Competitive interaction of canola (Brassica napus) against wild mustard (Sinapis arvensis) using replacement series method

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Abstract: A greenhouse experiment was conducted to evaluate the competitive effects of different densities of wild mustard as against rapeseed. The experiment was performed in a randomized complete block design with four replications using replacement series in which wild mustard and rapeseed were respectively planted in different ratios of 8:0, 6:2, 4:4, 2:6 and 0:8 plants per pot. Results indicated that the maximum dry weight, height, number of branches, number pod per plant, and number of grains per pod in rapeseed vs. the same traits in wild mustard were obtained in their monoculture states. Overall evaluation of relative yield showed that both species were exploiting the resources in same ways or mutual antagonism. Relative competition coefficient of rapeseed as against wild mustard just in the 6:2 treatment was greater than that in the other plant ratio treatments. Competition indices revealed that wild mustard benefited from a more competitive ability than rapeseed.

Key words: Competition; Rapeseed; Replacement series; Wild mustard

1. Introduction

Increasing costs of herbicide inputs in intensive crop production systems and the incidence of herbicide resistance in weeds have renewed interest in exploiting crop competitiveness to reduced herbicide use (Lemerle et al., 2001). Two factors contribute to crop competitiveness against weeds: ability to withstand competition (AWC), or the ability to maintain high yields in the presence of weeds, and weed suppressive ability (WSA), the ability of the crop to reduce weed biomass and seed production (Jannink et al., 2000). In order to measure the competition and other kinds of interference some growth quantitative measures such as yield are used (Wright, 1981). Yield can be considered as the seed yield or the biologic yield, while using yield for each species is considered the best measuring method of competition and rivalry. There are several different methods and schemes for studying the species relationships of plants. Among these methods additive plans, replacement plans and systematic ones can be mentioned (Javanshir et al., 2000). Replacement series experiment is a method of studying crop-weed competition (Radosevich et al., 1997). It includes pure stands as well as mixtures in which the proportion of two species studied is varied. The total plant density is kept constant over all treatments in such experiments. Rapeseed, from Brassicaceae, provides a convenient alternative for cereal-based agricultural systems, as it is broad leaved and can be grown as a break crop in a continuous run of cereals (Khachatourians et al., 2001). It is increasingly becoming a popular oilseed crop in Iran. Wild mustard is a dominant weed in rapeseed fields of Iran bringing about major yield losses. A strongly persistent seedbank, competitive growth habit, and high fecundity all contribute to its weedy nature ensuring that it will be a continuing problem (Warwick et al., 2000). Wild mustard densities of 10 plants m⁻² can reduce rapeseed seed yield by 20%, whereas 20 plants m⁻² can reduce rapeseed yield by more than 36% (Warwick et al., 2000). In addition to yield losses in rapeseed, wild mustard can reduce crop quality even at its low densities (Rose and Bell, 1982). Rapeseed seeds contaminated with wild mustard seeds had caused an increase in linolenic and erucic acid levels in the extracted oil and glucosinolate content in the meal (McMullan et al., 1994). The main objective of the current paper is to investigate the competitive ability of the canola against wild mustard, and evaluating of empirical yield loss model in predicting the effect of different densities of wild mustard on canola yield.

2. Materials and methods

The experiment was performed in a completely blocks randomized design with four replications using replacement series in which wild mustard and rapeseed were planted in different ratios of 8:0, 6:2, 4:4, 2:6 and 0:8 plants per pot in 2014. Mature seeds of wild mustard were collected from Dezfoul Experimental Station farm, located in 48°24’ eastern longitude and 32°22’ northern latitude. Wild mustard and rapeseed seeds were planted 1 and 2
cm deep, respectively, in 35 cm diameter plastic pots filled with a sandy clay loam soil. Plants were harvested from the soil surface at maturity and were oven dried at 75°C for 48h, while total shoot biomass for each species being determined. Measurements included shoot and root dry weight, plant height, number of branches per plant, number of pod per plant, number grain per pod and plant grain yield in rapeseed. Relative Yield (RY), Relative Yield Total (RYT) and Relative Crowding Coefficient (RCC) were calculated. Relative yield (RY) is a measure of the relative competitive ability of the two species. Large RY values indicate a high degree of competitiveness of one species relative to the other. Values of approximately one indicate that interspecific and intraspecific competition is equal. Values greater than one indicate that intraspecific competition is more than interspecific competition. Values less than one indicate that intraspecific competition is less than interspecific competition. RY was calculated using the equation (Ghadiri, 2005):

\[ RY = \frac{Y_{mix}}{Y_{mon}} \]

Where \( Y_{mix} \) and \( Y_{mon} \) are yields in mixture and monoculture.

