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Evaluation of different spring rapeseed (*Brassica napus* L.) genotypes for shattering tolerance

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Abstract

In order to study tolerance to shattering, 5 spring rapeseed genotypes including Option 500, Sarigol, RGS003, Hyola 401 and Hyola 60 were evaluated in a split plot experiment with 4 replications during two years. The main plots were included 4 harvesting dates including H_1: harvesting at seed color changing of ninety percentage of pods in main stem (physiological maturity), H_2: harvesting 10 days after the first harvesting of each genotype, H_3: harvesting 20 days after the first harvesting of each genotype and H_4: harvesting 30 days after the first harvesting of each genotype. Sub plots were included 5 studied genotypes. The differences of seed yield of each genotype in different harvesting dates with compare to its seed yield in first harvesting date (H_1-H_i) were considered as indices of shattering. Combined analysis of variance based on split-plot experiment revealed significant mean squares for genotypes, harvesting dates and harvesting × genotypes interaction effects and also year and its interaction effects to each studied factors. In this study, Hyola 401 and Sarigol had 3994 and 3267 kg.ha^{-1}, respectively. Significant mean square of genotype × harvesting dates revealed different ranks of shattering of genotypes in different harvesting dates. Amount of seed yield shattering was increased in third and fourth harvesting dates. On the basis of shattering index, Hyola-60 and Hyola 401 were more tolerant to shattering and Sarigol as well as Option 500 were more susceptible to shattering.

Key words: *harvesting date, rapeseed, shattering.*

Introduction

Resistance to shatter is an important trait for rapeseed improvement in Iran and most of the worlds, because the crop ripens and is harvested under hot and frequently windy summer conditions (Agnihotri *et al*., 1990; Bruce *et al*., 2002; Banga *et al*., 2011). Seed loss is generally divided into two periods, shattering before and during harvesting (Prakash *et al*., 1990; Liu *et al*., 1994; chandler *et al*., 2005). Factors in the field that influence the level of shattering include weather conditions prior to and during harvesting (Tan *et al.* 2006). Contacts among pods and other canopy components during windy conditions have also been assumed to contribute to shattering in the field. Further more, insect-pest and disease damage can result in accelerated ripening and pod shattering. Pods of *Brassica* species shatter during maturity and harvest resulting in marked losses of seed. Moreover the shed seeds may remain viable during several years and germinate to produce volunteer plants, which represent weeds in the following crops (Kadkol *et al*., 1991; Morgan *et al*., 1998; Prakash *et al*., 1998; Peng-Fei *et al*., 2011). Shattering involves detachment of the pod valves, which include the seed, from the replum. It could take place in ripe standing crops under windy conditions due to contact from other plants and in windrows from the impact of harvest machinery. Shatter-resistant canola varieties could be direct headed avoiding the cost and problem of windrowing the crop (Meakin and Roberts, 1990). Kadkol *et al*. (1986a) showed the occurrence of an abscission layer, consisting thin walled and non-lignified cells, in the sutures of pods of shatter-susceptible *Brassica* and the absence of the abscission layer in the shatter-resistant *B. rapa* types, *yellow sarson* and *brown sarson.* Shatter resistance in *B. rapa* var. Brown Sarson and var. Yellow Sarson is determined by 2-3 genes in crosses

with shatter-susceptible cv. Torch (Kadkol *et al*., 1986b, c; Squires *et al*., 2003). As an indirect selection scheme for tolerance to field shattering some breeding programs have simply evaded windrowing and have practised direct heading of breeding trials and plots. Whereas the varieties from these programs have not been properly characterised for shatter resistance, there appears to be substantial improvement in field shatter tolerance in them relative to older varieties. Overseas research suggests that genetic variation for pod shatter resistance exists among *B napus* lines (Wen *et al.*, 2008). Recently, Peng-Fei *et al.* (2011) evaluated 68 lines of *B. napus* for shatter resistance using a 'ripping' method and showed that ripping force varies from 0.59N to 2.75N in different *B napus* accessions. This study further investigated that the inheritance of shatter resistance was governed by two genes, with heritability of 50%. This suggests that significant genetic gain can be made through conventional breeding in rapeseed. However, further improvement is required to avoid the need to windrow. Morgan *et al*. (2000) reported that shatter resistance in *B. napus* was recessive and mostly determined by additive genes. In their study, correlation of shatter resistance with important agronomic traits was low, suggesting that it would be feasible to introgress the shatter resistance trait into commercial breeding lines. They also noted the absence of genetic linkage of pod strength with other pod characters such as short/long pod or rect/ horizontal pod. This suggested that it should also be possible to enhance shatter resistance by combining these characters. The traditional approach to breed canola for such higher levels of shatter resistance is based on interspecific hybridisation or resynthesis of *B. napus* using shatter-resistant species in U's triangle. Some researchers (Agnihotri *et al*. 1990; Prakash and Chopra, 1990) attempted to transfer shatter resistance from *Raphanus* into *B. napus* using *Raphanobrassica* as the bridging material. This resulted in material with variable fertility. Interspecific hybridisation with *B. Rapa* var. *Brown Sarson* and var. *Yellow Sarson* has been promising in primary results but additional work is required to fully characterise and assess the shatter-resistant selections for meiotic stability and agronomic traits (Kadkol *et al*., 1991; Wei *et al*., 2008). In another study, lines derived from complex crosses made for development of yellow seeded canola showed better shatter resistance than standard *B. napus* varieties (Wang *et al*., 2007). An example of resynthesis of *B. napus* to create variation for shatter resistance is provided by Summers *et al*. (2003) who studied a line, DK142, derived from resynthesizing *B. napus* using *B. oleracea alboglabra and B. rapa chinensis*. The objectives of the present study were to assess the extent of genetic variability for shatter resistance in rapeseed cultivars and also association of shattering in different harvesting dates.

