sciendo
DOI: 10.2478/ata-2024-0008

Acta Technologica Agriculturae 1
Nitra, Slovaca Universitas Agriculturae Nitriae, 2024, pp. 52–59

INVESTIGATING THE ESSENTIAL FACTORS FOR THRESHER LOSSES AND WASTE IN PEANUT HARVESTER CONSIDERING SEVERAL VARIETIES OF CROP

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This research investigated the performance of a model traction combine harvester (TCH) for harvesting several varieties of peanuts. The effect of independent factors including tested varieties at three levels (local Moghan, Goli Astana, and Turkish), tractor forward speed (FS) at three levels (4, 5, and 6 km·h^{-1}), and rotational speed (RS) of the thresher at three levels (500, 600, 700 rpm) on losses and wastes were studied and investigated. To analyse the obtained data, a factorial experimental design was used in the form of randomised complete blocks, and Duncan's multi-range test was used to compare the mean values. According to the findings, the effects of tractor FS and rotary speed of the thresher on the percentage of threshing losses were significant at the probability level of 1%. Also, the interaction effects of variety type and tractor FS, tractor FS, and rotary speed of the thresher on the percentage of threshing losses were significant at the 1% probability level. Also, the effects of variety type, tractor FS, rotary speed of the thresher, and all mutual effects on the percentage of threshing waste were significant at the 1% probability level. The results of comparing the average effects of the main factors showed that the FS of 6 km·h^{-1} had the highest average threshing loss (82.89%). Threshing losses were obtained in the Turkish variety with the lowest average value (2.51%) and in the local variety with the highest average value (3.53%).

Keywords: combine harvester; sustainable production; sustainable development; sustainable food production; smart agriculture; food security

According to statistics, about 16% of crops and about 28% of garden products are lost in different stages of production until consumption. These losses mean the loss of labour, fresh water, cultivated land, and chemical fertilisers in producing crops (Gustavsson et al., 2011). Peanut is a highly-grown plant in the leguminous family (Wang, 2018). Peanut roots have nitrogen-fixing nodules that begin to grow 15 days after planting. A mature peanut plant has 830 and 4000 nodes (Maiti and Wesche-Ebeling, 2002). Peanuts increase soil fertility by fixing nitrogen. Peanuts produced in Iran are mostly consumed as nuts. Groundnut pulp has a significant amount of fat-free dry matter, which makes it suitable for animal feed. Currently, the area under peanut cultivation is 26 million hectares, and the annual production of this area is close to 45 million tonnes (Rachaputi et al., 2021). The cultivated region of this product in Iran is also nearly three thous\and hectares (Hosseinzadeh-Bandbafha et al., 2018). The yield of peanuts is unlimited, so the timing of harvesting operations is essential to obtain the maximum output, grade, and quality of the product. The delay in harvesting peanuts due to the possibility of encountering bad weather and, as a result, weakening of pods, sprouting, and rotting of pods, causes a noticeable decrease in yield (Li et al., 2016).

The most sensitive part of peanut production is harvesting at the most suitable time to create maximum quality and yield (Wright et al., 2006). On the other hand, delay in harvesting after physiological maturity can lead to the separation of pods under the soil and increase losses (Singh and Oswalt, 1995). In addition, late harvest exposes the product to various pests; usually, the amount of damage to this product by problems is estimated between 10 and 30% (Umeh et al., 1999). Peanut harvesting is generally done in two ways, traditional and mechanised. Hand or manual tools are used in the conventional method, which is costly and time-consuming (Ademiluyi et al., 2011). Mechanised harvest is also done in two ways: a) one-time harvesting of the product, and b) two-stage harvesting (picking and drying, and threshing) (Azmoodeh-Mishamandani et al., 2014). The standard mechanised method in Iran is two-stage harvesting, in which, in the first stage, the peanut plant is removed from the ground by a digger-shaker-inverter machine, and after shaking, it is placed upside down on the surface of the land. Then, after reducing the humidity, peanuts are removed from the ground. The plant is separated by a combine and thresher (Azmoodeh-Mishamandani et al., 2014).

