Effects relative fitness of susceptible and tribenuron methyl resistant biotypes of wild mustard 
(Sinapis arvensis L.)

Massoumeh Abdollahipour¹, Javid Gharekhloo², Nasser Bagherani³, Mohammad Reza Taghvaei⁴

1. Department of Agriculture, Gorgan University of Agricultural Sciences and Natural Resources, Iran
2. Department of Agriculture, Gorgan University of Agricultural Sciences and Natural Resources, Iran
3. Agricultural and Natural Resources Research Center of Golestan
4. Parss Banooye Toos Agro industry
Corresponding Author email: M_abdollahipour@yahoo.com

Abstract : This research was conducted to study the relative fitness of wild mustard biotypes of Golestan provinces that are resistant to Acetolactate Synthase (ALS) Inhibitors. Green-house experiments plant dry matter, leaf area, plant height change, seed production and burial depth of resistant and susceptible biotypes of each province were compared under no competition with wheat condition. Effect of burial depth was significant on emergence of both resistant and susceptible biotypes of both weeds. In greenhouse experiments, significant differences were observed between resistant and susceptible biotypes of wild mustard in growth properties and seed production. Regarding the relative fitness of resistant biotypes of wild mustard of Aghala region in germination and emergence, it seems if certain management are not done in order to reduce germination and emergence of these biotypes, the population of these biotypes would increase and devolve in the future, and if so, there may be increasing problems by these biotypes.

Keywords: ALS, fitness, Management, Germination

Introduction

Wheat¹, one of the most important energy sources rich in proteins and fibers useful for human nutrition and it is customarily used almost in every corner of the world. This plant is the most important Iranian farm product and the preservation of its sustainable production is one of the strategic superiorities of the country. Various factors can cause a reduction in the farm plants performance, including the weeds. The loss resulting from the weeds in wheat farms can be divided into qualitative, quantitative and also the increase in the production costs (Mousavi, 2001). Wild Mustard² is among the weeds which incur the wheat crops with a lot of losses and damages. Wild mustard is from the family Brassicaceae. This weed enjoys a particular niche among the extant weeds in the family Brassicaceae and it has been proposed as an important weed in fall and sometimes cultivation season in a great many of the temperate to semi-warm regions and even in hot regions around the globe. According to the Iran’s climatic conditions such a weed usually causes substantial losses in the fall cropping period such as wheat, barley and rapeseed. The most effective and the most common method of fighting back such weeds in the country’s wheat farms is the use of inhibitory herbicides such as Acetolactate Synthase (ALS) enzyme (Gharakhloo and Zand, 2010).

There are 25 herbicides registered in our country for the selective control of the weeds on wheat and barley farms, out of which 5 herbicides belong to the group of ALS inhibitors and in the meantime the tribenuron Methyl herbicides with the commercial name of GRANSTAR have become the most common herbicides in this family applied for the control of the wild mustard weeds in the country’s wheat farms (Zand and Baghestani, 2002).

The frequent and unduly free use of the herbicides with the same mechanism of action causes the emergence of the herbicide-resistance phenomenon (Powles and Yu, 2010). And based on the definition provided by the weed science society of America (WSSA) this phenomenon is identified as the innate competency of a plant for survival and reproduction after being exposed to a dosage of a type of herbicide which is lethal to the sensitive species under normal conditions. Up to the present time, 470 biotype of the weeds out of its 250 species, including 145 dicotyledon species and 130 monocotyledon species have become herbicide-resistant in 86 farm plants from 66 countries worldwide (Heap, 2016).

Wild mustard’s resistance to Acetolactate Synthase inhibitors was first reported on farms in the northwest Manitoba, Canada in 1992 (Morrison & Devine, 1994; Moyes et al, 2002). On Alberta farms, there was also seen such herbicides-resistant biotypes in 1993 (Jeffers et al, 1996). Since the weeds become resistant to Acetolactate Synthase inhibitor herbicides after five consecutive years of application, thus the preliminary frequency of the alleles creating such a
resistance to the acetolactate synthase inhibitor herbicides is considerably greater than the other herbicides (Zand and Baghestani, 2002).

