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Effects of polymer cyclohexane application on lentil pod shatter in semi-arid region of Turkey

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Abstract

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Pod shattering in lentil which is vital plant of dry lands is a crucial feature for high yield. Selection of lentil variety is very important in order to reduce pod shatter. Some of lentil varieties are very productive; however, shattering loss decreases profitable yields. In this study, reduction of pod shatter in lentil varieties was investigated with application of polymer cyclohexane compounds. An experiment was conducted with split-split-plot experiment design with two lentil varieties (‘Firat-87’ and ‘Cagil’), two application time (podset and 15 days before harvest (DBH)) and three application doses (0, 0.5, 2 $l \cdot ha^{-1}$) as triplicate during two years. Effects of application time on podset were found statistically insignificant and application of 0.5 $l \cdot ha^{-1}$ dose was found effective for 15 DBH application time. As a result, 0.5 pod shatter polymer cyclohexane and 15 DBH was found as optimum doses and application time, respectively in order to reduce pod shatter loss by nearly 1% for semiarid region of Turkey.

Keywords: lentil shedding; polymer application; pod dehiscence; lentil yield loss

Lentil (*Lens culinaris* L.) is a cool-season crop with moderate resistance to high temperature and drought. About 75% of lentil production is done by the developing world. The three largest lentil producers are Canada, India, and Turkey accounting for 68% of global lentil production in 2002–06 (McVicar et al. 2010; Nleya et al. 2016). Lentil is a rich source of protein and other micronutrients (Fe, Zn, and β-carotene) for human consumption, and the straw is a valued animal feed (Erskine et al. 2016). However, pod shatter is an important yield loss parameter for lentil in the world. As estimated by Sosnowski et al. (1998), seed losses caused by shedding, reach up to about 20% of the crop. According to a study by Sosnowski et al. (1993) on lentil grown in Slovakia, seed losses with mechanical multi-stage harvesting were on the level of 14.2%. In regions of West Asia and North Africa reported lentil seed losses reach even up to 55% (Sidahmed, Jaber 2004).

Pod shatter is caused by the loss of cellular cohesion of pod of lentil plant, primarily degradation of the middle lamella which occurs as a result of raised activity of hydrolytic enzyme, inducing to the cell separation process (Meakin, Roberts 1990). Pod shatter may happen prior to harvest on account of adverse weather conditions or at the time of harvest due to impact of harvest machines. Pods shatter of lentil not only decreases yield, but also causes growth of competitive plants in subsequent crops (Gulden et al. 2003). Factors affecting pod shatter may contain biotic and abiotic stress factors (Kadkol et al. 1986; Summers et al. 2003). The major abiotic limiting factors to lentil production are low-moisture availability, high-temperature stress in spring and, at high elevations, cold temperatures in winter (Erskine et al. 2016).

Pod shattering can be reduced by uniformly choosing the early ripening and shattering resistant species (Nleya et al. 2016), selection of lentil spe-

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cies with thick replum (Hu et al. 2015), providing plant nutrients that restrict lentil growth in arid areas (Erskine et al 2016), increasing the water holding capacities of soils by different soil management techniques (McVicar et al. 2010; Kandel et al. 2013; Muehlbauer et al. 2016) and application of chemicals which decrease pod (siliqua) dehiscence (Szot et al. 1996; Szot et al. 2005). In this study, effects of polymer cyclohexane application rate on lentil pod shatter were investigated at semi-arid region of Turkey.

MATERIAL AND METHODS

Properties of lentil varieties. Two different lentil varieties ('Firat-87' and 'Cagil') which are widely grown in Harran Plain were sown during February, 2013 and 2014. 'Firat-87' variety is 40–50 cm in height and has red color cotyledons. It is resistant to cold and water stress. Thousand kernel weight of the variety is 35–40 g and yield is 1,750–2,250 kg·ha^{-1}. Cagil variety is 26–33 cm in height and has red color cotyledon as well. It is resistant to cold and water stress. Thousand kernel weight of this variety is 31–40 g and yield is 1,650–2,370 kg·ha^{-1}. (Anonymous 2016). Both species are classified as Persian lentil varieties (Nleya et al. 2016).