Agricultural harvesters are one of the most essential machines in this industry (Dočkalík and Jobbágy, 2022) because they can improve productivity and reduce costs (Unakitan and Aydin, 2018; Zami et al., 2014; Cerquitelli, 2017; Qi et al., 2016). On the other hand, harvest losses and waste are also significantly affected by threshing performance (Khir et al., 2013; Zareiforoush et al., 2010; Alizadeh and Bagheri, 2009). The amount of failure is considered as the leading factors to assess the performance of the threshing department, which is calculated by examining the unseparated seeds taken out of the combine

(Abdi and Jalali, 2013; Markowski et al., 2013; Karlen et al., 2014). The amount of waste is evaluated by calculating the amount of damaged seeds at the place of collecting seeds and it harms the market value and quality of the product (Lashgari et al., 2008; Khazaei et al., 2008; Behnke and Brune, 2014). However, little research has been done on investigating the threshing part of agricultural harvesters to reduce losses and waste and increase productivity (Li et al., 2016; Gang et al., 2016; Gbabo et al., 2013). In the following, it will be pointed out that the results of some of this research have been carried out in the context of examining the parameters affecting the harvester's loss.

Morvaridi et al. (2008) analysed the influence of advanced and thresher speeds in corn harvesters. According to the findings, the effect of the rotational speed (RS) of the thresher on the losses of the thresher was significant. In this research, the highest amount of losses was calculated with the hammer speed of 500 rpm (Morvaridi et al., 2008).

Pishgar-Komleh et al. (2013) assessed the loss of a corn harvester. The results indicated that forward speed (FS) significantly impacts the quality of the harvested product. In contrast, threshing speed significantly affects the quantitative and qualitative threshing losses (Pishgar-Komleh et al., 2013).

In research conducted in Bulgaria on the effect of different varieties on the loss rate of mechanised peanut harvesting, According to the findings, the loss rate of the Tsvetelina variety was 9.7%, the lowest among the selected varieties. At the same time, the highest loss was 30.6%, which was related to the Kremena variety (Velcheva and Uzundzhalieva, 2022).

The studies showed that the advanced speed, RS of the thresher and crop variety significantly affect the amount of product loss and waste, and it is possible to improve harvest management and minimise the loss and waste of the thresher according to the planted variety. The main innovation of the study is to investigate factors contributing to thresher losses and waste in the peanut harvester for several peanut varieties. The experiment likely aimed to identify the factors that lead to the most significant losses and waste during harvesting and to determine if there are differences in the performance of different peanut varieties under the same harvesting conditions.

Material and methods

Area of the study

This research was conducted in the Moghan agriculture industry with a location of 39° 40′ north latitude, 47° 31′ east longitude, and 50 m above sea level) in October 2022 (Azadmard et al., 2018) (Fig. 1). Average rainfall in this region is 275 mm, and average air temperature is 15.2 °C (Jouni et al., 2018).

Study parameters

Factorial experimental design was used as a completely randomised design with three treatments and three repetitions to conduct this research. The treatments included three varieties of peanuts (local Moghan, Goli Astana, and Turkish), three FSs (4, 5, and 6 km·h^{-1}), and three RSs of the thresher (500, 600, and 700 rpm). A digital distance meter (Lutron DT 2236, Lutron Electronic Enterprise,

