to the Asteraceae family was the most abundant weed in turfgrass fields followed by *T. repens*, *M. sativa*, *M. lupulina* and *C. dactylon*. This information would be important for further studies in the same fields and for the best integrated pest management (IPM) programs.

**REFERENCES**


چکیده

بررسی از علف‌های هرز زمین‌های چمن در دانشکده کشاورزی، دانشگاه شیراز در پنج سال متوالی 1387-1388 انجام شد. در زمین‌های چمن با چمن اسپورت پویش یافته، تندیس گیری از هرز زمین صورت گرفت. اندکه در میان تراکم‌های علف‌های هرز زمین‌های میانگین (F), گونه‌های میانگین تراکم زمین (MOFD) و فراوانی نسبی (RA) ترتیب شدند. نتایج نشان داد که بیشترین فراوانی (F) (100%) در میانگین تراکم زمین (MOFD) (1388/23 میلی‌متر) برابر با 76.28 درصدی علف‌های هرز به دست آمد. در نتیجه، نتایج نشان داد که کاهش شدید در میان تراکم علف‌های هرز زمین‌های چمن با چمن اسپورت پویش یافته در پنج سال متوالی 1387-1388 باعث کاهش گسترده‌ای در تراکم علف‌های هرز زمین‌های چمن با چمن اسپورت پویش یافته می‌شود.

کلمات کلیدی: چمن، چمن‌پروری، علف‌های هرز
Ability of Adjuvants in Enhancing the Performance of Pinoxaden and Clodinafop Propargyl Herbicides against Grass Weeds

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ABSTRACT

Adjuvants' ability in enhancing the performance of herbicides is a major priority in adjuvant research. To identify an appropriate adjuvant for pinoxaden and clodinafop propargyl herbicides against littleseed canarygrass (Phalaris minor Retz.), common wild oat (Avena fatua L.) and ryegrass (Lolium temulentum L.), three separate experiments were conducted under greenhouse conditions. In all experiments treatments consisted of five doses of pinoxaden and two doses of each of the three commercial formulations of clodinafop propargyl (Topik, Behpik & Karent), with and without the adjuvants Adigor, Citogate, Citohef and Volk. Performance of all herbicides increased with enhancing their concentrations against the tested plants except for clodinafop propargyl in case of wild oat. The addition of Volk (followed by Adigor) had the highest effect on pinoxaden efficacy against ryegrass and littleseed canarygrass, supporting the idea that either Volk or Adigor solubilizes the cuticular waxes thus facilitating their uptake. Adding Volk and Adigor had the highest and lowest influence on pinoxaden performance against wild oat, respectively. Totally, the adjuvant receptivity for pinoxaden was higher than for clodinafop propargyl. Between the two surfactants, Citogate was more effective than Citohef in enhancing the efficacy of pinoxaden against ryegrass and littleseed canarygrass, while, Citohef was more effective in increasing the efficacy of pinoxaden against wild oat.

Key words: adjuvant, clodinafop propargyl, littleseed canarygrass, pinoxaden, ryegrass, wild oat.

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INTRODUCTION

Winter wheat is one of the most important cereals in Iran. Annual grasses such as ryegrass, littleseed canarygrass, and wild oat reduce yield through competing for resources such as water, nutrient and light (Baghestani et al., 2007). The acetyl coenzyme-A carboxylase (ACCase) inhibiting herbicides, are the most effective and widespread method to control the above-mentioned weeds in Iran (Baghestani et al., 2008) which might result in evolution of resistance in grasses due to high selective pressure imposed by this group of herbicides (Devine & Shimabukuro, 1994). Moreover, environmental side-effects due to high usage of the ACCase inhibitors are probable (Rashed-Mohassel et al., 2010). A solution to the above-mentioned negative impacts of continuous application of ACCase herbicides is to use adjuvants and/or surfactants. These chemical compounds decrease the application dose of herbicides (Sharma & Singh, 2000). Adjuvants (e.g. methylated seed oils (Sharma & Singh, 2000) and surfactants (Rashed-Mohassel et al., 2009)) can reduce the surface tension of spray solution; thereby increase the chance of spray droplets to sit on the plant surface. Moreover, they can increase the droplets spread on leaf surface and enhance the foliar activity of post-emergence herbicides (Rashed-Mohassel et al., 2009) due to an increase in the infiltration rate of the active ingredient into the cuticular waxes. There are many factors that affect the suitability of an adjuvant (Green & Foy, 2000; Zolinger, 2000). Based on their type, adjuvant can directly/indirectly affect the formulations efficacy-related factors including atomization, deposition, retention, absorption and translocation (Zabkiewicz, 2000). Many researchers have stated that adjuvant performance depends on the interaction among herbicide, adjuvant and plant surface characteristics (Bunting et al., 2004a;Rashed-Mohassel et al., 2010).

The objective of the present research was to test and determine the ability of four different adjuvants in increasing the performance of pinoxaden and clodinafop propargyl against ryegrass, little seed canarygrass, and wild oat.

MATERIALS AND METHODS

Plant Materials

The seeds of ryegrass, little seed canarygrass, and wild oat were obtained from The Department of Weed Research at Iranian Plant Protection Research Institute, Tehran. The seeds were placed in Petri dishes in an incubator at alternating temperatures of 20/15°C and relative humidity of 45/65% under 16/8 hour light and dark cycle. After germination, six seedlings with uniform radical length (8-10 mm) were selected and planted 1 cm deep in 1.5 L plastic pots that were filled with a mixture of soil, peat, vermiculate, and sand (3:2:2:2 v/v/v/v). The pots were placed and kept in a greenhouse with a light/dark period of 16/8 hour at 25/15°C. A lamp was used to supply additional light and extend the day length. The plants were irrigated every three days and thinned to four per pot at one-leaf stage.
Chemicals, Treatments and Measurements

Separate experiments were established for each weed species in a completely randomized design with a factorial arrangement of treatments and six replications. Factor A was different herbicides including Pinoxaden EC 10% at 30, 40, 50, 60 and 70 g a.i. ha\(^{-1}\), and three commercial formulations of clodinafop propargyl EC 8% including Topik, Behpik and Karent, each at 48 and 64 g a.i. ha\(^{-1}\) applied against ryegrass, littleseed canarygrass, and wild oat. Factor B was using and not-using herbicides with the following adjuvants: (i) Adigor (a methylated seed oil, 44.8 % methylated rapeseed oil and 28.2 % ethoxylated alcohols, Syngenta, Switzerland); (ii) Citogate (a non-ionic surfactant, 100% alkylarylpolyglycol ether, Zarnegaran Pars Company, Karaj, Iran); (iii) Citohef (a non-ionic surfactant, 100% alkylarylpolyglycol ether, Hef Chemicals Company, Semnan, Iran); and (iv) Volk (petroleum oils, 80% EC, 800 g a.i. L\(^{-1}\) petroleum oils, associated with 200 g a.i. L\(^{-1}\) emulsifier, Melli Agrochemical Company, Alborz Industrial City, Ghazvin, Iran). All adjuvants were applied at 2 % (v/v). Herbicides were sprayed at three- to four-leaves stage by using a sprayer equipped with a Flat-fan nozzle, delivering 300 L spray solution ha\(^{-1}\) at 250 kPa. Thirty days after spraying, the number of survived plants per pot was recorded and the fresh and dry (dried at 70°C for 48 hours) above-ground biomass in each pot were measured. In addition, two days prior to harvest, assessment of visual weed control was conducted according to European Weed Research Council (EWRC) scoring on a scale of 1 to 9 representing 100%, 99-98%, 97-95%, 94-90%, 89-82%, 81-70%, 69-55%, 54-30% and 29-0.00% injury, respectively (Sandral et al., 1997). The data was subjected to analysis of variance using the GLM procedure in SAS (SAS Institute Inc., 2000). A physical slicing was performed due to significant interaction between experimental factors. Mean comparisons were performed using Duncan Multiple Range Test (DMRT) set at 0.05.

RESULTS AND DISCUSSION

Experiment 1: Ryegrass

Results (Tables 1 to 4) showed that all commercial formulations of clodinafop propargyl had greater effects on reducing the fresh (Table 1) and dry (Table 2) weights of ryegrass when applied without adjuvants compared with those of pinoxaden. In contrast, the addition of the adjuvants increased the foliar activity of pinoxaden more than that of clodinafop propargyl formulations \((P < 0.05)\). This indicated that adjuvant receptivity for pinoxaden was higher than that for clodinafop propargyl. The addition of Volk and Citohef had the highest and the lowest effects on performance of pinoxaden, respectively. It is possible to rank the tested adjuvants as Volk > Adigor > Citogate > Citohef in their decreasing ability to enhance the efficacy of pinoxaden. Petroleum oils such as Volk and methylated seed oils such as Adigor probably disrupt and solubilize cuticular waxes (Zabkiewicz, 2000) and
consequently, facilitate the penetration of the active ingredient (McMullan & Chow, 1993). The benefits of using these oils (e.g. Volk & Adigor) rather than surfactants (e.g. Citogate & Citohef) in enhancing the foliage activity of herbicides have been well documented in other studies (Bunting et al., 2004a; Ramsdale & Messersmith, 2002; Bunting et al., 2004b; Rashed-Mohassel et al. 2010). Sharma and Singh (2000) reported that an increase in the penetration of the active ingredient through softening or disrupting the cuticular waxes is a more effective factor than decreasing the surface tension of spray droplets in improving the foliar activity of glyphosate on *Bidens frondosa* and *Panicum maximum*. Therefore, the foliar activity of the pinoxaden might be increased due to the ability of either Volk or Adigor to soften or disrupt the cuticular waxes. Unlike pinoxaden, the addition of the adjuvants to clodinafop propargyl formulations did not significantly affect their performance. Nonetheless, Volk had the highest influence on improving the foliar activity of clodinafop propargyl formulations. Citohef application led to an insignificant antagonistic effect on the foliar activity of clodinafop propargyl formulations resulting in a decrease in performance of all formulations of this herbicide. The mortality of ryegrass plants was improved with an increase in concentration of pinoxaden especially when applied with adjuvants (Table 4). The mortality of ryegrass plants did not change in none of clodinafop propargyl formulations when applied with Adigor, Citohef, and Volk. However, Citohef led to a significant increase in survival of ryegrass plants (Table 3).

**Experiment 2: Little Seed Canarygrass**

Results (Tables 5-8) indicated that the foliar activity of herbicides was improved with increasing the concentration of pinoxaden. Pinoxaden at high concentrations (> 50 g a.i ha\(^{-1}\)) caused complete weed control (Table 8) and showed greater efficacy than all clodinafop propargyl formulations when used without adjuvants. The performance of pinoxaden was enhanced significantly \(P < 0.05\) when adjuvants were added. Adigor and Volk had the highest effect while Citogate and Citohef showed the lowest effect on pinoxaden performance. The addition of adjuvants to pinoxaden at 40 g a.i. ha\(^{-1}\) led to complete littleseed canarygrass control (Table 8). All adjuvants increased performance of clodinafop propargyl formulations against this weed. The application of adjuvants did not have any positive effect on formulations Behpik and Karent. In case of Topik formulation, however, Citogate and Citohef had the highest, and Adigor and Volk had the lowest effects on performance of this herbicide. Therefore, these results emphasize the dependency of adjuvant performance on herbicide properties and plant species as previous studies also stated (Johnson et al., 2002; Rashed-Mohassel et al., 2010). The data from this experiment showed that the number of surviving littleseed canarygrass plants increased when the adjuvants were added to clodinafop propargyl formulations (Table 7). However, all adjuvant-added clodinafop propargyl formulations showed
superior performance in reducing the fresh and dry weight of little seed canarygrass (Table 5 & 6). According to the EWRC index, all clodinafop propargyl formulations acted weaker than pinoxaden either with (> 30 g a.i. L⁻¹) or without (> 40 g a.i. L⁻¹) the adjuvants (Table 8). This indicates that the adjuvants are likely to improve the penetrability of the active ingredient (Johnson et al., 2002) which provides an opportunity to reduce herbicide application dose (Zabkiewicz, 2000).

**Experiment 3: Wild Oat**

Increasing pinoxaden concentration up to 60 g a.i. ha⁻¹ enhanced its weed control efficacy (Table 12). This herbicide controlled weeds completely at higher does. All adjuvant enhanced the efficacy of pinoxaden in decreasing the fresh (Table 9) and dry (Table 10) weights of wild oat. Volk was the most effective adjuvant as its addition to pinoxaden at 30 g a.i. ha⁻¹ led to complete control of wild oat, while higher herbicide dose was needed for other adjuvants to achieve complete weed control. It was clearly indicated that pinoxaden has a vigorous receptivity for adjuvant which might be related to weaker penetration of pinoxaden into wild oat leaf when applied without adjuvant. This can be a reason for why pinoxaden is being sold with a particular adjuvant (Adigor). However, the results from the present experiment indicated that the addition of Adigor had the lowest influence on pinoxaden performance among adjuvants. Generally, the adjuvants could be ranked as Volk being the most effective adjuvant followed by Citohef, Citogate, and Adigor. Based on the available literature (Singh & Mack, 1993; Kocher & Kocur, 1993), it seems that the tested adjuvants led to more cuticular penetration and stomata infiltration and subsequently, allowed better pinoxaden absorption and translocation. The efficacy of clodinafop propargyl formulations did not change significantly by increase in their concentration and all treatments resulted in complete control of wild oat (Table 12). Rashed-Mohassel et al., (2009) reported similar result that the Topik formulation of clodinafop propargyl at 48 and 64 g a.i. ha⁻¹ showed no significant difference in wild oat (Avena fatua L.) control ability. This finding can be related to high sensitivity of wild oat plant to clodinafop propargyl and/or high efficacy of this herbicide in controlling wild oat. Moreover, the addition of the adjuvants did not have any positive effect on efficacy of the three formulations of clodinafop propargyl against wild oat (Table 12).

Overall, our study showed that although Citogate and Citohef chemical characteristics and formulations are similar (non-ionic surfactants, 100% alkylarylpolyglycol ether) but they differ in their performance. In experiments 1 and 2, Citogate was more an effective adjuvant in enhancing the efficacy of pinoxaden against ryegrass and littleseed canarygrass, while in experiment 3, Citohef acted better in increasing the efficacy of pinoxaden against wild oat. These results indicated that the differences in leaf surface micromorphology can affect the efficacy of an adjuvant as previously shown in other studies (Collins & Helling, 2002; Sanyal et
Table 1. Effects of pinoxaden and three commercial formulations of clodinafop propargyl applied with and without adjuvants* on ryegrass fresh weight.

