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RESEARCH NOTE

Mechanical damage caused by the use of grain carts for transport during soybean seed harvest[1]

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ABSTRACT - Mechanical damage constitutes one of the factors limiting production of high quality soybean seeds. The aim of this study was to evaluate the effects on seed viability and mechanical damage caused to soybean seeds when using a grain cart, together with an auger unloading system, as a means of transporting grain from the combine to the truck. Seed samples were collected in two seed production fields in the region of Abelardo Luz, SC, Brazil, at three different times (10:00, 12:30, and 16:00) and from three places (in the combine grain tank, in the grain wagon, and in the truck). The percentages of broken seeds, moisture content, mechanical damage to the seed coat, and germination were evaluated. The use of auxiliary grain cart equipment contributed to an increase in breakage and mechanical injury in seeds, worsening seed viability. Seeds collected at lower moisture contents had higher breakage and higher rates of mechanical damage.

Index terms: *Glycine max,* transport system, physical damage, physiological quality.

Danos mecânicos causados pelo uso de graneleiro no transporte, durante a colheita de sementes de soja

RESUMO - Os danos mecânicos constituem-se em um dos fatores limitantes à produção de sementes de soja de alta qualidade. Objetivou-se avaliar a viabilidade e os danos mecânicos causados em sementes de soja, ao se utilizar a carreta graneleiro com sistema de descarga por caracol, como meio de transporte da colhedora para o caminhão. Em dois campos de produção de sementes da região de Abelardo Luz, SC, foram coletadas amostras das sementes colhidas em três diferentes horários, (10:00, 12:30 e 16:00 horas) e em três locais, (no graneleiro da colhedora, no graneleiro transportador e no caminhão). Avaliaram-se a percentagem de sementes quebradas, teor de água, dano mecânico no tegumento e germinação. O uso do equipamento auxiliar graneleiro transportador contribui para o aumento na incidência de sementes quebradas e injúrias mecânicas, comprometendo a sua viabilidade. Sementes colhidas com menores teores de água quebraram mais e tiveram maiores índices de danos mecânicos.

Termos para indexação: *Glycine max*, sistema de transporte, danos físicos, qualidade fisiológica.

Introduction

Seed quality attributes, characterized by genetic, physical, health, and physiological aspects, are of fundamental importance because of their effects on establishing the crop and on crop development, yield, and quality (Sarmento et al., 2010).

Peske et al. (2012) affirm that seeds are subject to the action of mechanical agents throughout management practices, from harvest up to sowing. According to Terasawa et al. (2009), low moisture contents in seeds at the time of

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harvest intensify mechanical damages from impacts on seeds during this process.

At harvest, mechanical damages mainly occur at the time of threshing. Damage occurs as a consequence of the impacts received in the threshing cylinder and specifically when the seeds pass through the concave (Pires et al., 2011). Mechanical damage may also occur in the other steps seeds undergo soon after harvest (Peske et al., 2012).

In soybean harvest, grain carts have been used in grain production fields as a means of transport of grain from the combine to the truck, mainly because of the agility of operations provided by this piece of equipment. This practice has also frequently been used in seed multiplication fields since speed and ease of operations during soybean harvest are likewise a continual effort of partners of seed multiplication companies.

Thus, the aim of this study was to investigate and quantify the occurrence of mechanical damage caused to soybean seeds and the effect of this damage on seed viability when a grain cart equipped with an auger unloading system is used as a means of grain transport from the combine to the truck at the time of harvest.

Materials and Methods

The study conducted in Abelardo Luz, SC, Brazil, was divided into two trials that accompanied the harvest of two soybean seed multiplication fields of the cultivars CD 202 RR and BMX Turbo RR in the 2012/13 crop season. The fields were at a horizontal distance of 15.0 km from each other and were at an average altitude of 830 m. Both fields were harvested on the same day. The temperature and relative humidity were 20 °C and 68%, 21.5 °C and 64%, and 24 °C and 60% for the times of 10:00, 12:30, and 16:00, respectively. For each trial, a completely randomized experimental design was adopted with two factors (the first being the sampling location and the second the time of collecting the samples) in a 3 × 3 factorial arrangement with four replications, for a total of 36 experimental units. The places sampled were the grain tanks of the combines (Location 1), the grain tanks of the grain carts (Location 2), and the trailers of the trucks that carried the seeds to the seed processing unit (Location 3). The times the samples were taken were 10:00, 12:30, and 16:00. Each collected sample represented an experimental unit.

For sample collection, a double-tube grain probe with open handle and 12 slots was used. Fifteen single samples were taken randomly that were then duly homogenized and used to compose combined samples with an average of 2.0 kg. Analyses were performed in the Seed Quality Control Laboratory of the *C. Vale Cooperativa Agroindustrial*, in *Palotina*, *PR*, by evaluating the percentage of broken seeds, the percentage of mechanical damage, and seed viability.