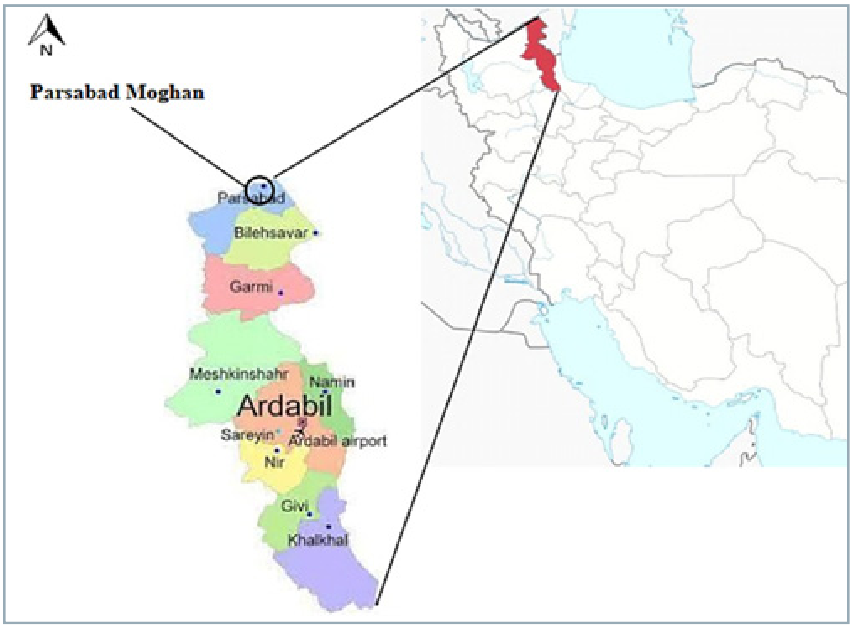

Fig. 1 Location of Moghan Plain in Parsabad, Ardabil, Iran

Fig. 2 Bajanakhlar plower model peanut TCH

Fig. 3 Peanut planter

Taipei, Taiwan) was employed to set the RS of the hammer axis. The PTO axis (1000 rpm) of John Deer tractor was used to obtain the required power of the threshing unit. Also, to compare the mean values, Duncan's multiple range test was used at the 5% probability level. The data obtained from the experiment were statistically analysed in Mstat C software.

Combine harvester

The harvesting combine used in this research was the peanut traction combine harvester (TCH) (Bacanaklar company, Turkey) (Fig. 2). This TCH can harvest a row of 130 cm comprehensive products from the ground. The thresher of this TCH is a spring tooth type that separates the peanut shell from the bush by combing the peanut bush.

Calculation of thresher losses and waste

To harvest peanuts, first, peanut plants were taken out of the ground by the peanut planter (Fig. 3). For better threshing, they were exposed to sunlight for at least 5 days and left until their final moisture content for threshing reached 14–15%. Then, 4 rows of dried bushes were turned into 1 row (because the harvesting machine was single-row) to perform the feeding operation for threshing more efficiently. Then the traction combine entered the field with a tractor to separate the peanut pods from the bush. To calculate the threshing losses, a cloth was tied at the outlet of peanut plants in the TCH. After traveling 10 m, the TCH was stopped, and all the contents collected were measured. Then, the remaining pods on the plant were separated, weighed, and recorded by a digital scale (GF-600, Aand D Company, Japan, resolution ±0.01 g). To calculate the threshing waste, all inputs to the seed tank for each FS and RS of the thresher were collected and transferred to the laboratory. Then, the amount of broken and damaged seeds was separated from healthy seeds and weighed by the digital scale.

Results and discussion

The results of the variance analysis of the data obtained from the tests and related to threshing damage (Table 1) showed that the effect of the factors of cultivar type, RS of the thresher, and tractor FS, as well as the mutual effects of the type of cultivar on the RS of the thresher, the type of cultivar on the FS of the tractor, and the speed of the tractor in the RS of the thresher, and the type of cultivar in the speed

Table 1 The results of variance analysis of the data obtained from the measurement of losses and threshing waste

Sources of changes	Degrees of freedom	Loss percentage	Waste percentage
Block	2	0.02 ns	2.13ns
Treatment	26	2.55**	638.46**
Tested seed	2	2.21ns	80.76**
Tractor FS	2	56.41**	353.84**
Thresher RS	2	4.47**	166.46**
Type of seed – tractor FS	4	28.43**	546.15**
Type of seed – thresher RS	4	0.78ns	117.30**
Tractor FS – thresher RS	4	30.15**	144.23**
Type of seed – tractor FS – thresher RS	8	80.97**	259.61**
Experimental error	52		

