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Full Length Article

Seed Viability and Yield of Chickpea (*Cicer arietinum*) Cultivars Threshed by Different Types of Beaters and Concaves

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Abstract

Effects of different beater- as spike-tooth, lama-tooth and wire loop-, and concave- PVC and chrome- types used in threshing of *Cicer arietinum* L. cvs. Akcin-91, Kusmen-99 cultivars and Local variety on germination speed and power, electrical conductivity of seed leachate, field emergence, phenological growth and seed yields of autumn and spring sown chickpea under rainfed condition were investigated. The experiments were arranged in a randomized complete block design with a factorial arrangement of treatments containing three replications. Visually undamaged seeds from all threshing treatments were used in both laboratory and field experiments. No significant differences were found among beaters and concave types regarding electrical conductivity, germination speed and power and also seed yield and 100-seed weight, while chickpea genotypes were differed for all these traits. Field emergence was significantly decreased in autumn sowing, when spike-toot beater used in the stationary threshing unit. Threshing efficiency of lama-tooth beater (93.91%), which has the highest unthreshed seed rate and total seed losses, was significantly lower than that in spike-tooth (97.73%) and wire loop (96.35%). Beaters were not differed for threshing efficiency. Akcin-91 and Kusmen-99 gave higher threshing efficiency than Local variety.

Keywords: Beater; Chickpea; Concave; Seed viability; Seed yield; Threshing

Introduction

Chickpea (*Cicer arietinum* L.) is the principal grain legume crop grown in the Mediterranean region and mainly cultivated as a rainfed crop (Valenciano *et al.,* 2010). South Asia is by far the largest producer of chickpea (76%) in the world with a share of more than 80% of area harvested. India and Pakistan, together cover more than 75% of total world chickpea area. The other top chickpea growing countries from the developing world include Iran and Turkey (5% share in world chickpea area each) (Akibode and Maredia, 2011). It is one of the most important grain legume crops in Turkey. It has an indispensable role in cereal-legume rotation systems in the dry area and is a vital component of the sustainable farming system in Turkey. It is generally sown in autumn to obtain high seed yield and suffer from water shortage during seed development in late spring or early summer and is also sown in spring to avoid from Ascochyta blight. In Turkey, the yearly sowing area and production is largely dependent on weather conditions. Chickpea production, sowing area and seed yield in Turkey during 2011 stood at 48748 tons, 446412 ha and 1090 kg ha^{-1}, respectively (TUIK, 2012).

Traditionally, chickpea is threshed by manual beating of plants with stick, or trampling under the hooves of animals or under tractor wheels, which is not only labor intensive, tedious and time consuming but also causes damage in form of bruising of seed coat or splitting, resulting in low recovery (Sinha *et al.,* 2009). Mechanical threshers have been developed for mainly grain crops as wheat, barley and rice.

Mechanical threshing process does not only affect the effective recovery of the grains, but it also leads to high grain loss (Olaoye *et al.,* 2010). Chickpea threshing is an important problem because of the high threshing seed losses. Modified threshers may cause significant amount of visible damages and high seed losses, if modifications are not compatible with the thresher or physical and mechanical characteristics of the crop. The most common cause of damage in seed mechanical handling is the particle velocity and rigidity (Paulsen *et al.,* 1981). It has been reported that combine harvester could be used for chickpea threshing in both Central Anatolia region and Cukurova region (Zeren *et al.,* 1991). Different types of mobile and stationary threshers or combine harvesters are used for threshing of chickpeas in Turkey.

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The subject of the present study was to determine the effects of different beater and concave type threshers used in chickpea threshing on visible and invisible seed damage and the reflections of seed viability to growth and yield of chickpea sown in both autumn and spring under rainfed conditions. Based on the percentage of broken seeds, undamaged seeds and unthreshed seeds, total threshing losses and also threshing efficiency of the thresher, an effort has been made to make a recommendation to small-scale chickpea farmers on best beater and concave type threshers manufactured by different materials.

