



## **Loss of Wheat Grains in Road Transport**

**Pedro Silvério Xavier Pereira<sup>1\*</sup>, Aloisio Bianchini<sup>2</sup>, Carlos Caneppele<sup>2</sup>,  
Antônio Renan Berchol da Silva<sup>2</sup>, Matheus Azevedo dos Santos<sup>3</sup>,  
Lucas Abrão Nasser Calixto<sup>4</sup>, Dryelle Sifuentes Pallaoro<sup>1</sup>  
and Thalles Alexandre Xavier Pereira<sup>5</sup>**

<sup>1</sup>*Department of Tropical Agriculture, Federal University of Mato Grosso, Cuiabá, Mato Grosso, Brazil.*

<sup>2</sup>*Department of Agronomy and Zootechny, Federal University of Mato Grosso, Cuiabá, Mato Grosso, Brazil.*

<sup>3</sup>*Department of Agronomy, Federal University of Mato Grosso, Cuiabá, Mato Grosso, Brazil.*

<sup>4</sup>*Department of Agronomy, State University of Ponta Grossa, Ponta Grossa, Paraná, Brazil.*

<sup>5</sup>*Department of Agronomy, Campo Novo dos Parecis, Mato Grosso, Brazil.*

### **Authors' contributions**

*This work was carried out in collaboration among all authors. Authors PSXP, AB, CC, ARBS, LANC conducted the experiment and wrote the first draft of the manuscript. Authors DSP, MAS, TAXP and PSXP discussed the results, correct and improve the writing of the manuscript in Portuguese and English versions. All authors read and approved the final manuscript.*

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### **ABSTRACT**

Wheat is an important cereal crop in Brazil and one of the major source of carbohydrates for baking. Grain losses on roads cause losses beyond the economic scope. Grains that fall around the highway are seeds with the potential to germinate, making it a "green bridge" for the transmission of diseases or hybridization between traditional, commercial and transgenic cultivars. The objective of this study was to establish the quantitative losses along the roads during the transportation of wheat grains in Paraná, as well as to verify the influence of short and long distance load on grain losses. The research was developed through a partnership between the National Supply Company

\*Corresponding author: E-mail: [pedro.sxp@hotmail.com](mailto:pedro.sxp@hotmail.com);

(CONAB) and the Nucleus of Storage Technology, at the Federal University of Mato Grosso. at the Federal University of Mato Grosso. A survey of wheat grain losses was carried out in the BR-376, approximately 295 km distance between the Port of São Francisco in Santa Catarina and Ponta Grossa in Paraná between March and April 2018. A total of 26 collection points were established along the highway. At each collection point an area of 1 m<sup>2</sup> was measured with the aid of a fixed frame of wood with the same area, at a distance of 1.3 m from the highway margin, in the north-south direction of the highway, which is the direction of the grain flow in BR-376 in the section considered). The grains were collected on the side of the road, along the gutters and near the lawn, with a broom, brush and dustpan. The collected material was placed in plastic bags properly identified and taken to the laboratory for separation and weighing. The experiment was carried out in subdivided plots, 26 plots (collection points), 4 subplots (collection times) and 3 replicates (collection areas at points). Statistical analyzes were performed using Assisat software. Differences among treatments were verified using analysis of variance (ANOVA) using the F test. When significant to the comparison of means for the treatments was performed by the Scott-Knott test. The section of the data referring to the short route that presented the highest loss index was the route in the interior of the city of Ponta Grossa-PR. The Ponta Grossa/Ponta Grossa destination also had the highest total loss, even though it was an average distance of 25 km. The route between the municipalities of Uraí/Ponta Grossa was the destination with the highest losses (122.55 kg of grains per trip). In almost all sections of the route denominated as long losses higher than acceptable in contracts (0.25%). The percentage of wheat grains lost is associated with the quality of the highways and trucks used in transportation.

*Keywords: Grain losses; highway; trucks; wheat grains.*

## 1. INTRODUCTION

Wheat is an important cereal crop in Brazil and one of the major source of carbohydrates for baking. The country produced approximately 5.42 million tons of wheat grains in the 2018 harvest [1].

Food losses, specifically in the transportation sector, occur due to several factors. According to transporters, cooperatives and producers, poor road conditions are the main causes of grain losses. Losses are estimated around 5% to 20% of the volume of grains produced in the country, when losses in the harvest, transport and storage stage are analyzed [2].