ns: not significant; **: significant at 1% probability level

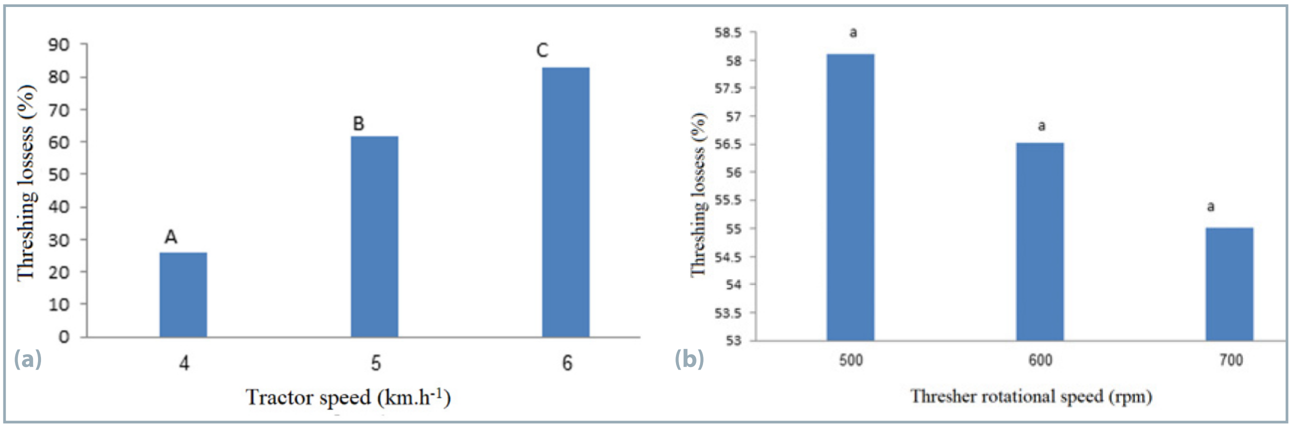

Fig. 4 The results comparing the average effects of the main factors investigated on threshing losses (5%)

of the tractor, in the RS of the thresher, are significant on the threshing losses at the 1% probability level. These results are consistent with the results of Asgari Arde et al. (2018).

Saeed Rad et al. (2012) studied the effect of RS of thresher cylinder, the distance between the thresher and anti-thresher, and feeding rate on grain sorghum threshing. The RS of the thresher was studied in four levels (650, 850, 1050, and 1250 rpm), the distance between the concave and thresher in three levels (5, 10, and 15 mm), and feeding rate in three levels (400, 500, and 600 kg·min^{-1}). According to the findings, by rising the RS of the thresher, the performance of the thresher enhanced in better separation of seeds from the cluster, and on the other hand, it caused a rise in the damage of seeds.

Comparing the average main effects (Fig. 4) of independent factors showed that the effects of tractor FS and threshing RS on the percentage of threshing waste were significant at the 1% level. The results of comparing the average impact of the main factors showed that the tractor FS of 6 km·h^{-1} had the highest average threshing loss (82.89%), and the tractor FS of 4 km·h^{-1} had the lowest average threshing loss (25.8%) with a significant difference. Also, by increasing the RS of the hammer from 500 to 700 rpm, a significant reduction in hammering losses from the average value (58.1%) to the average value (55.01%) has occurred, which is due to the high impact of hammer teeth on clusters. As a result, the percentage of seeds separated from the cluster is higher. The lowest thresher loss with a tractor FS of 4 km·h^{-1} was in the Turkish variety, averaging 21.5%. However, in the experiment with two local varieties and clay, only with a tractor FS of 6 km·h^{-1}, a significant change was achieved in the average interaction effect of the variety in tractor FS with the average value of threshing loss, respectively (89.13% and 82.93%), because enhancing the speed of the tractor is accompanied by an enhance in the amount of feeding and accumulation of materials.

The results of the comparison of the average interaction effect of tractor FS and thresher RS on threshing losses (Fig. 5) showed that in the tractor FS of 4 and 6 km·h^{-1}, a significant difference in threshing losses occurs with the increase of tractor FS. The tractor FS of 4 km·h^{-1} with the thresher RS of 700 rpm has the lowest amount of threshing losses (21.5%), and the tractor FS of 6 km·h^{-1} with the thresher RS of 500 rpm has the highest amount of threshing losses (89.13%). Also, the tractor FS of 5 km·h^{-1} with the RS of 500 rpm caused an average threshing loss of 66%.