It is important to understand the fitness results obtained from the alleles resistant to the herbicides under such circumstances and conditions as the presence and the absence of the herbicide in order for the evolution cycle of the herbicide resistance to be predicted (Neve et al, 2003). Also, the recent issue can be effective on the comprehension of the solutions and strategies that can be applied to manage resistance (Friesen et al, 2000; Walsh & Powles, 2007).

Plowing the soil is in a good connection with the burial of the seeds and it indirectly controls the seedling’s greenning and shooting (Forcella et al, 2000). In case that the necessary conditions are provided, the depth to which the seeds are buried is of a lesser effect on the shooting of the seedling. The required conditions for the offshoots, which are found to have an influence on the metabolic processes, include the sufficient humidity, appropriate temperature and for some of the seeds enough amount of the sun light. Thus, the depth of the seed placement instead of being considered as an independent factor per se has to be seen as a necessary condition for the sprouting of the seed. The effects of the depth in which the seeds are sown are, however, real and they may be of a great use in confrontation with the weeds (Rashed Mohassel and Mousavi, 2006).

In spite of the vast amplitude in which the weeds seeds are able to sprout and germinate, the majority of the weeds are usually germinating from the 1-4 Cm depth of the soil, and increasing the seed plantation depth causes a reduction in the seeds germination (Chachalis & Reddy, 2000). The reduction in the seed germination under such conditions can be a consequence of the weak gaseous exchange which occurs due to the germinating seeds oxygen consumption (Benvenoti, 2003; Norsworthy & Oliveira, 2006).

Traits such as the canopy elevation, the number of the fertile stems, the leaf area ratio (LAR)index, the cumulative dry matter, the crop growth velocity and the relative growth speed have all been found to be effective on the augmentation of the competitive competency (Baghestani and Zand, 2005). Duncan & Zimdahl (1991) also have pinpointed the leaf area ratio index, the relative growth speed and the crop growth velocity as the variables contributing to the increase in the competition capability. To evaluate the herbicide-sensitive and -resistant plants’ competition strength, characteristics such as the above-the-ground organs dry weight (Crooks et al, 2005; Park et al, 2004; Poston & Wilson, 2002; Sterling et al, 2001), the canopy elevation (Park et al, 2004; Marshall et al, 2001), leaf area ratio (LAR)(Crooks et al, 2005; Park et al, 2004), leaf dry weight (Crooks et al, 2005), relative growth speed (Crooks et al, 2005) and seed production (Warwick & Anderson, 1993) have been measured and taken into consideration.

The growth and the competition ability of the herbicide sensitive and resistant biotypes differ according to the type of the herbicide used and the plant species (Crooks et al, 2005). There are numerous reports indicative of the smaller competition ability strength and dry matter production rate in the resistant biotypes in contrast to the sensitive biotypes and a study performed on Amaranthus Rudis (Anderson et al, 1996) can be exemplified here as being reflective of such a finding. Akanda et al (1996) reported that XSMA-sensitive Xanthium strumarium in comparison to the resistant biotypes have been indicated to have higher canopy elevation and greater leaf area ratio (LAR) and it was also shown that the water consumption efficiency is higher in such resistant varieties. The comparison between the Acetolactate Synthase inhibitors (Crooks et al., 2005; Marshall et al., 2001; Massinga et al., 2005; Park et al., 2004), Picloram (Sterling et al, 2001), Acetyl Coenzyme A Carboxylase inhibitors (Wiederholt & Stolenberg, 1996) -sensitive and -resistant biotypes is suggestive of the differences existing between such biotypes in terms of growth characteristics such as height and biomass.

Ahrens and Stoller (1983) reported that triazine-sensitive Amaranthus Rudis have been found out to be producing greater number of the seeds. Holt (1988) also investigated the differences in the growth between the two Dolichorrhiza biotypes asserted that the sensitive biotype was found out to be generating more seeds. Weaver and Warwick (1982) also expressed that in a mixed sensitive and resistant Amaranthus Rudis population, the Atrazine-resistant population produced a greater number of seeds, but no difference was figured out under noncompetitive conditions in terms of seed production. Holt (1988) reported that under low light intensity conditions the susceptible biotype outperformed in terms of the number of the leaves, leaf area ratio (LAR) and the net absorption speed, but the sense of leaf area ratio (LAR) and the relative growth speed no differences could be ruled out between the triazine-sensitive and resistant biotypes. Under sufficient amount of light the resistant population acted more superiorly regarding the leaf area ratio and the susceptible population outperformed in terms of the net absorption speed.