Materials and Methods

Chickpea Cultivars

Cicer arietinum L. cvs. Akcin-91, simple leaved mutant Kusmen-99 and Local variety were used in the experiment. Akcin-91 and Kusmen-99 had rams-head shaped seeds, while Local variety consisted of the mixture of different shaped seeds. Seeds of all genotypes were sown into 40 × 50 m production plots in 30 cm between the rows and 10 cm between plants on November 6, 2003, raise a crop that was used for threshing by the machine. Chickpea plants were harvested manually in July 2004 and maintained in a well aerated depot until threshing was done.

Threshing Unit

A stationary chickpea threshing unit, designed and manufactured for use in threshing experiments in Agricultural Faculty of Ondokuz Mayis University, was used for threshing of chickpea plants (Koyuncu *et al.*, 2007). The length of the concave, the diameter and length of threshing drum were 0.9 m, 0.38 m and 0.9 m, respectively.

Five peripheral speeds (19.0, 14.5, 12.5, 10.5 and 8.0 m s^{-1}), five concave clearances (15, 20, 25, 30 and 35 mm) and four feeding rates (360, 540, 720 and 900 kg h^{-1}) were tested in the preliminary studies for their optimization, and were fixed at 12.5 m s^{-1}, 25 mm, and 720 kg h^{-1} for the 3 cultivars, 2 concaves and 3 beaters combinations.

Cross sections of the drum, shapes and dimensions of the beaters (mm) are illustrated in Figs. 1, 2 and 3. Three different beater types including spike-tooth, lama-tooth and wire loop were examined in the study. Two different types of concave manufactured from PVC and chrome were used in the threshing unit.

Threshing drum was operated by an electric motor with technical specifications as given in Table 1. A belt-pulley system provided the movement transfer between the threshing beater and the electric motor.

Complete plant material harvested at full maturity was loaded on a flat surface and fed into the hopper manually. The moisture contents of the grain and straw were determined by oven-drying method (ASAE, 1984). The average moisture contents of seeds and straw for all chickpea varieties were 7.5-8.5% and 10-12%, respectively.

Seeds inside unthreshed pods left as whole after threshing were removed from the pod shell by hand and cleaned. Weight of broken seeds, undamaged seeds and seeds obtained from unthreshed pods were determined separately to calculate percentage of broken seeds (PBS), undamaged seeds (PUDS), unthreshed seeds (PUS), total seed losses (TSL) and threshing efficiency (TE) according to Sharma and Devnani (1980), Bhutta *et al.* (1997) and Sessiz (1998) by using the following equations.

Broken seeds losses (%) = (Wbs/Wts) x 100; where Wbs = weight of broken seeds, Wts = weight of total seeds.

Undamaged seed (%) = (Wuds/Wts) x 100; where Wuds = weight of undamaged seeds, Wts = weight of total seeds.

Unthreshed seed losses (%) = (Wus/Wts) x 100; where Wus = weight of unthreshed seeds, Wts = weight of total seeds.

Total seed losses (%) = ((Wbs+Wus)/Wts) x 100; where Wbs = weight of broken seeds, Wus = weight of unthreshed seeds, Wts = weight of total seeds.

Threshing efficiency (%) = 100 – unthreshed seed losses or

Threshing efficiency (%) = 100 – (Wus/Wts); where Wus = the weight of unthreshed seeds in sample, Wts = the total weight of seeds in the sample.

Laboratory Tests and Field Experiments

Germination speed (GS) (%), germination power (GP) (%), 100-seed weight (HSW) (g) were determined according to ISTA (1999), electrical conductivity of the seed leakage (µ S cm^{-1} g^{-1}) as suggested by Hampton and Coolbear (1990), water absorption rate (WAR) (%) of seeds soaked at distilled water for 24 h were determined at the laboratory conditions.

In the field experiments, visually undamaged whole seeds obtained from all threshing treatments consisting of the combination of 3 cultivars, 3 beaters and 2 concaves were used. Experiment I (autumn sowing) and Experiment II (spring sowing) were setup on November 09, 2004 and April 15, 2005, respectively at the experimental area of Agricultural Faculty of Ondokuz Mayis University in Samsun, Turkey under rainfed condition at 41° 17' N, 36° 19' E, 120 m above sea level. The experiments were arranged in a randomized complete block design with a factorial arrangement of treatments containing three replications. Seeds were sown manually into 3 cm soil depth in 3 rows plot, 25 seeds for each row, with 30 cm between the rows and 10 cm between plants on the same row.