Percentage of damaged pods or wastes

The findings of the ANOVA of the data obtained from the experiments related to threshing losses (Table 1) showed that the effects of all factors, including variety, tractor FS, and the RS of the thresher on threshing losses are significant at probability level 1%. The average comparison of the main effects of the independent factors showed (Table 2) that a significant difference was observed in the threshing losses of all the three varieties tested. The local variety has the highest amount of threshing waste (3.53%), and the Turkish variety has the least threshing waste (2.51%). Therefore, the threshing losses in the local variety are more than in the other two varieties, and it can be concluded that the threshing of the local variety Niyar is less powerful. Increasing the tractor FS from 4 to 6 km·h^{-1} significantly reduces the threshing waste from 4.45% to 1.93%.

Also, by increasing the RS of the thresher from 500 to 700 rpm, threshing waste increases significantly from 2.13% to 3.92% because with the increase in the RS of the thresher the impact from the teeth increases and, as a result, causes more damage to pods in peanuts.

The results of comparison of the average interaction effect of the tested variety and tractor FS on threshing losses (Fig. 6) showed that in the experiment with three varieties, local, Goli and Turkish, there is a significant difference in threshing losses with the increase of tractor FS. The Turkish

Table 2 Comparison results of the average main effects investigated in threshing losses (%) on several varieties tested

Variety for test			Tractor FS (km·h^{-1})			Thresher RS (rpm)		
Local	Goli	Turkish	4	5	6	700	600	500
2.51c	2.98b	3.53a	4.45a	2.57b	1.93c	3.92a	2.91b	2.13c

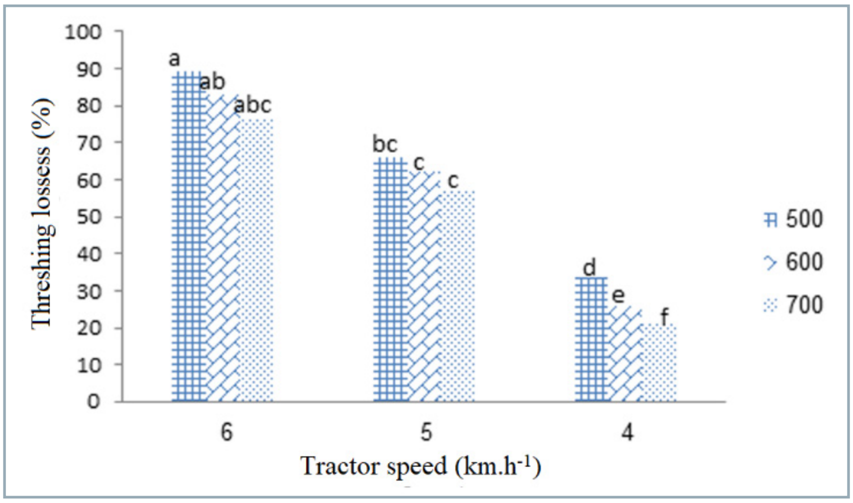

Fig. 5 The results of comparing the average interaction effects of tractor FS on thresher RS in threshing losses

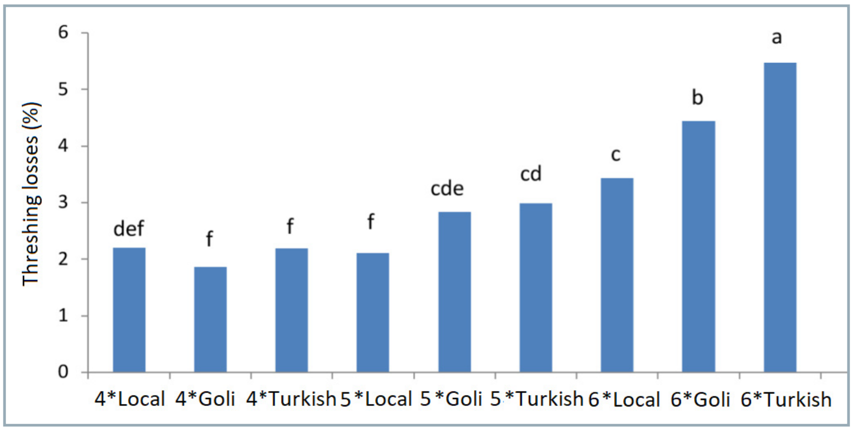

Fig. 6 The results of comparison of the average interaction effects of the tested variety and tractor FS on threshing damage. Similar letters indicate a non-significant difference of the interaction effect at the 5% probability level