The effect of the resistance to the herbicide on the fitness depends on factors such as the weed species, resistance mechanism and environmental conditions (Menalled & Smith, 2007; Goss & Dyer, 2003). Due to the same reason, the researchers have recommended that to predict the process and to counteract any further resistance the fitness evaluation procedures should be conducted concerning the non-triazine cases in a case to case format (Sterling et al, 2001).

The present study aims at the survey of the herbicide-resistant and –sensitive wild mustard biotypes which were collected from the farms in Golestan Province through taking advantage of a method so-called as ordinary and common greenhouse methodologies.

Materials and methods
The seeds used in the current experiment were collected from Aq Qala, Ali Abad and Gorgan Counties. After it was made sure that the biotypes are resistant and in order to obtain F1 seeds to eliminate the differences resulting from the maternal basic conditions, measures were taken to propagate the seeds and the susceptible and resistant biotypes. To serve such a purpose, the seeds were sown in the polyethylene pots at early August in 2011. Every pot was sown with six sprouted seeds and after it was insured that the seedling has been established in its position, four tow-leaf plantlets were kept in every pot. The pots were irrigated with a 2.4 g/l nitrogen solution once every two weeks in order for the young plants not to be imposed with nutritional stress. To eliminate the sensitive biotypes and to distinguish them from the resistant ones, the plants were sprayed with tribenuron methyl with a rate of 20 g/ha by taking advantage of the GRANSTAR commercial formulation of DF 75% in their three- to four-leaf stage. The plants were irrigated up to the complete ripening as required. The seeds were cultivated based on 8/16 lightness/darkness cycles and the temperature was alternatively kept at 10/22 degree centigrade. To prevent from the various phenotypes intermingling, every biotype was preserved inside a lare chamber. After the plants were completely ripened, the wild mustard seeds were picked up at 12th of May, 2012. The plants were coded in this manner that on the left-hand side the letters are indicative of the region, on the right-hand side the capital letters denote the plant species and the small letters showcase the biotype being sensitive or resistant.

### Table 1. Profile of areas in which seeds of susceptible and resistant biotypes of wild mustard have collected

<table>
<thead>
<tr>
<th>Row</th>
<th>Location and Type</th>
<th>Biotype code</th>
<th>Longitude</th>
<th>Latitude</th>
<th>Altitude</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Aghghala Resistant</td>
<td>Ag-Sr</td>
<td>54.16</td>
<td>36.20</td>
<td>150</td>
</tr>
<tr>
<td>2</td>
<td>Aghghala susceptible</td>
<td>Ag-Ss</td>
<td>54.21</td>
<td>36.58</td>
<td>150</td>
</tr>
<tr>
<td>3</td>
<td>Aliabad Resistant</td>
<td>Al-Sr</td>
<td>54.53</td>
<td>36.38</td>
<td>178</td>
</tr>
<tr>
<td>4</td>
<td>Aliabad susceptible</td>
<td>Al-Ss</td>
<td>54.46</td>
<td>36.54</td>
<td>178</td>
</tr>
<tr>
<td>5</td>
<td>Gorgan Resistant</td>
<td>G-Sr</td>
<td>54.40</td>
<td>36.29</td>
<td>27</td>
</tr>
<tr>
<td>6</td>
<td>Gorgan susceptible</td>
<td>G-Ss</td>
<td>54.37</td>
<td>36.55</td>
<td>27</td>
</tr>
</tbody>
</table>

Comparing the susceptible and resistant wild mustard biotype plantlets emergence from the depth

To evaluate the effects of the depth of sowing the seeds on the germination speed and the emergence of the sprouts in wild mustard, ten seeds were planted in plastic pots with a depth of 15 cm and diameter of 10 cm and every pot was considered as a propagation repetition. The depth in which the seeds were cultivated was considered as 0, 1, 2, 4, 6, 8 and 10 cm, respectively. To determine the amount of the soil inside every pot the consumed soil apparent weight was calculated.

