Cercetări Agronomice în Moldova
Vol. XLVII , No. 3 (159) / 2014

MECHANICAL DAMAGE TO CHICKPEA SEEDS AS AFFECTED BY NPK FERTILIZATION

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Received December 19, 2013

ABSTRACT. The aim of research was to determine the effect of nitrogen (N), phosphorus (P) and potassium (K) fertilizers onthe some physical properties and mechanical damage to chickpea seeds under impact. The martial for tests was from a field experiment with varied levels fertilization with nitrogen (0 and 50 kg/ha, N), phosphorus (0 and 100 kg/ha, P_2O_5) and potassium (0 and 100 kg/ha, K_2O). The variation of the mechanical damage was analyzed depending on the mode of varied fertilization, seed moisture content and impact energy. It was found that the chickpea seeds were bigger with NPK supply. The effects of phosphorus and potassium fertilizers rates on the mechanical damage to chickpea seeds was significant at 1% probability level (P<0.01) and increased its hardness and resilience therefore caused the better resistance to impact damage. Potassium fertilization ratehad the most influence and phosphorus fertilization rate had the least. The effect of the nitrogen fertilizer rate was not significant (P>0.05). Harvesting chickpea seeds at higher moisture content and lower impact energy should give lower breakage when NPK is supplied, as well as when no NPK is supplied.

Key words: Chickpea; Mechanical damage; Harvesting; Handling; Fertilization.

INTRODUCTION

Many of today’s seed production environments are managed at very high levels of chemical fertilizers to return plant nutrient to agricultural lands and ensure maximum yield potential. Consequently, it is important to understand the seed properties and resistance to impact changes in response to chemical fertilizers such as nitrogen, phosphorus and potassium. Chickpea (*Cicer arietinum* L.) seeds are subjected to a series of static and dynamic loads during harvesting, handling, processing, and storage. Such loads cause external and internal damage of seeds, which lead to decreases in quality and can eliminate both viability and vigor (Shahbazi, 2011). The harvesting and the postharvest operations negatively influence the quality of seeds. The

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machinery and equipment for harvesting, transportation, storage and processing caused significant mechanical damage to seeds i.e. skin rupture, seed fracture etc. The damage resulted from mechanical interaction between the biological material (seeds) and the materials in the machineries (steel, rubber etc.). Most authors admit that the seeds damage mainly occurs in the course of harvest and transport, when the seeds are damaged by impact forces.

The mechanical resistance to impact damage of seeds, among other mechanical and physical properties, plays a very important role in the design and selection of the operating parameters of the respective equipments – for harvesting, threshing, handling and other processing of the seeds (Baryeh, 2002). It is very important to use crops resistant to injury during harvesting techniques and to further introduce varieties and agro technical methods that ensure the maximum resistance to injury (Niewczas, 1994). Resistance to impacts can be advantageous (storage, biological form); on the other hand, high impact resistance is an unfavorable trait in processing because of higher energy costs and less efficiency in size reduction (Szwed and Tys, 2002).

Among biological, physical and thermal factors, an important role in the resistance to damage is played by the hardness and resilience of seeds. The higher resilience, the better resistance to damage and therefore higher sowing value/potential. Particularly important here are the seed cover, its structure, position and chemical composition (Gorzelany, 1999). These factors are affected by the mineral fertilization level (Szwed and Tys, 2002). Therefore, it is useful to determine the effects of various modes of fertilization of chickpea seed plantation on the mechanical damage of seeds. Another highly important factor that has a significant effect on the resistance to damage of seeds is their water (moisture) content. Water content in seeds affects their anatomical-morphological structure only to a slight degree (Dziki and Laskowski, 2007), but plays a significant role in affecting their elastic properties. Dry biological material is not too elastic and relatively brittle, and stress caused by external forces is more likely to disturb its inner structure. A higher moisture content increases the elasticity and deformability of seeds. Some researches prove the significant influence of moisture content upon the seed damage and state that the damage increases significantly as the moisture content decreases (Baryeh, 2002; Parde *et al*., 2002; Szwed and Lukaszuk, 2007; Shahbazi, 2011). According to numerous studies, a seed is less vulnerable to injuries from outer mechanical loads for an optimum value of water content (Niewczas, 1994). This feature may be important for selecting the time of harvest and postharvest process, aiming to minimize yield losses due to the share of damaged seeds.