To determine field emergence (FE), the numbers of emerged seedlings at the first leaf stage were counted daily until no further seedling appeared and expressed as the percentage of seedling emerged from the soil. Days to emergence (DE), days to first flowering (DFF), days to first podding (DFP), days to seed harvest (DSH), seed yield (SY)

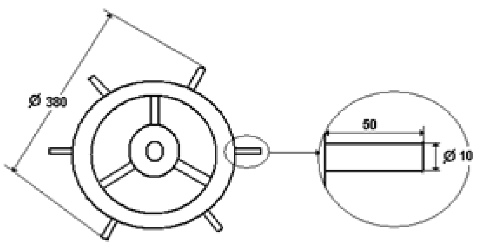

Fig. 1: Spike-tooth beater (all measurements are mm)

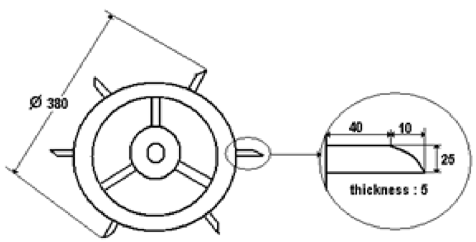

Fig. 2: Lama-tooth beater (all measurements are mm)

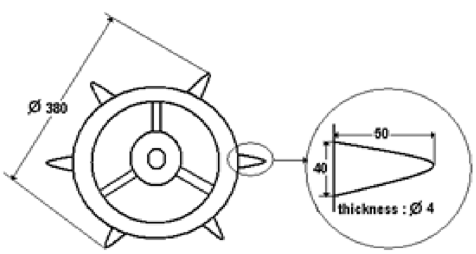

Fig. 3: Wire loop beater (all measurements are mm)

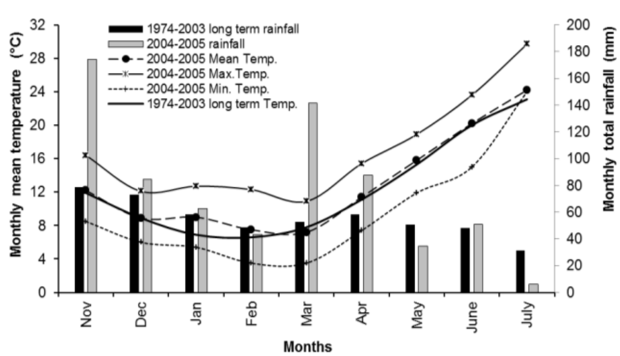

Fig. 4: The total precipitation (mm) and monthly mean temperatures (°C) during the field experiments and the long term (1974-2003)

and 100-seed weight (HSW) were also determined.

Physical and chemical properties of the experimental soil (Table 2) revealed that soil was clay loam, neutral in reaction, low in calcium, middle in phosphorus and organic matter, and rich in potassium. Climatic data of Samsun province on the monthly total precipitation (mm) and monthly mean temperatures (°C) during the study period between November 2004 and July 2005 and also for long term period between 1974 and 2003 are given in Fig. 4. Experimental site is located in an area with a long-term average rainfall of 499.9 mm for the November-July growing season and 685.6 mm for the study year.

Statistical Analyses

All data collected were subjected to an analysis of variance according to completely randomized blocks design. Duncan's multiple range tests was used for comparison of means showing statistical significance.

Results and Discussion

Data on germination experiment, electrical conductivity of seed leakage at the end of the 24 h, percentage of water absorbed by the seeds under the influence of different treatments are presented in Tables 3 and 4. It was found that main effects of beater and concave types used in the threshing unit and also their combinations had no significant effects on GS, GP, EC and WAR, while there were significant differences among chickpea genotypes.

