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Investigating the Effect of Some Operating Factors on the Performance of a Laboratory Cluster Threshing Machine – Case Study: Two Barley Varieties

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ABSTRACT

In many research institutes, it is necessary to thresh the product in clusters. For this purpose, a laboratory threshing unit is used. The purpose of this study was to investigate the effect of some factors including to common barley varieties in Ardabil province (Aras and Sahra), cluster amount (10 and 15 g), blade speed (450, 600 and 750 rpm), threshing time (10, 20 and 30 s) and the blade clearance from the bottom of the cylinder (2.5 and 3.5 mm). An inverter was used to change the speed of the thresh blade. A four-factor randomized complete block design (RCBD) was used to analyze the data. The results of analysis of variance showed that the effects of independent factors as well as the interactions of independent factors including cluster amount, blade clearance, blade speed and threshing time on threshing losses and damaged grains percent (except for the main interactions of blade speed in experiment with Sahra variety) was significant. The lowest and highest mean of damaged grain percent belonged to Aras and Sahra varieties, respectively. In general, threshing losses of Aras variety were higher than Sahra variety, but the damaged grains percent of Aras variety was lower. According to the results of the interactions of four factors, two factors the device evaluation, the best working conditions (minimum threshing loss and lowest damaged grains percent) in exchange for tests with cluster amount of 15 g, blade clearance of 3.5 mm, blade speed 600 rpm and the threshing time was 30 s.

INTRODUCTION

Barley (*Hordeum Vulgare*) is one of the most important agricultural crops in the world. Barley is a plant that has a wide climate range and is often compatible with arid and semi-arid regions. Barley grain composition depends on many factors such as variety, type of plant and its environmental conditions and includes sugars, protein, fat and ash. The major minerals of barely were Ca 24-31 mg%, P 117117-129 mg%, Fe 1.7 -2.9 mg%, Na 13-18 mg%, K 227-273 mg%, Zn 1.1-1.2 mg% and 38-45 mg% (Choe et al., 2005). Compared to wheat straw, barley straw has a higher nutritional value for livestock, so that it is equal to the fodder value of corn seeds. In comparison with wheat, barley crop is more resistant to drought and disease. Many researchers have reported the initial origin of this plant in the Zagros Mountains in western Iran, southern Anatolia and Palestine. Barley is an important food source for a large number of people in cold and dry regions (especially the Middle East and North Africa) (Parviz, 2018). Of course, today it is mostly used for animal food and preparation of fermented products. The performance of a special type of threshing unit (Jima drum), for barley and wheat, was determined from 2.25 to 2.5 qt/h and 2.2 to 2.86 qt/h, respectively (Bedad *et al.*, 2021). In this research, three levels of blade speed 1300, 1400 and 1500 rpm and three levels of feed rate 5, 10 and 15 kg/min were used. The obtained results showed that threshing efficiency varied in the range of 99.03% to 99.82% and 97.10%to 100% for wheat and barley, respectively. The damaged grains percent in the experiment with wheat and barley was reported as 0.19 to 0.87% and 0 to 9.2%, respectively (Singhal and Thierstein, 1987). Of course, in this report, the maximum of allowable threshing loss and damaged grains percent are represented 5% and 2%, respectively (Sharma et al., 1984). Maximum threshing efficiency, output capacity and minimum of damaged grains percent obtained for wheat in test condition of the drum speed 1400 rpm, feed rate 10 kg/min, and for barley 1300 rpm and feed rate 5 kg/min, respectively.

In a study, an axial flow thresher was evaluated to determine the effect of spike-tooth threshing cylinders on rice quality (with 18% moisture content) (Biaou Olaye *et al.* 2016). During it, the effects of threshing drum speed at four levels (600, 800, 1000 and 1200 rpm) and paddy weight for feeding at three levels (40, 50 and 60 kg) with three repetitions on threshing capacity(kg/h), threshing efficiency, cleaning efficiency, fuel consumption and total grain losses were investigated. The results of this study revealed that the threshing capacity mean ranged from 1326 to 2013 kg/h, the mean of fuel

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consumption ranged between 0.75 to 0.84 ml/kg, threshing efficiency mean was 100%. The damaged grains percent mean ranged from 2.63 to 16.45 %. The mean of cleaning efficiency ranged 95.57 to 96.79 %.