Upon arriving at the laboratory, submitted samples were classified in a set of two sieves (7.0 mm screen with round holes in the upper part and 4.5 mm screen with oblong holes in the lower part, plus a sieve pan). The material retained in the sieves was considered as seeds to analisis, and the rest was discarted. After that, the number of broken seeds retained in the sieve pan, which were weighed on an analytic balance with 0.1 g precision, and the result was expressed in percentage.

After that, the samples passed through a portable spiral separator for the purpose of removing defective and malformed seeds, and the fractions of good seeds were placed in 1-kg capacity paper boxes. Up to performance of laboratory analyses, the samples were stored in a climate-controlled room at a mean temperature of 18 °C and 50% relative humidity. Upon setting up the tests, the samples had mean moisture contents of 10.5%. To split the mean samples and obtain working samples, a sample divider was used, with 18 channels, following the procedures recommended in the Rules for Seed Testing (Brasil, 2009).

Seed moisture content was determined in the field at the time of harvest with the aid of the Dickey-John MINI GAC moisture analyzer. Results were expressed in moisture percentage, wet basis. Evaluation of mechanical damage was performed in the laboratory according to the methodology recommended by Krzyzanowski et al. (2004) through soaking seeds in a 5.25% sodium hypochlorite solution for 10 min. In this evaluation, seeds that released their seed coat were considered to be damaged; a count was performed in each of the four samples. Results were expressed in percentage of damaged seeds.

Viability of the lots was evaluated through the first germination count test according to the Rules for Seed Testing (Brasil, 2009). A Mangelsdorf germination chamber was used, regulated to a constant temperature of 25 °C, with eight replications of 50 seeds in rolls of germitest paper substrate. Before implementing the test, the seeds were pre-soaked to standardize their moisture content. Results were expressed in percentage of normal seedlings.

Statistical analysis of the data was carried out with the aid of the ASSISTAT 7.6 Beta computational software (Silva and Azevedo, 2009). The homogeneity of the variances of the dataset was verified through the Lilliefors test. Analysis of variance was carried out to verify the levels of significance of the factors and of their interactions. When the interactions were significant by the F test ($p<0.001$), the mean values were compared by the Tukey test at the level of 5% probability.

Results and Discussion

The factors tested, as well as their interactions, exhibited different responses in relation to the variables measured, for both cultivars. The results obtained in determination of seed moisture content are shown in Table 1.

There was significant interaction between the time and collection location factors for moisture content only for the cultivar BMX Turbo RR. Sampling of the BMX Turbo RR cultivar seeds showed that their moisture content decreased as the seeds were moved from Location 2 to Location 3 at the times of 10:00 and 12:30. At 10:00, the samples from the combine and from the grain cart exhibited values of 14.7% and 14.5%, respectively, not differing from each other. However, the samples taken from the truck grain trailer (Location 3) showed moisture content of 13.9%. Nevertheless, at the time of 12:30, significant differences were seen in the percentage of seed moisture among the three locations. For the time of 16:00, the seeds had a mean moisture content of 12.8%, and the values from the different locations sampled did not differ from each other. For that time, due to the low relative humidities that generally occur in that period of the day, quite likely the seeds had reached equilibrium moisture content with the ambient air. Silva (1986) explains that seeds are composed of hygroscopic substances that are able to exchange moisture with surrounding air due to partial vapor pressure. In the trial with the cultivar BMX Turbo RR, the mean values of moisture content in relation to time within the different sampling locations showed an effect of interaction of the factors. The percentage of seed moisture decreased as collection time advanced in the seeds taken from the grain tanks of the combine and of the grain cart (Locations 1 and 2, respectively). For the truck grain trailer (Location 3), the highest percentage was at 10:00, which did not differ from the other times.

For the cultivar CD 202 RR, the factors tested acted independently; they did not show significant interaction. Regarding sampling time, the seed moisture content decreased from 14.7% to 12.6% from 10:00 to 16:00. It can be inferred that such results are also due to the effect of a decrease in relative humidity as the day proceeded and, consequently, in the moisture content of the seeds collected. Pandolfo et al. (2007) explain that for the region under study, in normal days without rain, relative humidity tends to decrease as the day goes on. Analogous results were observed by Marcondes et al. (2005), who observed a reduction in relative humidity from two to three percentage points from the time of 10:00 to 18:00 when they evaluated the moisture content of seeds from two soybean cultivars during harvest.