Bad road conditions, where irregularities along with the large number of holes found cause tremor in the truck. The result of this agitation causes oscillation and displacement of these grains to the periphery, and if the truck is not in good condition and well fenced, these grains fall on the road [3].

Grain losses on roads cause losses beyond the economic scope. Grains that fall around the highway are seeds with the potential to germinate, making it the "green bridge" for the transmission of diseases or hybridization between traditional, commercial and transgenic cultivars [3].

When trucks exceed the value of 0.25% in the contract, grain losses are paid by the carrier. The economic impact occurs from the producer to the final consumer, who ends up paying more for the product [4].

Grain quantity is of great importance in the value of the product to the consumer. The final price is influenced by the quantity of product available. Thus, the demand and the percentage of grain being lost, the final price of the industrialized product will be more expensive in the consumer's Table. [5].

The objective of this study was to establish the quantitative losses along the roads during the transportation of wheat grains in Paraná, as well as to verify the influence of short and long distance load on grain losses.

## 2. MATERIALS AND METHODS

### 2.1 Experimental Site Description

The evaluation work was carried out at the Nucleus of Storage Technology of the Faculty of Agronomy and Animal Science, at the Federal University of Mato Grosso, Cuiabá - MT campus.

A survey of wheat grain losses was carried out in the BR-376, approximately 295 km distance between the Port of São Francisco in Santa

Catarina and Ponta Grossa in Paraná between March and April 2018.

## 2.2 Experimental Design Description

The experiment was carried out in subdivided plots, 26 plots (collection points), 4 subplots (collection times) and 3 replicates (collection areas at points).

A total of 26 collection points were established along the stretch, with a distance of 10 km from one point to the other, in order to give randomness to the collection points. For the distance between the points a margin of difference of 500 meters was accepted for more or less, in order to avoid points of collection in very dangerous places, lack of parking space or that in any way put safety at risk of collections.

At each collection point an area of 1 m<sup>2</sup> was fixed with the aid of a fixed frame of wood with the same area, at a distance of 1.3 m from the highway margin, in the north-south direction of the highway, which is the direction of the grain flow in BR-376 in the section considered; from

this first collection area, two more areas to be collected were selected, one 30 m before and the other 30 m after the first area fixed at the point. In the areas were collected all residues of grains present and demarcated with white spray paint, in addition each collection point was georeferenced with a GPS Garmin model Etrex legend.

### 2.2.1 Grain weight determination

The grains were collected on the side of the road, along the gutters and near the lawn, using a broom, brush and dustpan. The collected material was placed in plastic bags properly identified and taken to the laboratory for separation and weighing.

### 2.2.2 Identification of the points of wheat collection

The identification of the points of wheat collection on the highway from Port of São Francisco - Santa Catarina to CONAB in Ponta Grossa Paraná, with an approximate distance of 295 Km occurred as follows:

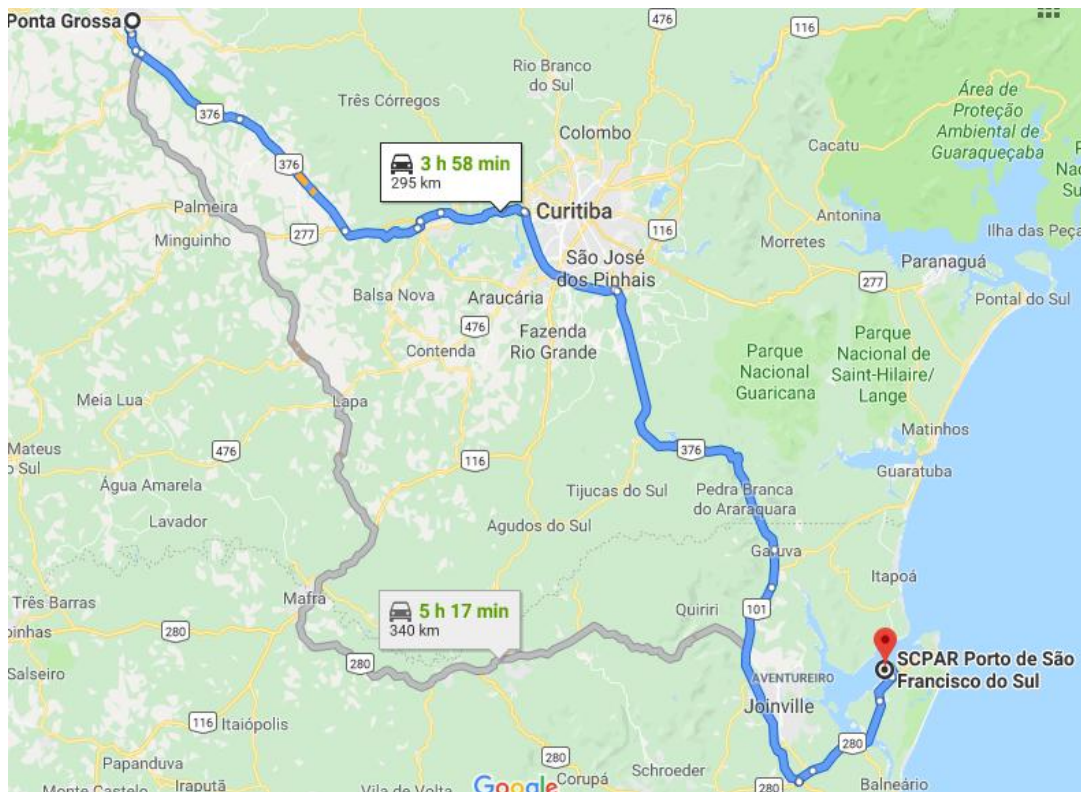


Fig. 1. Main route of wheat flow in the state of Paraná, Highway BR 277/376, scrub out from São Francisco-SC Port to Ponta Grossa, Paraná, Brazil

**Point 1** - Plate km 9. Exit San Francisco - This collection was located at the exit of the bridge of São Francisco do Sul, a simple track of good conservation in straight and level. First point of collection.

**Point 2** - Still in San Francisco do Sul, continuing in a simple track of good conservation in straight and level.

**Point 3** - Simple track of good conservation at the end of a level line, where very low rates of losses are observed.

**Point 4** - Start of the double track, without corrugations on the track, on level, optimally conserved track.

**Point 5** - P4 + 13.8 km. Departure from Joinville - SC, double track, after the exit of Joinville, well preservation track, with water drainage channels at the edges of the highway, possibly carrying grains that may have been deposited there.

**Point 6** - P5 +10.6 km. Well preserved double track with few losses and great vegetation around the highway, where accidents may occur due to the presence of food near the BRs.

**Point 7** - P6 + 10.2 km, double track of excellent conservation, point at the end of a slope slightly accented with few losses.

**Point 8** - P7 + 10.2 km, point in double track of good conservation in straight line with little slope, where plate is observed with speed 100-80 km/h. Not observed high losses.

**Point 9** - P8 + 10.4 km, point at the beginning of the ascent of the sea, low stretch of the trucks.

**Point 10** - P9 + 14.7 km, turn right. Point with small slope at the end of the ascent of the mountain, double track of good conservation.

**Point 11** - P10 + 10.2 km, at this point at the end of a steep slope, low speed point of the trucks. Signaling ripples on the runway for speed reduction due to the entry of the post just ahead.

**Point 12** - P11 + 10.0 km, place at the end of the additional lane, point at the end of the additional lane, with a tapering of the lane to two lanes in a small lane where braking and increased losses can occur.

**Point 13** - P12 + 10.3 km, point in double lane in straight level with traffic of trucks in high speed, losses occur, due to the speed of the trucks that transport grain.

**Point 14** - P13 + 10.4 km, point in double track, good conservation, great straight level. Trucks travel at high speeds, more losses may occur due to excessive speed of the truck.



**Fig. 2.** Wheat collection point near the port of São Francisco, Santa Catarina, Brazil



**Fig. 3. Wheat collection point, Highway BR 277/376, Santa Catarina, Brazil**



**Fig. 4. Wheat collection point in double lane, Rodovia BR 277/376, Santa Catarina, Brazil**



**Fig. 5. Preparation of the wheat sample collection point, BR 277/376, Paraná, Brazil**

**Point 15** - P14 + 10.3 km, well maintained highway, no holes, double lane on small slope before bridge headland. In the entrances and exits of bridges it is observed larger quantities of grains accumulated in the shoulders.

**Point 16** - P15 + 10.4 km, double track point of good conservation with small slope, arriving in Curitiba.

**Point 17** - P16 + 10.1 km, point next to highway with some faults, small holes and undulations but with reduction of speed due to inspection.

**Point 18** - P17 + 10.2 km, plate 60 km/h Point preceding the curve with a speed limit of 60km / h, that is, with slower truck traffic, reduction of losses.

**Point 19** - P18 + 10.1 km, point in double track, of great conservation in sloped curve with traffic of trucks in high speeds.