Relative Yield Total (RYT) describes how the species pair utilizes resources. Values of approximately one indicate that two species are competing for the same limiting resources. Values greater than one suggest that species are making demands on different resources, avoiding competition, or maintaining a symbiotic relationship. Values less than one imply mutual antagonism. When the RYT of a pair of species is approximately one, the combined yield of species in a mixture is predictable from species monocultures (Ghadiri, 2005). RYT was calculated using the equation:

\[ RYT = \sum_{i=1}^{n} RY \]

Relative Crowding Coefficient (RCC) is a measure of competitiveness between the two species. Large RCC values indicate a high degree of competitiveness of one species relative to the other. The RCC was calculated using the equation (Ghadiri, 2005):

\[ RCC = \frac{Y_{Amon}}{Y_{Amix}} \cdot \frac{Y_{Bmon}}{Y_{Bmix}} \]

Where \( Y_{Amix} \) and \( Y_{Bmix} \) are average yield per plant of A and B grown in mixture, respectively, \( Y_{Amon} \) and \( Y_{Bmon} \) are average yield per plant of A and B grown in monoculture, respectively (Ghadiri, 2005).

Means were compared using Duncans, Multiple Range Test \((P_{0.05})\) (SAS, 2002).

3. Results and discussion

3.1. Relative yield (RY) and relative yield total (RYT)

RY values indicate the relative competitive ability of the two species. In the replacement series experiment in order to determine the competitive response of rival species we use the relative yield measure of each species as well as total relative yield or relative productivity of land (Bauman, 2002; Ifitikh et al, 2006; Weiget and Jolliffe, 2003). Hence, the higher value of the relative yields of each species tends to higher its competitive strength. Gaudet and Keddy (1988) studied the competitive capability of 88 grass species in vase experiments and concluded that the biologic yield is a proper characteristic for indicating the competitive strength of a plant. The results showed that the relative yield of rapeseed decreased in the density ratio of 25 and 50 percent compared to the same density of wild mustard (Table 1). In comparison, rapeseed in a lower or even equal density was more sensitive to competition than wild mustard and hence it faced to sharp yield decrease. However, in the higher planting densities of 75 percent the relative yield of rapeseed increased and the value reached to 0.497 (Table 1). Regarding the higher values of wild mustard compared to rapeseed’s relative yield in higher density ratios of 50 and 75 percent it can be concluded that wild mustard possesses a higher competitive strength, as a consequence, was able to better use nutrition resources. Fleming et al. (1988) in a study on competitive relationship among winter wheat, jointed goat grass (Aegilops cylindrica) and downy brome (Bromus tectorum) found that the competitive ability of jointed goat grass and winter wheat was similar, but both species exhibited a more competitive ability than downy brome. RYT was lower than 1 in all mixture ratios (Table 1).

<table>
<thead>
<tr>
<th>Canola: mustard ratio</th>
<th>RY of rapeseed</th>
<th>RY of mustard</th>
<th>TRY</th>
</tr>
</thead>
<tbody>
<tr>
<td>75:25</td>
<td>0.173</td>
<td>0.694</td>
<td>0.04</td>
</tr>
<tr>
<td>50:50</td>
<td>0.169</td>
<td>0.521</td>
<td>0.04</td>
</tr>
<tr>
<td>25:75</td>
<td>0.04</td>
<td>0.654</td>
<td>0.04</td>
</tr>
</tbody>
</table>

This showed that rapeseed and wild mustard were exploiting the resources in same ways or mutual antagonism. Wall (1997) indicated that dog mustard (Erucastrum gallicum) and flax (Linum usitatissimum L.) were making exploitation of the same resources.

3.2. Relative competition coefficient

Relative competition coefficient of rapeseed in density ratios of 25 and 50 percent was lower than that was observed in wild mustard (Table 2) which means that wild mustard possesses a higher competitive strength compared to rapeseed even in equal density ratios. The capability of the plant for taking up nutritious factors such as water, different elements and light has a significant role in increasing its competitive ability (Fernandez et al, 2002). Among these light is the most important factor for creating rivalry in farming ecosystems because it is an instantaneous resource which cannot be stored.
that observed in shoot dry weight found in root dry weight, plant height and number branches plant$^{-1}$, too (Table 4). Ghadiri (2005), using a similar replacement series experiment, reported that pinto beans (\textit{Phaseolus vulgaris} L.) shoot and root dry matter decreased as the number of field bindweed (\textit{Convolvulus arvensis} L.) plants per pot increased.

