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Original scientific paper

EFFECTS OF GENOTYPE AND MECHANICAL DAMAGE DURING HARVEST ON FIELD PEA (*Pisum sativum* L.) SEED QUALITY

Đura KARAGIĆ, Slobodan KATIĆ, Aleksandar MIKIĆ, Milka VUJAKOVIĆ, Dragan MILIĆ, Sanja VASILJEVIĆ, Branko MILOŠEVIĆ

Institute of Field and Vegetable Crops, Novi Sad, Serbia

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Three field pea genotypes (NS Junior, Jezero and Javor) have been assessed for effects of genotype and mechanical damage during harvest on most important parameters of the physical quality of seed. Four harvest treatments were examined (hand harvest, mechanized harvest at 500, 650 and 800 rpm). After harvest, purity of harvested seed and percentages of seeds damaged by insects, seeds with cracked seed coat and broken seeds

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Corresponding author: Đura Karagić, Institute of Field and Vegetable Crops, Maksim Gorki St. 30, 21000 Novi Sad, Serbia, 064/82 05 745, djura.karagic@ifvcns.ns.ac.rs

were analyzed. Highest contents of seeds with damaged seed coat (9.0%) and broken seeds (11.3%) were found in Javor, the genotype with largest seeds. After seed processing, seed vigor, germination, proportion of atypical seedlings and 1000-seed weight were determined. Lowest values of seed vigor and germination (79.8% and 84.9%, respectively) and the largest proportion of atypical seedlings (11.4%) were found in the genotype Javor. Highly significant correlations were found between seed vigor, germination and atypical seedlings on one side and 1000-seed weight on the other (r = - 0.53**, r = - 0.51**, and r = 0.60**, respectively). Damages that increase the portion of atypical seedlings have the largest impact on the quality of pea seeds. This characteristic is determined by the genotype, which should be kept in mind when defining objectives of field pea breeding programs.

Key words: germination, field pea, seed coat, 1000-seed weight

INTRODUCTION

Most important factors that affect the physical quality of seed are agroecological conditions during filling and maturation stages, seed moisture at harvest, mechanical damage of seed during harvest and damages by diseases and pests (MATTHEWS, 1973; FOUGEREUX *et al.*, 1997; KANIUCZAK, 2005; MILOSEVIC *et al.*, 2007; LYSIAK, 2007).

Mechanical damage of seed during harvest results from contact with working parts of seed harvesters, when seed coat breaks and/or cotyledons are severed from the hypocotyl. Mechanical damage of seed cannot be completely avoided (BLANCHARD, 1990; KARAGIĆ *et al.*, 2002).

In a previous study, KARAGIĆ *et al.* (2008) had found differences in seed quality of field pea depending on the genotype, but sources of variations had not been determined. According to this study, seed germination of genotypes with largest seeds was lower by about 10% on average. Pea cultivars with large seeds are prone to mechanical damage during harvest (BIDDLE, 1981). Seed coat cracking before harvest, at the end of seed filling stage, has been observed in large-seeded genotypes (MOISE *et al.,* 2005; MILOŠEVIĆ *et al.,* 2010).

The objectives of this study were to quantify the extent of mechanical damage of pea seeds during harvest and to determine the magnitude in differences in seed damage among different pea genotypes.

MATERIAL AND METHODS

A field experiment was conducted during the 2007 and 2008 growing seasons at the experiment field of Institute of Field and Vegetable Crops, Novi Sad, northern Serbia (45°20’ N, 19°51’ E, 80 m above sea level). The area has a continental semiarid to semihumid climate, a mean annual air temperature of 11.0°C, an annual precipitation sum of 617 mm, and an uneven distribution of precipitation. The experiment was established in a loamy soil with pH 7.0, organic matter content of 2.82%, $N\text{-}NO_3$ of 10.7 ppm, P_2O_5 of 30.8 ppm and K_2O of 26.6 ppm (0 to 30 cm depth). The previous crop was winter wheat, whose straw was baled and removed after harvest.