**Point 20** - P19 + 10.4 km, point at the end of straight downhill with well maintained highway, trucks travel at high speeds.

**Point 21** - P20 + 10.6 km, small swell on the track, but good conservation, without holes. Location near the Federal Highway Police station, slow transit.

**Point 22** - P21 + 10.1 km, point in small slope, straight, Km 545. It has water drainage channels at the edges of the highway, possibly carrying grains that may have been deposited there.

**Point 23** - P22 + 10.4 km, point on slope, Km 534, straight, with road of great conservation, low loss index.

**Point 24** - P23 + 10.4 km, point in curve, in slope, with well preserved highway, near the commercial center, slow traffic, but with observed losses.

**Point 25** - P24 + 10.4 km, point in straight line with small slope of good conservation of the highway.

**Point 26** - P25 + 10.2 km, point before bridge, Cará-Cará river, sloping with good track conservation. It stands out for the excessive loss of soybean grains. Last point before Conab. At this point it was observed a lot of losses of other grains, mainly soybean and corn, due to many trucks transporting these grains also in the same period.

### 2.3 Statistical Analysis

Statistical analyzes were performed using software Assistat (2016), version 7.7. Differences among treatments were verified using analysis of variance (ANOVA) using the F test. When significant to the comparison of means for the treatments was performed by the Scott-Knott test.

### 3. RESULTS AND DISCUSSION

During the collection period, wheat transport was taking place from the port of São Francisco in

Santa Catarina to the CONAB Warehouse in Ponta Grossa-MT, with a frequency of approximately 5 truckloads of trucks per day.

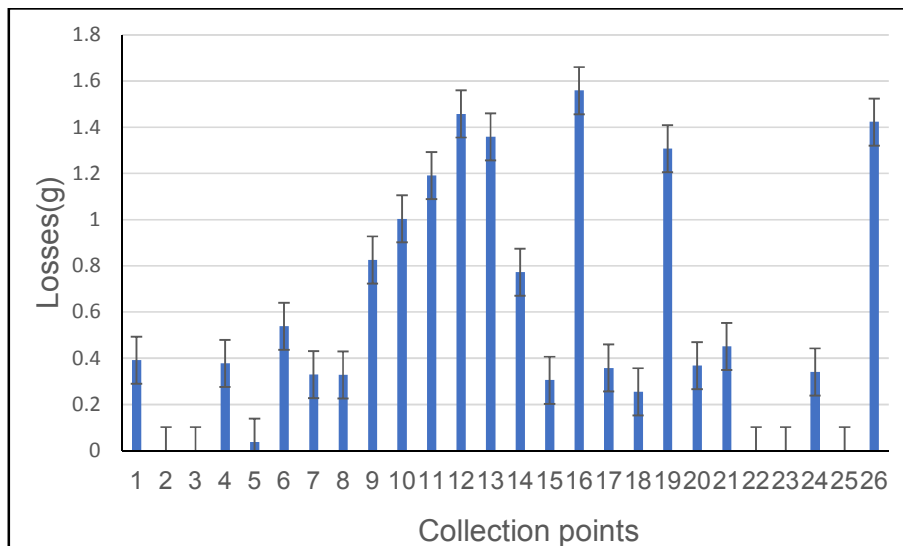
For a better evaluation, the data obtained were divided into short and long route taking into account the distance traveled in the transport of wheat grains. It was determined by short route, the highway with maximum distance of up to 100 km, and long route, stretch with distance greater than 100 km.

The observed wheat losses on the roads were carried out in four consecutive weeks in the same 26 already pre-defined points.

The highest losses of grain occurred at points 16, 12, 26, 13 and 19 of BR 376. During the period of collection on the roads the wheat transport flow was low, and the Highway had a good state of conservation (Table 1).



**Fig. 6. Wheat collection point near the city of Ponta Grossa, Paraná, Brazil**



**Fig. 7. Average wheat grain losses in grams of the points collected on the BR 376 highway, in 2018, between the stretches of São Francisco, Santa Catarina and Ponta Grossa, Paraná, Brazil**

**Table 1. Average wheat grain losses in grams of the points collected on the BR 376 highway, in 2018, between the stretches of São Francisco, Santa Catarina and Ponta Grossa, Paraná, Brazil**