Evaluation results a Multi-Crop thresher in test with millet product showed that the highest threshing and cleaning efficiencies of the device is 63.2 and 72.72%, respectively (Gbabo et al., 2013). The optimal drum speed was 800 rpm in grain moisture content 13 w. b. %. The performance optimization results of the axial flow thresher with two thresher designs (conical and cylindrical) with different thresher speed levels (1100, 1300 and 1500 rpm) and feeding rates (0.8, 1.1 and 1.4 kg/s) showed that by increasing the drum speed and the feed rate, the required power and threshing efficiency increase (Abdeen *et al.* 2021).the highest efficiency (98%) was obtained in the test with a cone-shaped drum under a drum speed of 1500 rpm and a feed rate of 1.4 kg/s. Also, the minimum required power (5.45 kW) was obtained in the test with this type of drum with a rotational speed of 1100 rpm and a feed rate of 0.8 kg/s.

The purpose of this research was to test a laboratory threshing unit in barley product threshing.

MATERIALS AND METHODS

Materials and equipment included a laboratory threshing unit equipped with an electro motor, digital optical-contact tachometer (RM-1500 PROVA), digital scale (AND-GF600), grain moisture meter (G-WON), inverter (Santerno), a timer. In tests, two barley varieties (Aras and Sahra) were used.

Technical specifications of the laboratory threshing unit

This device includes a chassis, an electro motor 0.5 hp, a connecting rood coupling with a blade and a cylinder and a cylinder cover (Fig. 1a). The electro motor is mounted on the chassis so that its axis passed inside the cylinder with a diameter and height of 225 and 110 mm, respectively. A connecting rood with a blade is installed on the axis of the electric motor (1-b) so that it is possible to move the blade relative to the bottom of the cylinder to adjusting of blade clearance and it fixed on the axis of the electro motor using a bolt.

The length, width, and thickness of the blade were equal to 100, 40 and 5 mm, respectively. The blade was coupled symmetrically on a cylinder the left and right (1-c). The used components and their connections are shown in Fig. 2.

a. Laboratory threshing unit | b. Cylinder located into blade | c. Blade

Fig 1. Laboratory threshing machine with its details

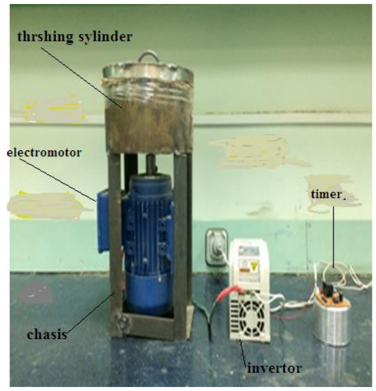


Fig 2. Test apparatus

The producer of conducting each experiment was as follow that a certain amount of the barley clusters were placed evenly and symmetrically inside the cylinder, and then the cylinder cover was placed on the cylinder. Then the electrical switch was on for a period of time as threshing time (10, 20, and 30s). The electro motor was automatically turned off. The threshing material was taken out of the cylinder and put inside a labeled bag. During the work, the clusters were placed between the blade and the bottom of the cylinder. They were exposed to the friction force and as a result they were threshed. In this device, which was evaluated for a barley product, the performance parameters of the device included the threshing losses and the damaged grains percent. Two common barley varieties in Mughan region from Ardabil province (*Aras* and *Sahra*) were used for the experiments. The independent factors included the blade speed, the cluster amount, the blade clearance and the threshing time. Of course, first a series of preliminary tests were performed on the device and then the levels of independent parameters were determined to accomplish experiments. An inverter was used to adjust the blade speed and a timer was used to adjust the threshing time. Therefore, the blade speed in three levels (450, 600, 750 rpm), threshing time in three levels (10, 20 and 30 s), the blade clearance in two levels (2.5 and 3.5 mm), the cluster amount two levels (10 and 15 g) were considered. And each experiment was done with replications. According to the number of levels of independent factors, 216 test samples were obtained. The samples were analyzed to determine the threshing losses (percentage of unthreshed grains) and the damaged grains percent.

To analyze the obtained data of each test, a factorial test was used in the form of a four-factor randomized complete design. Duncan's multiple range test (DMRT) was used to compare the effects means.

RESULTS AND DISCUSSION

Aras Variety

Threshing losses

The results of variance analysis of the data of two dependent factors (threshing losses and damaged grains percent) showed that the effects of cluster amount, blade clearance and the blade speed, the interactions effects of the blade clearance and blade speed, the threshing time at the level of probability 5% and the interactions effects of blade speed and threshing time on threshing losses were significant (P<5%) (Table 1).

The results of the comparison of the main effects mean (Table 2) showed that by increasing independent factors including the cluster amount from 10 to 15 g, the blade clearance from 2.5 to 3.5 mm, blade speed from 450 to 750 rpm, the threshing time from 10 to 30 s, the threshing losses mean were changed from 6.899 to 8.268%, 8.332 to 6.774%, 15.366 to 2.275% and 15.604 to 2.875%, respectively.