<table>
<thead>
<tr>
<th>Herbicides</th>
<th>Rate g a.i. ha(^{-1})</th>
<th>Fresh weight (g)</th>
<th>No adjuvant</th>
<th>Adigor</th>
<th>Citogate</th>
<th>Citohef</th>
<th>Volk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pinoxaden</td>
<td>30</td>
<td>2.22 a**</td>
<td>0.63 a</td>
<td>0.71 ab</td>
<td>1.19 a</td>
<td>0.29 bcd</td>
<td></td>
</tr>
<tr>
<td>Pinoxaden</td>
<td>40</td>
<td>2.19 a</td>
<td>0.34 cd</td>
<td>0.69 ab</td>
<td>0.46 cd</td>
<td>0.00 e</td>
<td></td>
</tr>
<tr>
<td>Pinoxaden</td>
<td>50</td>
<td>1.34 b</td>
<td>0.00 e</td>
<td>0.13 cd</td>
<td>0.42 cd</td>
<td>0.00 e</td>
<td></td>
</tr>
<tr>
<td>Pinoxaden</td>
<td>60</td>
<td>1.24 b</td>
<td>0.00 e</td>
<td>0.00 d</td>
<td>0.00 e</td>
<td>0.00 e</td>
<td></td>
</tr>
<tr>
<td>Pinoxaden</td>
<td>70</td>
<td>0.00 d</td>
<td>0.00 e</td>
<td>0.00 d</td>
<td>0.00 e</td>
<td>0.00 e</td>
<td></td>
</tr>
<tr>
<td>Clodinafop propargyl</td>
<td>48</td>
<td>0.46 dc</td>
<td>0.52 ab</td>
<td>0.87 a</td>
<td>0.97 ab</td>
<td>0.55 bc</td>
<td></td>
</tr>
<tr>
<td>Clodinafop propargyl</td>
<td>64</td>
<td>0.41 d</td>
<td>0.20 d</td>
<td>0.00 d</td>
<td>0.88 ab</td>
<td>0.59 bc</td>
<td></td>
</tr>
<tr>
<td>Clodinafop propargyl</td>
<td>48</td>
<td>0.81 bc</td>
<td>0.43 cb</td>
<td>0.40 bc</td>
<td>0.76 bc</td>
<td>0.59 b</td>
<td></td>
</tr>
<tr>
<td>Clodinafop propargyl</td>
<td>64</td>
<td>0.26 cd</td>
<td>0.29 d</td>
<td>0.23 cd</td>
<td>0.18 de</td>
<td>0.65 a</td>
<td></td>
</tr>
<tr>
<td>Clodinafop propargyl</td>
<td>48</td>
<td>0.58 bdc</td>
<td>0.46 b</td>
<td>0.68 ab</td>
<td>0.41 cd</td>
<td>0.25 cde</td>
<td></td>
</tr>
<tr>
<td>Clodinafop propargyl</td>
<td>64</td>
<td>0.62 bdc</td>
<td>0.21 d</td>
<td>0.28 cd</td>
<td>0.79 bc</td>
<td>0.16 ed</td>
<td></td>
</tr>
</tbody>
</table>

* All adjuvants were added at 0.2 % (v/v).
** Treatment means within a column followed by the same letter are not significantly different (\(P < 0.05\)) according to Duncan’s Multiple Range test.

Table 2. Effects of pinoxaden or three commercial formulations of clodinafop propargyl applied with and without adjuvants* on ryegrass dry weight.

<table>
<thead>
<tr>
<th>Herbicides</th>
<th>Rate g a.i. ha(^{-1})</th>
<th>Dry weight (g)</th>
<th>No adjuvant</th>
<th>Adigor</th>
<th>Citogate</th>
<th>Citohef</th>
<th>Volk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pinoxaden</td>
<td>30</td>
<td>0.27 cb**</td>
<td>0.12 a</td>
<td>0.11 b</td>
<td>0.17 a</td>
<td>0.05 a</td>
<td></td>
</tr>
<tr>
<td>Pinoxaden</td>
<td>40</td>
<td>0.22 cd</td>
<td>0.03 d</td>
<td>0.09 a</td>
<td>0.06 de</td>
<td>0.00 c</td>
<td></td>
</tr>
<tr>
<td>Pinoxaden</td>
<td>50</td>
<td>0.16 b</td>
<td>0.00 e</td>
<td>0.02 cd</td>
<td>0.04 ef</td>
<td>0.00 c</td>
<td></td>
</tr>
<tr>
<td>Pinoxaden</td>
<td>60</td>
<td>0.02 cd</td>
<td>0.00 e</td>
<td>0.00 d</td>
<td>0.00 g</td>
<td>0.00 c</td>
<td></td>
</tr>
<tr>
<td>Pinoxaden</td>
<td>70</td>
<td>0.00 f</td>
<td>0.00 e</td>
<td>0.00 d</td>
<td>0.00 g</td>
<td>0.00 c</td>
<td></td>
</tr>
<tr>
<td>Clodinafop propargyl (Topik)</td>
<td>48</td>
<td>0.06 ef</td>
<td>0.08 bc</td>
<td>0.06 bc</td>
<td>0.14 bc</td>
<td>0.06 a</td>
<td></td>
</tr>
<tr>
<td>Clodinafop propargyl (Topik)</td>
<td>64</td>
<td>0.05 ef</td>
<td>0.05 bc</td>
<td>0.00 d</td>
<td>0.12 ab</td>
<td>0.04 b</td>
<td></td>
</tr>
<tr>
<td>Clodinafop propargyl (Behpik)</td>
<td>48</td>
<td>0.08 de</td>
<td>0.04 c</td>
<td>0.06 bc</td>
<td>0.10 ab</td>
<td>0.04 a</td>
<td></td>
</tr>
<tr>
<td>Clodinafop propargyl (Behpik)</td>
<td>64</td>
<td>0.05 ef</td>
<td>0.09 bc</td>
<td>0.03 cd</td>
<td>0.02 gf</td>
<td>0.01 a</td>
<td></td>
</tr>
<tr>
<td>Clodinafop propargyl (Karent)</td>
<td>48</td>
<td>0.07 ef</td>
<td>0.03 c</td>
<td>0.07 b</td>
<td>0.05 c</td>
<td>0.05 b</td>
<td></td>
</tr>
<tr>
<td>Clodinafop propargyl (Karent)</td>
<td>64</td>
<td>0.90 a</td>
<td>0.03 bc</td>
<td>0.04 cd</td>
<td>0.11 d</td>
<td>0.04 b</td>
<td></td>
</tr>
</tbody>
</table>

* All adjuvant were added at 0.2 % (v/v).
** Treatment means within a column followed by the same letter are not significantly different (\(P < 0.05\)) according to Duncan’s Multiple Range test.
Table 3. The number of the survived plants of ryegrass after spraying with pinoxaden and three commercial formulations of clodinafop propargyl applied with and without adjuvants*.

<table>
<thead>
<tr>
<th>Herbicides</th>
<th>Rate g a.i. ha(^{-1})</th>
<th>No adjuvant</th>
<th>Adigor</th>
<th>Citogate</th>
<th>Citohef</th>
<th>Volk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pinoxaden</td>
<td>30</td>
<td>3.75 a**</td>
<td>2.00 a</td>
<td>2.00 a</td>
<td>2.50 a</td>
<td>1.00 b</td>
</tr>
<tr>
<td>Pinoxaden</td>
<td>40</td>
<td>3.25 a</td>
<td>1.00 b</td>
<td>1.50 ab</td>
<td>1.00 c</td>
<td>0.00 c</td>
</tr>
<tr>
<td>Pinoxaden</td>
<td>50</td>
<td>2.00 b</td>
<td>0.00 c</td>
<td>1.00 c</td>
<td>1.00 c</td>
<td>0.00 c</td>
</tr>
<tr>
<td>Pinoxaden</td>
<td>60</td>
<td>1.75 bc</td>
<td>0.00 c</td>
<td>0.00 d</td>
<td>0.00 d</td>
<td>0.00 c</td>
</tr>
<tr>
<td>Pinoxaden</td>
<td>70</td>
<td>0.00 d</td>
<td>0.00 c</td>
<td>0.00 d</td>
<td>0.00 d</td>
<td>0.00 c</td>
</tr>
<tr>
<td>Clodinafop propargyl (Topik)</td>
<td>48</td>
<td>1.00 c</td>
<td>1.00 b</td>
<td>1.50 abc</td>
<td>1.00 c</td>
<td>1.00 b</td>
</tr>
<tr>
<td>Clodinafop propargyl (Topik)</td>
<td>64</td>
<td>1.00 c</td>
<td>1.00 b</td>
<td>0.00 d</td>
<td>1.00 c</td>
<td>1.00 b</td>
</tr>
<tr>
<td>Clodinafop propargyl (Behpik)</td>
<td>48</td>
<td>1.25 bc</td>
<td>1.00 b</td>
<td>1.50 abc</td>
<td>1.00 c</td>
<td>1.00 b</td>
</tr>
<tr>
<td>Clodinafop propargyl (Behpik)</td>
<td>64</td>
<td>1.00 c</td>
<td>1.00 b</td>
<td>1.00 c</td>
<td>1.00 c</td>
<td>1.00 b</td>
</tr>
<tr>
<td>Clodinafop propargyl (Karent)</td>
<td>48</td>
<td>1.00 c</td>
<td>1.00 b</td>
<td>1.25 c</td>
<td>1.00 c</td>
<td>1.00 b</td>
</tr>
<tr>
<td>Clodinafop propargyl (Karent)</td>
<td>64</td>
<td>1.50 bc</td>
<td>1.00 b</td>
<td>1.00 c</td>
<td>1.00 c</td>
<td>1.00 b</td>
</tr>
</tbody>
</table>

* All adjuvant were added at 0.2 % (v/v).
** Treatment means within a column followed by the same letter are not significantly different (\(P < 0.05\)) according to Duncan’s Multiple Range test.

Table 4. Percent control of ryegrass by pinoxaden and three commercial formulations of clodinafop propargyl applied with and without adjuvant*.

<table>
<thead>
<tr>
<th>Herbicides</th>
<th>Rate g a.i. ha(^{-1})</th>
<th>No adjuvant</th>
<th>Adigor</th>
<th>Citogate</th>
<th>Citohef</th>
<th>Volk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pinoxaden</td>
<td>30</td>
<td>22.50 d**</td>
<td>83.75 d</td>
<td>76.25 cd</td>
<td>55.00 d</td>
<td>90.00 b</td>
</tr>
<tr>
<td>Pinoxaden</td>
<td>40</td>
<td>32.50 d</td>
<td>92.50 b</td>
<td>92.50 ab</td>
<td>91.25 a</td>
<td>100 a</td>
</tr>
<tr>
<td>Pinoxaden</td>
<td>50</td>
<td>71.25 c</td>
<td>100 a</td>
<td>92.50 ab</td>
<td>91.50 a</td>
<td>100 a</td>
</tr>
<tr>
<td>Pinoxaden</td>
<td>60</td>
<td>77.50 c</td>
<td>100 a</td>
<td>100 a</td>
<td>100 a</td>
<td>100 a</td>
</tr>
<tr>
<td>Pinoxaden</td>
<td>70</td>
<td>100 a</td>
<td>100 a</td>
<td>100 a</td>
<td>100 a</td>
<td>100 a</td>
</tr>
<tr>
<td>Clodinafop propargyl (Topik)</td>
<td>48</td>
<td>81.25 bc</td>
<td>85.00 c</td>
<td>77.50 cd</td>
<td>67.50 c</td>
<td>82.50 c</td>
</tr>
<tr>
<td>Clodinafop propargyl (Topik)</td>
<td>64</td>
<td>95.50 ab</td>
<td>90.00 bc</td>
<td>100 a</td>
<td>76.25 bc</td>
<td>88.75 bc</td>
</tr>
<tr>
<td>Clodinafop propargyl (Behpik)</td>
<td>48</td>
<td>68.00 c</td>
<td>70.00 e</td>
<td>73.75 d</td>
<td>68.75 c</td>
<td>75.00 d</td>
</tr>
<tr>
<td>Clodinafop propargyl (Behpik)</td>
<td>64</td>
<td>93.75 ab</td>
<td>91.25 bc</td>
<td>93.75 ab</td>
<td>93.75 a</td>
<td>86.25 bc</td>
</tr>
<tr>
<td>Clodinafop propargyl (Karent)</td>
<td>48</td>
<td>76.00 cd</td>
<td>87.50 cd</td>
<td>82.50 bcd</td>
<td>75.50 bc</td>
<td>87.50 bc</td>
</tr>
<tr>
<td>Clodinafop propargyl (Karent)</td>
<td>64</td>
<td>88.00 ab</td>
<td>100 a</td>
<td>90.00 abc</td>
<td>87.50 ab</td>
<td>92.50 b</td>
</tr>
</tbody>
</table>

* All adjuvant were added at 0.2 % (v/v).
** Treatment means within a column followed by the same letter are not significantly different (\(P < 0.05\)) according to Duncan’s Multiple Range test.
Table 5. Effects of pinoxaden and three commercial formulations of clodinafop propargyl applied with and without adjuvants* on littleseed canarygrass fresh weight.

<table>
<thead>
<tr>
<th>Herbicides</th>
<th>Rate</th>
<th>No adjuvant</th>
<th>Adigor</th>
<th>Citogate</th>
<th>Citohef</th>
<th>Volk</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>g a.i. ha(^{-1})</td>
<td>Fresh weight (g)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pinoxaden</td>
<td>30</td>
<td>3.04 a**</td>
<td>0.00 d</td>
<td>1.17 a</td>
<td>0.46 a</td>
<td>0.00 d</td>
</tr>
<tr>
<td>Pinoxaden</td>
<td>40</td>
<td>1.82 b</td>
<td>0.00 d</td>
<td>0.00 b</td>
<td>0.00 c</td>
<td>0.00 d</td>
</tr>
<tr>
<td>Pinoxaden</td>
<td>50</td>
<td>0.00 e</td>
<td>0.00 d</td>
<td>0.00 b</td>
<td>0.00 c</td>
<td>0.00 d</td>
</tr>
<tr>
<td>Pinoxaden</td>
<td>60</td>
<td>0.00 e</td>
<td>0.00 d</td>
<td>0.00 b</td>
<td>0.00 c</td>
<td>0.00 d</td>
</tr>
<tr>
<td>Pinoxaden</td>
<td>70</td>
<td>0.00 e</td>
<td>0.00 d</td>
<td>0.00 b</td>
<td>0.00 c</td>
<td>0.00 d</td>
</tr>
<tr>
<td>Clodinafop propargyl (Topik)</td>
<td>48</td>
<td>0.12 cd</td>
<td>0.18 a</td>
<td>0.17 b</td>
<td>0.11 b</td>
<td>0.15 a</td>
</tr>
<tr>
<td>Clodinafop propargyl (Topik)</td>
<td>64</td>
<td>0.09 d</td>
<td>0.23 a</td>
<td>0.11 b</td>
<td>0.11 b</td>
<td>0.15 a</td>
</tr>
<tr>
<td>Clodinafop propargyl (Behpik)</td>
<td>48</td>
<td>0.13 cd</td>
<td>0.10 b</td>
<td>0.16 b</td>
<td>0.11 b</td>
<td>0.14 ab</td>
</tr>
<tr>
<td>Clodinafop propargyl (Behpik)</td>
<td>64</td>
<td>0.12 cd</td>
<td>0.08 bc</td>
<td>0.09 b</td>
<td>0.07 b</td>
<td>0.14 ab</td>
</tr>
<tr>
<td>Clodinafop propargyl (Karent)</td>
<td>48</td>
<td>0.14 cd</td>
<td>0.10 b</td>
<td>0.15 b</td>
<td>0.07 b</td>
<td>0.09 c</td>
</tr>
<tr>
<td>Clodinafop propargyl (Karent)</td>
<td>64</td>
<td>0.13 cd</td>
<td>0.05 cd</td>
<td>0.09 b</td>
<td>0.06 b</td>
<td>0.10 bc</td>
</tr>
</tbody>
</table>

* All adjuvant were added at 0.2 % (v/v).
** Treatment means within a column followed by the same letter are not significantly different (P < 0.05) according to Duncan’s Multiple Range test.

Table 6. Effects of pinoxaden and three commercial formulations of clodinafop propargyl applied with and without adjuvant* on littleseed canarygrass dry weight.