Impact damage to seeds has been the subject of much research work because of the loss in product quality incurred during harvesting, handling and processing. Many studies have been conducted to determine the mechanical damage to seeds, such as: Kim *et al*. (2002) on maize, Parde *et al*. (2002) on soybean seed, Sosnowski (2006) on bean seed, Szwed and Lukaszuk (2007) on rapeseed and wheat kernels, Khazaei *et al*. (2008) on wheat seed, Khazaei (2009) on white kindey bean, Shahbazi (2011) on chickpea seed, Shahbazi *et al*. (2011a) on pinto bean, Shahbazi *et al*. (2011b) on navy bean and Shahbazi (2012) on wheat seed.

There is little information in the published literature investigating the effects of nitrogen, phosphorus and potassium fertilizers rate on chickpea seeds physical properties and resistance to impact. Therefore, the objective of this study was to investigate the effects of various fertilization levels on the some physical properties and mechanical damage to chickpea seeds under impact loading, at moisture contents of 8.5 to 15%.

MATERIALS AND METHODS

Chickpea seeds of the Arman cultivar were chosen to be used in this research. An experiment was conducted during 2010, 2011 and 2012 growing seasons, at the experimental research station of Lorestan University, Iran. The cropping system used in the experiment was irrigated continuous corn rotation, under conventional tillage in the winter. The chickpea plots were planted in a randomized complete block design with three replications. Chickpea cultivar and planting dates were chosen based on the best recommendation for farmer's practices in the area of the study. Crop management practices (except nitrogen, phosphorus and potassium fertilizers) varied among location depending on the requirements based on soil test results. Row spacing (six rows in each plot) was 0.2 m and plot length measured 4 m in length and 1.5 m in width.

The treatment methods were combinations of nitrogen (0 and 50 kg/ha, N), phosphorus (0 and 100 kg/ha, P_2O_5) and potassium (0 and 100 kg/ha, K_2O). The treatments were applied by hand, after cropping, in a 25 mm-wide band placed 5 cm to the side and 5 cm under the seeds row. After attaining optimum maturity, samples of seeds were harvested by hand, from a central area of each plot, and cleaned in an air screen cleaner. The initial moisture content of seed treatments was 8.5% (wet basis) determined with ASAE S352.2 (ASAE Standards, 1988). Higher moisture content samples (15 and 20%) were prepared by adding calculated amounts of distilled water, then sealing in polyethylene bags, and storing at 5ºC for 15 days.

To determine the the effects of different fertilizers rate on the some physical properties, 100 seeds were randomly selected from each sample, at the moisture content of 15%, which is the normal moisture level during harvesting and postharvest processing for chickpea seeds and their three linear dimensions namely, length (L), width (W) and thickness (T) were measured using a digital micrometer, with an accuracy of 0.01 mm. The average diameter of seeds was calculated by using the geometric mean from the three axial dimensions.

The geometric mean diameter (D_g) of the seeds was calculated with the following relationship (Mohsenin, 1970):

$$D_g = (L + W + T)^{1/3} \quad (1)$$

The laboratory apparatus used to impact seeds was operated in a way similar to the impacting energy instruments used by Asoegwu (1995), Kim *et al*. (2002), Oluwole *et al*. (2007) and Shahbazi *et al*. (2012).

In this study, the effects of nitrogen, phosphorus and potassium fertilizers rate, moisture content (8.5, 15 and 20%) and impact energy (0.1, 0.2 and 0.3 J) were studied, taking into account the percentage breakage of chickpea seeds. The factorial experiment was conducted as a randomized design, with three replicates. For each impact test 100 seeds were selected randomly from each sample and impacted with an impact device. After each test damaged seeds, including broken, cracked, and bruised seeds, were accurately identified and sorted by visual inspection. A handheld magnifying glass was used to augment the visual inspection. Sample mass was recorded with a digital electronic balance having an accuracy of 0.001 g. The percentage of seed breakage was calculated as:

$$\text{Seed breakage} = \frac{(\text{Weight of damaged seeds})}{(\text{Weight of total seeds}(\text{damaged} + \text{undamaged}))} \times 100 \quad (2)$$

Experimental data were analyzed using analysis of variance (ANOVA) and the means were separated at the 5% probability level applying Duncan's multiple range tests in SPSS 17 software.