Points	Averages
P16	1.559 a
P12	1.458 a
P26	1.423 a
P13	1.359 a
P19	1.308 a
P11	1.191 a
P10	1.004 a
P9	0.826 a
P14	0.773 a
P6	0.539 b
P21	0.451 b
P1	0.392 b
P4	0.378 b
P20	0.368 b
P17	0.358 b
P24	0.341 b
P7	0.329 b
P8	0.328 b
P15	0.305 b
P18	0.255 b
P5	0.037 c
P2	0.000 c
P3	0.000 c
P22	0.000 c
P23	0.000 c
P25	0.000 c

*\* Averages followed by the same letter do not differ statistically from each other at the 5% level of significance by the Scott-Knott test*

The section of the data referring to the short route that presented the highest loss index was the route in the interior of the city of Ponta Grossa-PR, this loss can be explained by the fact that for short routes it is preferable to use small trucks that in the majority of the times they are of greater age and in precarious conditions of conservation, mainly of the car bodies. According to Oliveira and Irceu [6] poorly maintained roads and old trucks are the main factors of losses. They are considered as the main causes for the waste of the production during the transport: the age advanced of the fleet, the poor conservation of the trucks and the bad conditions of good part of the Brazilian highways. Poor quality asphalt, construction faults, lack of conservation and excess weight of the trucks are some of the factors that affect the conditions of the national highways. Studies indicate that 1% of load above the limit in an isolated axis increases in 4.32% the pavement wear. That is, if the overhead is

5% in the truck, a highway designed to last 10 years has its useful life reduced to 8.1 years. If the weight exceeds 20%, the durability of the floor will fall to only 4.5 years [7]. The section between the municipality of Irati, Palmeira and Tibagi also presented values of losses above that admitted (Table 2).

The Ponta Grossa / Ponta Grossa destination also presented the highest total loss even though it was a 25 km average distance, this result can be explained by the high number of trips (4207) and the highest average of travel losses (59.45 kg), in addition, this section is characterized by using small trucks with poor conservation. According to Martins et al. [8], in Brazil the most used mode for transportation is the road, even with the transshipment to trains in some regions, and even ferries, the truck remains sovereign in the transport of the Brazilian crop. This modality that uses approximately 800,000 thousand trucks each year, which are advanced age and associating bad conservation mainly of the car bodies, collaborating with the loss of R \$ 2.7 billion each year, this figure would be used by the government and other links of the chain if the waste did not happen.

The area between Uraí and Ponta Grossa was the destination with the highest losses (122.55 kg of grains per trip), which was considered very high (Table 2). It was observed in almost all sections of the route denominated as long losses superior to the acceptable in the contracts (0.25%).

The highway between the municipalities of Rio Negro / Ponta Grossa obtained the largest losses which can be explained due to the large number of trips, 2190.

The general average resulted in a value higher than the admitted value of 0.25%, but the Teixeira Soares/Ponta Grossa route is responsible for raising the average value, since the other routes obtained an index lower than 0.25% (Table 3). The high index of the Teixeira Soares/Ponta Grossa route (BR 376) can be explained by the conservation of the roads and the non-adoption of methods that reduce the losses.

In short routes, the most careful selection of trucks for transportation resulted in a lower average of the maximum allowed value of 0.25%, with the exception of the Uiratã/Ponta Grossa and Uraí/Ponta Grossa routes that obtained respectively 0.23% and 0.31% (Table 3).



**Table 2. Results of wheat grains collections in Highways BRs 116, 153, 277 and 376, in the long-route stretches, municipalities distant up to 100 Km from Ponta Grossa, Paraná, Brazil**

<b>Source</b>	<b>Destiny</b>	<b>Total of travel</b>	<b>Distance (Km)</b>	<b>Total kilometers</b>	<b>Total lost (Km)</b>	<b>Average travel losses</b>	<b>Average (g) losses per km</b>	<b>Variance</b>	<b>Standard deviation</b>
Ubiratã	Ponta Grossa	265	480	127,20	21,489	81.09	0.169	0.030	0.172
Uraí	Ponta Grossa	47	300	14,100	5,760	122.55	0.409	0.026	0.266
Rio Negro	Ponta Grossa	2,190	150	328,50	102,47	46.79	0.312	0.134	0.367
Santa Cecília do Pavão	Ponta Grossa	227	250	56,750	12,690	55.90	0.224	0.043	0.208
São Mateus do Sul	Ponta Grossa	122	140	17,080	3,130	25.66	0.183	0.041	0.202
Paranaguá	Ponta Grossa	558	250	139,50	17,050	30.56	0.122	0.019	0.138
Paulo Frontin	Ponta Grossa	805	170	136,85	47,050	58.45	0.344	0.099	0.316
Arapongas	Ponta Grossa	30	266	7,980	1,390	46.33	0.174	0.010	0.101
Assaí	Ponta Grossa	143	266	38,038	7,440	52.03	0.196	0.012	0.110