<table>
<thead>
<tr>
<th>Herbicides</th>
<th>Rate</th>
<th>No adjuvant</th>
<th>Adigor</th>
<th>Citogate</th>
<th>Citohef</th>
<th>Volk</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>G a.i. ha(^{-1})</td>
<td>Dry weight (g)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pinoxaden</td>
<td>30</td>
<td>0.40 a**</td>
<td>0.00 e</td>
<td>0.24 a</td>
<td>0.60 a</td>
<td>0.00 d</td>
</tr>
<tr>
<td>Pinoxaden</td>
<td>40</td>
<td>0.24 b</td>
<td>0.00 e</td>
<td>0.00 e</td>
<td>0.00 c</td>
<td>0.00 d</td>
</tr>
<tr>
<td>Pinoxaden</td>
<td>50</td>
<td>0.00 d</td>
<td>0.00 e</td>
<td>0.00 e</td>
<td>0.00 c</td>
<td>0.00 d</td>
</tr>
<tr>
<td>Pinoxaden</td>
<td>60</td>
<td>0.00 d</td>
<td>0.00 e</td>
<td>0.00 e</td>
<td>0.00 c</td>
<td>0.00 d</td>
</tr>
<tr>
<td>Pinoxaden</td>
<td>70</td>
<td>0.00 d</td>
<td>0.00 e</td>
<td>0.00 e</td>
<td>0.00 c</td>
<td>0.00 d</td>
</tr>
<tr>
<td>Clodinafop propargyl (Topik)</td>
<td>48</td>
<td>0.04 c</td>
<td>0.05 b</td>
<td>0.05 c</td>
<td>0.04 b</td>
<td>0.06 a</td>
</tr>
<tr>
<td>Clodinafop propargyl (Topik)</td>
<td>64</td>
<td>0.04 c</td>
<td>0.10 a</td>
<td>0.05 cd</td>
<td>0.05 b</td>
<td>0.05 ab</td>
</tr>
<tr>
<td>Clodinafop propargyl (Behpik)</td>
<td>48</td>
<td>0.05 c</td>
<td>0.03 d</td>
<td>0.05 c</td>
<td>0.04 b</td>
<td>0.05 ab</td>
</tr>
<tr>
<td>Clodinafop propargyl (Behpik)</td>
<td>64</td>
<td>0.04 c</td>
<td>0.05 bc</td>
<td>0.03 d</td>
<td>0.03 b</td>
<td>0.05 ab</td>
</tr>
<tr>
<td>Clodinafop propargyl (Karent)</td>
<td>48</td>
<td>0.05 c</td>
<td>0.04 cd</td>
<td>0.05 c</td>
<td>0.02 bc</td>
<td>0.04 b</td>
</tr>
<tr>
<td>Clodinafop propargyl (Karent)</td>
<td>64</td>
<td>0.05 c</td>
<td>0.00 e</td>
<td>0.03 cd</td>
<td>0.02 bc</td>
<td>0.03 c</td>
</tr>
</tbody>
</table>

* All adjuvant were added at 0.2 % (v/v).
** Treatment means within a column followed by the same letter are not significantly different (P < 0.05) according to Duncan’s Multiple Range test.
Table 7. The number of survived plants of littleseed canarygrass after spraying with pinoxaden and three commercial formulations of clodinafop propargyl applied with and without adjuvants*.

<table>
<thead>
<tr>
<th>Herbicides</th>
<th>Rate g a.i. ha(^{-1})</th>
<th>No adjuvant</th>
<th>Adigor</th>
<th>Citogate</th>
<th>Citohef</th>
<th>Volk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pinoxaden</td>
<td>30</td>
<td>4.75 a**</td>
<td>0.00 c</td>
<td>3.50 a</td>
<td>1.25 bc</td>
<td>0.00 b</td>
</tr>
<tr>
<td>Pinoxaden</td>
<td>40</td>
<td>4.50 a</td>
<td>0.00 c</td>
<td>0.00 c</td>
<td>0.00 c</td>
<td>0.00 b</td>
</tr>
<tr>
<td>Pinoxaden</td>
<td>50</td>
<td>0.00 e</td>
<td>0.00 e</td>
<td>0.00 c</td>
<td>0.00 c</td>
<td>0.00 b</td>
</tr>
<tr>
<td>Pinoxaden</td>
<td>60</td>
<td>0.00 e</td>
<td>0.00 c</td>
<td>0.00 c</td>
<td>0.00 c</td>
<td>0.00 b</td>
</tr>
<tr>
<td>Pinoxaden</td>
<td>70</td>
<td>0.00 e</td>
<td>0.00 c</td>
<td>0.00 c</td>
<td>0.00 c</td>
<td>0.00 b</td>
</tr>
<tr>
<td>Clodinafop propargyl (Topik)</td>
<td>48</td>
<td>1.75 cd</td>
<td>1.50 b</td>
<td>2.25 ab</td>
<td>2.70 a</td>
<td>2.75 a</td>
</tr>
<tr>
<td>Clodinafop propargyl (Topik)</td>
<td>64</td>
<td>0.75 e</td>
<td>1.00 bc</td>
<td>1.25 bc</td>
<td>0.75 bc</td>
<td>2.00 a</td>
</tr>
<tr>
<td>Clodinafop propargyl (Behpik)</td>
<td>48</td>
<td>1.50 cd</td>
<td>2.25 a</td>
<td>3.00 a</td>
<td>1.75 ab</td>
<td>2.00 a</td>
</tr>
<tr>
<td>Clodinafop propargyl (Behpik)</td>
<td>64</td>
<td>1.00 cd</td>
<td>1.00 bc</td>
<td>1.50 b</td>
<td>1.75 ab</td>
<td>2.25 a</td>
</tr>
<tr>
<td>Clodinafop propargyl (Karent)</td>
<td>48</td>
<td>1.00 e</td>
<td>1.75 b</td>
<td>2.50 ab</td>
<td>2.00 ab</td>
<td>2.50 a</td>
</tr>
<tr>
<td>Clodinafop propargyl (Karent)</td>
<td>64</td>
<td>1.25 e</td>
<td>1.50 b</td>
<td>1.50 b</td>
<td>1.75 ab</td>
<td>2.25 a</td>
</tr>
</tbody>
</table>

* All adjuvant were added at 0.2 % (v/v).
** Treatment means within a column followed by the same letter are not significantly different (P < 0.05) according to Duncan’s Multiple Range test.

Table 8. Percent control of littleseed canarygrass by pinoxaden and three commercial formulations of clodinafop propargyl applied with and without adjuvants*.

<table>
<thead>
<tr>
<th>Herbicides</th>
<th>Rate g a.i. ha(^{-1})</th>
<th>No adjuvant Control (%)</th>
<th>Adigor</th>
<th>Citogate</th>
<th>Citohef</th>
<th>Volk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pinoxaden</td>
<td>30</td>
<td>22.50 c**</td>
<td>100 a</td>
<td>47.50 d</td>
<td>83.75 bc</td>
<td>100 a</td>
</tr>
<tr>
<td>Pinoxaden</td>
<td>40</td>
<td>23.75 c</td>
<td>100 a</td>
<td>100 a</td>
<td>100 a</td>
<td>100 a</td>
</tr>
<tr>
<td>Pinoxaden</td>
<td>50</td>
<td>100 a</td>
<td>100 a</td>
<td>100 a</td>
<td>100 a</td>
<td>100 a</td>
</tr>
<tr>
<td>Pinoxaden</td>
<td>60</td>
<td>100 a</td>
<td>100 a</td>
<td>100 a</td>
<td>100 a</td>
<td>100 a</td>
</tr>
<tr>
<td>Pinoxaden</td>
<td>70</td>
<td>100 a</td>
<td>100 a</td>
<td>100 a</td>
<td>100 a</td>
<td>100 a</td>
</tr>
<tr>
<td>Clodinafop propargyl (Topik)</td>
<td>48</td>
<td>61.25 b</td>
<td>81.25 b</td>
<td>66.25 bcd</td>
<td>60.00 d</td>
<td>60.00 b</td>
</tr>
<tr>
<td>Clodinafop propargyl (Topik)</td>
<td>64</td>
<td>87.50 a</td>
<td>86.25 ab</td>
<td>83.75 ab</td>
<td>91.25 ab</td>
<td>72.50 b</td>
</tr>
<tr>
<td>Clodinafop propargyl (Behpik)</td>
<td>48</td>
<td>55.50 b</td>
<td>58.75 c</td>
<td>60.00 cd</td>
<td>73.75 cd</td>
<td>71.25 b</td>
</tr>
<tr>
<td>Clodinafop propargyl (Behpik)</td>
<td>64</td>
<td>55.50 b</td>
<td>85.00 ab</td>
<td>78.75 bc</td>
<td>78.75 bc</td>
<td>71.25 b</td>
</tr>
<tr>
<td>Clodinafop propargyl (Karent)</td>
<td>48</td>
<td>86.25 a</td>
<td>72.50 b</td>
<td>67.50 bc</td>
<td>73.75 cd</td>
<td>60.00 b</td>
</tr>
<tr>
<td>Clodinafop propargyl (Karent)</td>
<td>64</td>
<td>70.00 b</td>
<td>76.25 b</td>
<td>78.75 bc</td>
<td>77.50 bc</td>
<td>70.00 b</td>
</tr>
</tbody>
</table>

* All adjuvant were added at 0.2 % (v/v).
** Treatment means within a column followed by the same letter are not significantly different (P < 0.05) according to Duncan’s Multiple Range test.
Table 9. Effects of pinoxaden and three commercial formulations of clodinafop propargyl applied with and without adjuvants* on wild oat fresh weight.

<table>
<thead>
<tr>
<th>Herbicides</th>
<th>Rate g a.i. ha⁻¹</th>
<th>No adjuvant</th>
<th>Adigor</th>
<th>Citogate</th>
<th>Citohef</th>
<th>Volk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pinoxaden</td>
<td>30</td>
<td>49.12 b</td>
<td>9.05 a</td>
<td>3.26 a</td>
<td>0.50 a</td>
<td>0.00 a</td>
</tr>
<tr>
<td>Pinoxaden</td>
<td>40</td>
<td>26.54 b</td>
<td>0.00 b</td>
<td>0.00 a</td>
<td>0.00 a</td>
<td>0.00 a</td>
</tr>
<tr>
<td>Pinoxaden</td>
<td>50</td>
<td>4.85 c</td>
<td>0.00 b</td>
<td>0.00 a</td>
<td>0.00 a</td>
<td>0.00 a</td>
</tr>
<tr>
<td>Pinoxaden</td>
<td>60</td>
<td>4.29 c</td>
<td>0.00 b</td>
<td>0.00 a</td>
<td>0.00 a</td>
<td>0.00 a</td>
</tr>
<tr>
<td>Pinoxaden</td>
<td>70</td>
<td>0.00 b</td>
<td>0.00 b</td>
<td>0.00 a</td>
<td>0.00 a</td>
<td>0.00 a</td>
</tr>
<tr>
<td>Clodinafop propargyl (Topik)</td>
<td>48</td>
<td>0.00 d</td>
<td>0.00 b</td>
<td>0.00 a</td>
<td>0.00 a</td>
<td>0.00 a</td>
</tr>
<tr>
<td>Clodinafop propargyl (Topik)</td>
<td>64</td>
<td>0.00 d</td>
<td>0.00 b</td>
<td>0.00 a</td>
<td>0.00 a</td>
<td>0.00 a</td>
</tr>
<tr>
<td>Clodinafop propargyl (Behpik)</td>
<td>48</td>
<td>0.00 d</td>
<td>0.00 b</td>
<td>0.00 a</td>
<td>0.00 a</td>
<td>0.00 a</td>
</tr>
<tr>
<td>Clodinafop propargyl (Behpik)</td>
<td>64</td>
<td>0.00 d</td>
<td>0.00 b</td>
<td>0.00 a</td>
<td>0.00 a</td>
<td>0.00 a</td>
</tr>
<tr>
<td>Clodinafop propargyl (Karent)</td>
<td>48</td>
<td>0.00 d</td>
<td>0.00 b</td>
<td>0.00 a</td>
<td>0.00 a</td>
<td>0.00 a</td>
</tr>
<tr>
<td>Clodinafop propargyl (Karent)</td>
<td>64</td>
<td>0.00 d</td>
<td>0.00 b</td>
<td>0.00 a</td>
<td>0.00 a</td>
<td>0.00 a</td>
</tr>
</tbody>
</table>

* All adjuvant were added at 0.2 % (v/v).
** Treatment means within a column followed by the same letter are not significantly different (P < 0.05) according to Duncan’s Multiple Range test.

Table 10. Effects of pinoxaden and three commercial formulations of clodinafop propargyl applied with and without adjuvants* on wild oat dry weight.

<table>
<thead>
<tr>
<th>Herbicides</th>
<th>Rate g a.i. ha⁻¹</th>
<th>No adjuvant</th>
<th>Adigor</th>
<th>Citogate</th>
<th>Citohef</th>
<th>Volk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pinoxaden</td>
<td>30</td>
<td>6.52 a**</td>
<td>0.99 a</td>
<td>0.31 a</td>
<td>0.03 a</td>
<td>0.00 a</td>
</tr>
<tr>
<td>Pinoxaden</td>
<td>40</td>
<td>3.23 b</td>
<td>0.00 b</td>
<td>0.00 b</td>
<td>0.00 a</td>
<td>0.00 a</td>
</tr>
<tr>
<td>Pinoxaden</td>
<td>50</td>
<td>0.60 b</td>
<td>0.00 b</td>
<td>0.00 b</td>
<td>0.00 a</td>
<td>0.00 a</td>
</tr>
<tr>
<td>Pinoxaden</td>
<td>60</td>
<td>0.32 cd</td>
<td>0.00 b</td>
<td>0.00 b</td>
<td>0.00 a</td>
<td>0.00 a</td>
</tr>
<tr>
<td>Pinoxaden</td>
<td>70</td>
<td>0.00 d</td>
<td>0.00 b</td>
<td>0.00 b</td>
<td>0.00 a</td>
<td>0.00 a</td>
</tr>
<tr>
<td>Clodinafop propargyl (Topik)</td>
<td>48</td>
<td>0.00 d</td>
<td>0.00 b</td>
<td>0.00 b</td>
<td>0.00 a</td>
<td>0.00 a</td>
</tr>
<tr>
<td>Clodinafop propargyl (Topik)</td>
<td>64</td>
<td>0.00 d</td>
<td>0.00 b</td>
<td>0.00 b</td>
<td>0.00 a</td>
<td>0.00 a</td>
</tr>
<tr>
<td>Clodinafop propargyl (Behpik)</td>
<td>48</td>
<td>0.00 d</td>
<td>0.00 b</td>
<td>0.00 b</td>
<td>0.00 a</td>
<td>0.00 a</td>
</tr>
<tr>
<td>Clodinafop propargyl (Behpik)</td>
<td>64</td>
<td>0.00 d</td>
<td>0.00 b</td>
<td>0.00 b</td>
<td>0.00 a</td>
<td>0.00 a</td>
</tr>
<tr>
<td>Clodinafop propargyl (Karent)</td>
<td>48</td>
<td>0.00 d</td>
<td>0.00 b</td>
<td>0.00 b</td>
<td>0.00 a</td>
<td>0.00 a</td>
</tr>
<tr>
<td>Clodinafop propargyl (Karent)</td>
<td>64</td>
<td>0.00 d</td>
<td>0.00 b</td>
<td>0.00 b</td>
<td>0.00 a</td>
<td>0.00 a</td>
</tr>
</tbody>
</table>

* All adjuvant were added at 0.2 % (v/v).
** Treatment means within a column followed by the same letter are not significantly different (P < 0.05) according to Duncan’s Multiple Range test.
Table 11. The number of survived plants of wild oat after spraying with pinoxaden and three commercial formulations of clodinafop propargyl applied with and without adjuvants*.