A two-factorial trial was organized in a system of random blocks, in four replications. The first factor, genotype, had 3 variants: NS Junior (G_1), Jezero (G_2) and Javor (G_3). These genotypes have been developed at Institute of Field and Vegetable Crops. The selected genotypes were typical representatives of three types of field pea cultivars, which significantly differed in their morphology. Genotype G_1 was characterized by indeterminate growth and normal leaf type, G_2 had determinate growth and afila leaf type and G_3 had determinate growth and normal leaf type.

Additionally, the studied genotypes differed significantly in seed size. The 1000-seed weight in G_1, G_2 and G_3 was 150 g, 230 g and 260 g, respectively. The second factor (rpm of combine drum) had 4 treatments: manual harvest (H_0), 500 rpm (H_1), 650 rpm (H_2) and 800 rpm (H_3). Plot size was 150 m^2 (5 x 30 m), except in the treatment with manual harvest, where it was 25 m^2 (5 x 5 m). The treatments were separated by a 2 m buffer zone.

In both years, 2007 and 2008, planting was done in the first 10 days of March, at the row distance of 12.5 cm. All cultivation practices typically used in field pea seed production were applied. Harvest was performed in the stage of full maturity. Seed moisture at the time of harvest was 13-14%. After harvest, average samples of 5 kg were measured for the proportion of pure seeds (PS-%), insect-damaged seeds (ID-%), seed coat-damaged seeds (SC-%) and broken seeds (BS-%). Harvested seed was processed in a laboratory thresher, and the quality of the processed seeds was assessed by standard methods, according to ISTA Rules (1999), using average sample of 1000 g. The following quality parameters were assessed: seed vigor (V-%), germination (G-%), the proportion of atypical seedlings (AS-%), the sum of normal and atypical seedlings (GAS-%) and 1000-seed weight (SW-%).

The obtained results were subjected to the analysis of variance (ANOVA). Treatment mean differences were calculated by the least significant difference (LSD) test at 0.05 probability level. Statistical analyses were performed by MSTAT-C software (MSTAT-C, 1988). Because the analyses of variance for seed quality indicated no treatment x experimental time interaction, the values are reported as means of the two growing seasons.

Correlation coefficients were computed between the tested parameters, the number of pairs was n = 48, correlation significance was tested by the t-test.

RESULTS AND DISCUSSION

Differences in harvested seed purity between G_1 and G_2 were not significant (Table 1). However, the purity in G_3 was significantly lower, by 11.0% and 6.8%, respectively. As expected, the highest purity was obtained by hand harvest, 94.3%. The effect of mechanized harvest on seed purity was significant for all treatments. The purity in H_1 and H_2 was lower by 15.3% and 20.1%, respectively, compared with the value in H_0. The lowest purity was achieved in H_3, 66.5%.

Impurities in the harvested seed consisted of seeds damaged by insects, seeds with cracked seed coat and broken seeds. Differences in the portions of seeds damaged by insects were not significant, both among the genotypes and among the different harvest treatments.

The effect of the genotype on the proportion of SC was significant (Table 1). The smallest portion of cracked seeds was in G_1, 5.3%. Compared with G_1, the portions of SC in G_2 and G_3 were higher by 34.0% and 69.8%, respectively.

Table 1. Average contents of pure seed without visible damages (PS-%), seeds with cracked seed coat (SC-%), seeds damaged by insects (ID-%) and broken seeds (BS-%) in harvested seed of field pea, depending on genotype and harvester drum speed, for the period 2007-2008