The increasing of threshing losses was due to increase in the cluster amount within the cylinder. Of course in the threshing units, the threshing efficiency also decreases with the increase in feed rate. The increasing threshing losses mean is due to the increase in blade clearance because of reducing the friction force.

By increasing two factor i.e. blade speed and threshing time, the threshing losses have been reduced significantly. These cases may also be caused by compression as a result of increased friction or impact on the clusters. The results of this research are consistent with the results of most previous researches. Increasing the cluster amount from 10 to 15 g, has caused a significant decreasing in the damaged grains percent (from 2.57 to 1.24 %), which is due to the reduction of the applied force. Of course, it should be noted that threshing losses have increased. The reduction in the damaged grains percent is caused by increasing the blade clearance. Because by reducing that blade clearance, the force applied to the grain decreases. The initial increase in the damaged grains percent by the increase in the blade speed, created from increasing in the exerted force on the grains. A significant increase of the damaged grains percent mean vis the threshing time has made it possible for the mass of grains to be fully exposed to the force of friction. Some interaction effects on threshing losses were not significant. Therefore, the presenting of mean comparison results of them were negligible. The results of the comparison of the interaction effects means of cluster amount and blade speed (Fig. 3a) on threshing losses mean showed that in test with each two levels of cluster amount, with increasing blade speed, threshing losses were significantly reduced.

Table 1. The results of variance analysis of the data related to the threshing losses and damaged grain percent of the tested varieties

		Sum of squares			
Variation sources	Freedom degree	Threshing losses		Damaged grains percent	
		Aras variety	*Sahra* variety	*Aras* variety	*Sahra* variety
Replication	2	21.651^{ns}	2.987^{ns}	0.428^{ns}	0.817^{ns}
Grain value (A)	1	46.952*	17.307**	47.132**	58.680**
Blade clearance (B)	1	65.495*	19.553**	333.955**	382.396**
Interaction (A×B)	1	1.172^{ns}	60.672**	44.917**	69.773**
Speed blade (C)	2	3425.198**	296.347**	3.200*	3.200^{ns}
Interactions (A×C)	2	113.233*	1.150 ns	16.800**	21.555**
Interactions (B×C)	2	25.233^{ns}	5.357*	2.719^{ns}	2.640^{ns}
Intractions (A×B×C)	2	6.432^{ns}	35.930**	16.682**	27.876**
Threshing time(D)	2	3497.99**	156.892**	118.957**	147.075**
Interaction (A×D)	2	4.952^{ns}	24.761**	22.056**	37.022**
Interaction (B×D)	2	31.904^{ns}	14.076**	108.370**	132.700**
Interactions (A×B×D)	2	16.433^{ns}	75.080**	19.018**	39.700
Interactions (C×D)	4	935.055**	26.623**	9.012**	3.343^{ns}
Interactions (A×C×D)	4	13.545^{ns}	26.887**	13.345**	6.756^{ns}
Interactions (B×C×D)	4	111.656*	22.096**	10.995**	4.437^{ns}
Interactions (A×B×C×D)	4	3.533^{ns}	96.031**	11.570**	9.037^{ns}
Error	70	809.645	46.434	33.868	125.280
Total	107	9130.280	928.363	813.025	1071.442

^{ns} not significant * significant (P<%5) ** significant (P<1%

Table 2. Comparison of the main effects mean on threshing losses and damaged grain percent for Aras variety

Evaluated factors	Cluster amount		Blade clearance		Blade speed			Threshing time		
	10 g	15g	2.5 mm	3.5mm	450 rpm	600 rpm	750 rpm	10 s	20s	30 s
Threshing loss	6.889^{b}	8.268^{a}	8.332^{a}	6.774^{b}	15.366^{a}	5.109^{b}	2.275^{c}	15.604^{a}	4.552^{b}	2.857^{c}
Damaged grains percent	2.570^{a}	1.149^{b}	3.668^{a}	0.151^{b}	1.679^{b}	2.092^{a}	1.95^{ab}	0.618^{c}	1.921^{b}	3.188^{a}

The comparison results of the interaction effects mean of threshing time and blade speed (Fig. 3b) showed that at the threshing time level of 10 s, with the increase of the blade speed, the threshing losses increases sequentially. The experiment at the threshing time levels of 20 and 30 s, the threshing losses was significantly reduce only by changing the blade speed from 450 to 600 rpm.

The mean comparison results of the blade clearance and the blade speed (Fig. 3c) showed that in the experiment with the level of the blade clearance of 2.5 mm, by increasing the blade speed, the threshing losses were significantly reduced, but in the experiment with the level of 3 mm, Only by changing the blade speed from 450 to 600 rpm, the reduction of losses has been significant.