In relation to the location from which samples were taken, there was no significant difference in moisture content between the grain tank of the combine and the grain cart. However, in the truck grain trailer, there was a significant decrease in the percentage of seed moisture content, which declined to 13.5%. This phenomenon is quite likely due to grain movement from one piece of equipment to another, which made the seeds enter in contact with the air and lose moisture. According to Peske et al. (2012), contact with ambient air makes the moisture content in seeds decline due to equilibrium moisture content.

Table 1. Moisture content (%) of soybean seeds, cultivars BMX Turbo RR and CD 202 RR, collected at three different times and in three different locations.

Time of collection	Collection location			
	Location 1	Location 2	Location 3	Means
	BMX Turbo RR			
10:00	14.7 Aa	14.5 Aa	13.9 Ba	14.4
12:30	14.3 Ab	13.8 Bb	13.1 Cb	13.8
16:00	12.6 Ac	12.7 Ac	12.9 Ab	12.8
Means	13.9	13.7	13.3	
CV (%)	1.2			
	CD 202 RR			
10:00	15.0	14.8	14.4	14.7 a
12:30	14.4	14.1	14.0	14.2 b
16:00	12.7	12.7	12.4	12.6 c
Means	14.0 A	13.9 A	13.5 B	
CV (%)	1.4			

Mean values followed by the same uppercase letters in the line and lowercase letters in the column do not differ statistically from each other by the Tukey test at the level of 5% probability.

The percentages of broken seeds are shown in Table 2. The factors acted independently for both cultivars. For the time factor, the cultivar BMX Turbo RR had a higher mean value of percentage of broken seeds at 16:00. The response was similar for the cultivar CD 202 RR, which also showed a higher percentage of broken seeds at 16:00. Both cultivars thus show an increase in the percentage of broken seeds in accordance with time, possibly brought about by the reduction in their moisture content as the day went on, in agreement with the data of Table 1. Evaluation of the seed collection locations for both cultivars shows that the highest percentages of broken seeds were found in the truck grain trailers. Undoubtedly, this increase can be credited to the bulk of seeds passing through one more location (the grain cart), which has an auger unloading system. Moreover, after the mass of seeds passed through the grain cart, the mechanical damages increased 8.7% on average for the cultivar BMX Turbo RR and 12.8% for CD 202 RR. If the grain cart equipment had not been used, this increase in mechanical damage in the mass of seeds could have been avoided. Mechanical damage is accumulative, which may result in a high number of damaged seeds. This corroborates the idea that as the seeds are subjected to movement, the tendency is toward an increase in the occurrence of mechanical damage. Thus, according to Mondo et al. (2009), damage is more accentuated and increases significantly as the number of impacts on the seed increase.

A factor that may influence the results in comparison between cultivars is the size of their seeds and the composition of their seed coats in terms of a greater or smaller amount of lignified material (Carvalho and Novembre, 2012). These authors, who tested different methods for detection of mechanical damage in soybean seeds, attribute different performances among the cultivars to their seed coats. In the same way, comparing mechanical threshing of seeds with manual threshing, it was evident that the impacts supplied by the first system tend to bring about greater damage. The results of the present study corroborate those of these authors because the more seeds were subjected to mechanized processes and, consequently, to impacts, the more injuries were detected. The cultivars analyzed in this study have different seed sizes, because the mean values of 1000 seed weight for BMX Turbo RR was 195.15 g, and 158.24 g for CD 202 RR. According to Souza et al. (2009), the influence of mechanical damage on seed quality and vigor depends on the size and depth of damage and where it occurs.

The percentages of mechanical damage evaluated by the method of soaking in sodium hypochlorite solution are shown in Table 3. It also shows that the time and collection location factors acted independently from each other.

For the cultivar BMX Turbo RR, the percentage of mechanical damage differed as harvest proceeded to later times. There was an increase in the percentage of mechanical damage, ranging from 10.4% to 19.8%. Such results confirm those found for the percentages of broken seeds shown in Table 2.

For the cultivar CD 202 RR, mechanical damage was 10.9% at the time of 10:00, and it increased from this time on, reaching 12.4% at 16:00. There was a similar response for this variety in relation to the broken seed percentage variety. These results are corroborated by Marcondes et al. (2010), who evaluated harvest times and threshing systems for soybean seeds. These authors found that seeds collected at 10:00 with a moisture content greater than 15% had lower

Table 2. Mean values of percentages of broken seeds of the soybean cultivars BMX Turbo RR and CD 202 RR, collected at three different times and in three different locations.

Cultivar	Time			Location			CV%
	10:00	12:30	16:00	Location 1	Location 2	Location 3	
BMX Turbo RR	7.0 C[1]	12.1 B	19.6 A	12.4 b	12.0 b	14.3 a	10.1
CD 202 RR	8.2 B	7.5 B	10.4 A	8.1 b	8.6 b	9.4 a	8.7

[1]Mean values followed by the same uppercase letters in the line (for Time) and lowercase letters in the line (for Location) do not differ statistically from each other by the Tukey test at the level of 5% probability.