### Wild mustard weeds growth and germination attributes

The experiment was conducted in a completely randomized format. Three repetitions were considered for every biotype. The empirical plots included the polyethylene pots with a diameter of 20 cm and the volume of 2.5 l soil. The soil which was applied in this experiment for the pots to be filled with was comprised of 50% cultivation soil and 50% leaf compost. Every pot was planted with four sprouted seeds and every pot was considered as a propagation repetition cycle. The pots were irrigated with a 2.4 g/l nitrogen solution once every two weeks (Gharakhloo, 2008) in order to prevent them from being imposed with nutritional stress. The first sampling was undertaken ten days after the seedlings germination and the later sampling stages were conducted in regular ten-day intervals. It is necessary to state that according to the F1 generation seeds usage in these experiments and the subsequent elimination of the differences related to the maternal base in the entire biotypes, a limited number of the seeds obtained in F1 generation of the seeds were taken into use in the present experiment.

### The measured traits in the current experiments are

The stem and the main root lengths were measured by the use of a ruler;  
The leaf area ratio (LAR) was calculated by means of a leaf area measurement device;  
The root system volume was measured through putting the cleaned roots in a scalar cylinder and the volume differentials were calculated;  
The wet leaf, stem and root weights;  
The leaf, stem and root dry weight via putting them inside an oven with a temperature of 60 °C for 48 hours and then they were weighted on a precise 0.01 g scale.

There was made use of a sigmoid 3-parameter function (1) in order to account for the variations in the canopy elevation, root length, the dry stem and root volume and weights.

$$ y = \frac{a}{1 + e^{\frac{x-x_0}{b}}} $$

(1)
where,
y: elevation, length, volume or the dry weight;
x: days after germination
a: maximum height, length, volume or the dry weight
b: the curve slope in the turning point
$X_0$: the time the curve turns

To study the leaf area ratio variations process, the leaf dry weight and crop growth rate (CGR) during the course of time were computed by making use of a Gaussian function (2) (Tahmasebi, 2010).

$$y = a \left[ 1 - 0.5 \left( \frac{x - x_0}{b} \right)^2 \right]$$  \hspace{1cm} (2)

where,
y: leaf area, crop growth rate, dry weight on every day of interest
x: the day after sowing the seed
a & b: equation coefficients
$X_0$: the time to reach to 50% of sprouting capacity
t: time

**Discussion and results**

The effect of the seeds burial depth was found to be statistically significant on the susceptible and resistant biotypes of the wild mustard germination percentage (table 2). No changes were traced in resistant biotypes sprouting percentage in 1 to 2 cm depths, but the wild mustard susceptible biotypes prefer greater depths. Due to the same reason, there is a need for trying to sow the seeds in greater depths in order for the sensitive and susceptible biotypes to find higher presence opportunities. In 4 to 6 cm (as medium depths) the results are quite inverse, that is the resistant biotypes spraying percentages approaches zero and this is while the sensitive biotypes still have the ability to germinate. So, if the management objective is to eliminate all of the sensitive and resistant biotypes deep plowing is recommended (25 cm and higher), but if there is the intention to increase the sensitive species population ratio in contrast to the wild mustard resistant species then shallow plowing can serve this purpose. From 8 cm depth on germination did not occur for any of the biotypes.

Numerous studies indicated the decrease in the seed germination with the increase in the sowing depth (Chachalis and Reddy, 2000; Benvenoti et al, 2001). Mohler and Galford (1997) stated that a trivial increase in the burial depth causes an increase in the seeds germination and they also expressed that the reason behind such an effect can be the moisture stress in the soil superficial substrate. Tahmasebi et al (2010) forced the reduction of evaporation and moisture stress on the soil level through covering the experimental units with Whatman paper. Another researcher obtained the same results via covering the soul level with filtering paper (Norsworthy and Olivieira, 2006; Benvenoti et al, 2001).