RESULTS AND DISCUSSION

The mean values for the some physical properties of chickpea seeds, at different fertilization rates of NPK, are presented in *Table 1*. The effect of NPK fertilization dose on the chickpea seeds properties such as width (W) and geometric mean diameter (D_g) was significant at 1% and 5% probability levels, respectively, but the effect on the length (L) and thickness (T) was not significant. With increase in the fertilization doses of NPK, all the measured geometrical properties of chickpea seeds increased. A fertilization dose of 0/0/100 kg/ha of NPK exhibited the highest average seeds length (L) and a fertilization dose of 50/100/0kg/ha of NPK exhibited the highest average seeds width (W), thickness (T) and geometric mean diameter (D_g) (*Table 1*).

Analysis of variance indicated that all the three independent variables, namely NPK fertilization dose, moisture content and impact energy, created significant effects on the mechanical damage to chickpea seeds at 1% probability level ($P<0.01$). Impact energy had the most significant influence (F=2470.523), and moisture content (F=689.862) and NPK fertilization dose (F=291.123) had the least, respectively, within the ranges studied for variables (*Table 2*). In addition, the interaction effects of the NPK fertilization dose ×moisture content, NPK fertilization dose × impact energy, moisture content ×

impact energy and the interactions effect of the three independent variables significantly influenced the percentage breakage of chickpea seeds at 1% probability level (P<0.01) (*Table 2*).

Table 1 - Some physical properties of chickpea seeds as a function of NPK fertilization dose (100 observations, at moisture content of 15% for seeds of 2100, 2011 and 2012 growing seasons)

Fertilization N/P/K (kg/ha)	Physical property			
	Length (mm)	Width (mm)	Thickness (mm)	D_g (mm)
0/0/0	7.629 (0.53) c	6.127 (0.54) c	6.094 (0.57) bc	2.706 (0.06) c
0/0/100	8.243 (0.86) a	6.503 (0.44) ab	6.296 (0.53) ab	2.759 (0.06) ab
0/100/0	8.085 (0.73) ab	6.585 (0.65) ab	6.312 (0.56) ab	2.756 (0.07) ab
0/100/100	7.891 (0.50) bc	6.553 (0.45) ab	6.384 (0.49) ab	2.750 (0.05) ab
50/0/0	7.833 (0.69) bc	6.349 (0.71) bc	6.188 (0.60) abc	2.729 (0.07) abc
50/0/100	7.843 (0.67) bc	6.280 (0.65) bc	6.165 (0.49) abc	2.726 (0.06) abc
50/100/0	7.868 (0.53) bc	6.786 (0.54) a	6.442 (0.45) a	2.762 (0.05) a
50/100/100	7.831 (0.51) bc	6.419 (0.43) bc	5.950 (0.89) c	2.722 (0.06) bc

*Dates in parentheses are standard deviation. a-c-means followed by different letters are significantly different from others in the same column (P < 0.05).

Table 2 - Analysis of variance (Mean square) for the percentage breakage of chickpea seeds as affected by NPK fertilization dose, moisture content and impact energy

Source of variation	DF	Mean square error	F value
NPK Fertilization Dose (FD)	7	2323.594	291.123**
Moisture Content (MC)	2	5506.119	689.862**
FD × MC	14	96.808	12.129**
Impact Energy (IE)	2	19718.437	2470.523**
FD × IE	14	326.348	40.888**
MC × IE	4	418.442	52.427**
FD × MC × IE	28	22.586	2.830**
Error	144	7.981	

**: significant at the 0.01 probability level

The results of Duncan's multiple range tests for comparing the mean values of thepercentage breakage of seeds, at different fertilization levels of NPK, are presented in *Fig. 1*. It is evident from *Fig. 1* that the percentage breakage of seeds decreased with increase in NPK fertilization dose in comparing control dose (0/0/0). In *Fig. 1*, the highest percentage damage to seeds was 39.90%, which recorded for seeds from the plot with a 0/0/0 kg/ha (control) N/P/K fertilization dose. The lowest damage to seeds was14.60%, which recorded for the seeds fertilized with N/P/K dose of 0/0/100 kg/ha. No reported results for the effect of the nitrogen, phosphorus and potassium fertilizers doseon the mechanical damage to chickpea seeds were found to compare with the results obtained in this study. However, the significant effects of fertilizers dose on the value of seeds mechanical damage have been reported by other researchers (Gorzelany, 1999; Shahbazi *et al*., 2012). Gorzelany (1999) reported that beans from the plot with a fertilization dose: N-40 kg/ha, P_2O_5-120 kg/ha and K_2O-70 kg/ha exhibited the highest resistance to cracking. Shahbazi *et al*. (2012) reported that the percentage breakage of triticale seeds decreased from 32.592 to 16.9268% as the fertilization level of zinc sulphate increased from 0 to 60 kg/ha.