The results of interaction means comparison of blade clearance and threshing time (Fig. 3d) showed that in both levels of blade clearance, by increasing of threshing time, losses have decreased significantly. The results investigation of the mean comparison of four factors showed that the highest and lowest values of threshing losses are 26.903 and 0.000% in experiment condition of cluster amount of 10 g, blade clearance of 3.5 mm, blade speed 450 rpm and threshing time 10 s and cluster amount of 15 g, the blade clearance of 2.5 mm, the blade speed 750 rpm and the threshing time 30 s, respectively.

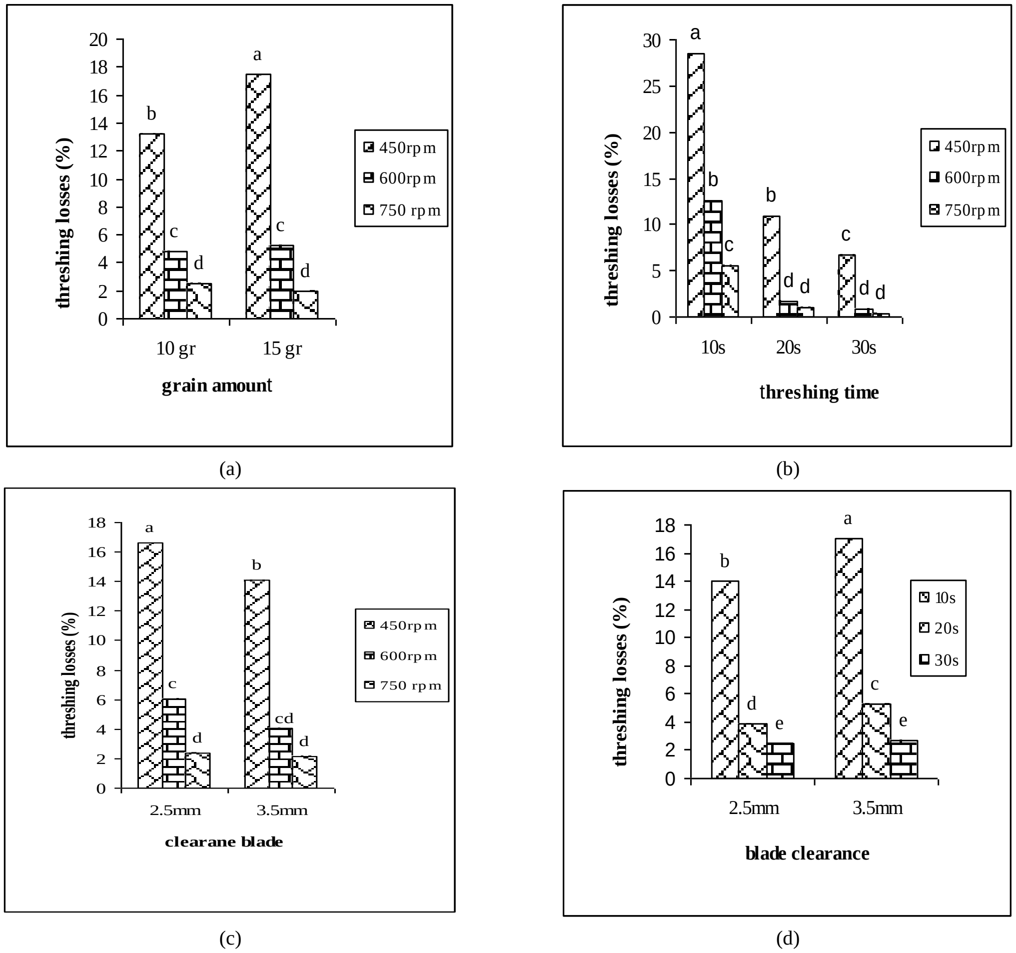


Fig 3. a) The results of the mean comparison of the interaction effects of cluster amount and blade speed b) the threshing time and blade speed, c) blade clearance and blade speed d) blade clearance and threshing time on threshing losses for Aras variety

(Unsimilar letters indicate a significant difference at the 5% probability level)