<table>
<thead>
<tr>
<th>Herbicides</th>
<th>Rate g a.i. ha⁻¹</th>
<th>No adjuvant</th>
<th>Adigor</th>
<th>Citogate</th>
<th>Citohef</th>
<th>Volk</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>wild oat (plant pot⁻¹)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pinoxaden</td>
<td>30</td>
<td>5.00 a**</td>
<td>1.00 a</td>
<td>0.75 a</td>
<td>0.25 a</td>
<td>0.00 a</td>
</tr>
<tr>
<td>Pinoxaden</td>
<td>40</td>
<td>2.00 b</td>
<td>0.00 b</td>
<td>0.00 b</td>
<td>0.00 a</td>
<td>0.00 a</td>
</tr>
<tr>
<td>Pinoxaden</td>
<td>50</td>
<td>0.50 c</td>
<td>0.00 b</td>
<td>0.00 b</td>
<td>0.00 a</td>
<td>0.00 a</td>
</tr>
<tr>
<td>Pinoxaden</td>
<td>60</td>
<td>0.50 c</td>
<td>0.00 b</td>
<td>0.00 b</td>
<td>0.00 a</td>
<td>0.00 a</td>
</tr>
<tr>
<td>Pinoxaden</td>
<td>70</td>
<td>0.00 d</td>
<td>0.00 b</td>
<td>0.00 b</td>
<td>0.00 a</td>
<td>0.00 a</td>
</tr>
<tr>
<td>Clodinafop propargyl (Topik)</td>
<td>48</td>
<td>0.00 d</td>
<td>0.00 b</td>
<td>0.00 b</td>
<td>0.00 a</td>
<td>0.00 a</td>
</tr>
<tr>
<td>Clodinafop propargyl (Topik)</td>
<td>64</td>
<td>0.00 d</td>
<td>0.00 b</td>
<td>0.00 b</td>
<td>0.00 a</td>
<td>0.00 a</td>
</tr>
<tr>
<td>Clodinafop propargyl (Behpi)</td>
<td>48</td>
<td>0.00 d</td>
<td>0.00 b</td>
<td>0.00 b</td>
<td>0.00 a</td>
<td>0.00 a</td>
</tr>
<tr>
<td>Clodinafop propargyl (Behpi)</td>
<td>64</td>
<td>0.00 d</td>
<td>0.00 b</td>
<td>0.00 b</td>
<td>0.00 a</td>
<td>0.00 a</td>
</tr>
<tr>
<td>Clodinafop propargyl (Karent)</td>
<td>48</td>
<td>0.00 d</td>
<td>0.00 b</td>
<td>0.00 b</td>
<td>0.00 a</td>
<td>0.00 a</td>
</tr>
<tr>
<td>Clodinafop propargyl (Karent)</td>
<td>64</td>
<td>0.00 d</td>
<td>0.00 b</td>
<td>0.00 b</td>
<td>0.00 a</td>
<td>0.00 a</td>
</tr>
</tbody>
</table>

* All adjuvant were added at 0.2 % (v/v).
** Treatment means within a column followed by the same letter are not significantly different (P < 0.05) according to Duncan’s Multiple Range test.

Table 12. Percent control of wild oat by pinoxaden and three commercial formulations of clodinafop propargyl applied with and without adjuvants*.

<table>
<thead>
<tr>
<th>Herbicides</th>
<th>Rate g a.i. ha⁻¹</th>
<th>No adjuvant</th>
<th>Adigor</th>
<th>Citogate</th>
<th>Citohef</th>
<th>Volk</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Control (%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pinoxaden</td>
<td>30</td>
<td>15.00 c**</td>
<td>89.50 b</td>
<td>78.25 b</td>
<td>95.50 a</td>
<td>100 a</td>
</tr>
<tr>
<td>Pinoxaden</td>
<td>40</td>
<td>56.25 b</td>
<td>100 a</td>
<td>100 a</td>
<td>100 a</td>
<td>100 a</td>
</tr>
<tr>
<td>Pinoxaden</td>
<td>50</td>
<td>93.25 a</td>
<td>100 a</td>
<td>100 a</td>
<td>100 a</td>
<td>100 a</td>
</tr>
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<td>Pinoxaden</td>
<td>60</td>
<td>92.75 a</td>
<td>100 a</td>
<td>100 a</td>
<td>100 a</td>
<td>100 a</td>
</tr>
<tr>
<td>Pinoxaden</td>
<td>70</td>
<td>100 a</td>
<td>100 a</td>
<td>100 a</td>
<td>100 a</td>
<td>100 a</td>
</tr>
<tr>
<td>Clodinafop propargyl (Topik)</td>
<td>48</td>
<td>100 a</td>
<td>100 a</td>
<td>100 a</td>
<td>100 a</td>
<td>100 a</td>
</tr>
<tr>
<td>Clodinafop propargyl (Topik)</td>
<td>64</td>
<td>100 a</td>
<td>100 a</td>
<td>100 a</td>
<td>100 a</td>
<td>100 a</td>
</tr>
<tr>
<td>Clodinafop propargyl (Behpi)</td>
<td>48</td>
<td>100 a</td>
<td>100 a</td>
<td>100 a</td>
<td>100 a</td>
<td>100 a</td>
</tr>
<tr>
<td>Clodinafop propargyl (Behpi)</td>
<td>64</td>
<td>100 a</td>
<td>100 a</td>
<td>100 a</td>
<td>100 a</td>
<td>100 a</td>
</tr>
<tr>
<td>Clodinafop propargyl (Karent)</td>
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<td>100 a</td>
<td>100 a</td>
<td>100 a</td>
<td>100 a</td>
<td>100 a</td>
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<tr>
<td>Clodinafop propargyl (Karent)</td>
<td>64</td>
<td>100 a</td>
<td>100 a</td>
<td>100 a</td>
<td>100 a</td>
<td>100 a</td>
</tr>
</tbody>
</table>

* All adjuvant were added at 0.2 % (v/v).
** Treatment means within a column followed by the same letter are not significantly different (P < 0.05) according to Duncan’s Multiple Range test.

Acknowledgements

The financial support from the Department of Weed Research, the Iranian Plant Protection Research Institute, Tehran is gratefully acknowledged.

REFERENCES


چکیده
توانایی مویان‌ها در افزایش کارکرد علف‌کش‌ها از اولویت‌های اصلی تحقیقات در زمینه مویان محصول می‌شود. به منظور شناسایی مویان‌های مناسب برای علف کش‌های پیتونسدان و کلوپیدنافوب پروپراهزیل برای کنترل علف‌های هرز، علف قناری، (Lotium temulentum L.)، بولاف و عشی (Avena fatua L.)، Phalaris minor Retz. (Avena fatua L.) و دو علف‌های دیگر از ریشه‌های نمک‌زا تجاری کلوپیدنافوب پروپراهزیل بهبودی و کارکرد مویان به روش آزمایشگاهی موفقیت آمیزی به فرمولسیون نمک‌زا شناخته شدند. نتایج تحقیق حاصل از آزمایش نشان داد که با افزایش ضریب کنترل علف کش، کارایی هرز و علف قناری در کنترل علف‌های هرز در صورت بهبود و کارکرد مویان به روش کلوپیدنافوب پروپراهزیل کاهش می‌یابد. بنابراین بهبودی مویان در کنترل علف‌های هرز و علف قناری داشته که در تاپید این مطلب است که مویان‌های وارک، کاربرد و آیدیگور کوتیکول موم زده با را و جواد حلالی و بیدین سان جرب از افرادی می‌پایند. همچنین، کاربرد ورک و آیدیگور به ترتیب بهترین و کمترین تأثیر بر روی کارایی علف کش های پیتونسدان در کنترل بولاف و عشی داشت. در مجموع، تمام علف‌کش‌های پیتونسدان برای جذب مویان موفقیت در کنترل علف کش کلوپیدنافوب پروپراهزیل بود. همچنین، مویان سنتیگتی در مقایسه با سنتیگتی لارش در افراد کارایی علف کش پیتونسدان در برای علف‌های هرز و علف قناری داشت در حالتی که سنتیگتی در افراد کارایی پیتونسدان در برای علف‌های هرز و عشی موفقیت بود.

کلمات کلیدی: مواد افزودنی، کلوپیدنافوب پروپراهزیل، علف قناری، پیتونسدان، چچم، بولاف و عشی.
Effects of Row Spacing and Weed Control Duration on Yield, Yield Components and Oil Content of Canola

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ABSTRACT

In order to study the effects of row spacing and weed control duration on yield, yield components and oil content of canola, a factorial experiment was conducted using randomized complete block design with 3 replications. The factors comprised row spacing at 2 levels (25 and 35 centimeter) and weed control 4, 8 leaf stages and formation of flower buds. Weeds were permitted to grow by the crop after the above mentioned growth stages. Two check treatments as control, including weedy and weed free were also selected. Evaluated traits were number of pods plant⁻¹, number of grains pod⁻¹, 1000-grain weight, grain yield, oil content and oil yield. Results showed that different row spacing had significant effect on all traits except oil content. Increase in row spacing was significantly accompanied by increase in pod number plant⁻¹ and 1000-grain weight. Other traits were significantly decreased with increasing row spacing. In addition, increase in weed control duration resulted in significant increase in all traits except oil content. The interaction of row spacing x weed control duration was also significant for all traits except 1000-grain weight and oil content. Based on the results, the highest values of grain and oil yield were related to 25 centimeter row spacing on total weed free check and the lowest amounts of these traits were obtained from 35 centimeter row spacing on weedy check treatment.

Key words: row spacing, weed control duration, grain yield, oil content, canola

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INTRODUCTION

Canola (*Brassica napus* L.) is the third largest oilseed crop production, after soybean and palm producing as much as 14.7% of total vegetable edible oil in the world (Yasari *et al*., 2008).

It is well known that weeds interference with crop plants causes serious impacts either in the competition for light, water, nutrients and space or in the allelopathy. Canola as a slow growing crop is particularly exposed to severe competition by weeds. Faster growth of weeds is disadvantageous for light and hence photosynthesis needed for rapeseed plants. Through this light deprivation, a less energy is available to crop plant for metabolic production and hence growth, yield and its quality of rapeseed plant will be reduced. In addition, weeds with branched, vigorous root systems inhibit the development of canola plant through severe nutrition deprivation (Roshdy *et al*., 2008). Duration of weed interference is one of the effective factors on weed-crop competition. Weed interference with crops is not similar in various growth and development stages; therefore, weed-crop competition capability is different in their life cycle (Tollenaar *et al*., 1994). Reduction of weed interference and increase in control durations causes increase in yield and yield components. Aghaalikhani and Yaghoobi, (2008) reported that yield of canola increased with increasing the weed control duration. (Hamzei *et al*., 2007) found that grain and oil yield of canola were increased significantly by increasing length of weed-free period. Roshdy *et al*., 2008 also expressed that yield and yield components of canola were increased in weed control treatments, but oil content was not affected.

Row spacing or density is one of the most important management factors indicating amount of radiation intercepted per plant (Fernando *et al*., 2002). Adjusting row spacing is an important tool to optimize crop growth and the time required for canopy closure, along with maximum biomass and grain yield (Ball *et al*., 2000; Turgut *et al*., 2005; Svecnjak *et al*., 2006; Haddadchi & Gerivani, 2009). Some investigations concluded that narrow row spacing resulted in higher yield than boarder rows. Plants growing in too wide rows may not efficiently utilize the natural resources such as light, water and nutrients, whereas growing in too narrow rows may result in severe inter and intra-row spacing competition (Ali *et al*., 1999). Therefore, it is of crucially important to manipulate the row spacing to increase plant productivity (Yazdifar & Ramea, 2009). Yazdifar & Ramea, 2009 reported that the highest grain yield of canola was obtained at 12 cm row spacing, followed by 7.4% reduction in grain yield as row spacing increased to 24 cm. Ozer, 2003 also expressed that grain yield was significantly affected by spacing within rows, and canola yields were higher at the narrow (15 cm) row spacing compared to the middle (30 cm) and broader (45 cm) spacings.

The objective of this study was to evaluate the effects of row spacing and weed control duration on yield, yield
components and oil percent of canola (*Brassica napus* L.).

**MATERIALS AND METHODS**

The experiment was conducted in paddy fields of Rasht Rice Researches Institute (51° 3'E longitude, 37° 16' N latitude and an altitude of -7 m below sea level) during 2008-2009. The total annual precipitation in the studied region is 1039 millimeters in the growing season; soil texture was silty clay loam with pH of 6.7 with approximately 1.63% organic matter. The experimental design was a factorial randomized complete block with 3 replications. The factors comprised row spacing at 2 levels (25 and 35 cm) and weed control duration in 7 levels (including hand weeding until the end of crop emergence (*V_c*) along with 2, 4, 8 leaf stages (represented as *V_2*, *V_4*, *V_8*, respectively) and formation of flower buds (FB)). Weeds were permitted to grow by the crop after the above mentioned growth stages. Two check treatments including weedy and weed free were also selected. In mid-September, the land was plowed with moldboard plow. According to soil and water recommendations by the Rice Research Institute, basic fertilizers including 100 kg.ha⁻¹ urea, 150 kg.ha⁻¹ ammonium phosphate and 150 kg.ha⁻¹ potassium sulphate were added to the soil simultaneously during plowing. The field was subsequently flattened by rotary. Experimental units were created in 2.5×3.5 m dimensions and 0.5 m away from the adjacent experimental units. The blocks were also 2 meters apart from each other. Considering the climate conditions of Rasht and likelihood floodings due to meteoric precipitations, some drainage channels were devised between the blocks and experimental units. Plant density for the 25 and 35 row spacing was 80 and 57 plants.m⁻² and number of planting rows were 7 and 10 rows for desired row spacing’s respectively. The plant spacing on rows was also 5 cm. Seeds were planted in the mid-November 2008 in rows with approximately 1-2 cm deep. The selected canola cultivar was Hyola 401. Topdress urea fertilizer was used as much as 100 kg.ha⁻¹ during two stages, exiting from the rosette stage (before stem elongation) and squaring stage (before flowering). Metaldehyde was also used particularly in the early stages of rapeseed growth in order to control the existing snails in the farm. Irrigation is not required due to adequacy of atmospheric precipitations during canola growth stages. Treatments were hand-harvested when 30-40% of the seeds changed their color from green to brown (late May in 25 row spacing and early June in 35). Seed moisture was about 25% at harvest. Following the harvest, plants were remained on the field for 2 days to be dried under sunlight. Seed moisture at this time was about 12%. Subsequently, threshing was done and straws were separated from the seeds. To determine the yield components (including number of pods.plant⁻¹ and number of grains.pod⁻¹) 10 plants were selected randomly from each treatment and the traits were measured. Grain yield was determined from 5 m⁻² of each plot after removing marginal effect. Grain weight
was determined by grain counter device. In this way/manner, 1000 grains were selected from each yield sample and weighted. Seed oil content was also determined with the soxhlet apparatus. SAS software v.9 (PROC GLM) was used to analyze the data and mean comparison was determined using the Tukey’s multiple range tests (at 1 and 5% levels of probability).

RESULTS AND DISCUSSION

Number of Pods. Plant$^{-1}$

Results (Table 1) showed that the effect of row spacing and duration of weed control on pods number. plant$^{-1}$ were significant (P<0.01, Table 1). In addition, row spacing and weed control duration had an interaction effect on number of pods. plant$^{-1}$. Weed control duration influenced maximum number of pods. plant$^{-1}$ with the most in the 25 row spacing treatment. In other words, increase in row spacing and increase in weed control duration increased number of pods. plant$^{-1}$. The highest and lowest number of pods. plant$^{-1}$ were related to the total weed free check in 35 cm row spacing (212.20 pods) and total weedy check in 25 cm row spacing (73 pods), respectively (Table 3).

Increase in row spacing significantly increased the number of pods. plant$^{-1}$, which shows that this trait, in 25 cm row spacing, was 15.08% lower than 35 cm row spacing (Table 2). This might have been the result of decline in light interception by plant canopy in narrower row spacing. Therefore, initiation of constituent buds on secondary branches declined. The decrease in the number of secondary branches is the main cause of decline in pods number. plant$^{-1}$. Furthermore, the diminishing carbohydrate supply with exceeding competition among the plants at the flowering time is another reason (Eilkaee & Emam, 2003). This result was consistent with those of (Majnon Hosseini et al., 2006 & Ozer, 2003).

In both row spacing, number of pods. plant$^{-1}$ in control treatments indicated an uptrend with increase in duration of weed-free and reached its highest value in weed-free check. The lowest number of pods. plant$^{-1}$ was also related to weedy check in both row spacing (Table 3). The average of pods number. plant$^{-1}$ in weed-free check in comparison with weedy check indicated an increase of 143.9% (Table 2). The reason for decline in the number of pods. plant$^{-1}$ is increase in the duration of weed interference which can be attributed to the presence of weeds competing with agricultural crops resulting in the diminish of canola competition ability for receiving light and nutrients as well as allocation of less generated materials to the fertile organs. In order to maintain the equilibrium between generated materials of the source and amount of consumed materials in the reservoir, some of the flowers shed (Safahani Langerodi et al., 2008) and decreasing number of flowers ultimately led to a decline in the number of pods in the weedy check treatment. This result was consistent with the results of the research done by (Khoshnam, 2007 & Keramati et al., 2008).