Analysis of variance obtained from the randomized complete design of the data on the percentage breakage of chickpea seeds was used to determine the effect of the nitrogen, phosphorus and potassium fertilizers rate on the mechanical damage to chickpea seeds. The results are shown in *Table 3*. From this table, it can be seen that the effects of phosphorus and potassium fertilizers rate on the mechanical damage to chickpea seeds are significant at 1% probability level ($P<0.01$). Potassium fertilization rate had the most influence ($F=22.297$), while the phosphorus fertilization rate ($F=14.563$) had the less effect. The effect of the nitrogen fertilizer rate is not significant ($P>0.05$).

The average values for the percentage breakage of seeds (*Fig. 1*) were found to be 25.527 and 26.849% for nitrogen rates of 0 and 50 kg/ha, respectively, shown that damage to seed increased with increasing nitrogen rate. The percentage breakage of seeds decreased with increase in the phosphorus and potassium fertilizers rate. The mean values of the percentage breakage of seeds at phosphorus rates of 0 and 100 kg/ha were found to be 30.592 and 21.784%, respectively. The data were 31.637 and 20.739% for 0 and 100 kg/ha potassium fertilizer rates, respectively (*Fig. 1*).

The results confirm that not only the dose of chemical fertilizers has significant effects on the biological, physical and mechanical properties of materials of plant origin, but it also affects the seed hardness and resilience, which play an important role in the resistance to damage. In addition, the results show that the fertilization rate of phosphorus and potassium had significant effects on the chickpea seeds hardness and resilience, therefore leading to a higher resistance to impact damage.

Fig. 2 shows the percentage breakage of chickpea seeds in the interaction between NPK fertilization dose and seed moisture content. As follows from *Fig. 2*, for all the NPK doses considered, the percentage damage to seeds decreases with increase in their moisture content. In *Fig. 2* the mean values of the percentage breakage of seeds were 35.726, 24.289 and 18.548% for the moisture content of 8.5, 15 and 20%, respectively, at all NPK fertilization doses. These results confirm that, as the moisture content has significant effects on the elastic properties of materials of plant origin, it also has a bearing on the effects of impact damage. At higher moisture contents, the elasticity of seeds will increase, which causes that their firmness to increase, thus leading to a greater absorption of energy during impact, increasing the resistance to damage. On the other hand, at lower moisture contents, the seeds are more brittle, and thus, more prone to physical damage caused by impact (Khazaei *et al.*, 2008; Khazaei, 2009).

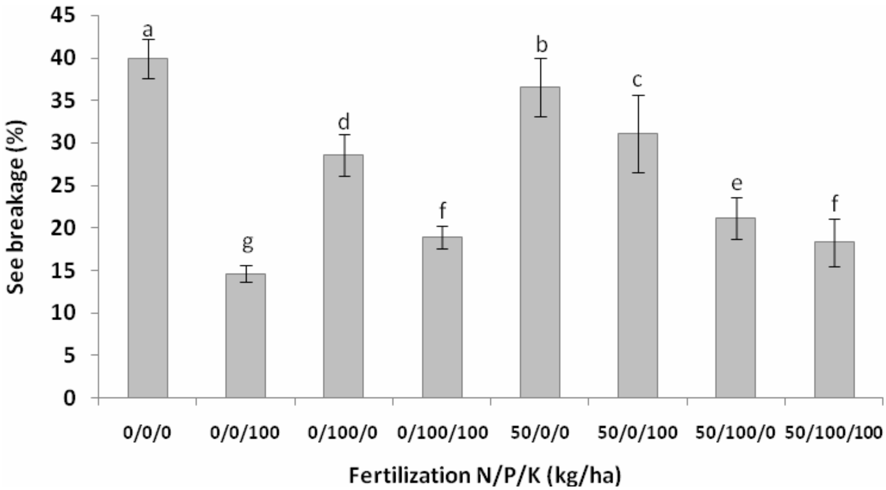

Figure 1 - Effect of the N/P/K fertilization dose on the percentage breakage of chickpea seeds. Averages with the same letter have no significant difference at the 5% probability level.