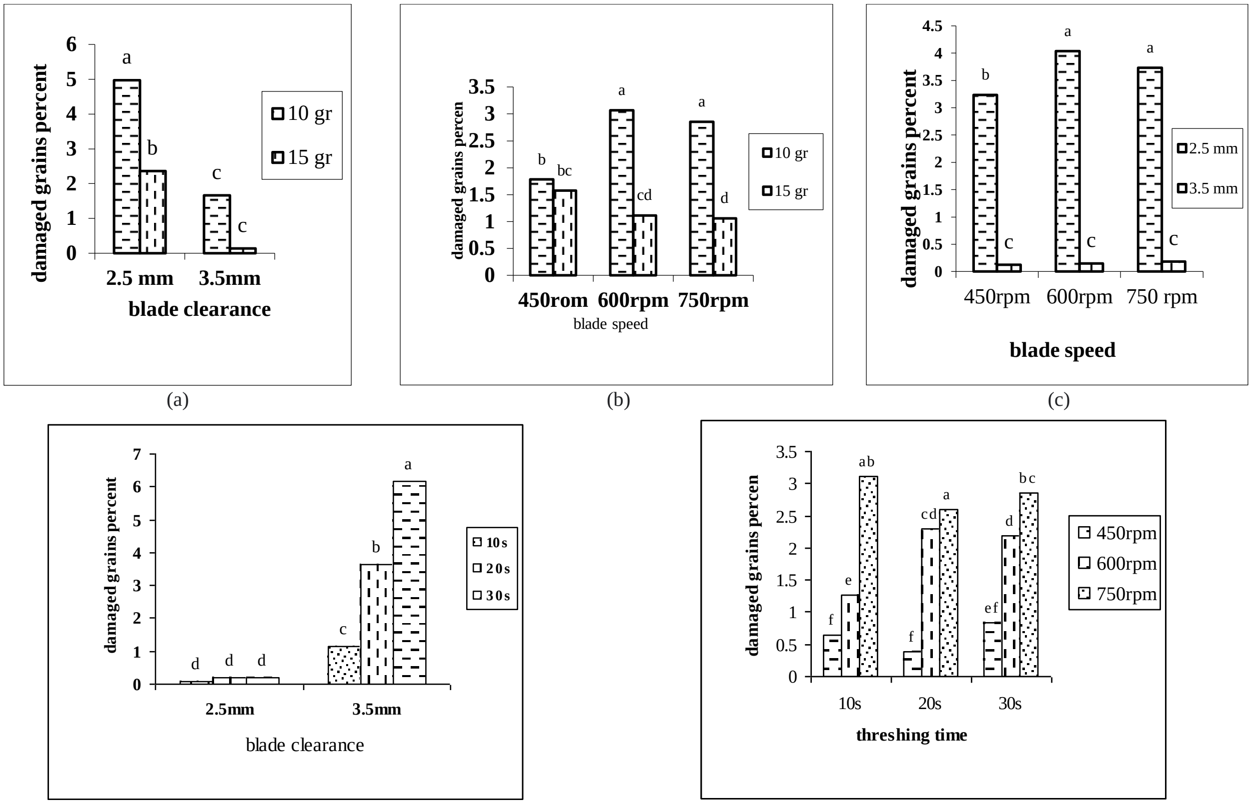
Damaged grains percent

The results of the comparison of the main effects mean (Table 2) showed that by increasing the cluster amount from 10 to 15 g, the blade clearance of 2.5 to 3.5 mm, damaged grains percent decreased from 2.570 to 1.249%, 3.668 to 0.151%, respectively. While by increasing blade speed from 450 to 600 rpm and threshing time from 10 to 30 s, its value increased from 1.1679 to 2.092% and 0.618 to 3.188%, respectively. All these results seem logical from a scientific and practical point of view and are consistent with the results of similar researches. The mean comparison results of the blade clearance effects in the grains amount (Fig. 4a) showed that in the experiment with both levels of the blade clearance, by increasing of cluster amount, the damaged grains percent increased. The comparison results of the interaction effects mean of blade speed and cluster amount (Fig. 4b) also showed that with the increase of cluster amount, in experiment of level of 450 rpm, there was no significant decrease damaged grains percent, but at the other two levels, the damaged grains percent means decreased were significant.

The comparison results of the interaction effects mean of blade speed and blade clearance (Fig. 4c) also showed that in the experiment with each level of blade speed, with increasing of blade clearance, the damaged grains percent decreased significantly, but in the experiment with both levels from the cluster amount, with increasing of threshing time, the damaged grain percent has increased successively. The comparison results of the effects mean of cluster amount and threshing time on the damaged grains percent (Fig. 4d) showed that at both levels of cluster amount, with increasing of threshing time, the damaged grains percent mean was increased significantly consecutively.

The comparison results of interactions effects means of threshing time and blade speed on the damaged grains percent (Fig. 4e) showed that in experiment all three levels of threshing time, with the increase of blade speed, damaged grains percent increased significantly.

The comparison results of interactions effects means of four factors showed that in the tests with 10 g and 20 g and blade clearance of 3.5 mm, and all levels of blade speed and beating time, the damaged grains percent was less than 1%. The lowest (0%) and the highest (10.309%) damaged grains percent, respectively. In experiments with the levels of independent factors (10 g, 2.5 mm, 450 rpm and 10 s) and the levels of independent factors 10 g, 3.5 mm, 600 rpm and 30 s were obtained.