Materials and Methods

To study tolerance to shattering, 5 spring rapeseed (*Brassica napus* L.) genotypes including Option500, Sarigol, RGS003, Hyola401 and Hyola60 were grown in a split plot experiment with 4 replications at the Baykola Agriculture Research Station located in Neka, Iran (53Ú, 13^2 E longitude and $36^Ú$ 43^2 N latitude, 15 m above sea level) during two cropping seasons 2008-09 and 2009-10. The main plots were included 4 harvesting dates including H_1: harvesting at seed color changing of ninety percentage of pods in main stem, H_2:10 days after the first harvesting of each varieties, H_3:20 days after the first harvesting of each genotypes and H_4:30 days after the first harvesting of each genotypes. H_1 treatment was done by hand and then be windowed and other stages (H_2, H_3 and H_4) were harvested by harvesting machine. Sub plots were included 5 rapeseed genotypes. Each sub plot was consisted of four rows 5 m long and 30 cm apart and also plant to plant spacing on each row was 5 cm. Crop management factors like land preparation, crop rotation, fertilizer, and weed control were followed as recommended for local area. All the plant protection measures were adopted to make the crop free from insect-pests and diseases. The differences of seed yield of each genotypes in different harvesting dates with compare to its seed yield in first harvesting date (H_1-H_i) were considered as indices of shattering. Combined analysis of variance of split-plot experiment was done for seed yield. All statistical analyses were carried out using SAS software version 9 (SAS INSTITUTE INC, 2004).

Results and Discussions

Combined analysis of variance based on split-plot experiment for seed yield is presented in Table 1. Significant mean squares of genotypes reveled significant differences among the genotypes. Harvesting dates had also significant effects on seed yield. Significant harvesting × genotypes interaction effects mean squares for seed yield also indicated trend of seed yield variation of the genotypes were varied in the different harvesting dates.

Table 1: Combined analysis of variance, harvesting dtae and variety effects on seed yield

S.O.V	df	MS	F-test	p-value
Year(Y)	1	3874707.9	180.95**	0.000
R(Y)	6	209812.3	9.79**	0.000
Harvesting dates (H)	3	5971726.1	278.89**	0.000
Y ×H	3	93516.8	4.36*	0.018
Error1	18	21412.2	-	-
Variety(V)	4	4275328.9	273.53**	0.000
Y ×V	4	584610.7	37.40**	0.000
H ×V	12	180756.4	11.56**	0.000
Y ×H ×V	12	40578.3	2.59**	0.005
Error2	96	15629.9	-	-

* and **: Significant at 0.05 and 0.01 probability levels.
Y: year, R: replication, H: harvesting dates, V: veriety.