Harvester drum speed	Genotype	PS	ID	SC	BS
H_0	G_1	94.9	5.1	0.0	0.0
	G_2	94.2	5.8	0.1	0.0
	G_3	93.9	4.8	1.3	0.0
	Mean	94.3	5.3	0.4	0.0
H_1	G_1	82.9	3.9	6.1	7.1
	G_2	81.3	5.1	6.6	7.0
	G_3	75.5	5.1	8.1	11.3
	Mean	79.9	4.7	6.9	8.5
H_2	G_1	79.8	6.0	6.6	7.6
	G_2	76.9	4.8	8.9	9.4
	G_3	69.2	5.3	11.4	14.1
	Mean	75.3	5.4	9.0	10.4
H_3	G_1	73.5	5.6	8.3	12.6
	G_2	66.3	4.4	13.0	16.3
	G_3	59.7	5.2	15.3	19.8
	Mean	66.5	5.1	12.2	16.2
Mean	G_1	82.8	5.2	5.3	6.8
	G_2	79.7	5.0	7.1	8.2
	G_3	74.6	5.1	9.0	11.3
	Mean	79.0	5.1	7.1	8.8
LSD 0.05	*for G*	4.68	0.42	1.33	2.12
LSD 0.05	*for H*	6.22	0.56	1.82	3.36
LSD 0.05	*for GxH*	12.06	1.14	3.68	8.85

Cracks in the seed coat cause the loss of a basic function of the seed coat, the control of water absorption rate during seed swelling and germination (DEL VALLE *et al*., 1992). In the process of seed cleaninig is not possible to completely remove the seeds with cracked seed coat, which makes the sensitivity of the seed coat to cracking a highly unfavorable property of field pea genotypes (ARMSTRONG, 1995).

The portion of SC in the treatment with hand harvest amounted to 0.4% on average. The differences found among the genotypes were on the verge of significance. In fact, no seed coat damage was observed in G_1, the damage was in traces in G_2, and it amounted to 1.3% in G_3. In the treatment H_0, seed cracking occurred before harvest, during the seed filling stage.

In the case of large-seeded genotypes, seed coat cracking has been observed before harvest, at the end of the seed filling stage. The seed coat matures earlier than cotyledons and it loses elasticity. Abundant rainfall during that time will increase soil moisture, cotyledons will continue to grow and the seed coat will inevitably crack (DOBRZANSKI and SZOT, 1997; MOISE *et al.,* 2005). This imperfection of the seed coat is an avenue for pathogenic organisms and adverse environmental factors to affect seed quality (YAKLICH and BARLA-SZABO, 1993). According to FOUGEREUX *et al.* (1997), however, water stress during seed filling decreases seed yield, but the effect on seed quality is not significant.

Effect of mechanized harvest on SC was significant in all treatments, the increased drum speed tending to increase the portion of SC. According to YAKLICH and BARLEUX-SZABÓ (1993) the seeds with a cracked seed coat were larger, on average, than the seeds with a normal seed coat. In our study, however, there was no significant correlation between the portion of SC and 1000-seed weight (Table 3).

The portion of broken seeds after harvest was significantly higher in G_3 than in G_1 and G_2 by 66.2% and 37.8%, respectively. Mechanized harvest significantly increases the portion of broken seeds in all treatments. A significant interaction was found between the G_3H_3 and G_3H_2 treatments.

The effect of genotype on seed vigor was significant only in G_3, where V was lower by 19.3% compared with the other genotypes. In the treatment of hand harvest (H_0), the average seed vigor was 92.1%, varying from 97.3% in G_1 to 84.7% in G_3 (Table 2). The increased drum speed in treatments H_1 and H_2 did not cause significant differences in relation to H_0. However, treatment H_3 significantly lowered the energy of germination, to 88.0%. Highly significant negative correlations were found between seed vigor on one side and the portions of seeds with cracked seed coats, broken seeds and 1000-seed weight on the other (Table 3).

Seed germination in G_1 and G_2 was identical to their seed vigor (Table 2). Significantly lower seed germination was noted in the genotype G_3, 84.9%. KARAGIĆ et al. (2002) found domestic field pea varieties to have the average seed vigor of 85.5% and the average viability of 88.0%, varying from 81 to 95%.

The average seed germination in the treatment with hand harvest was 93.7%. The increased drum speed in H_3 significantly reduced the germination to 89.7%. Correlations between seed germination on one side and the portion of seeds with the cracked seed coat and broken seeds were highly significant, r = -0.52**, and r = -0.55**, respectively (Table 3). Differences in seed germination between H_1 and H_2 were nonsignificant. Also, there were no significant differences in seed germination between these two treatments and hand harvest. However, seed germination in the G_3 treatment and manual harvest, in which there was no mechanical damage, was 89.7%. This value was significantly lower than those in G_1 and G_2 (97.3% and 94.2%, respectively). The lower germination rate in G_3 can only be due to the genotype. Highly significant negative correlations were found between germination on one side and the portion of atypical seedlings and 1000-seed weight on the other, r= -0.98**and r= -0.51** (Table 3).