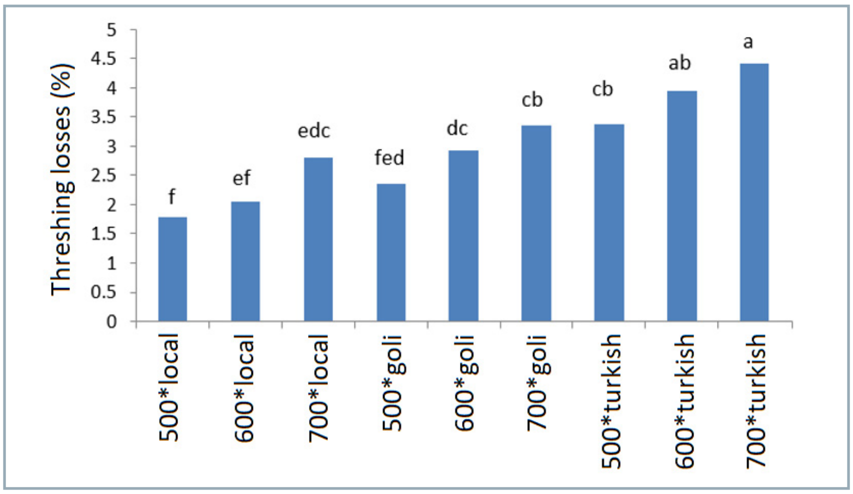

Fig. 7 The results of comparison of the average interaction effects of the tested variety and tractor FS on threshing damage. Similar letters indicate a non-significant difference of the interaction effect at the 5% probability level

variety has the highest threshing losses (5.48% at the tractor FS of 6 km·h^{-1}). Also, the local variety at the 4 km·h^{-1} tractor FS has the lowest threshing losses (2.2%).

The results of comparison of the average interaction effect of the tested variety and the RS of the thresher on threshing losses (Fig. 7) showed that in the experiment with three varieties, local, Goli and Turkish, with the increase of the RS of the thresher, a significant increase in threshing losses was achieved. Thus, the local variety with the RS of 500 rpm has the lowest amount of threshing waste (1.78%), and the Turkish variety has the highest threshing loss (4.42%). The threshing waste in the Turkish variety is more than in the other two varieties, and it can also be concluded that the Turkish variety requires less power for threshing.

The results of comparison of the average interaction effects of tractor FS and the RS of the thresher (Fig. 7) on threshing losses showed that in the experiment with three levels of tractor FS (4, 5, and 6 km·h^{-1}), with the increase of the RS of the thresher, there was a significant increase in threshing losses. The tractor FS 4 km·h^{-1} with the RS of 500 rpm has the lowest threshing losses (1.31%), and the tractor FS 6 km·h^{-1} with the RS of 700 rpm has the highest threshing losses (5.44%).

The comparison results of the average interaction effect of variety type, tractor FS, and thresher RS on threshing losses (Fig. 8) showed that the local variety has a significant difference only in the tractor FS of 5 km·h^{-1} and the RS of 700 rpm. The highest threshing losses were obtained at the tractor FS of 4 km·h^{-1} and the thresher RS of 700 rpm (2.34%). Also, in the local variety, at the tractor FS of 5 km·h^{-1}, with the increase of thresher RS from 500 to 700 rpm, a significant difference in average threshing waste was obtained. In the Goli variety, there was a significant difference in the tractor FS of 4 km·h^{-1} and the RS of 600 to 700 rpm for threshing losses.