(d) (e)

Fig 4. a) The comparison results of the two interaction effects mean of cluster amount and blade clearance b) blade speed and cluster amount, c) blade speed and blade clearance, d) blade clearance and threshing time e) threshing time and the blade speed on the damaged grains percent.
(Unsimilar letters indicate a significant difference at the 5% probability level)

Sahra variety

Threshing losses

The results of the variance analysis of the data showed that the main effects of all four factors, *i.e.* the blade clearance, the cluster amount, the blade speed and the threshing time and also most of their interaction effects (except for the main effects of the cluster amount and the blade speed) had a significant effect on the threshing loss at the probability level 1% (Table 1). By comparing the main effects means of independent factors (Table 3), it was found that by increasing the cluster amount from 10 to 15 g, the threshing losses mean decreased from 2.732 to 1.931%. Increasing the blade clearance from 2.5 to 3.5 mm, the contrary to the result obtained in the experiment with *Aras* variety, has caused a significant increase in the threshing losses from 1.906 to 2.757%. The reason for this difference may be due to the difference in the physiological characteristics of the clusters of the two tested varieties (for example, cluster volume). By increasing the blade speed from 450 to 750 rpm, the threshing losses mean has decreased significantly from 4.674% to 1.111%. The threshing time from 10 to 20 s, the threshing losses mean has decreased significantly from 4.033 to 1.579%. Also, with the increase of threshing time from 10 to 30 s, the threshing losses mean decreased significantly from 4.033 to 1.384%.

Table 3. The comparison results of the main effects mean on threshing losses and the damaged grains percent (Sahra variety)

Evaluated factors	Cluster amount		Blade clearance		Blade speed			Threshing time		
	10 g	15g	2.5 mm	3.5mm	450 rpm	600 rpm	750 rpm	10 s	20s	30 s
Threshing losses	6.899^{b}	8.268^{a}	8.332^{a}	6.774^{b}	14.366^{a}	5.109^{b}	2.275^{c}	15.604^{a}	4.551^{b}	2.857^{c}
Damaged grains percent	2.570^{a}	1.249^{b}	3.668^{a}	0.151^{a}	1.679^{b}	2.092^{a}	1.950^{ab}	0.618^{c}	1.921^{b}	3.188^{a}

(Unsimilar letters indicate a significant difference at the 5% probability level)

The comparison results of interaction effects mean of the cluster amount and the blade clearance (Fig. 5a) showed that at the level of cluster amount of 10 g, with increasing of the blade clearance from 2.5 to 3.5 mm, the threshing losses increased significantly, but in the experiment with the cluster amount of 15 g, with increasing the blade clearance, there is no significant change in the threshing losses. The comparison results of the interaction effects mean of blade speed and cluster amount (Fig. 5b) showed that by increasing the cluster amount for all levels of the blade speed, a significant reduction in threshing losses has been created. The comparison results of the interaction effects mean of blade clearance and blade speed (Fig. 5c) showed that only by increasing the blade speed from 450 to 600 rpm, a significant reduction in losses occurred. But with a further increase in the blade speed, there is no significant change in the threshing losses. The comparison results of the interaction effects mean of the cluster amount in the threshing time (Fig. 5d), showed that in the experiment with both levels of cluster amount, only by increasing the threshing time from 10 to 20 s, a significant reduction in the threshing losses was created. The comparison results of the interaction effects mean of threshing time and blade clearance (Fig. 5e) showed that at two levels of threshing time of 10 and 20 s, with increasing of the blade clearance, the threshing losses increased. The comparison results of the interaction effects mean of threshing time and blade speed (Fig. 5f) showed that in the experiment with all three levels of threshing time, only by increasing the blade speed from 450 to 600 rpm, there was a significant decrease in the threshing losses mean. The comparison results of the interaction effects mean of four factors on the threshing losses showed that in test conditions including 1, the cluster amount of 10 g, blade clearance of 2.5 mm, two levels of blade speed 600 and 750 rpm, two levels of threshing time 20 and 30 s, 2, the cluster amount of 15 g, the blade clearances of 2.5 mm and 3.5 mm, both blade speed levels 600 and 750 rpm, and two levels of threshing time 20 and 30 s, the beating loss mean is less than 1%. In general, in the experiment with the *Sahra* variety, the threshing loss mean at the threshing time of 10 s, blade speed of 450 rpm, was more than 1%.