Table 3. Mean values of percentages of mechanical damage of soybean cultivars BMX Turbo RR and CD 202 RR collected at three different times and in three different locations.

Cultivar	Time			Location			CV%
	10:00	12:30	16:00	Location 1	Location 2	Location 3	
BMX Turbo RR	10.4 C[1]	12.8 B	19.8 A	14.3 b	13.8 b	15.0 a	9.5
CD 202 RR	10.9 B	12.3 A	12.4 A	10.7 c	11.7 b	13.2 a	7.3

[1]Mean values followed by the same uppercase letters in the line (for Time) and lowercase letters in the line (for Location) do not differ statistically from each other by the Tukey test at the level of 5% probability.

values for mechanical damage than seeds collected at 18:00 with moisture content below 12%, as determined by the sodium hypochlorite test.

The two cultivars had a similar response in evaluation of collection locations. The highest mean values of mechanical damage, for both cultivars, was found in the truck grain trailers. The cultivar BMX Turbo RR had a mean of 15.0%, and the cultivar CD 202 RR, a mean of 13.2% for this variable.

This result can be explained by the impacts the seeds were subject to throughout all the steps. Due consideration should be given to the fact that the result also confirms results found for percentages of broken seeds, shown in Table 2. In a trial that evaluated the physiological performance of seeds from four soybean cultivars collected at different steps in processing, Silva et al. (2011) found a similar response. According to these authors, their data show that, in general, the greater the number of steps seeds are subjected to, the lower their values of viability and vigor. Respecting the due proportions relative to each one of the studies, these data corroborate those found in the present study. The results of viability from the first germination count are shown in Table 4.

The time and collection location factors acted independently in the cultivars tested. For the cultivar BMX Turbo RR, there was significant interaction between the factors. In sampling performed at 10:00, the highest value (89%) was obtained in the seeds collected from the combine grain tank. In the other locations (the grain cart and the truck grain trailer), the values for first germination count were lower; however, they were not statistically different from each other. For the time of 12:30, there were no differences in this variable among the collection locations. Yet, for the time of 16:00 in seeds collected from the combine grain tank and from the grain cart, higher germination percentages were obtained (92% and 89%), differing from the results obtained from the samples taken from the truck grain trailer. Such results were expected because, according to the percentages of broken seeds and mechanical damage presented in Tables 2 and 3, respectively, it is reasonable that the germination percentage declined.

For the cultivar CD 202 RR, the factors did not interact. The sampling times did not affect the result of first germination count, and there was no significant difference in the mean values. Nevertheless, the collection locations significantly influenced the response variable. A higher mean value in germination percentage is found in the seeds collected from the combine grain tank. It can be inferred that the effect of passing the bulk of seeds through the grain cart and, consequently, through its auger unloading mechanism led to these results. Peske et al. (2012) emphasize that auger-type seed transport equipment tends to negatively affect seed viability.

Souza et al. (2009) state that though seeds undergo mechanical damage, some may germinate, but generate abnormal or low vigor seedlings. Thus, vigor tests must be performed that are able to detect such effects. For Marcos-Filho (2015), the first count of the germination test may be interpreted as a vigor test. The author further emphasizes that injuries that occur in the seeds during harvest can be manifested either immediately or latently, affecting, above all, storage potential, thus reducing their vigor.

As there may be differences among the models of equipment available on the market, it is necessary to conduct new and deeper studies. However, even taking into consideration the limitations in carrying out this study, it allowed important conclusion to be drawn for practical application in seed fields.

Table 4. Percentages of germination by the first count of the germination test of soybean seeds, cultivars BMX Turbo RR and CD 202 RR, collected at three different times and in three different unloading mechanisms.

Time of collection	Collection location			
	Location 1	Location 2	Location 3	Means
	BMX Turbo RR			
10:00	89 Ab	86 Ba	83 Bb	86
12:30	87 Ab	87 Aa	88 Aa	88
16:00	92 Aa	89 Aa	87 Bab	89
Means	89	87	86	
CV (%)	2.9			
	CD 202 RR			
10:00	90	87	82	86
12:30	86	86	86	86
16:00	90	85	83	86
Means	89 A	86 B	84 B	
CV (%)	2.6			

Mean values followed by the same uppercase letters in the line and lowercase letters in the column do not differ statistically from each other by the Tukey test at the level of 5% probability.

Conclusions

The use of auxiliary grain cart equipment contributed to an increase in breakage and mechanical injuries in seeds, worsening the results of seed viability. This study also showed that harvesting seeds at lower moisture contents contributed to an increase in the percentage of broken seeds and seeds with mechanical damage.

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