Number of Grains. Pod$^{-1}$
Results (Table 1) showed that the effect of row spacing and duration of weed control on number of grains.pod\(^{-1}\) were significant (P<0.01). In addition, row spacing and weed control duration had an interaction effect on number of grains.pod\(^{-1}\). Weed control duration influenced maximum number of grains.pod\(^{-1}\), mostly in the 25 row spacing treatment. In other words, decrease in row spacing and increase in weed control duration increased number of grains.pod\(^{-1}\). The highest and lowest number of grains.pod\(^{-1}\) were related to the total weed free check in 25 cm row spacing (29.32 seeds) and total weedy check in 35 cm row spacing (17.82 seeds), respectively (Table 3).

Increase in row spacing significantly decreased the number of grains.pod\(^{-1}\); therefore this trait in 25 cm row spacing was 12.648% higher than 35 cm row spacing (Table 2). This phenomenon can be justified as follow; as the row spacing decreases (plant density increases), the plant competition for absorbing environmental resources exceeds resulting in decrease in the production of photosynthetic materials and its transfer to grains (Leach et al., 1999; Salehi, 2004). Consequently, the existing grains reduce in size but increase in number. These results were consistent with the results obtained by (Rahman et al., 2009) & Ozoni Davaji, 2006) who believed that the increase in plant density up to an optimal level would result in the enhancement of number of grains. On the contrary, obtained results from this experiment contradicted the results of (Abadian et al., 2008 & Eilkaee & Emam, 2003) which concluded that row spacing does not significantly affect number of grains in the pods. In their opinion, narrow row imposes its impact via reduction of number of pods, and as a result, there is no considerable decline in the number of grains in the pods.

In both row spacings, number of grains.pod\(^{-1}\) in control treatments showed an uptrend with increase in duration of weed-free and reached its highest value in weed-free check. The lowest number of grains.pod\(^{-1}\) was also related to weedy check in both row spacings (Table 3). The average of grains number.pod\(^{-1}\) in weed-free check was 47.71% higher than weedy check (Table 2). Reduction in grain number.pod\(^{-1}\) in weedy check treatment can be attributed to the diminishing absorption of generated materials by the agricultural crop and consequently draping and elimination of the grains (Leach et al., 1999). This result was consistent with the results reported by (Khoshnam, 2007 & Keramati et al., 2008).

1000-Grain Weight

Results of the current experiment (Table 1) indicated that the effect of row spacing and duration of weed control on 1000-grain weight were significant (P<0.01). The Results also showed no significant response of 1000-grain weight with interaction between these factors. The highest and lowest 1000-grains weight were related to the total weed free check in 35 cm row spacing (4.56 g) and the total weedy check in 25 cm row spacing (3.1 g), respectively (Table 3).

Increase in row spacing significantly increased the 1000-grain weight, so that
this trait in 35 cm row spacing was 3.67% higher than 25 cm row spacing (Table 2). Reduction of grain weight in narrower row spacing can be attributed to the formation of smaller grains because of more limited access to environmental resources particularly light due to higher competition among plants; declining production of photosynthetic materials and finally, transfer of less photosynthetic materials to the grains especially at the time of grain filling (Salehi, 2004; Abdolrahmani, 2003). This result was consistent with the results obtained by (Shekari & Javanshir, 2000; Abdolrahmani, 2003 & Sedghi et al., 2008), while contradicted with the results of (Abadian et al., 2008 & Eilkaee & Emam, 2003). The latter researchers believed that different row spacing (plant density) have no significant effects on 1000-grain weight. Their reason was that grains act as strong physiological reservoirs and rarely respond to the treatments like row spacing (plant density).

In both row spacing, 1000-grain weight in control treatments showed an uptrend with increase in duration of weed-free and reached its highest value in weed-free check. The lowest 1000-grain weight also related to weedy check in both row spacing (Table 3). The average of 1000-grain weight in weed-free check in comparison with weedy check indicated an increase up to 43% (Table 2). The reason for declining 1000 grain weight due to increase in the duration of weed interference can be explained as follows: in the case of weed competition the amount of produced photosynthetic materials diminished due to the restricted availability of environmental resources specifically sunlight which reduces 1000-grain weight (Safahani Langerodi et al., 2008; Eftekhar et al., 2005). Similar results were also reported by (Eftekhar et al., 2005 & Keramati et al., 2008).

**Grain Yield**

Results (Table 1) indicated that the effect of row spacing and duration of weed control on grain yield were significant ($P<0.01$). In addition, row spacing and weed control duration had an interaction effect on grain yield. Weed control duration influenced maximum grain yield the most in the 25 row spacing treatment. In other words, decrease in row spacing and increase in weed control duration increased grain yield. The highest and lowest amounts of grain yield were related to the total weed free check in 25 cm row spacing ($4432.27 \text{ kg.ha}^{-1}$) and the total weedy check in 35 cm row spacing ($1940.33 \text{ kg.ha}^{-1}$), respectively (Table 3).

Increase in row spacing significantly decreased grain yield in manner that this trait in 25 cm row spacing was 19.29% higher than 35 cm row spacing (Table 2). The reason can be postulated in a way which grain yield is a function of some parameters including: the number of pods.plant$^{-1}$, number of grains.pod$^{-1}$ and 1000-grain weight. Although the decrease in row spacing decreased the yield of individual plant via reduction of pods number as well as the 1000-grain weight due to exceeded competition among plants for utilizing environmental resources. On the other hand, the increase in the total number of plants compensated the weaker yield of single plants. Accordingly, the
The overall yield was enhanced per surface area (Salehi, 2004). This result was consistent with the results observed by (Ozer, 2003 & Yazdifar et al., 2007).

In both row spacing, grain yield in control treatments showed an uptrend with increase in duration of weed-free and reached its highest value in the weed-free check. The lowest grain yield also related to weedy check in both row spacings (Table 3). The average of grain yield in weed-free check as compared to weedy check indicated an increase equivalent to 81.07% (Table 2). The reason of grain yield reduction in weedy treatment can be attributed to the reduction of yield components including pod number/plant$^{-1}$, grain number/pod$^{-1}$ and 1000-seed weight due to competition of weeds with agricultural crop which ultimately reduced the grain yield (Safahani Langerodi et al., 2008). This result was consistent with the research result of (Hamzei et al., 2007).

### Oil Content

Obtained results (Table 1) showed no significant response of oil content to row spacing, weed control duration and their interaction. The highest and lowest amounts of oil content were related to weed free until emergence in 35 cm row spacing (40.49 %) and total weedy check in 35 cm row spacing (39.20 %), respectively (Table 3). The reason of no significant effect of row spacing on oil content is due to the fact that oil content is a trait with high heritability and less influenced by environmental conditions (Abadian et al., 2008). This result was consistent with the results obtained by (Ozer, 2003 & Abadian et al., 2007 &

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**Table 1.** Analysis of variance for the effects of row spacing, weed control duration and their interaction on studied traits for canola

<table>
<thead>
<tr>
<th>S.O.V</th>
<th>df</th>
<th>Pod no plant$^{-1}$</th>
<th>Grain no pod$^{-1}$</th>
<th>1000-grain weight</th>
<th>Grain yield</th>
<th>Oil content (%)</th>
<th>Oil yield</th>
</tr>
</thead>
<tbody>
<tr>
<td>Replication</td>
<td>2</td>
<td>205.49$^{**}$</td>
<td>118.93$^{**}$</td>
<td>0.02$^{ns}$</td>
<td>167974.47$^{**}$</td>
<td>0.002$^{ns}$</td>
<td>27243.32$^{**}$</td>
</tr>
<tr>
<td>Row spacing</td>
<td>1</td>
<td>3967.32$^{**}$</td>
<td>74.80$^{**}$</td>
<td>0.35$^{**}$</td>
<td>3260400.10$^{**}$</td>
<td>1.13$^{ns}$</td>
<td>535484.71$^{**}$</td>
</tr>
<tr>
<td>Weed control duration</td>
<td>6</td>
<td>10926.91$^{**}$</td>
<td>65.27$^{**}$</td>
<td>1.17$^{**}$</td>
<td>2977861.78$^{**}$</td>
<td>0.85$^{ns}$</td>
<td>483162.54$^{**}$</td>
</tr>
<tr>
<td>R×W</td>
<td>6</td>
<td>82.57$^{**}$</td>
<td>1.21$^{**}$</td>
<td>0.004$^{ns}$</td>
<td>72204.36$^{**}$</td>
<td>0.28$^{ns}$</td>
<td>10326.14$^{**}$</td>
</tr>
<tr>
<td>Error</td>
<td>26</td>
<td>9.35</td>
<td>0.16</td>
<td>0.006</td>
<td>673.79</td>
<td>0.18</td>
<td>359.06</td>
</tr>
<tr>
<td>C.V%</td>
<td></td>
<td>6.18</td>
<td>8.72</td>
<td>2.92</td>
<td>14.80</td>
<td>3.08</td>
<td>12.47</td>
</tr>
</tbody>
</table>

* and $^{**}$: Significant at 5% and 1% probability level, respectively  
ns: non significant
Table 2. Means comparison of studied traits in different treatments of row spacing and weed control duration

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Pod no plant (^1)</th>
<th>Grain no pod (^1)</th>
<th>1000-grain weight (g)</th>
<th>Grain yield (kg ha(^{-1}))</th>
<th>Oil content (%)</th>
<th>Oil yield (kg ha(^{-1}))</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Row spacing</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>25 cm</td>
<td>129.98 b</td>
<td>24.51 a</td>
<td>3.85 b</td>
<td>3504.09 a</td>
<td>39.87 a</td>
<td>1397.86 a</td>
</tr>
<tr>
<td>35 cm</td>
<td>149.42 a</td>
<td>21.84 b</td>
<td>4.03 a</td>
<td>2946.85 b</td>
<td>39.76 a</td>
<td>1172.03 b</td>
</tr>
<tr>
<td><strong>Weed control duration</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>WF0</td>
<td>81.07 g</td>
<td>18.59 g</td>
<td>3.14 e</td>
<td>2341.65 g</td>
<td>39.32 c</td>
<td>921.14 g</td>
</tr>
<tr>
<td>WFv(_c)</td>
<td>94.15 f</td>
<td>19.97 f</td>
<td>3.68 d</td>
<td>2556.10 f</td>
<td>40.12 ab</td>
<td>1024.14 f</td>
</tr>
<tr>
<td>WFv(_2)</td>
<td>126.38 e</td>
<td>21.77 e</td>
<td>3.85 c</td>
<td>2810.43 e</td>
<td>39.83 abc</td>
<td>1120.05 e</td>
</tr>
<tr>
<td>WFv(_4)</td>
<td>138.93 d</td>
<td>23 d</td>
<td>3.95 c</td>
<td>3162.69 d</td>
<td>40.14 ab</td>
<td>1269.90 d</td>
</tr>
<tr>
<td>WFv(_8)</td>
<td>164.60 c</td>
<td>25.07 c</td>
<td>4.16 b</td>
<td>3618.58 c</td>
<td>39.60 abc</td>
<td>1433.15 c</td>
</tr>
<tr>
<td>WFFB</td>
<td>175.03 b</td>
<td>26.34 b</td>
<td>4.28 b</td>
<td>3848.79 b</td>
<td>39.43 bc</td>
<td>1518.24 b</td>
</tr>
<tr>
<td>CWF</td>
<td>197.73 a</td>
<td>27.46 a</td>
<td>4.49 a</td>
<td>4240.07 a</td>
<td>40.29 a</td>
<td>1708.01 a</td>
</tr>
</tbody>
</table>

The means with same letter do not have statistically significant difference at 5% probability level.  
WFv\(_c\), WFv\(_2\), WFv\(_4\), WFv\(_8\) and WFFB: Weed free until the growth stages of emergence, 2-leaf, 4-leaf, 8-leaf and flowering bud initiation  
WF0: 0 day weed free  
CWF: Complete weed free

Table 3. Means comparison of row spacing \(\times\) weed control duration interaction on studied traits

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Pod no plant (^1)</th>
<th>Grain no pod (^1)</th>
<th>1000-grain weight (g)</th>
<th>Grain yield (kg ha(^{-1}))</th>
<th>Oil content (%)</th>
<th>Oil yield (kg ha(^{-1}))</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Row spacing</strong> (\times) Weed control duration</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>25 cm (\times) WF0</td>
<td>73 i</td>
<td>19.35 g</td>
<td>3.1 h</td>
<td>2742.97 h</td>
<td>39.45 a</td>
<td>1081.66 h</td>
</tr>
<tr>
<td>25 cm (\times) WFv(_c)</td>
<td>87.3 h</td>
<td>20.74 fg</td>
<td>3.56 g</td>
<td>2971.53 g</td>
<td>39.75 a</td>
<td>1181.51 g</td>
</tr>
<tr>
<td>25 cm (\times) WFv(_2)</td>
<td>120.83 f</td>
<td>23.16 de</td>
<td>3.75 fg</td>
<td>3177.05 f</td>
<td>40.08 a</td>
<td>1273.07 f</td>
</tr>
<tr>
<td>25 cm (\times) WFv(_4)</td>
<td>132.07 e</td>
<td>24.21 cd</td>
<td>3.86 def</td>
<td>3368.5 e</td>
<td>40.22 a</td>
<td>1355.24 e</td>
</tr>
<tr>
<td>25 cm (\times) WFv(_8)</td>
<td>151d</td>
<td>26.63 b</td>
<td>4.04 cde</td>
<td>3793.33 c</td>
<td>39.76 a</td>
<td>1507.84 c</td>
</tr>
<tr>
<td>25 cm (\times) WFFB</td>
<td>162.04 c</td>
<td>28.13 a</td>
<td>4.19 bcd</td>
<td>4042.98 b</td>
<td>39.64 a</td>
<td>1603.0 b</td>
</tr>
<tr>
<td>25 cm (\times) CWF</td>
<td>183.27 b</td>
<td>29.32 a</td>
<td>4.41 ab</td>
<td>4432.27 a</td>
<td>40.22 a</td>
<td>1782.69 a</td>
</tr>
<tr>
<td>35 cm (\times) WF0</td>
<td>89.13 h</td>
<td>17.82 h</td>
<td>3.19 h</td>
<td>1940.33 k</td>
<td>39.20 a</td>
<td>760.62 k</td>
</tr>
<tr>
<td>35 cm (\times) WFv(_c)</td>
<td>101 g</td>
<td>19.21 gh</td>
<td>3.80 ef</td>
<td>2140.67 j</td>
<td>40.49 a</td>
<td>866.76 j</td>
</tr>
<tr>
<td>35 cm (\times) WFv(_2)</td>
<td>131.93 e</td>
<td>20.38 fg</td>
<td>3.94 def</td>
<td>2443.81 i</td>
<td>39.57 a</td>
<td>967.03 i</td>
</tr>
<tr>
<td>35 cm (\times) WFv(_4)</td>
<td>145.80 d</td>
<td>21.78 ef</td>
<td>4.04 cde</td>
<td>2956.88 g</td>
<td>40.06 a</td>
<td>1184.56 g</td>
</tr>
<tr>
<td>35 cm (\times) WFv(_8)</td>
<td>178.2 b</td>
<td>23.52 d</td>
<td>4.27 bc</td>
<td>3443.83 e</td>
<td>39.44 a</td>
<td>1358.46 e</td>
</tr>
<tr>
<td>35 cm (\times) WFFB</td>
<td>187.67 b</td>
<td>24.55 cd</td>
<td>4.37 ab</td>
<td>3654.60 d</td>
<td>39.22 a</td>
<td>1433.46 d</td>
</tr>
<tr>
<td>35 cm (\times) CWF</td>
<td>212.2 a</td>
<td>25.59 bc</td>
<td>4.56 a</td>
<td>4047.87 b</td>
<td>40.35 a</td>
<td>1633.32 b</td>
</tr>
</tbody>
</table>

The means with same letter do not have statistically significant difference at 5% probability level.  
WFv\(_c\), WFv\(_2\), WFv\(_4\), WFv\(_8\) and WFFB: Weed free until the growth stages of emergence, 2-leaf, 4-leaf, 8-leaf and flowering bud initiation  
WF0: 0 day weed free  
CWF: Complete weed free
Yazdifar et al., 2007), but was inconsistent with results obtained by (Eilkaee & Emam, 2003 & Fathi et al., 2002). They believed that oil content in canola is inversely related to seed size and decreases by reduction in pod numbers and relative increasing of seed size in higher densities.