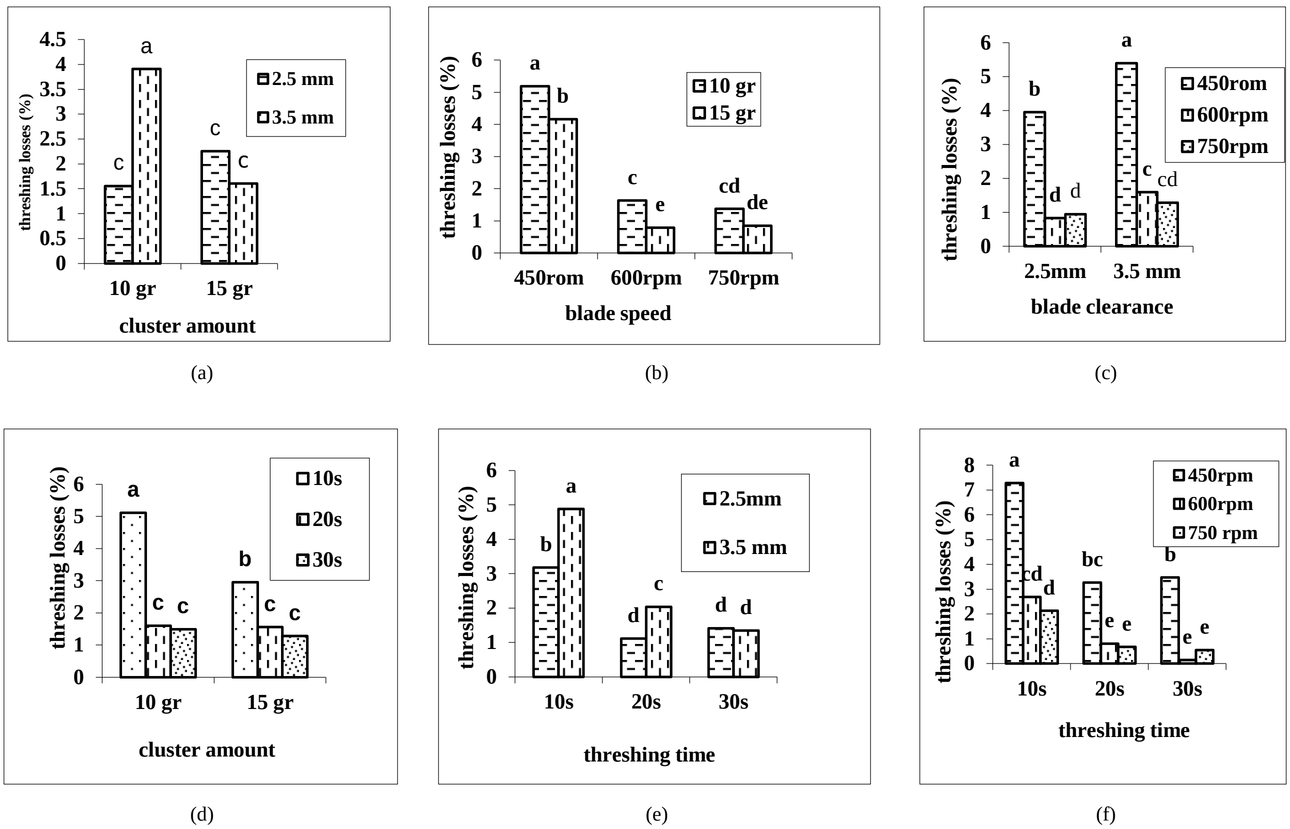


Fig 5. a) The results of comparing the average of the two interaction effects of cluster amount and blade clearance, b) blade speed and cluster amount, c) blade speed and blade clearance, d) amount of cluster and time of threshing, e) threshing time and blade clearance f) threshing time and blade rotation speed, on the average threshing losses of the Sahra variety

Damaged grain percent

The comparison results of the main effects mean of the tested independent factors on the (Table 3), showed that with the increase of the cluster amount from 10 to 15 g, the damaged grain percent decreased from 2.871 to 1.397%. Increasing the blade clearance from 2.5 mm to 3.5 mm, damages grain percent decreased from 4.016 to 0.253. Increasing the threshing time from 10 to 30 s, damages grain percent increased significantly from 0.765 to 3.616%. The comparison results of the two interaction effects mean on the damaged grain percent showed that in the second level of the blade clearance, with the increase of the cluster amount, there was a significant decrease in the damaged grain percent mean (Fig. 6a). In the experiment with all three levels of blade speed, with the increase of the cluster amount from 10 to 15 g, a significant decrease in the damaged grain percent mean has occurred. In the experiment with the cluster amount 10 g, with increasing the threshing time from 10 to 30 s, there was a significant increase in the damaged grain percent, while in the experiment with the cluster amount of 15 g, between the mean effects of threshing time 10 s and 30 s, a significant increase was observed. Increasing the blade speed from 450 to 750 rpm in the experiment with a blade clearance of 3.5 mm did not cause a significant change in the damaged grain percent. But changes in blade speed (in the experiment with a blade clearance of 2.5 mm) successively increased the damaged grain percent.