Akçin-91 and Local variety were superior than Kusmen-99 for GS and GP (Table 4). EC of seed leachate is a measure of minor injury or invisible injury to seed (Sinha *et al.,* 2009). No evident differences were found in terms of EC values that could indicate internal injury of the seeds among beaters, concaves and also their combinations. Local variety consisted of a mixture of different shaped (rams-head shaped, pea shaped, owl’s shaped) seeds, and hence it reflected the highest GP and EC values (Table 4). In many cases, it is difficult to establish a consistent relationship between laboratory and field results, since environmental conditions in the seedbed are highly variable and unpredictable (Egli and TeKrony, 1995). Peksen *et al.* (2005) stated that GP and FE were 62.98% and 52.89% in Kusmen-99, while GP and FE were 98.00% and 91.11% in Akçin-91 and 100.00% and 92.88% in Local variety, respectively. Field planted seeds are exposed to unfavorable conditions, thus commonly used standard germination tests cannot predict field emergence. Our data on germination and electrical conductivity test were confirmed by Qasim *et al*. (2010) who stated that standard germination test provided a more sensitive predictor of field emergence than the other laboratory seed quality tests.

Beaters had significant effect on field emergence (FE) only in Experiment I, while beaters and concaves had no significant effects on all investigated traits in both Experiment I and II (Table 5). Use of spike-toot beater in the threshing unit significantly decreased FE when compared to lama-toot and wire loop beaters in Experiment I (Table 6).

A significant interaction was observed between concave and cultivars for FE. With the exception of days to seed harvest (DSH) determined in autumn sowing, chickpea

Table 1: Technical specifications of the electric motor operated threshing drum

Type	AGM 132 M 6a
Voltage-current	Δ380 V, 9.4 A
Power	4 kW
Cos φ	0.81
Rotation	935 rpm
Frequency	50 Hz
Transmission to beater	96 %

Table 2: Some physical and chemical properties of the soil in the experimental area

Properties	Unit	Value
Saturation	%	88.00
Sand	%	19.92
Silt	%	22.86
Clay	%	57.22
EC	dSm^{-1}	0.28
pH		6.63
$CaCO_3$	%	0.57
P_2O_5	$kg^{-1}da$	8.8
K_2O	$kg^{-1}da$	74.0
Organic matter	%	2.38

Table 3: ANOVA results and significance of F values for germination speed (GS), germination power (GP), electrical conductivity (EC) of seed leakage and water absorption rate (WAR) of chickpea seeds threshed by different beaters and concaves

Sources of variation	df	F-values			
		GS (%)	GP (%)	EC (μ S cm^{-1} g^{-1})	WAR (%)
Replication	2	1.681	0.508	0.768	1.500
Beater (B)	2	1.774	1.373	0.470	0.925
Concave (Co)	1	1.007	1.025	0.309	1.338
Cultivar (Cu)	2	24.091**	13.982**	31.127**	27.313**
B x Co	2	1.967	1.445	0.191	2.138
B x Cu	4	1.718	1.469	0.317	1.123
Co x Cu	2	0.345	0.725	0.444	0.117
B x Co x Cu	4	0.718	1.757	0.387	0.762
Error	34				

**Significant at 1% probability level

Table 4: Means and Duncan's multiple range groups regarding germination speed (GS), germination power (GP), electrical conductivity (EC) of seed leakage and water absorption rate (WAR) of chickpea seeds threshed by different beaters and concaves

Factors		GS (%)	GP (%)	EC (μ S cm^{-1} g^{-1})	WAR (%)
Beaters	Lama-toot	90.67	97.11	3.74	113.08
	Spike-toot	91.78	94.00	3.97	111.88
	Wire loop	86.00	92.44	3.48	112.35
Concaves	PVC	88.15	93.33	3.62	112.02
	Chrome	90.82	95.70	3.85	112.86
Cultivars	Akcin-91	93.78a**	98.44a**	3.24b**	115.24a**
	Kusmen-99	76.67b	85.78b	2.02b	113.25a
	Local	98.00a	99.33a	5.93a	108.83b

**Significant at 1% probability level

cultivars used in the study showed significant differences regarding field emergence (FE), days to emergence (DE), days to first flowering (DFF), days to first podding (DFP), seed yield (SY) and 100 seed weight (HSW) due to their genotypic differences (Table 5).