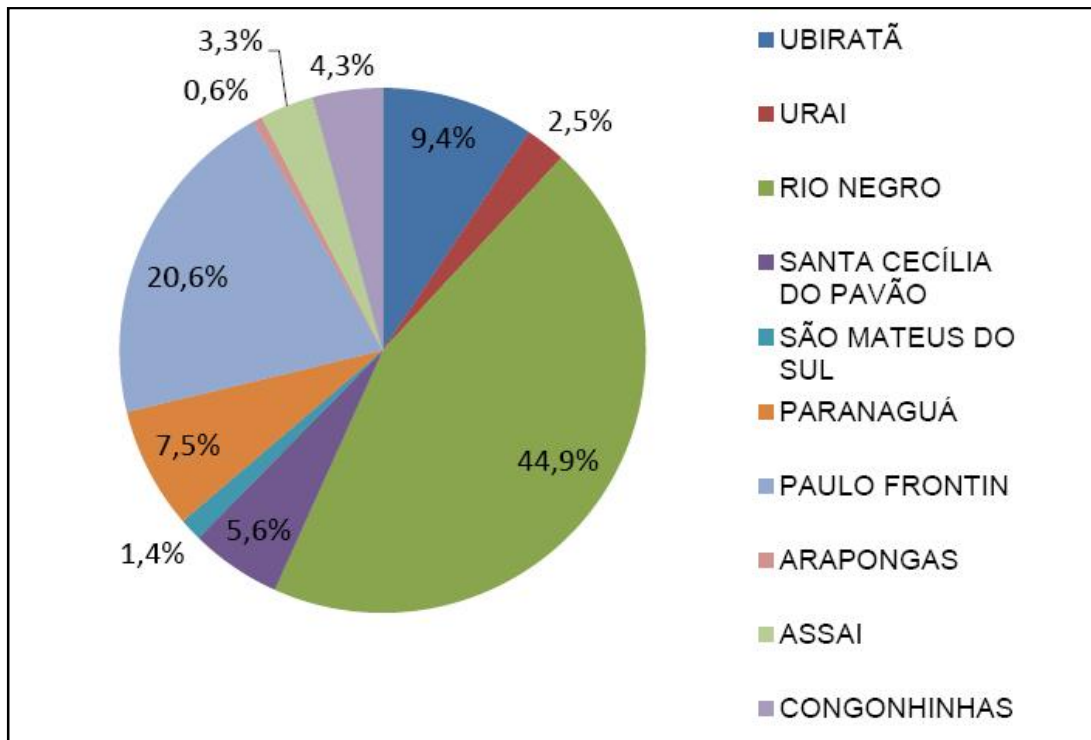


Fig. 8. Total wheat grain losses in Highways BRs 116, 153, 277 and 376, in the long-route stretches, municipalities distant up to 100 km and Ponta Grossa, Paraná, Brazil

Table 3. Index (%) of wheat losses in Highways BRs 277, 376,153 and 116, in the short and long highways, municipalities distant up to 100 Km. Paraná, Brazil

Departure	Destination	Percentage index
Irati	Ponta Grossa	0,16%
Palmeira	Ponta Grossa	0,15%
Ponta Grossa	Ponta Grossa	0,18%
Teixeira Soares	Ponta Grossa	2,84%
Tibagi	Ponta Grossa	0,10%
Ubiratã	Ponta Grossa	0,23%
Uraí	Ponta Grossa	0,31%
Rio Negro	Ponta Grossa	0,15%
Santa Cecília do Pavão	Ponta Grossa	0,17%
São Mateus do Sul	Ponta Grossa	0,08%
Paranaguá	Ponta Grossa	0,08%
Paulo Frontin	Ponta Grossa	0,18%
Arapongas	Ponta Grossa	0,14%
Assaí	Ponta Grossa	0,15%
Congonhinhas	Ponta Grossa	0,20%
Average		0,34%

#### 4. CONCLUSION

The research verified the main factors for grain grain losses. The quality of highways and trucks are the key factors in reducing grain losses.

It is indicated to adhere to the use of revised trucks. According to the condition of the highway, stipulate a maximum speed for grain conveyors. The solution for the reduction of losses of grains in the transport also passes through investments of the public and private initiative.

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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