### 4. Yield and Yield Components of Rapeseed

#### 4.1. The Number of Pods per plant

Results (Table 3) showed that the effect of density ratios on pods plant$^{-1}$ was significant (P$<$0.01). Wild mustard density influenced maximum number pods plant$^{-1}$. The highest and lowest number of pods plant$^{-1}$ was related to 100:0 (110 pod) and 25:75 (38 pod) ratios. Decrease in rapeseed density significantly decreased the number of pods plant$^{-1}$ (Table 4). This might have been the result of decline in light interception by plant canopy. 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 plant$^{-1}$. Furthermore, the diminishing carbohydrate supply with exceeding competition among the plants at the flowering time is another reason (Eilkaee and Emam, 2003). This result was consistent with those of (Majnon Hosseini et al., 2006; Ozer, 2003). 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 lower density of rapeseed. Black Shaw et al. (2002) reported the decrease of the pod number of rapeseed in competition with charlock.

#### 4.2. The Number of grains per pod

Results (Table 3) revealed that the effect of density ratios on grains pods$^{-1}$ was significant (P$<$0.01). The highest and lowest number of grains pods$^{-1}$ were concerned to the ratios of 100:0 (15.4) and 25:75 (6.7). Increased wild mustard density significantly decreased the number of rapeseed grains pods$^{-1}$ (Table 4). This phenomenon due to the plant competition for absorbing environmental resources that resulting in reduction of photosynthetic materials and its transfer to rapeseed grains (Rahman et al., 2009; Ozeri Davaji, 2006).

### Table 2: Relative competition coefficient for rapeseed and wild mustard in different ratios of rapeseed and wild mustard

<table>
<thead>
<tr>
<th>Treatment</th>
<th>RCC of canola</th>
<th>RCC of mustard</th>
<th>Total RCC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canola: mustard ratio</td>
<td>75:25</td>
<td>0.986</td>
<td>0.203</td>
</tr>
<tr>
<td></td>
<td>50:50</td>
<td>0.209</td>
<td>0.565</td>
</tr>
<tr>
<td></td>
<td>25:75</td>
<td>0.04</td>
<td>1.89</td>
</tr>
</tbody>
</table>

### 3.3. The dry weight, branch number and plant height of rapeseed

The shoot dry weight of rapeseed was significantly affected by the density (Table 3) as by increasing the density of wild mustard the biomass of rapeseed was decreased. The dry weight reduction of rapeseed in ratio of 25:75 was more than 69% compared to the pure culture (100:0). The decrease in shoot dry weight of rapeseed in competition with wild mustard return to the rivalry in taking up nutrition elements, light and humidity (Rahimian and Shariati, 1999; Tingle et al., 2003; Ross and von Acker, 2005; Soleimani et al., 2010). In the study of Safahani et al. (2007) the biological yield of rapeseed, hayola 401, in the mixed cultivation with weeds decreased up to 61%. In the experiment carried out by Jafari Zadeh and Modhj (2011) by increasing the density of malva weed the biological yield of wheat was significantly reduced. Mirshekari et al. (2008) stated that season-long interference of weeds cause to 40% reduction in biological yield of rapeseed. A very similar changing pattern similar to

### Table 3: Analysis of variance for the effects of Different Ratios of Rapeseed-Wild mustard Plantation on studied traits for rapeseed

<table>
<thead>
<tr>
<th>S.O.V</th>
<th>df</th>
<th>Shoot dry weight</th>
<th>Root dry weight</th>
<th>Plant height</th>
<th>Branch no plant$^{-1}$</th>
<th>Pod no plant$^{-1}$</th>
<th>Grain no pod$^{-1}$</th>
<th>1000-grain weight</th>
<th>Grain yield</th>
</tr>
</thead>
<tbody>
<tr>
<td>Block Treatment Error</td>
<td>3</td>
<td>24.15**</td>
<td>0.846**</td>
<td>8.99**</td>
<td>0.571***</td>
<td>14.36**</td>
<td>0.268**</td>
<td>0.022**</td>
<td>0.353**</td>
</tr>
<tr>
<td>Error</td>
<td>3</td>
<td>36.928**</td>
<td>8.38**</td>
<td>2120.9**</td>
<td>63.54**</td>
<td>3864.6**</td>
<td>60.72**</td>
<td>0.54**</td>
<td>46.23**</td>
</tr>
<tr>
<td>Treatment Error Total CV%</td>
<td>9</td>
<td>15.03</td>
<td>0.799</td>
<td>37.35</td>
<td>0.585</td>
<td>32.22</td>
<td>1.34</td>
<td>0.144</td>
<td>0.636</td>
</tr>
<tr>
<td></td>
<td>15</td>
<td>6.8</td>
<td>8.8</td>
<td>6.65</td>
<td>7.51</td>
<td>7.35</td>
<td>7.18</td>
<td>13.74</td>
<td>9.26</td>
</tr>
</tbody>
</table>

*ns, ** non-significant and significant at 1% probability level, respectively*
yield components including; the number of pods. The reason can be attributed to the reduction of yield in manner that in ratio of 75:25 the reduction of mustard ratios significantly decreased plant grain competition against weeds is reported (Harker 1999) showed that increasing the density of the charlock weed to 200 plants m$^{-2}$ decreases the yield of rapeseed up to 75%. Amini et al. (2006) showed that the interference of the rye causes a decrease in the cumulative dry matter of wheat which in turn reduces the grain yield. In other researches the decrease in the grain yield of rapeseed in competition against weeds is reported (Harker et al., 2001; Safahani et al., 2007; Mac Mullan 1994).