The reason of no significant differences between control and interference treatments in oil content can be explained by the fact that oil content is a polygenetic trait and is controlled by many genes, so it is unlikely that all genes exposed to environmental stress tend to weed competition (Shahvardi et al., 2002). This result was consistent with the results obtained by (Khoshnam, 2007 & Hamzei et al., 2007).

**Oil Yield**

Results (Table 1) showed that the effect of row spacing and duration of weed control on oil yield were significant (P<0.01). In addition, row spacing and weed control duration had an interaction effect on oil yield. Weed control duration influenced maximum oil yield the most in the 25 cm row spacing treatment. In other words, decrease in row spacing and increase in weed control duration increased oil yield. The highest and lowest amounts of oil yield were related to the total weed free check in 25 cm row spacing (1782.69 kg.ha⁻¹) and total weedy check in 35 cm row spacing (760.62 kg.ha⁻¹), respectively (Table 3).

Increase in row spacing significantly decreased oil yield, which this trait in 25 cm row spacing was 19.46% higher than 35 cm row spacing (Table 2). The reason for this can be explained by the fact that oil yield is obtained from multiplying the grain yield in oil percent and is a function of these components (Abadian et al., 2008). While oil percentage was not influenced by different row spacing, oil yield was directly affected by grain yield and because of the grain yield of 25 cm row spacing was higher than 35 cm row spacing, oil yield increased in this row spacing. The result was in agreement with (Faraji, 2005 & Ozoni Davaji, 2006) which believed that increase in plant density up to the optimum level increases the oil yield. This result was also inconsistent with the result obtained by (Abadian et al., 2008). Abadian et al., 2008 believed that row spacing (plant density) has no effect on oil yield.

In both row spacing, oil yield in control treatments showed an uptrend with increasing duration of weed-free and reached its highest value in weed-free check. The lowest harvest index also related to weedy check in both row spacings (Table 3). The average of oil yield in the weed-free check indicated about 85.42% increase in comparison with the weedy check (Table 2). The reason of oil yield reduction in weedy treatment can be explained by the fact that during weed competition with crop, seed yield decreased due to reduction of yield components including pod number per plant, grain number per pod and 1000-grain weight, while oil percent did not changed. Considering that the oil yield is a function of grain yield and oil percent, with no change in oil percent, oil yield was directly decreased by grain yield. This
result was in agreement with (Khoshnam, 2007 & Hamzei et al., 2007) findings.

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Effects of Row Spacing and Weed Control Duration on Canola Yield: A Comprehensive Review


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چکیده

به منظور بررسی اثرات فاصله ریف کاشت و مدت کنترل عفونت‌های هرز بر عملکرد، اجزای عملکرد و درصد روغن کازا، ازمایشی در سال زراعی 88 به صورت فاکتوریل در قالب طرح بلک های کامل تصادفی در 3 تکرار در موسسه تحقیقات برق کشور واقع در شهرستان رشت به اجرا درآمد. فاکتورهای ازمایشی شامل فاصله ریف در 3 سطح (25 و 35 و 35 سانتی‌متر) و کنترل عفونت‌های هرز در 7 سطح (شامل و نیمه شرکت و انجام توانایی مراحل سبز شدن، 2 برگ، 4 برگ، 8 برگ و نمایپوش (تشکیل گانه‌های که) بود. پس از این مراحل، به عفونت‌های هرز اجازه فراهم کردن گیاه زراعی داده شد. دو تیمار تداخلی و کنترل کلی به عنوان شاهد در نظر گرفته شدند. نتایج ارزیابی شامل تعداد تعداد وحشی‌های در بیور تعداد دانه، عملکرد دانه، درصد (مقدار) روغن و عملکرد روغن بود. نتایج نشان داد که فاصله ریف های کاشت مختلف اثر معنی‌داری بر تمامی صفات به جز درصد روغن دانه، افزایش فاصله ریف کاشت با افزایش تعداد خرچنگ در بیور و وزن هزار دانه همراه بود. نتایج بیشترین مقدار عملکرد دانه و روغن مربوط به فاصله ریف 25 سانتی‌متر در تیمار کنترل کامل بوده و کمترین میزان این صفات نیز به فاصله ریف 35 سانتی‌متر در تیمار تداخل کامل اختصاص داشت.

کلمات کلیدی: فاصله ریف، مدت کنترل عفونت‌های هرز، عملکرد دانه، میزان روغن، کازا
Timing of Velvetleaf Management in Soybean (Glycine Max (L) Merrill)

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ABSTRACT

Velvetleaf (Abutilon theophrasti Medic) is one of the most important warm season weeds in soybean fields. To the aim of this study is to determine the critical period of velvetleaf control in two cultivars of soybean, Williams as indeterminate and Persian as determinate, with different growth patterns. The experiment was conducted at the University of Agriculture and Natural Resources of Gorgan, Iran in 2007 using a randomized complete block design along with four replicates. The experiments consisted of two sets of treatments; one set was to keep the plot weed-free until the growth stages of 2-leaf (V2), 4-leaf (V4), 6-leaf (V6) stages, beginning of flowering (R1) and beginning of pod set (R3). The second set was interference treatments that velvetleaf was allowed to grow within the plot throughout the above-mentioned growth stages. Weedy and weed-free checks were also included in the study. The effect of control treatments were significant on final height, branch number per plant, leaf area index, dry matter, yield, and pod number per plant, while seed number in pod and 100-seed weights of soybean were not significantly affected. The effects of interference treatments were significant on all traits except 100-seed weights. Using the Gompertz and Logistic equations it was found that the critical period of controlling velvetleaf in both cultivars under study, considering 5% allowed decrease in yield, was between 260 to 943 CGDD or 14-51 DAE, which is approximately from 2-leaf stage to beginning of flowering. With a 10% allowed decrease, is the number would be between 320 to 752 CGDD or 18-41 DAE, which is approximately 3 to 6-leaf growth stage for both cultivars.

Key word: Soybean, Velvetleaf, yield component, competitive periods
INTRODUCTION

Using herbicides is an important component of successful soybean production in modern agriculture and since many herbicides are available to farmers, a biological vision should replace the unconditional use of such herbicides. Knowing the critical period for weed control in major crops can aid decision making on the right timing of weed removal in cropping systems and herbicides application (Eyherabide & Cendoya, 2002). Early research on weed competition used multiple comparison tests to calculate the critical period (Zimdahl, 1980). However Cousens, (1988) suggested that regression analysis is more appropriate and reliable in calculating the critical period.

Leaf stages or accumulated thermal units could improve comparisons because the leaf appearance rate is highly dependent upon ambient temperatures (Tollenaar et al., 1979). Working with this hypothesis (Hall et al., 1992) determined that in Canada the beginning of the critical period for corn widely varied from the 3 to 14 leaf stages of corn and ended on average at the 14-leaf stage. Wide research show that there is no stable critical period for weed control in soybean (Hadizadeh & Rahimian Mashhadi, 1998). The beginning and duration of the critical period for weed control can vary depending on several factors, including the crop and weed characteristics, environmental variables (Hall et al., 1992), cultural practices and the assumptions made regarding the methods employed to determine the critical period for weed control.

For example, the critical period of Sorghum halopens control in soybean was determined to be 4-5 weeks after planting (Williams et al., 1984). The critical period of weed control in soybean was coinciding with V2 (with acceptable yield loss of 5%) in climate condition of Mashhad (Hadizade & Rahimiyan Mashhadi, 1998). (Chohocar & Balyan, 1999) reported that this period in soybean is 30-45 days after sowing and if weed-free condition was more than 45 days it would have resulted in 74% increase in grain yield of soybean. (Van Acker et al., 1993a) reported that the critical period of weed control in soybean is about 30 days after emergence. Fellows & Roeth (1992) show that the onset of the critical period of weed competition in soybean may be earlier than 2 weeks or later than 6 weeks after emergence.

Competitive crop cultivars are important matters of an integrated weed management program, they must have high leaf area index (LAI), height and dry matter accumulation during the reproductive period strongly affecting yield components. Decreasing leaf area of plant is one of the consequences of interference of weeds in relation to yield reduction. For example (Akey et al., 1990) reported that although soybean was taller than velvetleaf during early growth period but fast growth, high transition rate and more partitioning of photosynthesis to the stems in velvetleaf resulted in leaf senescence of lower part and more branching in upper part of velvetleaf. Thus soybean was not successful in competition. Kropff et
al., (1992) showed that leaf area index (LAI), leaf area growth rate, specific leaf area, and height increase determine the outcome of competition between sugar beet (Beta vulgaris L.) and common lambsquarters (Chenopodium album L.). In a simulation study Weaver et al. (1992) found that taller corn hybrids with greater leaf area index and dense canopy of tomato (Lycopersicon esculentum) had greater tolerance to velvetleaf (Abutilon theophrasti) (Lindquist & Mortensen, 1998; Lindquist et al., 1998).

Forcella, (1987) found that a tall fescue genotype with enhanced leaf area expansion was more able to maintain yield when competing with velvetleaf. Wheat (Challaiah et al., 1983) and potato (Sweet et al., 1974) cultivars that had greater LAI and intercepted more light were found to suppress weeds better. Barker et al., (2006) and Evans et al., (2003a) found biomass partitioning coefficients of leaves increased in competition with weed more than weed-free condition but total biomass partitioning was less. In the tolerance mechanism of crops in regards to weeds, suitable biomass partitioning between different parts of plant is more important than total accumulated biomass (Evans et al., 2003b).

"Williams" and "Persian" are two commonly used commercial cultivars of soybean in Iran. Velvetleaf (Abutilon theophrasti Medic.) is a troublesome annual weed in many maize and soybean cropping systems in Gorgan, Iran. This study was conducted to study timing of velvetleaf management in two different cultivars of soybean with different growth pattern, Williams as indeterminate and Persian as determinate.

**MATERIALS AND METHODS**

The experiment was conducted in 2007 at the Experiment Station of Gorgan’s Agriculture and Natural Resource University Iran. The soil type was clay loam, pH of 7.5-8 and 0.5% organic matter. The land was ploughed and cultivated before planting. According to local soil test recommendations, basal dose of 100 kg/ha phosphates ammonium, 300 kg/ha sulphur and 50 kg/ha urea were incorporated in to the soil. Seed dormancy was broken by immersing the seeds into sulfuric acid of 96% for 20 minute (Lacroix & Staniforth, 1964).

The experiments consisted of two series of treatments; the first set was control treatments that the plots were kept weed-free until the growth stages of 2, 4 and 6-leaf stages, beginning of blooming and beginning of pod set. The second set was interference treatments that velvetleaf was permitted to grow within the crop until the above-mentioned growth stages. Weedy and weed-free controls were also included in this study. The experimental design was a randomized complete block with four replications for the Williams and Persian cultivars.

Before planting soybean, treated velvetleaf seeds were planted symmetrically by hand on 17th of June then field was sprinkler-irrigated. Seeds of Williams and Persian cultivars were planted in 8 rows spaced 50 centimeters apart and irrigated up to field capacity threshold, on 20th of June. After
planting, the entire field was sprinkler-irrigated till seedling establishment and furrow-irrigated until 2 weeks prior to harvest. After seedling emergence, velvetleaf seedlings were thinned to the density of 10 plants m$^{-1}$ of rows. All naturally occurring weed species were removed by hand throughout the growing season. No herbicides were used before and after planting or emergence.

**Plant Sampling**

Parameters such as plant height, leaf area and plant dry matter for both soybean cultivars and velvetleaf were measured at each mentioned growth stages. All measurements were made on plants in the middle row of the plots. Height was the distance from the ground to the highest leaf. The leaf area of green leaves was measured using an optical leaf area meter.

At maturity stage, 18th October and 10th October 2006 for Williams and Persian cultivars, respectively, a 3-m length of the two central rows of each plot was harvested by hand to measure grain yield. Additionally, 100-seed weights were determined according to the recommendations of the International Seed Testing Association (ISTA). At harvest, number of branches, pods per plant and number of seeds per pod were measured on 20 randomly selected plants in the center rows of each plot, except the rows used for yield measurement.

**Data Analysis**

Analyses were conducted separately for each cultivar and data on plant growth parameters were subjected to analysis of variance. Data were analyzed for comparison of means (P<0.05). SAS statistical software (SAS, 1988) was used to analyze the data, including analysis of variance (ANOVA) and comparison of means based on a LSD procedure (Gomez & Gomez, 1984).

A logistic model provided the best fit for the maximum weed-infested period in the preliminary tests, therefore the model was also used to describe the effect of increasing duration of weed infestation on the yield of soybean (Ratkowsky, 1990) as follow as

$$Y = C + \frac{D}{1 + \exp (-A + BX)} \quad [1]$$

Where $Y$ is the yield as a percentage of the weed-free control, $A$ and $B$ are parameters that determine the shape of yield falling ($A$, is shape of the curve where yield fall is 50 percent and $B$ is shape of the curve in the minimum of yield), $C$ is the lower yield asymptote or minimum yield in the presence of weed interference, $D$ is the difference between the upper and lower yield asymptotes, and $X$ is the days after soybean emergence (DAE) or growth degree day (GDD), which is equal to weed infested duration from soybean emergence time until weed removal and control time. The Gompertz model was used to describe the effect of increasing length of weed-free period on soybean yield (Ratkowsky, 1990):

$$Y = A \exp (-B \exp (-KX)) \quad [2]$$

Where $Y$ is the yield as a percentage of the weed-free control, $A$ is the upper yield asymptote or maximum yield in the absence of weed interference, $B$ and $K$ are parameters that determine the shape of yield rising, and $X$ is DAE or GDD, which is equal to the weed-free period from
soybean emergence time. The critical period for velvetleaf control in soybean in regard to DAE or GDD was calculated for specific yield loss level of 10 and 5% for each cultivar. Relationship between soybean seed yield percentage and velvetleaf dry weight, and height, was obtained using of segmented models for both cultivars.

RESULTS AND DISCUSSION

Soybean Leaf Area

Reduction in maximum leaf area index (LAI\textsubscript{Max}) was found in both cultivars due to increased length of the velvetleaf interference period and leaf area index. The effects of control treatments until 2- and 4-leaf stages were significant on maximum leaf area index of soybean while in interference treatments up to V\textsubscript{2} and V\textsubscript{4} there was no significant effect on LAI\textsubscript{Max} in both cultivars when compared with the control (Table 1). Velvetleaf left beyond 4-leaf stage of soybean showed increase in LAI more than that of soybeans which could indicate of a one set competition. Leaf area index defines the ability of canopy to intercept PPFD and is an important factor in determining DM accumulation. Thus, any reduction in LAI below the canopy implies less PPFD interception and influences yield directly (Loomis \textit{et al.}, 1968). Because velvetleaf has broad and wide leaves and produces most of its leaves above the soybean’s canopy, a successful strategy in the competition for light (Regnier & Harrison, 1993; Rajcan & Swanton, 2001). In this experiment, a longer presence of velvetleaf in the plots led to decrease in soybean yield when compared to the weed-free control.

In our study maximum LAI of soybean coincided approximately with pod set stage which had a polynomial equation (R\textsuperscript{2}=0.80) with soybean yield in both cultivars (Figure 1).

![Figure 1. Relationship between Maximum leaf area index of soybean and soybean percent yield compared to weed-free check](image)

Eik and Hanway (1966) also reported high positive linear correlation between leaf area of corn at silking and final grain yield. Evans \textit{et al.}, (2003a) found that the relationship between grain yield and
maximal leaf area was not linear but was positively correlated ($R^2 = 0.90$).

**Height and Dry Matter**

An overall ANOVA indicated significant effect of control and interference treatments on the soybean dry matter and height ($P < 0.0001$) (data not shown). Increasing length of the weed interference period led to increased height of soybean. The highest soybean height belonged to weedy check that was 27% which is 38% more than weed-free check for Persian and Williams cultivars, respectively (Table 1).