Soil characteristics and climate data. Soil of experiment plots had alkaline and calcareous properties with low organic matter content. Soil texture was heavy and clay content was 55% (Karagöktas et al. 2014). Climate data of experiment station was attained from General Directorate of Meteorology of Turkey (Fig. 1).

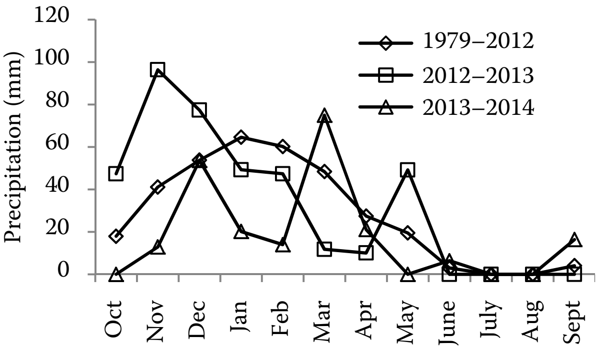

Fig. 1. Yearly precipitation of experiment station

Experimental design. Experiment was conducted in order to determine effects of doses (three application doses (0, 0.5 and 2 l·ha^{-1}) on lentil pod shatter using split-split-plot experiment design with two red lentil varieties ('Firat-87' and 'Cagil'), two application time (podset and 15 days before harvest (DBH)) and as triplicate during the year, 2013 and 2014, separately. Sowing of plots was organized with 120 kg·ha^{-1} lentils in 0.80 m × 5 m = 4 m^2 plot with 20 cm row-space and 5 cm distance between plants in March. Required fertilizer need of lentil applied as 40 kg·ha^{-1} N and 70 kg·ha^{-1} P_2O_5 at sowing.

Polymer cyclohexane application. Polymer cyclohexane which contains 450 g·l^{-1} Carboxyle Sytren Butadin Copolymer and 100 g·l^{-1} Alkylfenyl Hydroxy polyoxyetylene was applied at two different stages of plant growth as 0 (Control), 0.5 and 2 l·ha^{-1} with hand fluid sprayer until soaking lentil plants. Application doses were determined according to the cost of chemicals.

Plot harvest and pod shatter loss determination. Application plots were harvested with plot harvester and pod shatter ratio for each plot was determined on the basis of randomized 625 cm^2 area with 25 × 25 cm quadrate. Harvest yield was determined according to the harvest done by plot harvester and pod shatter was measured according to the count of shattered pods of lentil for each plot. Loss percent was calculated using the following Eq. (1):

$$Loss(\%) = \frac{podshatter}{podshatter + harvested\ yield} \times 100 \qquad (1)$$

Statistical analyses. Statistical analyses were performed using SPSS 17 software program with split-split-plot experiment design with LSD test to determine main effects of year, application time and lentil variety according to application doses. Experiment parameters which are variety, year and application time were performed as separate experiment with statistics program to reveal effects of doses.

RESULT AND DISCUSSIONS

Effects of doses on lentil yield, pod shatter and loss percent

Mean effects of two years of polymer cyclohexane application on lentil harvest yield (HY) were found statistically insignificant (Table 1). While lentil HY increased with 0.5 l·ha^{-1} polymer cyclohexane application, it and decreased with 2 l·ha^{-1} application dose.