For FE, the superior cultivar was Local variety, and was followed by Akçin-91. The most weak field establishment was recorded in Kusmen-99 in Experiment I and II. Field emergence for spring sowing (Experiment II) was lower than half of FE determined in autumn sowing (Experiment I) due to low precipitation under rainfed condition. Elapsing time from seed sowing to the counting of final field establishment (DE) were about two times longer in autumn sowing than that in spring sowing (Table 6) as a result of combined effect of low temperature and high precipitation (Fig. 4). Ozdemir and Karadavut (2003) found that chickpea sown in mid of the November as a winter crop emerged at the end of December and days to emergence were about 45 days in both 2000 and 2001. Days to emergence, flowering and maturity in present experiments were in agreement with those recorded by Ozdemir and Karadavut (2003). Local chickpea variety was found to be the earliest chickpea genotype for DE, DFF and DFP in Experiment I and for DE, DFF and DFP in Experiment II (Table 6).

Seed yield and 100-seed weight did not differ for beater, concave and beater × concave combinations in both Experiment I and II (Table 5). Stand establishment may be weak under unsuitable environmental conditions such as cold, wet or dry seedbed during germination. In this case, seed yields were decreased by low plant density depending on poor stand establishment. Seed yield of Kusmen-99 decreased due to low plant density as a result of poor FE. HSW of Kusmen-99 was higher than that in Akcin-91 and Local variety depending on decreasing competition among plants for sunlight, soil water and also plant nutrients. Autumn sowing gave higher seed yield than spring sowing (Table 6) primarily because of drought condition in growing period (Fig. 4). In most of studies, the high yield potential of winter crop has been attributed to the extended growing period and favorable rainfall during winter and early spring (Ozdemir and Karadavut, 2003; Aydogan *et al.*, 2009). Seed yield of Akcin-91 and Local chickpea variety were about two times higher than that of Kusmen-99 in autumn sowing and three times higher in spring sowing (Table 6).

There were significant differences among beaters on percentage of broken seeds (PBS), unthreshed seeds (PUS) and threshing efficiency (TE), PBS, PUS and TE, while no significant differences for total seed losses (TSL) and undamaged seeds percentage (PUDS). A significant interaction was found between beater and concave for PBS (Table 7). Using spike-tooth beater increased PBS and decreased PUS when compared to lama-tooth and wire loop beater (Table 8). Spike-tooth beater with sharp-edged (Fig. 1) had the strong impact force to separate the seeds from the pod shells containing the seeds. Therefore, the highest TE and the lowest PUS were obtained from spike-tooth beater. TE determined for beaters ranged between 93.91% in lama-tooth and 97.73% in spike-tooth beater. TE of wire loop

Table 5: ANOVA results and significance of F values for field emergence (FE), days to emergence (DE), days to first flowering (DFF), days to first podding (DFP), days to seed harvest (DSH), seed yield (SY) and 100 seed weight (HSW) of chickpea seeds threshed by different beaters and concaves