In this study, more height and shading of velvetleaf led to increase in soybean height in the interference treatments. Higher competition for light in the interference treatments resulted in increase in crop height which is brought about by the change of light quality for the crop (reduced R/FR ratio) (Rajcan & Swanton, 2001; Kropff et al., 1993; Berkowitz, 1987). It seems that increase of soybean height is due to increase of internodes distances, and not to the increase of number of nodes (Akey et al., 1990). Previous studies showed that in high competitive situation as internodes distances increase, the number of internodes which are the potential positions for branching and reproductive organs decrease, which this case is important for final grain yield (Adelusi et al., 2006; Domiguez & Hume, 1978).

The final height of velvetleaf when compared with soybean height in weedy and weed-free controls was 2.3 and 2.9 times more than Persian cultivar and 2 and 2.5 times more than Williams cultivar, respectively.

In this study, increase in velvetleaf height resulted in severe decrease in soybean yield so when velvetleaf height reached to 60% of maximum height in weedy check the reduction of soybean yield was 93% when compared with weed-free check (Figure 2).

![Figure 2](image_url)

**Figure 2.** Relationship between height of velvetleaf and soybean percent yield compared to weed-free check ($Y = 94.2314 - (1.454 \times X)$, $X_0 = 60$, $R^2 = 0.95$)

Ngoujio et al., (2001) reported that in the competition between velvetleaf and tomato, velvetleaf was taller than tomato during the growing season despite tomato reaching its maximum height. Weaver et al., (1992) found that duration of the weed-free period in the plant was mainly
dependent on the height and leaf area expansion of the weed. The experiments also showed that taller weeds caused more yield losses in crop. Stoller & Woolley (1985) showed that a major strategy of velvetleaf for light-competition is the placement of leaves above the competing plants (over-topping), in a short crop, such as soybean, which requires a rise in height.

Dry matter differences of soybeans in various interferences and control periods were significant (p < 0.0001). In both cultivars, significant loss in total soybean dry weight began when weed removal was delayed until V₆, and the cause would be rapid increase in velvetleaf dry weight and its LAI. Dry matter accumulation of soybeans in the interference treatments till V₆, R₁, R₃ stages in weedy check compared with free check, were 42, 60, 80 and 82.4% less for Persian cultivar and 28, 38, 54, and 60% less for Williams cultivar (Table 1).

Weed-infested conditions for the entire growing season led to 60 an 82% reduction in soybean dry weight, compared with full-season weed-free treatments, of Williams and Persian cultivars, respectively (Table 1). Traore et al., (2003) in grain sorghum, and Ngouajio et al., (2001) in tomato, found that dry matter accumulation in different cultivars grown in the presence of weed was drastically reduced compared to cultivars grown in free weed conditions.

In control weedy treatments, reduction of soybean dry matter when weed was not controlled until V₂ and V₄ stage was significant in Williams and Persian cultivars, respectively (Table 1). Soybean competition was good enough to prevent dry matter losses when weeds germinated beyond V₂ and V₄ stages in the Williams and Persian cultivars, respectively. Bedmar et al., (1999) mentioned that weed biomass at harvest was reduced when corn was kept weed free for 10-20 days after emergence (5-6 leaf corn stage). Bhan & Kukula (1987) pointed out that beneficial effect of reduced weed competition is apparent from the increased dry matter accumulation in chickpea, which is ultimately reflected in seed yield. Reduction of crop yield as a response to increasing weed dry weight has been reported in many researches (Adelusi et al., 2006; Knezevic et al., 2003; VanAkcer, 1992).

In this study also the soybean yield was decreased by increasing the velvetleaf dry weight. The reduction trend of soybean yield against velvetleaf biomass in the two cultivars were similar, which a segmented model was fit for data from both cultivars (Figure 3).

Deduction of soybean yield will be beyond 88%, if velvetleaf biomass reaches to 650 g m⁻², while further increase in velvetleaf biomass has no further effect on the reduction of soybean yield (Figure 3).
Figure 3. Relationship between biomass of velvetleaf and soybean percent yield compared to weed-free check

\[ Y = 88.888 - (0.119 \times X), \quad X_0 = 650, \quad R^2 = 0.97 \]

Overall, 1% of soybean seed yield was lost for every 7.3 g/m\(^2\) increase in velvetleaf dry weight.

In both cultivars under study, few weeds emerged after the two-leaf and four-leaf stages of soybean, and those that did emerge accumulated little shoot biomass. The canopy closure by the soybean may have prevented the weeds from establishment after the two-leaf and four-leaf stages in Williams and Persian cultivars, respectively. Weed biomass proved to be a better indicator of weed interference than weed density (Wooley et al., 1993). Strahan et al. (2000) reported that by increasing period of interference, weed dry weight increased which will decrease by increasing control period. In addition, weed biomass accumulation at harvest was dramatically reduced when soybean was kept weed free till at least the \(V_2\) and \(V_4\) stage of growth.

Few weed seedlings emerged after these stages of growth and were not considered to represent a problem for mechanical harvesting.

Table 1. Percentage values of weed-free control for morphological traits under different weed-free (WF) and weed-infested (WI) treatments assessed at soybean harvest for two cultivars

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Williams</th>
<th>Persian</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Soybean leaf area index</td>
<td>Soybean height</td>
</tr>
<tr>
<td>WF (V_2)</td>
<td>77 b</td>
<td>122 a</td>
</tr>
<tr>
<td>WF (V_4)</td>
<td>87 ab</td>
<td>118 b</td>
</tr>
<tr>
<td>WF (W_2)</td>
<td>96 a</td>
<td>101 c</td>
</tr>
<tr>
<td>WF (F_2)</td>
<td>98 a</td>
<td>98 c</td>
</tr>
<tr>
<td>WF (H_2)</td>
<td>00 a</td>
<td>100 c</td>
</tr>
<tr>
<td>WFC</td>
<td>100 a</td>
<td>100 c</td>
</tr>
<tr>
<td>WI (V_2)</td>
<td>99 a</td>
<td>109 c</td>
</tr>
<tr>
<td>WI (V_4)</td>
<td>98 a</td>
<td>105 c</td>
</tr>
<tr>
<td>WI (W_2)</td>
<td>72 b</td>
<td>117 b</td>
</tr>
<tr>
<td>WI (F_2)</td>
<td>61 c</td>
<td>130 a</td>
</tr>
<tr>
<td>WI (H_2)</td>
<td>50 d</td>
<td>133 a</td>
</tr>
<tr>
<td>WC</td>
<td>48 d</td>
<td>138 a</td>
</tr>
</tbody>
</table>

WFC, weed-free control. WC, weedy control (unweeded for all of the season)
Soybean Yield and Yield Components

Grain yields (% of weed-free check) resulting from the different periods of weed competition in both cultivars are shown in table 2. Highly significant (P < 0.001) differences were found between treatments in both cultivars. The weedy control gave a 76 and 90% reduction compared to weed-free treatment in Williams and Persian, respectively.

Higher grain yield mean was observed in weed-free check of Williams that was 30% more than Persian cultivar (data not shown).

In both cultivars reduction in grain yield was the result of, increase in length of the weed interference period, simultaneous reduction in plant dry weight, number of branches, pods per plant and seed number per pod (Table 2). This was supported by significant and positive correlation between seed yield and plant dry weight, number of branches, pods per plant and seed number per pod, in both cultivars (0.99, 0.85, 0.97, and 0.61, for Williams and 0.97, 0.89, 0.91, and 0.59 for Persian). A similar result was reported for soybean, where weed interference also occurred mainly through the reduced number of pods and branches per plant (Orwick & Schreiber, 1979; VanAcer et al., 1993b; Chhokar & Balyan, 1999).

In this study, averaged weight of 100-seed was not significantly reduced by velvetleaf interference and thus there was no significant correlation between the 100-seed weight and seed yield (0.32 and 0.15 for Williams and Persian cultivars, respectively).

There was a significant difference in the averaged seed number per pod in the weedy check for Persian cultivar, and in weedy check and interference until R5 for Williams, when compared with their free control treatments.

Reduction trend of seed number per pod may be because of miscarriage of ovum, tiny seeds and also less seed loading which led to increase percentage of single seed per pod. Apparently, seed number per pod has no special effect on changes in grain yield as a result of velvetleaf interference. This was supported by small correlations between seed yield and seed number per pod (0.61 and 0.54 for Williams and Persian cultivars, respectively).

The average number of pods per plant of either cultivar was significantly decreased by increasing duration of weed interference after planting. The reduction in pod number per plant due to weed interference varied between cultivars.

In Persian, the reduction in pod number by increase in duration of velvetleaf interference was greater than in the Williams (data not shown). This is supported by (Kelly et al., 1987) who found that indeterminate cultivars (as a group) had greater yield stability than determinate cultivars. These results are in agreement with work by (Adams, 1967 & Bennet et al., 1977) which showed that the greatest negative response to stress during bean development occurred in the pod number. Pod number per plant is the first yield component determined in the reproductive phase followed by seeds per pod and seed weight (Adams, 1967). Thus
pod number per plant is likely the most sensitive yield component to weed interference. The findings of the present study showed that grain yield and number of pods per plant were affected by velvetleaf interference. Hagood et al. (1980) reported that 1.4–40 density of Abutilon theophrasti plants per square meter decreased number of pods in plant. These results indicate that the 100-seed weight is not significantly affected by interference and control treatments. Generally in interference treatments because of decrease in pod number per plant, assimilates were distributed within less pods and thus the 100-seed weight showed no differences when compared with control treatments in which pod number per plant was increased because of favorable conditions, therefore assimilates were distribute within more pods.

In Williams, seed yield was 76% less when velvetleaf was allowed to compete all season long, in comparison to velvetleaf control in the full season. When velvetleaf introduction was delayed till the 6-leaf stage, soybean seed yield increased by 45%. Similar yield values were observed with the other introduction periods (V₆ to R₃) (Table 2). These data suggest that if velvetleaf competition is delayed till V₆ or later, soybean seed yields would not be significantly reduced. Other researchers have recorded similar yield trends when johnsongrass (Sorghum halepense Pers.) and smellmelon (Cucumis melo) emergence is delayed in corn and cotton, respectively (Ghosheh et al., 1996; Tingle & Steele, 2003).

Soybean effectively competed with velvetleaf till V₄ before a yield loss was observed. When velvetleaf was allowed to compete with soybean at V₆, R₁, R₃, and during full season, soybean seed yield reduced 33 to 76%.

These data suggest that effective control measures should be implemented before the 6-leaf stage (Table 2). Croster and Masiunas, (1998) showed that the best pea yields resulted when eastern black nightshade was controlled during the first 2 weeks of the growing season.

In Persian, soybean grain yield with the velvetleaf present in full season was 90% less than velvetleaf control in the full season.

When velvetleaf was allowed to compete with soybean for only up to 2-leaf stage, a yield reduction of 6 and 4% was observed for Persian and Williams cultivars, respectively (Table 2). Gargouri and Seely (1972) reported 10 to 44% pea yield losses when wild oat were removed 2 or 4 weeks after emergence, but with weed removal before these stages no seed yield loss was observed. Here we provide additional evidence that early velvetleaf control is crucial for optimal soybean yield.
Table 2. Percentage values of weed-free control for Soybean yield and yield components under different weed-free (WF) and weed-infested (WI) treatments assessed at soybean harvest for two cultivars

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Williams</th>
<th>Persian</th>
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<tr>
<td></td>
<td>Branches/</td>
<td>Pods/</td>
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<tr>
<td>WF V&lt;sub&gt;2&lt;/sub&gt;</td>
<td>66 c</td>
<td>42 c</td>
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<tr>
<td>WF V&lt;sub&gt;4&lt;/sub&gt;</td>
<td>74 b</td>
<td>65 b</td>
</tr>
<tr>
<td>WF V&lt;sub&gt;6&lt;/sub&gt;</td>
<td>101 a</td>
<td>99 a</td>
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<tr>
<td>WF R&lt;sub&gt;1&lt;/sub&gt;</td>
<td>102 a</td>
<td>101a</td>
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<td>WF R&lt;sub&gt;3&lt;/sub&gt;</td>
<td>100 a</td>
<td>100a</td>
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<tr>
<td>WFC</td>
<td>100a</td>
<td>100a</td>
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<tr>
<td>WI V&lt;sub&gt;2&lt;/sub&gt;</td>
<td>104 a</td>
<td>98 a</td>
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<td>WI V&lt;sub&gt;4&lt;/sub&gt;</td>
<td>102 a</td>
<td>97 a</td>
</tr>
<tr>
<td>WI V&lt;sub&gt;6&lt;/sub&gt;</td>
<td>68 b</td>
<td>70 b</td>
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<tr>
<td>WI R&lt;sub&gt;1&lt;/sub&gt;</td>
<td>56 c</td>
<td>52 c</td>
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<tr>
<td>WI R&lt;sub&gt;3&lt;/sub&gt;</td>
<td>54 c</td>
<td>39 c</td>
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<td>WC</td>
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<td>28 b</td>
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<td>83 a</td>
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<td></td>
<td>21 bc</td>
<td>22 d</td>
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<tr>
<td></td>
<td>14 c</td>
<td>18 d</td>
</tr>
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</table>

WFC, weed-free control. WC, weedy control (unweeded for all of the season)  
N.S: Non Significant

The Gompertz and Logistic models generally described the data well, as indicated by the C.V and R<sup>2</sup> values (Table 3). Cousens, (1988) suggested the Gompertz equation is useful to describe the relationship between the lengths of the weed control and grain yield. Hall et al., (1992) also suggested the use of Logistic equation for determination of the influence of increase in duration of weed interference on yield. The crop developmental stage at which weed interference occurs is an important factor in determining potential yield losses.

The length of weed-free period, required to prevent yield loss, varied for the different cultivars and accepted levels of yield loss (Table 4). If a 5% yield loss gives a marginal benefit compared with the cost of weed control, so the beginning of the weed-free period required to prevent more than a 5% yield loss ranged from 260 to 431 CGDD (approximately 14 to 24 DAE or 2-3 leaf stages) when a yield loss of 10% was acceptable, beginning of the weed-free period ranged from 320 to 528 CGDD (approximately 18-29 DAE or 3-4 leaves) for Persian and Williams cultivars, respectively (Table 4; Figure 4). Prior to these times, velvetleaf presence did not influence the soybean seed yield.

Soybean growth and development are sufficiently plastic at 2 to 4-leaf stages to recover yield potential after velvetleaf is removed. In other crops, it has been also reported that weed interference can be tolerated up to a certain period before it causes irrevocable yield loss (Dawson, 1986). In our study, the end of the critical period of velvetleaf interference to prevent more than > 5% crop yield loss ranged from 770 to 943 CGDD (approximately 42 to 51 DAE or 7- leaf stage to R1) and for less than 10% crop yield loss was from 643 to 752 CGDD (approximately 35 to 41 DAE or 5- 6 leaf stage) for Persian and Williams cultivars, respectively (Table 4; Figure 4). These stages coincided with the soybean canopy closure in both cultivars. The few weeds emerging after the mentioned stages accumulated little shoot biomass and did not affect the seed yield. Soybean canopy closure may have reduced both establishment and competitive ability
of later emerging weeds. Other researchers have also reported that the establishment and competition of weeds were reduced following crop canopy closure (Swanton & Weise, 1991; Malik et al., 1993; Martin et al., 2001).

In general, the critical time for weed free condition varied between cultivars and accepted percentage of yield loss. The length of the critical period of velvetleaf required in Williams cultivar to prevent yield loss, was somewhat less than the Persian cultivar probably due to difference in their growth habit. Regardless of variability in the extent and occurrence of the critical period of velvetleaf control, critical period of velvetleaf control for an accepted yield loss was variable across the both cultivars and varied between 260 to 943 CGDD or 14-51 DAE, which is approximately from 2-leaf stage to beginning of flowering. Other authors have reported critical weed-free periods in a similar range, from 14 to 42 DAE for soybean in competition with single weed species (Eaton et al., 1976; Harris and Ritter, 1987; Stoller et al., 1987; Zimdahl, 1987) and community weeds (Vanacker et al., 1993b; Knezevic et al., 2003). This weed-free period indicates that duration of a residual herbicide in soybean need not to be greater than 51 DAE, or at beginning of flowering stage of soybean growth, in order to prevent a yield loss greater than 5%.