4.3. The Weight of 1000 grains

Results of the current experiment (Table3) indicated that the effect of density ratios on 1000-grain weight were significant (P<0.01). The highest and lowest 1000-grains weight was related to the ratios of 100:0 (4.4g) and 25:75 (1.1g). Increased wild mustard density significantly reduced the 1000-grains weight of rapeseed (Table4), which indicated the intensity of competition and significant shortage of resources. Reduction of rapesean grain weight in lower density can be attributed to the formation of smaller grains because of more limited access to environmental resources particularly light due to higher competition, declining production of photosynthetic materials and finally, transfer of less photosynthetic materials to the grains at grain filling period (Salehi, 2004; Abdolrahmani, 2003).

4.4. Grain yield

Grain yield (Table4) influenced markedly by density ratios (P<0.01). Comparing the averages showed that the maximum and minimum yields of individual plant were at the density ratios of 100 and 25 by 8.1g and 0.3 g, respectively. Increase in wild mustard ratios significantly decreased plant grain yield in manner that in ratio of 75:25 the reduction exceed by 62% in compare to 0:100 ratio (Table4). The reason can be attributed to the reduction of yield components including; the number of pods plant$^{-1}$, number of grains pod$^{-1}$ and 1000-grain weight. Rapeseed lower density 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. Van Acker and Oree (1999) showed that increasing the density of the charlock weed to 200 plants m$^{-2}$ decreases the yield of rapeseed up to 75%. Amini et al. (2006) showed that the interference of the rye causes a decrease in the cumulative dry matter of wheat which in turn reduces the grain yield. In other researches the decrease in the grain yield of rapeseed in competition against weeds is reported (Harker et al., 2001; Safahani et al., 2007; Mac Mullan 1994).

5. Conclusion

The results of the present study were based on competition indices indicated that rapeseed was of a less competitive ability than wild mustard. Also, there was a significant negative correlation observed between wild mustard density and rapeseed yield components which implies that a high density of wild mustard can cause serious yield reduction in rapeseed.

References


Table 4: Means comparison of rapeseed studied traits in different ratios of rapeseed-wild mustard plantation

<table>
<thead>
<tr>
<th>% Presence of rapeseed</th>
<th>Shoot dry weight (g)</th>
<th>Root dry weight (g)</th>
<th>Plant height (cm)</th>
<th>Branch no plant$^{-1}$</th>
<th>Pod no plant$^{-1}$</th>
<th>Grain no pod$^{-1}$</th>
<th>1000-grain weight (g)</th>
<th>Grain yield plant$^{-1}$ (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>25</td>
<td>10.1$^{a}$</td>
<td>1.1$^{b}$</td>
<td>64$^{a}$</td>
<td>5.2$^{a}$</td>
<td>39$^{a}$</td>
<td>6.7$^{a}$</td>
<td>1.1$^{a}$</td>
<td>0.3$^{a}$</td>
</tr>
<tr>
<td>50</td>
<td>16.2$^{bc}$</td>
<td>3.3$^{a}$</td>
<td>88$^{a}$</td>
<td>8.7$^{a}$</td>
<td>66$^{a}$</td>
<td>9.8$^{a}$</td>
<td>2.1$^{a}$</td>
<td>1.4$^{a}$</td>
</tr>
<tr>
<td>75</td>
<td>22.3$^{a}$</td>
<td>3.9$^{a}$</td>
<td>98$^{a}$</td>
<td>12.7$^{a}$</td>
<td>92$^{a}$</td>
<td>12.3$^{a}$</td>
<td>3.2$^{a}$</td>
<td>3.8$^{a}$</td>
</tr>
<tr>
<td>100</td>
<td>33.4$^{c}$</td>
<td>4.1$^{a}$</td>
<td>115$^{a}$</td>
<td>13.8$^{a}$</td>
<td>110$^{a}$</td>
<td>15.4$^{a}$</td>
<td>4.4$^{a}$</td>
<td>8.1$^{a}$</td>
</tr>
</tbody>
</table>

The means with same letter do not have statistically significant difference at 5% probability level.