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Table 1. Pairwise comparison of effects of polymer cyclohexane doses on harvest yield, pod shatter and loss percent

Parameter	Means	Doses (l·ha^{-1})		Mean difference (i–j)			LSD(0.05)		
		(i)**	(j)	HY	PS	L	HY	PS	L
HY (kg·ha^{-1})	1,134	0	0.5	–66.3	7.75*	0.951*	134.1	5.18	0.829
PS (kg·ha^{-1})	85.7		2	28.5	10.3*	0.801	134.1	5.18	0.829
L (%)	7.31								
HY (kg·ha^{-1})	1,201	0.5	0	66.3	–7.75*	–0.951*	134.1	5.18	0.829
PS (kg·ha^{-1})	77.9		2	94.9	2.54	–0.150	134.1	5.18	0.829
L (%)	6.36								
HY (kg·ha^{-1})	1,106	2	0	–28.5	–10.3*	–0.801	134.1	5.18	0.829
PS (kg·ha^{-1})	75.4		0.5	–94.9	–2.54	0.150	134.1	5.18	0.829
L (%)	6.51								

*significant at the 0.05 level; **means for respective *i* application doses without considering year, lentil varieties, and application time; HY – harvest yield, PS – pod shatter, L – loss percent

Effects of polymer cyclohexane application on lentil pod shatter (PS) and loss percent (*L*) were statistically significant (Table 1). Lentil PS was reduced with increased application doses. However, 0.5 and 2 l·ha^{-1} doses behaved statistically similar. Lentil loss percent decreased with 0.5 l·ha^{-1} dose as compared with the control (0 l·ha^{-1}) application, however, 2 l·ha^{-1} application doses were found statistically insignificant as compared with the 0.5 l·ha^{-1} dose.

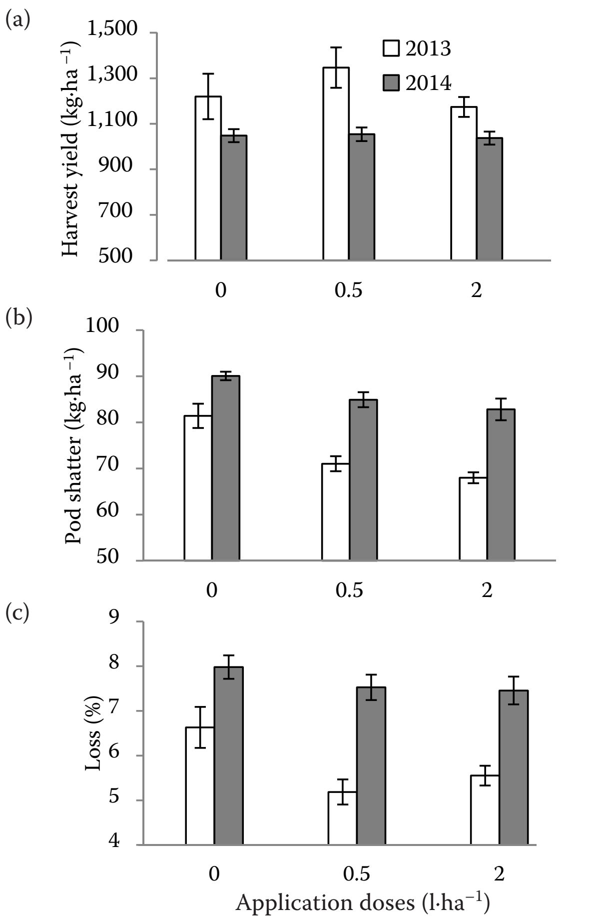

Fig. 2. Effects of application doses on (a) years' yield, (b) pod shatter and (c) loss percent

Application of polymer cyclohexane and some other starches on lentil and pod resistance against dehiscence were studied by Szot et al. (2005). Researchers revealed that polymer cyclohexane and potato starch had positive effect on pod shatter resistance and force required for pod dehiscence increased from 0.83 to 1.21 Newton (N) on polymer cyclohexane application and from 0.97 to 1.11 N on potato starch application. As a results application of polymer cyclohexane increased the pod shatter resistance. However, effects of polymer cyclohexane on pod shatter act distinctively according to the locations and crops. Burton et al. (2005) revealed that polymer cyclohexane application on canola had been ineffective on pod shatter reduction, but for one of the locations, harvest time was extended by polymer application.