Table 3 - Analysis of variance (Mean square error) for the percentage breakage of chickpea seeds as affected by the nitrogen, phosphorus and potassium fertilizers rate

Source of variation	DF	Mean square error	F value
Nitrogen fertilization rate	1	94.407	0.328^{ns}
Phosphorus fertilization rate	1	4188.803	14.563**
Potassium fertilization rate	1	6413.560	22.297**
Error	208	287.639	

**: significant at the 0.01 probability level; ^{ns}: not significant

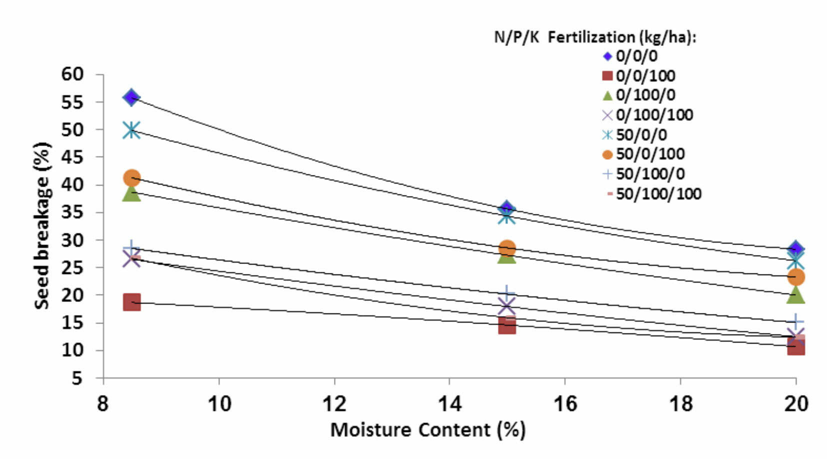

Figure 2 - Chickpea seeds breakage variation with seed moisture content at different NPK fertilization doses

As shown in *Fig. 2* the rates of increase in percent damage to seeds by decrease in their moisture content are not the same for all the levels of NPK fertilizer rates. The effect of moisture content on the damage is stronger at lower NPK doses than at higher ones. The data of the percentage breakage of seeds in *Fig. 2* varied from 10.656 to 55.756%. The minimum value (55.756%) was obtained for theNPK dose of 0/0/0 kg/ha, with 8.5% moisture content. The maximum value (10.656) was obtained for the interaction of NPK dose of 0/0/100 kg/ha and the moisture content of 20%. *Fig. 2* reveals that for all the NPK doses, there is no linear relation between the damage rate and seed moisture content. Regression analysis was used to find and fit the best general models to the data. Results showed that the percent damaged seed was a polynomial function of their moisture content, at all the NPK fertilization doses considered. The equations representing the relationship between the percentage breakage of seeds and moisture content for each NPK fertilization dose and their coefficients of determination (R^2) are presented in *Table 4*.

Fig. 3 shows the percentage breakage of seeds in the interaction between NPK fertilization dose and impact energy. The figure reveals that at all the NPK fertilization doses, seed damage increased as the impact energy increased; however, due to the significant interaction effects between NPK fertilization dose and impact energy, the rates of increase in damage are not the same for NPK fertilization doses. In *Fig. 3* the mean values of the percentage breakage of seeds were 8.441, 28.923 and 41.198% for the impact energies of for 0.1, 0.2 and 0.3 J, respectively, at all NPK fertilization doses. Referring to *Fig. 3*, of all the impact energies the highest damages to seeds were recorded for a NPK fertilization dose of 0/0/0 kg/ha, which were 15.622, 43.011 and 61.056% for the impact energies of for 0.1, 0.2 and 0.3 J, respectively. The highest resistance to mechanical damage (lower damage) at all impact energies was recorded for seeds fertilized with a NPK dose of 0/0/100 kg/ha, which were 3.889, 15.367 and 24.633% for the impact energies of for 0.1, 0.2 and 0.3 J, respectively (*Fig. 3*). The curves showing the values of the percent damaged seeds versus impact energy for the analyzed NPK fertilization doses (*Fig. 3*) can be expressed as a linear function:

$$S_b = a + bIE \quad (3)$$

where: S_b is seed breakage (%), a, b are coefficients and IE is impact energy (J). *Table 5* presents the values of function coefficients.