The means value of the genotypes in different harvesting dates are presented in Table 2. The genotypes Hyola401 and Sarigol had highest and least seed yield means value, respectively in different harvesting dates. All of the genotypes had also low means value in forth harvesting date. The differences of each harvesting date from first harvesting date which is indicating shattering index are presented in Table 3. The differences of seed yield of the genotypes in first and second harvesting dates (H_1-H_2) were varied from 119.8 to 289.92 kg.ha^{-1} in Hyola60 and Sarigol, respectively. On the basis of (H_1-H_2) index means value, Sarigol was more susceptible to shattering than the other genotypes and followed by Option500 and RGS003 were also susceptible to shattering. Earlier researchers (Wen *et al.* 2008; Peng-Fei *et al.* 2011) reported genetic variations for pod shatter resistance among *B napus* lines. Recently, Peng-Fei *et al.* (2011) evaluated 68 lines of *B. napus* for shatter resistance using a 'ripping' method and showed that ripping force varies from 0.59N to 2.75N in different *B napus* accessions. This study further investigated the inheritance of shatter resistance and reported that two genes control shatter resistance, with heritability of 50%. This suggests that significant genetic gain can be made through conventional breeding in rapeseed. The differences of seed yield of the genotypes in first and third harvesting dates (H_1-H_3) ranged from 245.36 to 670.32 kg.ha^{-1} in Hyola60 and Option500, respectively. High means value of (H_1-H_3) index were detected for Option500, RGS003 and Sarigol indicated of low tolerance to shattering of these genotypes. The differences of seed yield of the genotypes in first and forth harvesting dates (H_1-H_4) were more varied than (H_1-H_2) and (H_1-H_3) indices, therefore (H_1-H_4) index is more valuable index for screening the rapeseed genotypes for tolerance to shattering. The means value of (H_1-

H_4) index were varied from 488.79 to 1302.49 kg.ha^{-1} in Hyola60 and Sarigol, respectively. On the basis of (H_1-H_4) index, Option and Sarigol were more susceptible to shattering than the other genotypes. Percentage of seed yield shattering in compare to first harvesting date are presented in Table 4. Seed yield shattering in second harvesting date were varied from 3 to 8.87 percentage in Hyola401 and Sarigol, respectively but its means value in third harvesting date were varied from 7.07 to 20.05 in Hyola60 and Option500, respectively. In forth harvesting date, seed yield shattering was varied from 14.13 to 39.87 in Hyola60 and Option500, respectively.

Table 2: Seed yield (kg ha^{-1}) of rapeseed genotypes in different harvesting dates during 2008-10

Genotype	First harvesting date (H_1)	Second harvesting date (H_2)	Third harvesting date (H_3)	Forth harvesting date (H_4)
Hyola 401	3993.5	3873.7	3683.4	3158.1
Option 500	3342.7	3154.4	2672.4	2311.3
RGS 003	3561.2	3366.5	2990.9	2765.5
Sarigol	3267.1	2977.1	2736.1	1964.5
Hyola 60	3459.8	3294.7	3214.5	2971.1

H_1: harvesting at seed colour changing of ninety percentage of pods in main stem, H_2:10 days after the first harvesting of each genotypes, H_3: 20 days after the first harvesting of each genotypes and H_4: 30 days after the first harvesting of each genotypes.

Table 3: Least significant differences (LSD) test for average means value of seed yield (kg ha^{-1}) shattering of the rapeseed genotypes for two years (2008-10)

Genotype	H_1-H_2	H_1-H_3	H_1-H_4
Hyola 401	119.8	310.1**	835.4**
Option 500	188.3*	670.3**	1031.4**
RGS 003	194.6*	570.3**	795.7**
Sarigol	289.9**	530.9**	1302.5**
Hyola 60	165.1	245.4**	488.8**

* and **: Significant at 0.05 and 0.01 probability level

H_1: harvesting at seed colour changing of ninety percentage of pods in main stem, H_2:10 days after the first harvesting of each genotypes, H_3: 20 days after the first harvesting of each genotypes and H_4: 30 days after the first harvesting of each genotypes.

Table 4- Percentage (%) of seed yield shattering of the rapeseed genotypes for two years (2008-10)

Genotype	$[(H_1-H_2)/H_1]\times100$	$[(H_1-H_3)/H_1]\times100$	$[(H_1-H_4)/H_1]\times100$
Hyola 401	3.0	7.8	20.9
Option 500	5.6	20.1	30.9
RGS 003	5.5	16.0	22.3
Sarigol	8.9	16.3	39.9
Hyola 60	4.8	7.1	14.1

H_1: harvesting at seed colour changing of ninety percentage of pods in main stem, H_2:10 days after the first harvesting of each genotypes, H_3: 20 days after the first harvesting of each genotypes and H_4: 30 days after the first harvesting of each genotypes.

In general sufficient genetic variation for shattering resistance was detected among the genotypes. Although different methods were used for evaluation of shattering resistance but delaying in harvesting dates in compare to physiological maturity is also suitable way for detecting the shattering tolerance of rapeseed genotypes in natural condition. The differences of seed yield of the genotypes in first and forth harvesting dates (H_1-H_4) were more varied and also more valuable index for screening the rapeseed genotypes for shattering tolerance. Among the genotypes, Option 500 and Sarigol were more susceptible to shattering and Hyola 60 and Hyola 401 were relatively more tolerant to shattering.

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