The highest threshing losses were obtained at the tractor FS of 4 km·h^{-1} and the thresher RS of 700 rpm (2.49%). Also, a significant difference in the average threshing damage was observed in the Goli variety at the tractor FS of 5 km·h^{-1} with an increase

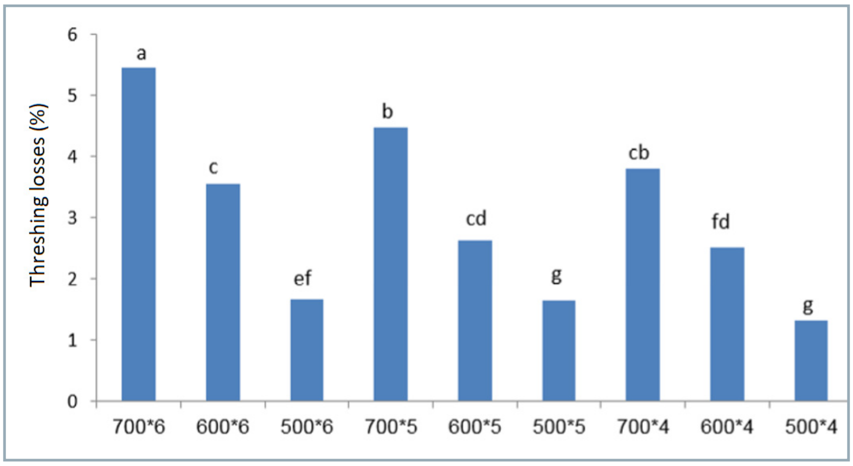

Fig. 8 The results of comparison of the average interaction effect of tractor FS on the RS of the thresher

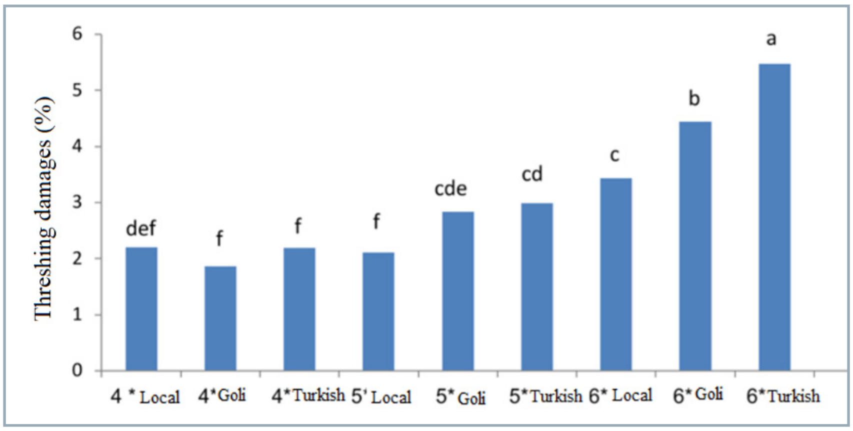

Fig. 9 The results of comparison of the average interaction effects of the tested variety and tractor FS on threshing damage. Similar letters indicate a non-significant difference of the interaction effect at the 5% probability level

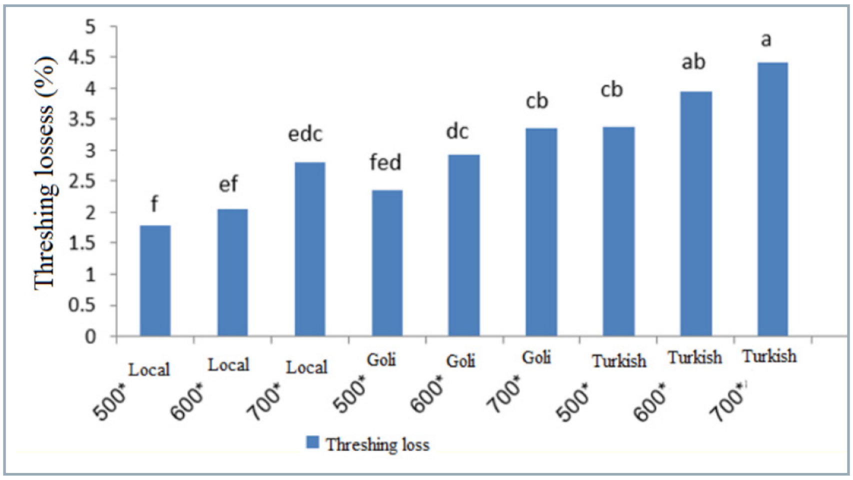

Fig. 10 The results of comparison of the average interaction effects of the tested variety and tractor FS on threshing damage. Similar letters indicate a non-significant difference of the interaction effect at the 5% probability level

in the RS of the thresher from 500 to 700 rpm, which could be due to the physiological and mechanical properties of the Goli variety.

