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Estimated losses in soybean (*Glycine max* (L.) Merril) harvest according to the speed and rotation of the trail system

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Abstract

The soybean crop (*Glycine max*. (L.) Merril) shows strong participation in the Brazilian economy. Therefore, the aim of the present study was to quantify the losses in the cutting and feeding platform and in the trail system in mechanized soybean harvest by analyzing different speed and rotation adjustments of the trailing cylinder. The experiment was carried out in a commercial soybean plot on a farm located in the municipality of Brejo (MA), during the 2017/2018 harvest. The harvester evaluated was a Case IH 8120, with a maximum power of 34.2 kW, axial flow system, and 12.2-m platform equipped with a conveyor system (draper). The experiment was conducted in two different areas. Area 1 was planted with the Brasmax® Opus (BMX Opus) cultivar, while area 2 was cultivated with the BRS 9383 cultivar. The treatments consisted of three machine speeds (4 km h^{-1}, 6 km h^{-1}, and 7 km h^{-1}), associated with the rotation levels of 500 rpm and 800 rpm in the trail system. The experimental design used was randomized blocks in a 3 x 2 factorial arrangement, with four replications. For the BMX Opus cultivar, harvest losses did not influence the travel speeds and rotations evaluated in the experiment due to the marked instability within the treatments. The BRS 9383 cultivar showed satisfactory results at a speed of 4 km h^{-1} combined with a rotation of 800 rpm, which obtained acceptable numbers for the soybean harvest (54.09 kg ha^{-1}).

Keywords: Agricultural mechanization; productivity; trailing cylinder, waste, smart harvest.
Abbreviations: PL_Platform losses; IML_losses of the internal mechanisms; TP_total losses.

Introduction

Soybeans (*Glycine max* (L.) Merril), one of the most economically valuable crops, are grown on approximately 125.8 million ha worldwide which result in the production of 337.9 million tons of soybean (Liu et al., 2020; FAO, 2020). The United States, Brazil, Argentina, China, and India are countries that control the global production of soy (Pagano and Miransari, 2016). However, improper practice of this operation causes significant losses and damages and decreases productivity (Ferreira et al., 2007). Thus, for a satisfactory grain production performance, mechanized grain harvesting is practiced by establishing quality standards that are aimed, in particular, at preventing and minimizing excessive losses, which directly influence the final profitability of the crop (Compagnon et al., 2012).

In mechanized soybean crops, harvesting losses can be classified into quantitative and qualitative, both of which are related to the machine used in the operation and its adjustments, which normally tend to be dynamic due to the characteristics of the crop and its inherent factors (Cassia et al., 2015). Losses on the cutting and feeding platform are influenced by the speed of the reel and harvester. Therefore, regulation is extremely important for reducing the losses that occur in this unit (Holtz and Reis, 2013).

In a study by Mesquita et al. (2001), it was found that the increase in harvest speed results in higher loss rates. Cunha et al. (2009) reported lower losses in the harvest at speeds close to 4.5–5.5 km h^{-1}. According to studies by Schanoski et al. (2011) and Pinheiro and Pinheiro (2012), 75% of losses occur on the cutting platform and 25% occur on the trail, separation, and cleaning system.

The quality of the harvest depends on the operator's knowledge of the working capacity of the entire system and the state of conservation of the machine and on operation at speeds and rotations in the trail systems that are appropriate to both the needs of the crop and the machine itself (Schanoski et al., 2011). Upon evaluating the quantitative losses of grains in soybean harvest, Pinheiro Neto and Gamero (2000) have stated that the large opening

of the hollow (slack), combined with the low rotation of the cylinder, results in greater losses. However, the regional factor still significantly influences the results obtained. This is because the development of soybean cultivars is influenced by environmental factors such as temperature, rainfall, relative humidity, and soil water content (Ribeiro et al., 2016). Based on this, it is extremely important to evaluate the performance of the genotypes in different locations and environments in order to subsidize a recommendation adjusted for each cultivation situation.
In view of the global relevance of soybean cultivation, the aim of this study was to quantify the losses incurred as a result of mechanized soybean harvesting in the soybean production system as a function of the speed of displacement and rotor rotation in two soybean cultivars.