Effects of doses during application years

Effects of polymer cyclohexane application on lentil yield; pod shatter and loss percent were different in different years and were found statistically significant ($LSD_{0.05}$) (Table 2). This difference resulted from the discrete precipitation and variable temperatures (Fig. 1). First year of lentil yield was higher than the second year (Fig. 2a). However, first year lentil pod shatter was lower than the second year application (Fig. 2b). Higher lentil yield re-

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Table 2. Pairwise comparison of effects of years on harvest yield, pod shatter and loss percent

Parameter	Means	Doses (l·ha^{-1})		Mean difference (i–j)			LSD(0.05)		
		(i)**	(j)	HY	PS	L	HY	PS	L
HY (kg·ha–1)	1,247								
PS (kg·ha–1)	73.4	2013	2014	200.1*	–12.5*	–1.867*	20.85	1.424	0.147
L (%)	5.79								
HY (kg·ha–1)	1047								
PS (kg·ha–1)	85.9	2014	2013	–200.1*	12.5*	1.867*	20.85	1.424	0.147
L (%)	7.65								

for abbreviations explanation see Table 1

sulted from higher precipitation in 2013 and lower pod shatter resulted from precipitation which took place at pod ripening stage (Fig. 1). Effects of application doses on loss percent were different during two years. Loss percent decreased with 0.5 l·ha^{-1} application dose, however, it did not change with 2 l·ha^{-1} application dose and behaved similarly (Fig. 2c). Different weather patterns, especially temperature and rainfall in each year could be essential factors affecting pod shattering.

Nleya et al. (2016) stated that in all the regions where lentil is grown, seed yield can be optimized by timing the seeding so that crop development and growth occurs when climatic variables such as rainfall and temperature are favorable. Similarly, Zhang and Bellaloui (2012) pointed out that relatively lower temperatures and abundant rainfall during the late growing season can cause delayed shattering in April-planted MG IV soybeans. Hot weather and low precipitation affects lentil yield and physiology of lentil plant which causes pod shatter (Erskine et al. 2016). As lentil plants are grown in arid and semi-arid regions, plants utilize all the available water until maturity of seed and due to reduction in available water, drying of plant may cause dehiscence of pods. As a consequence, the seed maturing process and the period thereafter cause heat-stress and results in pod shatter.

Effects of doses on lentil varieties

Polymer cyclohexane was examined at three application doses and mean effects of polymer cyclohexane on two red lentil varieties were found statistically significant ($LSD_{0.05}$) for harvest yield (HY), pod shatter (PS) and loss percentage (L) respectively (Table 3).

Individual effects of application doses on harvest yield of ‘Firat-87’ lentil variety was statistically insignificant; however, the highest application doses (2 l·ha^{-1}) decreased the harvest yield of Cagil variety and found statistically significant (Fig. 3a).

Individual effects of polymer cyclohexane doses on pod shatter and loss percent of two red lentil varieties’ was found statistically significant. Pod shatter of two lentil varieties decreased with 0.5 l·ha^{-1} doses; however, pod shatter reduction was not observed with increasing application dose (2 l·ha^{-1}) (Fig. 3b). Similarly, loss percent of two lentil varieties was decreased with 0.5 l·ha^{-1} polymer application and was not affected as compared with the 2 l·ha^{-1} dose (Fig. 3c).

Previous studies indicated that there were significant differences in shattering resistance among different varieties (Chorąży 1988; Carper 1995) and the characteristic of seed shattering is genetically controlled by different features (Dębski, Dębska 1989; Carper 1995; Coboru 1999).

Effects of doses on polymer application time

Polymer cyclohexane were examined as three application doses and mean effects of polymer cyclohexane on two application time were found statistically significant ($LSD_{0.05}$) respect HY, PS and L (Table 4).