In fall, when the humidity and temperature conditions have been optimally provided the herbicide-sensitive and resistant biotypes begin sprouting and germinating. According to the similarity between the conditions under which the current experiment was undertaken and the farm conditions it can be expected that the deep plowing operations can cause the entire wild mustard susceptible and resistant biotypes cease germination. And in case that the seeds are buried in the greater depth in the soil (via deep plowing) and if the conservative and protective soil tillage systems are taken advantage of for the planting operations during the later years the wild mustard weeds including sensitive and resistant ones can more likely be reduced. Of course, the survival rate and the seeds striving in the soil should be investigated in separate experiments.

<table>
<thead>
<tr>
<th></th>
<th>Ag-Sr</th>
<th>Ag-Ss</th>
<th>Al-Sr</th>
<th>Al-Ss</th>
<th>G-Sr</th>
<th>G-Sr</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>16.23 b</td>
<td>10 c</td>
<td>12.73 b</td>
<td>6.67 cd</td>
<td>14.87 b</td>
<td>8.03 b</td>
</tr>
<tr>
<td>1</td>
<td>27.6 a</td>
<td>16.23 b</td>
<td>22.9 a</td>
<td>15.17 b</td>
<td>22.23 a</td>
<td>18.2 a</td>
</tr>
<tr>
<td>2</td>
<td>26.33 a</td>
<td>26.93 a</td>
<td>26.27 a</td>
<td>26.93 a</td>
<td>23.7 a</td>
<td>22.3 a</td>
</tr>
<tr>
<td>4</td>
<td>18.03 b</td>
<td>9.4 c</td>
<td>14.1 b</td>
<td>9.4 bc</td>
<td>14.1 b</td>
<td>0 c</td>
</tr>
<tr>
<td>6</td>
<td>0 c</td>
<td>11.37 bc</td>
<td>0 c</td>
<td>10 bc</td>
<td>0 c</td>
<td>0 c</td>
</tr>
<tr>
<td>8</td>
<td>0 c</td>
<td>0 d</td>
<td>0 c</td>
<td>0 d</td>
<td>0 c</td>
<td>0 c</td>
</tr>
</tbody>
</table>
The means with similar letters in every column are not indicative of statistically significant differences in 5% level by the use of LSD method.

**Evaluation of the growth attributes in susceptible and resistant biotypes**

The significant difference between the measured traits and the comparison of the growth characteristics means among the wild mustard sensitive and resistant biotypes is indicative of the resistant biotypes superiority over the susceptible ones (table 3). Disregarding the region of growth, the entire wild mustard resistant biotypes enjoyed a higher canopy height, wider leaf area and greater root volume, and heavier dry weight in contrast to the susceptible biotypes of such species. The higher root weight to above-the-ground ratio in resistant biotypes in respect to the susceptible ones can be held accountable for their tolerance to dry conditions.

The great majority of the studies performed regarding the fitness pertain to the triazines-susceptible and resistant biotypes. Soltani et al (2008) announced that the resistance based on the objective regarding the triazines is connected with the mutation and the replacement of the serine by glycine in position 264 of the Protein D in photosystem II which brings about a condition for preventing the triazines to the target location. Such a replacement leads to the reduction in electron transfer between QA and QB in photosystem II and to the decrease in photosynthesis capacity, as well. Such a mutation can lead to the reduction in the resistant biotypes fitness in terms of growth characteristics including the above-the-ground organs dry weight (Holt, 1988), canopy elevation (Weaver and Warwick, 1982) and leaf area (Holt, 1988) in non-competition conditions in some of the cases. Of course, there are reports indicating that the triazine-sensitive and resistant biotypes fitness does not differ in the sense of their above-the-ground dry weight (Ahrens and Stoller, 1983; Holt, 1988) and their relative growth rate (Holt, 1988). The sensitive and resistant biotypes fitness rates were also investigated regarding the other herbicide families. Powles and Howat (1990) reported that the above-the-ground plant organs’ dry weight, canopy elevation and leaf area of the Acetyl Coenzyme A Carboxylase inhibitors-resistant goose grass population were found to be smaller than the susceptible population. There are numerous reports suggesting that there is no difference between the susceptible and resistant biotypes fitness rates among which one can refer to the Sulfonil Urea-sensitive and resistant Kochia Scoparia biotypes (Thompson et al, 1994), organic Arsenic-sensitive and resistant Xanthium Strumarium (Haigler et al, 1994).