Results and discussion

Descriptive analysis of the variables

The average values for the plant height, height of insertion of the first pod, cutting height of the plant, height of cutting bar of the harvester platform, and stem diameter, accompanied by the standard error of the estimate and the water content (wet basis) for the cultivars Brasmax Opus (Area 1) and BRS 9383 (Area 2), are shown in Table 1.
The mean values obtained for the plant height of Brasmax (BMX) Opus and BRS 9383 were 36.73 ± 0.43 and 58.37 ± 1.12 cm, respectively. These results indicate that the two harvested areas had booths of different sizes. This could be attributed to the precocity and the sensitivity of the BMX Opus to the climatic instabilities that occurred in the 2017/2018 crop season in the eastern Maranhense mesoregion. Rosa et al. (2016) analyzed the effect of sowing times on several soybean cultivars under study in northern Mato Grosso and observed that BMX Opus had an average height of approximately 94 cm, which indicates that this variety tends to present an increased size.
The height of insertion of the first pod ranged from 13.37 ± 0.21 cm (BMX Opus) to 14.24 ± 0.34 cm (BRS 9383). Although they had different plant heights, the two cultivars exposed pod projections at similar heights. Pereira Júnior et al. (2010) identified these variables as parameters related to the flow of harvested material and reported 15 cm as the normal cutting height in mechanized soybean harvesting. The observed values for the insertion of the first pod were close to the ideal value, ameliorating the losses caused by the pods that were not harvested by the harvester platform.
The height of the harvester's cutting bar was slightly higher for area 2 (BRS 9383) which exhibited a mean of 8.42 ± 0.34 cm, as compared to area 1 (BMX Opus) which exhibited a mean of 7.22 ± 0.22 cm. This difference might be related to the fact that the plants of cultivar BRS 9383 were larger, which led the operator to work with a slightly higher platform. According to Paixão (2015), the cutting height of the platform is among the main factors that influence losses in mechanized soybean harvesting. In the present study, both cultivars had their plants cut below the height of insertion of the first pod, which minimized losses from the platform.
The water content varied from 12.60% (BMX Opus) to 13.00% (BRS 9383) and thus, fit within the range of 12% to 14% defined by Embrapa (2011), as the point of harvest of Soy grains. Carvalho and Novembre (2012) reported that water contents below 12% and above 16% cause immediate mechanical damage to the soybean harvest.

Losses in mechanized soybean harvest

The analysis of variance and the t test revealed that for the speed and rotation split, there was no difference between the averages obtained from the treatments for the BMX Opus cultivar in area 1 (Table 2). In this way, the losses in the harvest were not influenced by the displacement speeds or the rotations used in the experiment. Possibly because there was marked instability within the treatments, the fraction losses in the platform and losses in the internal mechanisms were expressed in terms of value by the variation coefficient of 46.27 and 80.04%, respectively.
In this regard, Silva et al. (2013) reported that a high variability is recurrent in studies on quantitative losses in mechanized harvesting, which normally have a wide variation coefficient. It is important to note that, although the averages did not differ among the treatments evaluated for the BMX Opus cultivar, all the regulations proposed in the study resulted in total losses above the acceptable levels established by Embrapa (2011), which classify losses greater than 60 kg ha^{-1} as excessive.
It is also interesting to note that losses on the platform were responsible for the largest amount of losses that occurred. Considering that the cutting height was lower than the insertion height of the first pod, the high level of losses in the platform could be attributed not to the cutting deficiency, but to the grain threshing by the reel action.
Essentially, the speed of 7 km h^{-1} with a rotation of 800 rpm promoted a higher level of losses, 36.48 kg h^{-1} above the recommended value, while the speed of 6 km h^{-1} associated with the rotation of 800 rpm inferred a contribution of 8.08 kg h^{-1} more than the acceptable value, which was closer to the harvest target. Therefore, it is important to guide the producer towards the most assertive regulations because, although there was no statistical difference, the loss of cumulative harvest yield could culminate in a fall in profitability for the producer, even more so, in such a challenging agricultural frontier such as the East Maranhense, which presents strong climatic instability and predominantly cohesive soils.
For area 2 (Table 3), the effects of speed on losses on the platform (PP), rotation over losses from internal mechanisms (PMI), and speed and rotation over total losses (TP) were significant ($p < 0.05$). There was no significant effect of the interaction (speed × rotation) for any of the variables analyzed. The variation coefficient exceeded 40% for losses on the platform and internal mechanisms. However, Toledo et al. (2008) explained that in certain situations, the variation coefficient could reach up to 170%, depending on the methodology used.
The lowest volume of losses on the platform (32.15 and 34.76 kg ha-1) were found at a speed of 4 km h^{-1}, while at 7 km h^{-1}, the losses incurred (53.23%) were found to be greater than those incurred at the lower speed (82.13 and 60.94 kg ha^{-1}) proposed in the experiment. These results are in agreement with those of Mesquita et al. (2001), who pointed out that the increase in harvest speed results in greater losses in the platform. According to Cunha et al. (2009), the lowest losses in the harvest were observed at speeds close to the range of 4.5–5.5 km h^{-1}, which corroborates the best performance of the harvester in the present study.
For the internal mechanisms, it was found that the rotation of 800 rpm promoted lower losses compared to 500 rpm, which is the standard regulation adopted on the farm. These

Table 1. Mean plant height values (PH), insertion height of first pod (IHFP), trunk diameter (TD), plant cutting height (PCH), cutting rod height (CRH), humidity (H), and the standard error associated for the soybean cultivars explored in areas 1 and 2.