Table 3. (A) Coefficient estimates (along with standard errors) for the Gompertz equation (increasing length of weed-free period in the two cultivars). (B) Coefficient estimates (and standard errors) for the Logistic equation (increasing length of weed-infested period in the two cultivars).

<table>
<thead>
<tr>
<th>Cultivars</th>
<th>Parameter estimates</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>A</td>
</tr>
<tr>
<td>Williams</td>
<td>102.4 (3.05)</td>
</tr>
<tr>
<td>Persian</td>
<td>99.00 (2.73)</td>
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<tr>
<td></td>
<td>A</td>
</tr>
<tr>
<td>Williams</td>
<td>5.88 (1.13)</td>
</tr>
<tr>
<td>Persian</td>
<td>3.96 (0.57)</td>
</tr>
</tbody>
</table>

*Where A is the upper yield asymptote or maximum yield in the absence of weed interference, B and K are parameters that determine the shape of the curve or shape of yield rising. **Where A and B are parameters that determine the shape of the curve or shape of yield falling, C is the lower yield asymptote or minimum yield in the presence of weed interference, D is the difference between the upper and lower yield asymptotes.

Table 4. The critical duration of velvetleaf-infested period and the critical length of velvetleaf free period in soybean in days after crop emergence (DAE), crop development stage and cumulative growth degree day (CGDD), as calculated by the Gompertz and Logistic equations for each cultivar for 5 and 10% yield loss levels.

<table>
<thead>
<tr>
<th>ALYL a</th>
<th>Critical duration of weed-infested period</th>
<th>5%</th>
<th>10%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>DAE</td>
<td>Crop stage b</td>
<td>CGDD</td>
</tr>
<tr>
<td>Williams</td>
<td>24</td>
<td>V3</td>
<td>431</td>
</tr>
<tr>
<td>Persian</td>
<td>14</td>
<td>V2</td>
<td>260</td>
</tr>
</tbody>
</table>

a: Accepted Levels of Yield Loss
b: According to Fehr and Caviness
Weed control under these conditions should be based on post-emergence herbicides and/or cultivation, but if any yield loss is unacceptable, control practices must begin as soon as possible after soybean emergence.

It is suggested that velvetleaf interference will not reduce soybean yields under normal environmental conditions if velvetleaf is controlled in a timely manner with post-emergence herbicides.

The results showed that soybean tolerates weed interference till the 2-3 leaves stage, so post-emergence herbicides must be sprayed before this stage to control the weeds effectively. With the aid of known 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).

Variability in the occurrence of the critical period of weed control may be attributed to a number of factors including differences in growth characteristics of cultivars and the crops (Burnside, 1979; Zimdahl, 1980).

Figure 4. Soybean yield response to increasing length of velvetleaf-free period (▲) and duration of velvetleaf infestation(■) in cumulative growth degree day for Williams (A) and Persian (B) estimated from Gompertz and Logistic equations (statistical information on the regression lines is given in Table 2).

In this study, since all conditions in the research were constant (e.g. climate, soil parameters, agronomic practices and weed characteristics) therefore the differences in the critical period of two cultivars is attributed to characteristics of the cultivar.

As the Persian cultivar was more sensitive to velvetleaf interference than Williams, it also had a higher yield reduction. This information could be used by farmers to target mechanical weeding operations to control weeds at the stage with maximum benefit to the crop.

Conclusions

The results of this study indicate that velvetleaf is a serious weed problem in soybean production. The critical period of weed control, based upon an arbitrary 5% level of yield loss, varies between 260 to 943 CGDD or 14-51 DAE, which represents approximately V2 to R1 stages of the crop growth. We have confirmed that
the timing of significant yield loss varies between two soybean cultivars, as (Zimdahl, 1988) noted that the critical period is not an inherent property of the crop. The variation of weed biomass is in reverse to variation in crop yield. Increase in length of interference period led to reduce in soybean dry weight, number of branches, pods per plant, seed number per pod and finally reduction of soybean yield. Weeds that emerged after the 2- to 4-leaf soybean stage (14-29 DAE) grow in a competitive disadvantage in regard to the crop. The beginning of the critical period corresponded with the beginning of an increase in total velvetleaf biomass at the 2- to 4-leaf stage of soybean growth. Knowledge of the critical period of weed control and the morphological changes occurring in the crop may provide useful information upon future weed control recommendations.

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چکیده
گاوانیه‌ی یکی از مهم‌ترین علف‌های هرز تابستانه در مزارع سویا می‌باشد. به منظور یافتن دوره پرحوایی کنترل علف هرز گاوانیه در دو رقم سویا با الگوهای رشدی متفاوت (رقم ویلیامز به عنوان رقم رشد نامحدود و رقم سحر یا پرحسن به عنوان رقم رشد محدود) آزمایشی در دانشگاه علوم کشاورزی و منابع طبیعی گرگان در سال 2007 با استفاده از طرح یک بلوک های کامل تصادفی در چهار تکرار صورت گرفت. برای تعیین دوره پرحوایی گاوانیه از دو سری تیمار استفاده شد. تیمارهای تراجم که در آنها تا مرحله دو برگ، چهار برگ، هشت برگ، چهار بخش جلگه، اولوی گلدهی و اولوی غلاف‌بندی سویا، به گاوانیه اجازه تراجم داده شد و از آن پس تا انتهای فصل رشد تمام علف‌های هرز کنترل شدند. در کنار این تیمارها یک تیمار به عنوان شاهد تراجم در نظر گرفته شد که به گاوانیه اجازه حضور در تمام طول فصل رشد داده شد. سری دوم، تیمارهای کنترل بودند که در آنها تا مرحله رشد دیده یاد شده علف‌های هرز کنترل و از آن پس به گاوانیه تا انتهای فصل رشد اجازه تراجم داده شد. این تیمارها نیز همان روش شاهد کنترل (کنترل تمام علف‌های هرز در طول فصل رشد) بودند. اثر تیمارهای کنترل بر ارتقاء نهایی سویا، تعداد شاخه جانی در بوته، شاخه سطح برگ، وزن خشک، عملکرد و تعداد غلاف در هر بوته سویا معنی‌دار گشت اما بر تعداد دانه در غلاف و وزن سد دانه سویا تأثیر معنی‌داری نداشت. اثر تیمارهای تراجم نیز بر تعداد صفات فوق به غیر از وزن سد دانه معنی‌دار گردید. حساسیت ترین جزء عملکرد به حضور گاوانیه، تعدا غلاف در بوته بود. نتایج این تحقیق بر اساس معاودات پرازبر داده شده گامبیتر و لجستیک بر حسب درجه روز رشد، نشان داد که دوره پرحوایی کنترل علف هرز گاوانیه در دو رقم سویا با 5% کاهش عملکرد محاسبه می‌باشد. در مرحله دو برگ (14 روز پس از کاشت) تا اوایل گلدهی (61 روز پس از کاشت) متوالی 443 (CGDD) روز پس از کاشت، متوالی 340 (CGDD) روز پس از کاشت و شش برگ (31 روز پس از کاشت) در نظر گرفته 10% کاهش عملکرد مجاز دوره پرحوایی بین مرحله سه برگ (18 روز پس از کاشت) و شش برگ (31 روز پس از کاشت) کاشتن، 752 (CGDD) می‌باشد.

کلمات کلیدی: سویا، گاوانیه، اجزا عملکرد، دوره رقابت
بسم الله الرحمن الرحیم

راهنماي تنظیم مقاله

مقاله‌هایی که باید در مرحله دانش علف‌های هرز ارسال می‌گردد، به ترتیب تحقیقات در زمینه علف‌های هرز و یا علوم وابسته به آن باشد و قیلا چاب و یا هم‌مانند به مجالات دیگر فرستاده نشده باشد.

1- مقاله باید روی کاغذ A4 با حاشیه 5/1 سانتی متری از چهار طرف و فاصله سطور دو‌سانی (11 میلی متر با کامپیوتر) نویسند.

وریای صفحات مقاله بسته شماره گذاری در سه سطح ارسال شود. ضمنا نسخه الکترونیکی مقاله نیز باید به آدرس Isws1@yahoo.com ایمیل شود.

2- عنوان مقاله باید کوتاه و رسا باشد و ترجمه انگلیسی آن نیز زیر عوان فارسی نوشته شود.

3- نام و نام خانوادگی نویسنده (نویسنده‌انگلیسی) و نام موسسه محل تحقیق زیر نویسنده (نویسنده‌انگلیسی) نوشته شود.

4- چکیده مقاله باید شامل مطالب مهم یافته‌های تحقیق باشد و حتماً الگوی 150 کلمه تجاوز نکند.

5- متن مقاله با زیر عوان‌های درجه یک شامل مقدمه، مواد و روش‌ها، نتایج و بحث تنظیم شود. نتایج و بحث می‌تواند در هم ادغام شود. در صورتی که لازم باشد از شخصی سازمانی تشکر شود، این مطلب با زیر عوان درجه یک "سپاسگزاری" در متن مقاله بعد از بحث (نتایج و بحث) آورده می‌شود.

6- زیر عوان‌های درجه یک و درجه دو در حاشیه مقاله قرار گیرند. تگ‌فرم و مطلب با دو نقطه از آن جدا می‌شود.

7- برای اوزان و مقدار از سیستم متریک استفاده شود. ارقام و اعداد مربوط به اوزان و مقدار در صورتیکه در آغاز جمله باید باحرف نوشته شود. ارقام همیشه در هر جمله با حرف نوشتگی شود.

8- نوع چاپ در زبان فارسی Bzar و در زبان انگلیسی Times New Roman

9- انگلیسی 14 باشد.

10- فاصله خطوط متن 1/5 باشد.

11- نتایج که به صورت شکل تنظیم می‌گردد ترجیحاً در نرم افزار اکسل (Excel) باشد. قابل مربوطه نیز جداگانه ذخيره و ارسال گردند.

برای رسم نمودارها بهتر است از ویژه‌ای دایره، مثلث، مربع و لوزی به صورت تیپ و توخالی استفاده شود.
12- ترجمه انگلیسی عنوان و زیر عنوان های جدول‌ها و شرح شکل‌ها و نقگ‌ها در زیر نوشتی فارسی آنها درج شود، بطوریکه:

اطلاعات جدول‌ها و شکل‌ها قابل استفاده خوانندگان انگلیسی زبان نیز باشند.

13- اسامی علمی باحوریهای بین‌المللی نوشته و یا زیر آنها خط کشیده شود. اسامی علمی در عنوان و در جکیده بدون اسم نام گذار

ولی در مقاله، آنجا که برای اولین بار می‌آید با اسم نام گذار نوشته شود. نام علمی در صورت تکرار بدون اسم نام گذار و نام

جنس و ASHINGTON آن (حرف زیرگرد) و یک نقطه نوشته می‌شود. بیضیه‌ای است اسم نام گذار طبق قواعد مربوط خلاصه نوشته

می‌شود.

14- استفاده از جدول، وقتی مجاز است که نوشتار اطلاعات بدست آمده (نتیجه) را بیان در متن آورده در متن آورده. عنوان جدول‌ها با گویا

باشد به نحوی که نباید تابید به متن مقاله مراحج شود. اعداد جدول به انگلیسی و حتی ا لی اکان بدون اندازه و در صورت لزوم تا دو

رقم اشارات داشته شود. اصطلاحات و علائم در متن جدول را می‌توان با زیرنوسی رنگی کرد. در جدول فقط از خطوط افقی استفاده

شود. عنوان جدول در متن نوشتار باید در خط زیر یک یکم تا هم به فاصله تقریبی یک میلی متر از بیش‌ترین جدول جدای گردید. اعداد و ارقام و

مطالب جدول نیایش در متن مقاله تکرار شده باشد. اباعد جدول‌ها با یای طوری تنظیم شود که در یک صفحه مجله (طولی یا عرضی

) یک یک گر در.

15- ترجمه انگلیسی عنوان و زیر عنوان های جدول‌ها و شرح شکل‌ها و نقگ‌ها در زیر نوشتی فارسی آنها درج شود، بطوریکه:

اطلاعات جدول‌ها و شکل‌ها قابل استفاده خوانندگان انگلیسی زبان نیز باشند.


16- کلیه مطالب استفاده به زبان انگلیسی و مطالب انگلیسی زیر تنظیم شود.

17- در مورد نام نشریات پایه‌ای (دروی) که یک کلمه‌ای است، تمام حروف آن در متن مطلب علمی نوشته می‌شود مانند:

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نوشته شود.

18- وقتی مقاله‌ای به عنوان منبع مورد استفاده قرار گرفته باشد و به زبان غیر لاتین چاپ شده، متن آن به زبان انگلیسی ترجمه می‌شود لازم است این صفحات، زبان اصلی آن (متن دارسی یا زبان) در پرانتس قید شود. در صورتی که به زبان غیر لاتین چاپ شده باشد و در این صورت منبع به زبان لاتین داده شود و در دیگر در پرانتس

زبان اصلی قید گردد. مثال (In Persian with English summary).

19- مقالات باید دارای خلاصه با متن کامل به زبان انگلیسی باشند.

20- کلیه مقالات با یک پست به دفتر مجله دائنش علف‌های هرز به نام: نهار- موسسه تحقیقات گیاه‌پرستی کشور -

بخش تحقیقات علف‌های هرز - مجله دائنش علف‌های هرز - گذشت 19858131111 فرستاده شود.
21- ساختار یک مقاله کوتاه علمی شامل بخش‌های زیر است:
عنوان فارسی و انگلیسی، نویسنده، محل انجام کار، چکیده، واژه‌های کلیدی، مقدمه، کوتاه، بدون نوشتن عنوان "مقدمه "، روش بررسی (بدون عنوان‌های فرعی)، نتایج و بحث (بدون عنوان‌های فرعی)، چکیده انگلیسی مثل مقالات کامل مجله، منابع و انداده حداکثر 4 صفحه مجله شامل جدول‌ها، شکل‌ها و حداکثر 2.
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منشی مجله: مسجدی نیا، موسسه تحقیقات گیاهپزشکی کشور

درجه علمی-پژوهشی این مجله طی نامه شماره ۱۲۴۶/۱۲۸۲/۱۳۹۱/۲۰۰۹۱۷۰۳/۲۰۱۷ به نایب وزارت علوم، تحقیقات و فن آوری رسیده است.

هیئت تحریریه در پیشرفت، رد و خلاصه نموذج مقالات دریافتی مجاز می‌باشد.

مقاله‌های باید مطابق دستورالعمل مجله تدوین شود.

این مقاله دوبار در سال به چاپ می‌رسد.

پژوهشگر: محمد اصلانی

چاپ و صحافی: چاپ توالی

آدرس: خیابان اقلیمی - خیابان فخر رازی - کوچه نیک‌پور پلاک ۳
این مجله برای اعضای انجمن علوم علف-هایرژ ایران رایگان ارسال می‌شود. حق عضویت در این انجمن، مبلغ ۵۰۰۰۰۰ ریال می‌باشد ولی برای دانشجویان ۵۰٪ تخفیف منظور می‌شود. اشتراک سالانه مجله برای موسسات، کتابخانه‌ها، شرکت‌ها و غیره ۵۰۰۰۰۰ ریال است. وجه عضویت و یا اشتراک‌باید به حساب جاری شماره ۴۵۲۰۰۳-۲۰۰۶-۲۰۰۲۰۰۰۰۰۰۰ نزد یکتاک تجارت شعبه دانشگاه شهید بهشتی تهران (کد ۴۲۰) بانک انجمن علوم علف-هایرژ واریز شده و فیش آن همراه با فرم مربوط به دفتر مجله ارسال شود. فرم عضویت و اشتراک در پایگاه اینترنتی انجمن نیز در دسترس می‌باشد.

نشانی: دفتر مجله دانش علف-هایرژ، موسسه تحقیقات کیاهپزشکی کشور، تهران، صندوق پستی ۱۴۵۴-کد پستی ۱۹۸۵۷۱۳۱۳۳ تلفن و فاکس: ۲۲۴-۳۸۲۳۹۵۵
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