**Table 3. comparing the wild mustard susceptible and resistant biotypes mean growth indicators**

<table>
<thead>
<tr>
<th>Biotypes</th>
<th>Canopy elevation (cm)</th>
<th>Leaf area (cm²)</th>
<th>Main root length (cm)</th>
<th>Root volume (mm³)</th>
<th>Leaf dry weight (g)</th>
<th>Stem dry weight (g)</th>
<th>Root dry weight (g)</th>
<th>The root weight to above-the-ground organs ratio</th>
<th>SLA¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ag-Sr</td>
<td>42.17 a</td>
<td>48.97 a</td>
<td>29.58 a</td>
<td>2.65 a</td>
<td>12.87 a</td>
<td>5.93 a</td>
<td>1.01 a</td>
<td>0.05 a</td>
<td>3.80 b</td>
</tr>
<tr>
<td>Al-Sr</td>
<td>42.17 a</td>
<td>49.16 a</td>
<td>29.17 ab</td>
<td>2.70 a</td>
<td>12.77 a</td>
<td>5.85 a</td>
<td>0.97 a</td>
<td>0.05 a</td>
<td>3.84 b</td>
</tr>
<tr>
<td>G-Sr</td>
<td>42.03</td>
<td>49.12 a</td>
<td>28.97 b</td>
<td>2.62 a</td>
<td>12.87 a</td>
<td>5.91 a</td>
<td>0.99 a</td>
<td>0.05 a</td>
<td>3.81 b</td>
</tr>
<tr>
<td>G-Ss</td>
<td>34.03</td>
<td>44.87 b</td>
<td>22.17 c</td>
<td>2.21 b</td>
<td>11.17 b</td>
<td>4.52 b</td>
<td>0.67 b</td>
<td>0.41 b</td>
<td>4.01 a</td>
</tr>
</tbody>
</table>

The means with similar means in every column do not indicate a statistically significant difference in 5% level by making use of LSD method.

**Leaf area, leaf dry weight, crop growth rate (CGR) in wild mustard**

Three-parameter Gaussian function was well capable of accounting for the variations in the leaf area, leaf dry weight, crop growth rate in both the wild mustard susceptible and resistant biotypes during the course of the growth stages (figures 1, 2 and 3 and tables 4, 5 and 6). The lowest leaf area belonged to the first sampling stage. The leaf area in both of the susceptible and resistant biotypes was maximized in 105 and 106 days post sowing, respectively. During the seventh
up to tenth sampling stage the leaf area gradually shrank. G-Ss biotype enjoyed a smaller leaf area in respect to the resistant biotypes.

The minimum dry leaf weight pertained to the first sampling stage. With an increase in the leaf area the leaf dry weight increased gradually. In susceptible biotype the dry leaf weight gradually decreased from 105 days post sowing on. This diminishing trend was observed from the 104 days post sowing in biotypes Al-Sr and Ag-Sr.

In early growth stages, the growth rate was very slow due to the small photosynthesizing area and the plant being tiny, but with an increase in the leaf area the growth rate elevated linearly and it reached to its maximum level in about 87 days post germination. In the last sampling stage the growth rate was extremely reduced as a result of the bush senescence and the plants getting close to its termination point and the yellowing of the photosynthesizing organs.