Table 2. Average vigor (V-%), germination (G-%), abnormal seedlings (AS-%), sum of normal and abnormal seedlings (GAS-%), and 1000-seed weight (SW-g) in processed field pea seed, depending on genotype and harvester drum speed, for period 2007-2008

Harvester drum speed	Genotype	V	G	AS	GAS	SW
H_0	G_1	97.3	97.3	0.3	97.6	157.2
	G_2	94.2	94.2	3.6	97.9	248.1
	G_3	84.7	89.7	8.3	97.9	261.9
	Mean	92.1	93.7	4.0	97.8	222.4
H_1	G_1	94.6	94.6	1.6	96.2	151.7
	G_2	96.0	96.0	2.8	98.8	249.4
	G_3	78.5	85.3	9.9	95.3	256.2
	Mean	89.7	92.0	4.8	96.7	219.1
H_2	G_1	95.1	95.1	1.3	96.3	153.8
	G_2	96.0	96.0	1.8	97.8	248.5
	G_3	80.2	83.8	11.6	95.4	252.3
	Mean	90.4	91.6	4.9	96.5	218.2
H_3	G_1	93.7	93.7	2.8	96.4	155.7
	G_2	94.5	94.5	2.8	97.3	246.7
	G_3	75.9	81.0	15.8	96.8	256.6
	Mean	88.0	89.7	7.1	96.8	219.6
Mean	G_1	95.2	95.2	1.5	96.6	154.8
	G_2	95.2	95.2	2.7	97.9	248.2
	G_3	79.8	84.9	11.4	96.3	256.8
	Mean	90.1	91.8	5.2	97.0	219.8
LSD 0.05	*for G*	2.36	1.86	1.07	1.43	2.65
LSD 0.05	*for H*	3.82	3.05	1.68	1.97	4.31
LSD 0.05	*for GxH*	6.73	5.28	2.90	2.33	7.45

The average portion of atypical seedlings was 5.2%, with a high variation of the actual values from 0.3% to 15.8% (Table 2). The coefficient of variation for atypical seedlings was 39.84%. The lowest portion of atypical seedlings was 1.5%, in genotype G_1. A significantly higher percentage of atypical seedlings was in genotype G_2, 2.7%. The highest number of atypical seedlings was in genotype G_3, 11.4%, significantly higher than in the previous two genotypes. There were no significant differences in the portion of atypical seedlings in manual harvest on one side (4.0%) and mechanized harvests H_1 and H_2 on the other. A significant increase of atypical seedlings was registered in H_3 (7.1%).

When impact of mechanical damage during harvest is not considered (treatment H_0), the lowest portion of atypical seedlings was in genotype G_1, 0.3%, while significantly higher portions of atypical seedlings were in G_2 and G_3 (3.6% and 8.3%, respectively).

Table 3. Correlation coefficients for the portions of pure seed (PS), seeds with cracked seed coat (SC), seeds damaged by insects (ID), broken seeds (BS), vigor (V), germination (G), abnormal seedlings (AS), sum of normal and abnormal seedlings (GAS), and 1000-seed weight (SW) depending on genotype and harvester drum speed, for period 2007-2008

	ID	SC	BS	V	G	AS	GAS	SW
PS	ns	-0.99**	-0.99**	0.47**	0.55**	-0.51**	0.45**	ns
ID		ns	ns	ns	ns	ns	ns	ns
SC			0.98**	-0.44**	-0.52**	0.49**	-0.40**	ns
BS				-0.47**	-0.55**	0.50**	-0.47**	ns
V					0.99**	-0.97**	0.52**	-0.53**
G						-0.98**	0.55**	-0.51**
AS							-0.38**	0.60**
GAS								ns

ns, *, ** - insignificant and significant at the 0.05 and 0.01 levels of probability, respectively

The increase of mechanical impact of seed harvest resulted in an almost linear increase in the portion of atypical seedlings only in treatment G_3. The percentages of atypical seedlings in H_1, H_2 and H_3 were 9.9%, 11.6% and 15.8%, respectively (Table 2). The investigation of MIHAILOVIĆ *et al.* (2003) indicated that the average content of atypical seedlings in local field pea cultivars was 4.1%, the actual values varying from 1.1% in Pionir to 5.7% in Javor.