Cultivar	Variables					
	PH ± EP (cm)	IHFP ± EP (cm)	TD ± EP (mm)	PCH ± EP (cm)	CRH ± EP (cm)	H (%)
Brasmax Opus	36.73 ± 0.43	13.37 ± 0.21	6.23 ± 0.15	7.22 ± 0.22	4.6 ± 0.51	12.60
BRS 9383	58.37 ± 1.12	14.24 ± 0.34	9.02 ± 0.99	8.42 ± 0.34	5.6 ± 0.51	13.00

Table 2. Mean values of losses on the platform (PL), internal mechanisms (IML), and totals (TL) for the speed interaction (S) x rotation (R), analysis of variance (ANOVA) resume, significant minimum difference (SMD), and coefficient of variation (CV) for area 1 (BMX Opus cultivar).

	PL (kg ha^{-1})		IML (kg ha^{-1})		TL (kg ha^{-1})	
	Rotation (rpm)		Rotation (rpm)		Rotation (rpm)	
Speed (Km h^{-1})	500	800	500	800	500	800
4,0	69.59 aA	71.41 aA	9.50 Aa	14.23 aA	79.09 aA	85.64 aA
6,0	70.01 aA	45.01 aA	10.90 Aa	23.08 abA	80.92 aA	68.08 aA
7,0	66.87 aA	90.66 aA	10.48 aA	5.82 bA	77.35 aA	96.48 aA
ANOVA						
S	0.90 ^{NS}		1.62 ^{NS}		0.29 ^{NS}	
R	0.00 ^{NS}		1.03 ^{NS}		0.10 ^{NS}	
S x R	1.17 ^{NS}		1.46 ^{NS}		0.48 ^{NS}	
MSD	48.06		14.88		49.0	
CV	46.27		80.04		40.42	

Means followed by equal letters, lower case in the columns, and upper case in the lines, do not differ by the Student's t test at the 5% level of significance; NS indicates not significant at 5% level of significance by the ANOVA.

Table 3. Mean values of losses on the platform (PL), internal mechanisms (IML), and total (TL) for the interaction speed (S) x rotation (R), analysis of variance (ANOVA) summary, minimum significant difference (MSD), and coefficient of variation (CV) for area 2 (BRS 9383 cultivar).

	PL (kg ha^{-1})		IML (kg ha^{-1})		TL (kg ha^{-1})	
	Rotation (rpm)		Rotation (rpm)		Rotation (rpm)	
Speed (Km h^{-1})	500	800	500	800	500	800
4,0	32.15 aA	34.76 aA	56.35 aA	19.32 aB	88.50 aA	54.09 Aa
6,0	55.23 abA	30.82 abA	46.19 abA	29.87 aA	101.42 aA	60.69 Aa
7,0	82.13 bA	60.94 bA	75.37 bA	23.16 aB	157.50 bA	84.10 Ab
F test						
S	7.87 *		1.09 ^{NS}		7.28 *	
R	3.09 ^{NS}		23.68 *		19.46 *	
S x R	1.09 ^{NS}		2.07 ^{NS}		1.16 ^{NS}	
MSD	30.10		26.69		41.43	
CV	40.48		42.46		30.19	

Means followed by equal letters, lower case in the columns, and upper case in the lines do not differ by the Student's t test at the 5% level of significance; NS indicates not significant at 5% level of significance by the ANOVA; * means significant at 5% level of significance by the ANOVA.

results are in agreement with those obtained by Chioderoli et al. (2012), who stated that the first adjustment (800 rpm), when adopted, improves efficiency and reduces quantitative losses. It is important to note that the harvester analyzed in this study is axial and, therefore, has greater harvesting capacity. Campos et al. (2005) validated that axial harvesters reduce the loss rates because they allow the harvested material to remain inside the machine for longer, making the trail system more skilled.

Under commercial conditions, the total estimated losses could be significant, especially the harvest carried out at 7 km h^{-1} for the two rotations (500 rpm and 800 rpm), which resulted in losses well above the ideal rates (Table 3). However, at a speed of 4 km h^{-1}, which is within the recommended range for mechanical harvesting, combined with a rotation of 800 rpm, it was possible to obtain acceptable numbers for the soybean harvest with the BRS 9383 cultivar (54.09 kg ha^{-1}).