Individual effects of polymer cyclohexane doses on harvest yield for two application times were found statistically insignificant for podset application and significant for 15 DBH application time (Fig. 4a). Lentil yield haven’t changed with podset application times. However, decreased with 2 l·ha^{-1} application doses at 15 DBH application time.

Individual effects of polymer cyclohexane doses on pod shatter and loss percent during two application times were found statistically significant for 15 DBH application time and insignificant for podset application time. Pod shatter and loss percent values were

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Table 3. Pairwise comparison of effects of **used varieties** on harvest yield, pod shatter and loss percent

Parameters	Means	Doses (l/ha)		Mean difference (i–j)			$LSD_{(0.05)}$		
		(i)**	(j)	HY	PS	L	HY	PS	L
HY (kg·ha^{-1})	1,244								
PS (kg·ha^{-1})	78.17	Cagil	Firat-87	195.3*	–3.056*	–1.311*	20.85	1.424	0.147
L (%)	6.07								
HY (kg·ha^{-1})	1,049								
PS (kg·ha^{-1})	81.22	Firat-87	Cagil	–195.3*	3.056*	1.311*	20.85	1.424	0.147
L (%)	7.38								

for abbreviations explanation see Table 1

Table 4. Pairwise comparison of effects of application time on harvest yield and pod shatter and loss percent

Parameters	Means	Doses (l·ha^{-1})		Mean difference (i–j)			$LSD_{(0.05)}$		
		(i)**	(j)	HY	PS	L	HY	PS	L
HY (kg·ha^{-1})	1172								
PS (kg·ha^{-1})	80.4	podset	15 DBH	50.28*	1.44*	0.134*	20.85	1.424	0.147
L (%)	6.79								
HY (kg·ha^{-1})	1122			–195.3*	3.056*	1.311*			
PS (kg·ha^{-1})	79.0	15 DBH	podset	–50.28*	–1.44*	–0.134*	20.85	1.424	0.147
L (%)	6.66								

for abbreviations explanation see Table 1

not affected by application doses with podset application; however, both parameters were decreased by application doses at 15 DBH application time (Fig. 4b,c). Pod shatter of lentil decreased with increasing application doses at 15 DBH application and loss percent value decreased with 0.5 l·ha^{-1} application dose at 15 DBH application time and 0.5 l·ha^{-1} dose was not affected as compared with the 2 l·ha^{-1} application dose at 15 DBH application time (Fig. 4b,c).

Application time of polymer is recommended by the product company stated as 15 days before harvest (Anonymous 2017) and the results were con-