In the Turkish variety, there were only three treatments, including the FS of 4 km·h^{-1} and RS of 600 rpm, the FS of 4 km·h^{-1} and RS of 700 rpm, and the tractor FS of 5 km·h^{-1} and RS of 500 rpm. A significant difference was observed. The highest threshing losses were obtained at the tractor FS of 4 km·h^{-1} with the RS of 700 rpm (2.7%), and the lowest threshing losses were obtained at the tractor FS of 5 km·h^{-1} with the RS of the thresher at 500 rpm (1.9%). Therefore, the most suitable linear speed of the thresher is the speed at which, in return, the percentage of threshing losses does not exceed 2%, and the rate of waste does not exceed 1%. With the increase of the RS of the thresher, the amount of threshing waste or damage to the pods increased. Because the pods and bushes of different varieties of peanuts have additional resistance to the impact from the hammering tooth according to plant physiology, and with the increase of the RS of hammering, threshing loss was reduced. According to the results of the tests performed in all varieties, it can be seen that the highest amount of threshing loss was obtained in the experiment with the local variety, tractor FS 4 km·h^{-1}, and RS 700 rpm (2.34%). The lowest amount of threshing loss (1.9%) was obtained with the Turkish variety, tractor FS 5 km·h^{-1}, and the RS of the thresher 500 rpm.

The results of comparison of the average interaction effect of the tested variety and tractor FS on threshing losses (Fig. 9) showed that in the experiment with three varieties, Goli, local and Turkish, with the increase of tractor FS, there was a significant difference in threshing losses. It is created in such a way that the Turkish variety has the highest amount of threshing waste with an average of 5.48% in the tractor FS of 6 km·h^{-1}, and the local variety has the lowest amount of threshing waste with an average of 2.2% in the tractor FS of 4 km·h^{-1}.

The results of comparison of the average interaction effect of the tested variety and thresher RS on threshing losses (Fig. 10) showed that in the experiment with three varieties, Goli, Turkish and local, with an enhance in the RS of the thresher for the entire surface, there was a significant increase in resulting threshing losses. The local variety with the RS of 500 rpm has the lowest amount of threshing waste with an average of 1.78%, and the Turkish variety has the highest amount of threshing waste with an average of 4.42%. The threshing loss in the Turkish variety is more than in the other two varieties, and it can also be concluded that the Turkish variety requires less power to thresh.

Conclusion

- The results of comparing the average effect of tractor FS indicated that there is a significant difference in threshing losses. The highest threshing losses (4.45%) were obtained at 6 km·h^{-1}, and the lowest threshing losses (1.92%) were obtained at the 4 km·h^{-1}.
- The factors involved in the losses and wastes of the peanut harvesting machine are the FS of the tractor, the RS of the thresher, the type of varieties, and the timing of harvesting. Also, the results of the variance analysis of the data obtained from experiments showed that the three effects of tractor FS, thresher RS, and the type of variety on threshing losses are significant at the 1% probability level.
- The type of variety, speed of movement, and RS significantly affected the percentage of waste.
- The highest threshing losses are in the local variety (3.53%) and the lowest in the Turkish variety (2.51%).
- In general, with the increase in the RS of the thresher, threshing wastes increase, and threshing losses decrease.
- The threshing of the tested varieties depends on plant physiology, the number of blows of the threshing tooth, and the distance between the thresher and separator.
- The average amount of waste increases with the increase of tractor FS and thresher RS.
- Accordingly, the following points are suggested:
- The chassis of the device should be strengthened so that it is possible to test the machine at high speeds of the thresher.
- Threshers and separators with different dimensions should be designed and made available based on the product type and variety.
- The machine should be tested for other varieties of peanuts.

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