Table 4. three-parameter Gaussian function \( y = a t^{-0.5} e^{\left[-\frac{t-b}{c}\right]^2} \) coefficients for describing the leaf area variations trend in wild mustard susceptible and resistant biotypes according to the time in greenhouse experiments

<table>
<thead>
<tr>
<th>Biotypes</th>
<th>Coefficients</th>
<th>( R^2 )</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>G-Ss</td>
<td>109.5415 (2.6147)</td>
<td>33.2263 (1.0593)</td>
<td>106.3422 (0.9471)</td>
</tr>
<tr>
<td>G-Sr</td>
<td>121.0212 (4.3091)</td>
<td>33.1506 (1.5771)</td>
<td>106.5447 (1.4102)</td>
</tr>
<tr>
<td>Al-Sr</td>
<td>124.3087 (3.7677)</td>
<td>33.7857 (1.3685)</td>
<td>105.2713 (1.222)</td>
</tr>
<tr>
<td>Ag-Sr</td>
<td>122.7922 (4.0330)</td>
<td>34.0262 (1.5025)</td>
<td>105.2502 (1.3388)</td>
</tr>
</tbody>
</table>

The numbers inside the parentheses are reflective of the regression coefficients estimation standard errors.

Table 5. three-parameter Gaussian equation coefficients for describing the dry leaf weight variations in wild mustard susceptible and resistant biotypes in greenhouse experiments

<table>
<thead>
<tr>
<th>Biotypes</th>
<th>Coefficients</th>
<th>( R^2 )</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>G-Ss</td>
<td>26.0095 (1.4403)</td>
<td>35.4489 (2.7027)</td>
<td>105.0947 (2.3833)</td>
</tr>
<tr>
<td>G-Sr</td>
<td>28.0557 (1.4956)</td>
<td>36.5167 (2.7351)</td>
<td>105.3555 (2.3935)</td>
</tr>
<tr>
<td>Al-Sr</td>
<td>30.8869 (0.9275)</td>
<td>34.8786 (1.4186)</td>
<td>104.5909 (1.2582)</td>
</tr>
<tr>
<td>Ag-Sr</td>
<td>32.5026 (0.886)</td>
<td>33.9353 (1.2375)</td>
<td>104.9843 (1.1045)</td>
</tr>
</tbody>
</table>

The numbers inside the parentheses are reflective of the regression coefficients estimation standard errors.
Figure 3. the mean crop growth rate variations trend in wild mustard resistant and susceptible biotypes

Table 6. three-parameter Gaussian equation coefficients for describing the crop growth rate in wild mustard susceptible and resistant biotypes in greenhouse experiments

<table>
<thead>
<tr>
<th>Biotypes</th>
<th>A (0.0001)</th>
<th>B</th>
<th>X₀</th>
<th>R²</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>G-Ss</td>
<td>0.5185</td>
<td>27.0146</td>
<td>87.0767</td>
<td>0.98</td>
<td>&lt; 0.0001</td>
</tr>
<tr>
<td>G-Sr</td>
<td>0.56</td>
<td>27.3752</td>
<td>86.4545</td>
<td>0.98</td>
<td>&lt; 0.0001</td>
</tr>
<tr>
<td>Al-Sr</td>
<td>0.584</td>
<td>27.6227</td>
<td>85.4127</td>
<td>0.98</td>
<td>&lt; 0.0001</td>
</tr>
<tr>
<td>Ag-Sr</td>
<td>0.5873</td>
<td>27.715</td>
<td>85.8391</td>
<td>0.98</td>
<td>&lt; 0.0001</td>
</tr>
</tbody>
</table>

The numbers inside the parentheses indicate the regression coefficients estimation standard error.

Wild mustard seed production

Although the amount of the seed produced by the G-Sr genotype is higher than the other biotypes under noncompetitive conditions, no significant difference was observed between the resistant biotypes. There was observed a significant difference between the susceptible and resistant biotypes in terms of the amount of the seeds produced (Table 7). Some researchers have reported the susceptible and resistant hybrid amaranthus rudis biotypes differences in terms of the seed production under single-crop cultivation plots (Ahrens and Stoller, 1983; Thompson et al, 1994). Some others like Weaver and Warwick (1982) have come to the realization that the red rooted amaranthus rudis susceptible biotype exhibits superior performance regarding the dry seed weight. Such a discrepancy in the obtained results can be attributed to the difference in the plant species.