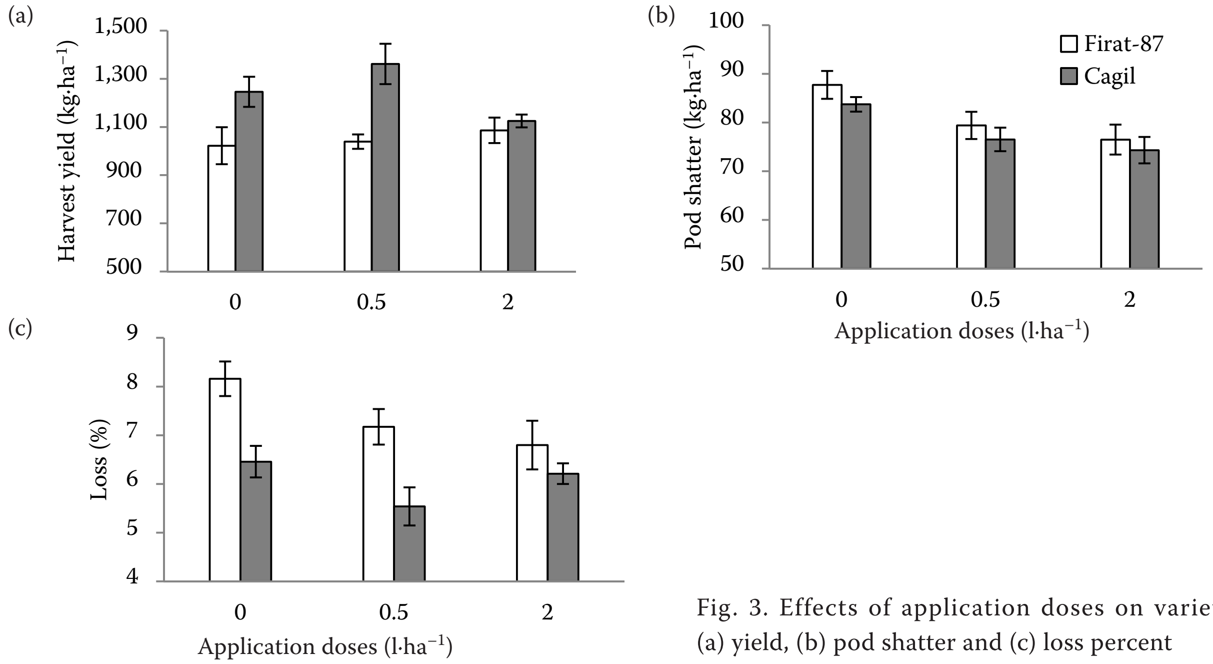

Fig. 3. Effects of application doses on varieties (a) yield, (b) pod shatter and (c) loss percent

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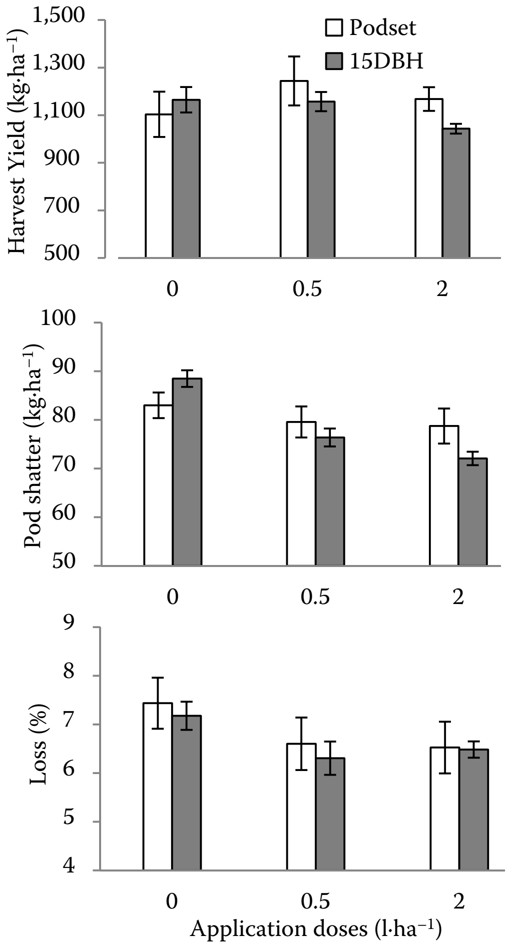

Fig. 4. Effects of application doses on application times' (a) yield, (b) pod shatter and(c) loss percent

firmed by this study as compared with the podset application. We assume that effects of polymer cyclohexane applied at podset were hindered because of moisture loss of pods, decomposition of polymer by precipitations or sun. As a result, 15 DBH polymer cyclohexane application was effective for lentil plant to reduce pod shatter.

CONCLUSION

Effects of polymer cyclohexane application on red lentil varieties were statistically insignificant for harvest yield, significant for pod shatter and loss percent. Response of two varieties was similar for pod shatter and loss percent. Effective application dose was 0.5 $l \cdot ha^{-1}$ for both the lentil varieties as compared with 2 $l \cdot ha^{-1}$ dose. In addition, effects of podset application time were found to be statistically insignificant and application of 0.5 $l \cdot ha^{-1}$ polymer cyclohexane dose was found to be effective for 15 DBH application time. Lastly, precipitation during podset ripening time increased the effect of polymer cyclohexane and reduced the pod shatter and loss percent.

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