Table 4 - Equations representing the relationship between the percentage breakage of chickpea seeds and moisture content at different NPK fertilizationdoses

Fertilization N/P/K (kg/ha)	Equation	R^2
0/0/0	$S_b = 0.142M^2 - 6.453M + 100.3$	0.999
0/0/100	$S_b = -0.013M^2 - 0.306M + 22.24$	0.998
0/100/0	$S_b = 0.027M^2 - 2.401M + 57.10$	0.999
0/100/100	$S_b = 0.019M^2 - 1.762M + 40.06$	0.997
50/0/0	$S_b = 0.066M^2 - 3.952M + 78.61$	0.999
50/0/100	$S_b = 0.079M^2 - 3.813M + 67.98$	0.999
50/100/0	$S_b = 0.021M^2 - 1.788M + 42.09$	0.998
50/100/100	$S_b = 0.082M^2 - 3.597M + 51.29$	0.999

All the indexes are significant at the level of 99.99%; S_b = percentage seed breakage, M= moisture content (%)

Table 5 - The values of function coefficients (Eq. 3)

Fertilization N/P/K (kg/ha)	Coefficients		R^2
	a	*b*	
0/0/0	-5.537	227.1	0.986
0/0/100	-6.114	103.7	0.996
0/100/0	-8.707	186.7	0.978
0/100/100	1.833	85.55	0.999
50/0/0	-10.66	237.2	0.969
50/0/100	-10.17	206.1	0.977
50/100/0	-7.377	143.1	0.955
50/100/100	-5.811	120.7	0.979

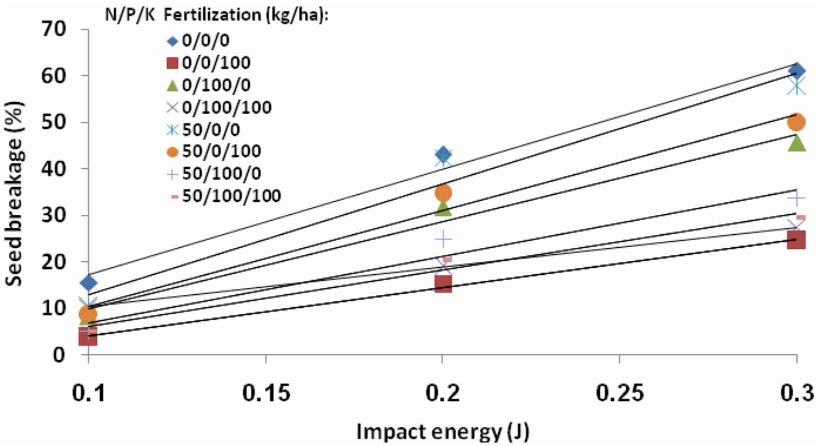

Figure 3 - Chickpea seeds breakage versus impact energy at different NPK fertilization doses

CONCLUSIONS

From the results of this study, the following conclusions can be drawn: the effect of NPK fertilization dose on the chickpea seeds width (*W*) and geometric mean diameter (D_g) was significant at 1% and 5% probability levels, respectively but the effect on the length (*L*) and thickness (*T*) was not significant. There was a significant difference between the percentage breakage of chickpea seeds at different fertilization dose of NPK fertilization, moisture content and impact energy at the 1% probability level ($P<0.01$). It was found that increasing the fertilization rate of phosphorus and potassium had a significant effect on the mechanical damage to chickpea seed and increased its hardness and resilience therefore caused the better resistance to impact damage. Potassium fertilization ratehad the most influence and phosphorus fertilization rate had the least. The effect of the nitrogen fertilizer rate was not significant. As the moisture content of the seeds increased from 8.5 to 20%, the amount of the percentage breakage of seeds decreased from 35.726 to 18.548%, at all the NPK fertilization doses. Increasing the impact energy from 0.1 to 0.3 J caused an increase in the percentage breakage of seeds from 8.441 to 41.198%, at all the NPK fertilization doses.

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