The comparison results of interaction effects of four factors on the damaged grain percent showed that 1- in the experiment with the cluster amount of 10 g, for all the levels of other independent factors, 2- in the experiment with the cluster amount of 15 g, the blade clearance of 3.5 mm, at experiment with all levels of blade speed and threshing time, the damaged grain percent was less than 1%.

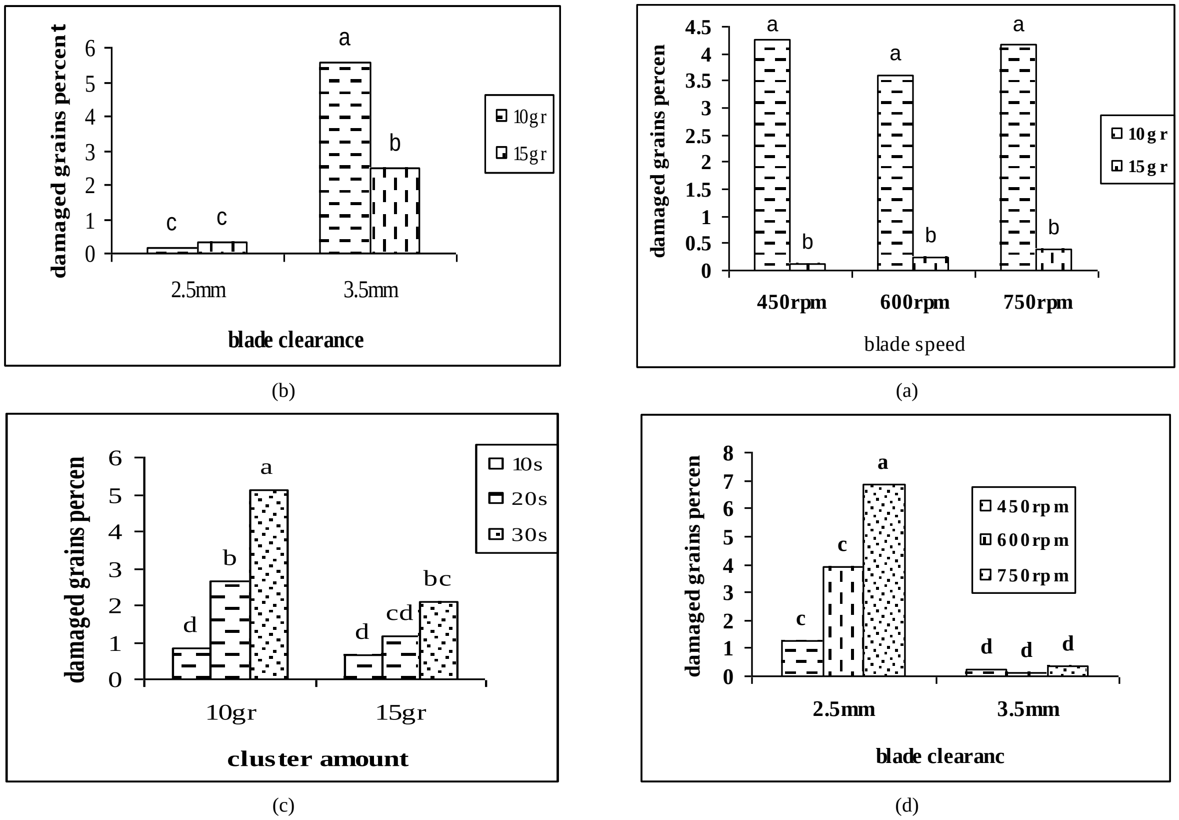


Fig 6. The comparison results of the interaction effects mean (a) blade clearance and cluster amount (b) speed blade and blade clearance (c) cluster amount and threshing time d) blade clearance and blade speed on the damaged grain percent.

CONCLUSIONS

- The used laboratory cluster threshing machine had the ability to thresh barley varieties (Aras-*Sahra*) in an efficient manner.
- The threshing losses mean of *Sahra* variety were less than the threshing losses mean of *Aras* variety.
- The least number of broken and damaged grains belonged to the *Aras* variety and the most broken and damaged grains belonged to the *Sahra* variety.
- In most of the cases belonging to both varieties and blade clearance of 3.5 mm, the damaged grains percent were less than 1%, but at blade clearance of 2.5 mm, the damaged grains percent has increased significantly, which indicates improper blade clearance of 2.5 mm for the laboratory threshing unit.

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