Table 7. comparing the mean produced seeds between the wild mustard susceptible and resistant biotypes

<table>
<thead>
<tr>
<th>Biotypes</th>
<th>Amount of the seeds produced (g/ bush)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ag-Sr</td>
<td>0.85 a</td>
</tr>
<tr>
<td>Ag-Ss</td>
<td>0.66 c</td>
</tr>
<tr>
<td>Al-Sr</td>
<td>0.83 a</td>
</tr>
<tr>
<td>Al-Ss</td>
<td>0.67 bc</td>
</tr>
<tr>
<td>G-Sr</td>
<td>0.86 a</td>
</tr>
<tr>
<td>G-Ss</td>
<td>0.71 b</td>
</tr>
</tbody>
</table>

The means with similar letters are not indicative of a statistically significant difference in 5% level by taking advantage of the LSD method.

According to the idea that wild mustard is an annual weed and its reproduction occurs through seed propagation from year to year, if the resistant biotype seeds production on the farm can be found to be significantly higher than the susceptible biotype, then it is expected that the resistant biotype will enjoy an extensive development rate in the years to come in the regions from where it has been collected and it can turn out to be a serious problem, therefore such a problem should be counteracted by taking advantage of various methods.

The effect of the seed burial depth was found to be statistically significant on the wild mustard susceptible and resistant biotypes germination rates. If the objective is to eliminate the entire susceptible and resistant biotypes then deep plowing is recommended, but if the increase in the wild mustard species population is intended shallow plowing can serve the purpose.
In evaluating the wild mustard susceptible and resistant biotypes in terms of the growth attributes and the seed production traits a significant difference was observed. In the sense of the germination and growth characteristics Ag-Sr biotype was shown to demonstrate superior results.

Therefore, according to the relative fitness of the Ag-Sr biotype regarding sprouting and germination if special managerial measure is not taken which can be significantly effective on shooting and germination reduction it can be seen in near future that this biotype population will develop in which case there is the possibility that increasingly greater problems can occur. That is because a substantial number of the seeds produce offshoots and germinate every year and then a far more substantial amount of the seeds would be produced in the next generation subsequently and they would be added to the seed bank. Also, problems originating from competition and allelopathy which will result in the crop performance reduction and also the problems derived from the crop harvest disruptions will be repeated every year.

In case that the herbicide selective stress is eliminated and if the resistant plants are found to have lower fitness in respect to the susceptible plants, the susceptible plants in a population will take the resistant ones position in the course of time. But, if such differences are negligible or non-applicable, the resistant bushes frequency and abundance will not likely be reduced, in which case the resistant plants long-term management becomes in need of adopting strategies which bring about a reduction in the selection intensity and also pooling of the managerial strategies. Such strategies include the rational application of the herbicides, making use of the resistant weeds unique biological aspects and manipulation of the farming systems for the purpose of maximizing the chemical and non-chemical management strategies efficiency. According to the topics mentioned up to the present point, the use of the combinatory methods including observing the farm phytosanitary precautions and cleansing of the machinery in contaminated areas or in suspicious regions (Beckie, 2005), burning out the plant residuals, changing the land preparation methodology and timing (Legere et al, 2000), planned plowing (Ismail et al, 2002), the use of appropriate farming alternation (Beckie, 2005), the use of the agricultural varieties and crops possessing high competition capabilities (Zand and Baghestani, 2002), setting the sowing density and date (Zand and Baghestani, 2002), observing the alternation in applying herbicides and making a mixed use of them (Beckie, 2005) can all be effective on limiting the susceptible and resistant biotypes.

Suggestions
   Evaluating the effect of crop planting date on germination, competition and seed production in wild mustard especially the resistant genotypes
   The survey of the plowing timing, plowing depth and the type of the tillage tools effect on germination, competition competency and seed production in wild mustard
   The survey of the herbicide-susceptible and resistant biotypes seeds sustainability in seed banks
   The survey of the combinatory counteracting measures for the purpose of controlling the susceptible and resistant biotypes

Evaluating the susceptible and resistant biotypes competition power in respect to the farming crops
The survey of the consumed fertilizers effect on growth characteristics and seed production in susceptible and resistant biotypes on farms under cultivation of crops such as wheat

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