In this respect, harvesting at a speed of 4 km h^{-1} with a rotation of 800 rpm could elicit an increase of 35.68% (30.01 kg of soybeans per ha) in the quantity offered as compared to an increase of 65.66% (103.41 kg of soybeans per ha) obtained at regulations of 7 km h^{-1} with rotation of 500 rpm. In a production area above 500 ha, which is the traditional part of the eastern Maranhense mesoregion, this could culminate in a significant increase in profitability for soy producers.

The increase in the speed of harvest is carried out to take advantage of the best market prices and evade the unstable weather conditions in the late rainy summer in the East of Maranhão. Attractive prices are generally associated with the fact that the harvest in this mesoregion occurs in the off-season of other producing regions in Brazil, such as the Midwest and South. In this respect, establishing adequate operational conditions is essential, as it could provide the producer with increased crop profitability.

Materials and methods

Experimental area description

The experiment was carried out in a commercial soybean plot located in Brejo (MA), during the 2017/2018 harvest. The municipality is located in the eastern Maranhense mesoregion, with the geographic coordinates of reference between the latitudes S 03° 52' 57” and E 03° 31' 48” and longitudes W 43° 01' 05” and W 42° 31' 48” and altitude ranging from 200 to 400 m with wavy relief and smooth wavy relief.

The soil of the experimental area was classified as yellow Latosol with a significant presence of Argisol. According to the Thorntwaite classification, the climate of the region could be determined as C2W2A'a ', that is, subhumid, megathermic, and with moderate water deficiency in winter, with annual rainfall between 1600 and 2000 mm (GEPLAN, 2002).

Variables evaluated

The experiment was conducted in two distinct areas. In area 1 (A1), BMX Opus was sown, while in area 2 (A2), BRS 9383 was sown. The agronomic characteristics of the two cultivars were measured by the plant height, height of insertion of the first pod, and stem diameter for ten random plants from the useful area of each plot.

Plant height was determined by the distance between the soil surface and the apical part of the plant, the results of which were expressed in centimeters (cm) and measured using a millimeter measuring tape. The height of insertion of the first pod (cm) was measured by the distance between the soil surface and the first pod inserted in the branch. The stem diameter (mm) was measured using a digital caliper, 2 cm from the soil surface.

In addition to the aforementioned variables, the cutting height (cm) of the plants was measured by determining the distance between the soil surface and the apical portion of the cut stem and the height of the cutting bar of the platform which is obtained by the distance between the ground surface and the positioning of the cutting bar. For the grains, the water content (%) was estimated using the Motomco model 919, based on ten samples of 100 g collected from the grain harvester.

Equipments

The harvester evaluated was a Case IH 8120, with a maximum power of 34.2 kW (468 hp), an axial flow system with a double rotor, and a cutting platform of 12.2 m (40 ft), equipped with a conductive track system (draper). The reel adjustment was automatically made by setting the tangential speed 15% above the displacement speed of the harvester.

Experimental design

The treatments consisted of three machine speeds (4 km h^{-1}, 6 km h^{-1}, and 7 km h^{-1}), associated with two levels of rotor rotation (500 rpm and 800 rpm) in the trail system. In this way, the experiment was conducted in a 3 x 2 factorial arrangement in four complete randomized blocks, totaling 24 experimental units in 25-m long plots, spaced 40 m apart.

Losses evaluation

Losses were measured using the methodology proposed by Bragachini (1992). The methodology in question consists of the use of four metallic frames, which were each 56 cm in diameter. For this, the frames were launched after the platform passed, so that two rims remained externally to the track of the wheelsets and the others remained between the track.

After the harvester passed, all grains remaining on the ground were collected and classified as platform losses (PL), while those above the frame were determined as losses of the internal mechanisms (IML). Total losses (TP) were calculated by adding up the previous losses. The samples collected in the field were taken to the laboratory, where their masses were measured and extrapolated to kg ha^{-1}. Natural losses were excluded from the analysis, as they were insignificant.

Statistical analysis

The data obtained were tabulated, and then subjected to analysis of variance (ANOVA), comparing the means by the Student’s t-test at 5% significance using the SISVAR 5.0 software (Ferreira, 2018).

Conclusion

The speed of 6 km h^{-1} with a rotation of 800 rpm resulted in the lowest rate of total losses (68.08 kg ha^{-1}), while the speed of 7 km h^{-1} with the rotation of the cylinder at 800 rpm resulted in loss (96.48 kg ha^{-1}) that was higher than the expected level.

For the BRS 9383 cultivar of the Embrapa, soybean harvesting at speeds of 4 and 6 km h^{-1} at 800 rpm is recommended, as, at 54.09 and 60.69 kg ha^{-1}, respectively, both these parameter settings resulted in acceptable levels of total losses.

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