The average sum of seed germination and the portion of atypical seedlings was 96.95% (Table 2). No significant difference was found in the sum of germination and atypical seedlings either among the genotypes or between different methods and speeds of harvest. This allows to indirectly estimate the type and intensity of damage of field pea seed during harvest. Mechanical damage of seed during harvest does not cause severing of cotyledons from the embryo. The dominant form of damage is cracking of seed coat. These cracks result in the loss of the primary role of seed coat and this is the regulation of the rate of water absorption during germination (POWELL and MATTHEWS, 1979; SHEREENA and NEBEESA, 2005; MILOŠEVIĆ *et al.,* 2010a).

The average 1000-seed weight was 219.8 g (Table 2). The lowest weight was in G_1, 154.8 g, the highest in G_3, 256.8 g. The weight of 1000 seeds is determined by the genotype, and there were no significant differences among the different harvest treatments. Our results are in agreement with those of MIHAILOVIĆ *et al*. (2003). In addition to highly significant negative correlations with seed vigor and germination, 1000-seed weight was positively correlated with the portion of atypical seedlings r = 0.60** (Table 3). A number of authors reported a marked proclivity of genotypes with large seeds to damage during harvest (BIDLLE 1981;

BLANCHARD, 1990). Our results indicated that there existed differences among the genotypes with large seeds in the rate of damage during harvest. Content of atypical seedlings was the major source of variation in seed quality of field pea. In other words, damages that increase the portion of atypical seedlings have the largest impact on the quality of pea seeds. This characteristic is determined by the genotype, which should be kept in mind when defining objectives of field pea breeding programs.

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UTICAJ GENOTIPA I MEHANIČKIH OŠTEĆENJA TOKOM ŽETVE NA KVALITET SEMENA PROTEINSKOG GRAŠKA (*Pisum sativum* L.)

Đura KARAGIĆ, Slobodan KATIĆ, Aleksandar MIKIĆ, Milka VUJAKOVIĆ, Dragan MILIĆ, Sanja VASILJEVIĆ, Branko MILOŠEVIĆ

Institut za ratarstvo i povrtarstvo, Novi Sad

I z v o d

Ispitivan je uticaj genotipa i mehaničkih oštećenja tokom žetve na najznačajnije parametre fizičkog kvaliteta semena proteinskog graška kod tri genotipa (NS Junior, Jezero i Javor), pri četiri tretmana žetve (ručna žetva, mehanizovana žetva pri 500, 650 i 800 ^{o}/min). Utvrđena je čistoća naturalnog semena posle žetve, udeo semena oštećenih od insekata, semena sa napuklom semenjačom i polomljenih semena. Najviši sadržaj semena sa oštećenom semenjačom (9.0%) i polomljnog semena (11.3%) utvrđen je kod genotipa sa najkrupnijim semenom, Javora. Nakon dorade semena utvrđeni su energija klijanja, klijavost, udeo atipičnih klijanaca i masa 1000 semena. Najnižu energiju klijanja (79.8%) i klijavost (84.9%) i najveći udeo atipičnih ponika (11.4%) imao je genotip Javor. Takođe, pucanje semenjače pre žetve najizraženije je kod Javora, koji je na tretmanu ručne žetve imao najnižu energiju klijanja i klijavost (84.7% i 89.7%) i najveći udeo atipičnih ponika (8.3%). Utvrđene su visoko signifikantne korelacije energije klijanja, klijavosti i udela atipičnih ponika sa masom 1000 semena (r = - 0.53**, r = - 0.51**, i r = 0.60**).

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