Sources of variation	df	F-values						
		FE (%)	DE	DFF	DFP	DSH	SY (kg ha^{-1})	HSW (g)
		Experiment I (Autumn sowing on November 9, 2004)						
Replication	2	5.781**	1.982	2.362	3.711*	2.216	1.417	1.318
Beater (B)	2	5.986**	0.782	1.546	1.127	1.978	0.096	0.587
Concave (Co)	1	1.927	0.024	1.789	0.909	1.932	0.808	0.321
Cultivar (Cu)	2	161.004**	10.527**	39.368**	29.715**	0.555	18.381**	26.877**
B x Co	2	1.038	0.952	0.472	0.359	2.090	0.320	1.282
B x Cu	4	1.214	0.755	1.530	2.109	0.410	1.209	2.253
Co x Cu	2	4.253*	1.315	1.828	1.577	0.563	0.684	2.382
B x Co x Cu	4	0.336	0.088	0.770	1.066	0.543	1.690	1.475
Error	34							
		Experiment II (Spring sowing on April 15, 2005)						
Replication	2	0.732	5.457**	1.671	3.216	5.462**	2.479	0.026
Beater (B)	2	1.671	0.455	0.008	0.357	1.366	0.311	2.688
Concave (Co)	1	1.407	0.105	0.000	0.153	0.000	1.971	0.464
Cultivar (Cu)	2	12.374**	11.998**	6.422**	30.988**	5.546**	23.355**	47.236**
B x Co	2	0.763	2.763	0.214	0.357	3.967*	2.107	1.933
B x Cu	4	1.998	0.752	0.234	0.868	2.550	3.510*	0.924
Co x Cu	2	0.953	1.364	0.594	0.970	1.198	1.674	0.055
B x Co x Cu	4	1.924	5.124**	0.915	0.868	2.169	2.475	3.767*
Error	34							

*Significant at 5% probability level, **Significant at 1% probability level

Table 6: Means and Duncan's multiple range groups for field emergence (FE), days to emergence (DE), days to first flowering (DFF), days to first podding (DFP), days to seed harvest (DSH), seed yield (SY) and 100 seed weight (HSW) of chickpea seeds threshed by different beaters and concaves

Factors		F-values						
		FE (%)	DE	DFF	DFP	DSH	SY (kg ha^{-1})	HSW (g)
		Experiment I (Autumn sowing on November 9, 2004)						
Beaters	Lama-toot	80.67a**	38.50	177.22	188.78	235.50	1990.4	40.81
	Spike-toot	75.11b	38.06	177.56	189.06	236.67	1902.2	41.49
	Wire loop	79.56ab	38.78	179.28	190.44	221.00	1903.4	41.16
	PVC	77.48	38.41	178.70	189.89	226.11	2017.0	41.01
Concaves	Chrome	79.41	38.48	177.33	188.96	236.04	1847.0	41.30
	Akcin-91	84.44b**	38.56ab**	177.61b**	188.83b**	228.28	2432.1a**	40.06b**
Cultivars	Kusmen-99	61.11c	39.72a	183.78a	194.28a	228.56	1129.7b	43.82a
	Local	89.78a	37.06b	172.67c	185.17c	236.39	2234.3a	39.58b
		Experiment II (Spring sowing on April 15, 2005)						
Beaters	Lama-toot	34. 89	15.89	53.00	61.000	101.44	745.8	40.90
	Spike-toot	31.56	16.00	53.06	61.222	100.28	815.9	39.20
	Wire loop	37.11	15.61	53.06	60.944	100.28	828.7	39.19
	PVC	36.00	15.89	53.04	61.111	100.67	861.6	39.53
Concaves	Chrome	33.04	15.78	53.04	61.000	100.67	731.9	40.00
	Akcin-91	41.56a**	15.78ab**	53.72a**	62.33a**	102.22a**	1070.0a**	39.63b**
Cultivars	Kusmen-99	26.44b	16.89a	53.39ab	59.61c	99.72b	354.3b	43.96a
	Local	35.56a	14.83b	52.00b	61.22b	100.06ab	966.0a	35.70c

**Significant at 1% probability level

beater was very close to that of spike-tooth beater. Separating effects of the lama-tooth beater were low as they had rounded-edge at the right top side (Figs. 2 and 3).

Concave types did not show any differences for PBS, PUS, TSL, UDS and TE. The percentage of undamaged seeds and broken seeds was found as 97.8 and 1.40% by Zeren *et al.* (1991). Anwar and Gupta (1990) found that threshing efficiency, damaged grain and total seed losses were 93.0%, 2.2% and 9.1% in chickpea threshing, respectively. Senol and Dursun (2002) stated that undamaged grain ratio, broken grain ratio, pod ratio, foreign material ratio were 92.83%, 4.16%, 1.75% and 1.26%, respectively when determined at 13% grain moisture content and 9 mm of concave clearance in chickpea threshed by Hege 140 combine harvester.

Among all factors examined in the study, varietal differences were the most important source of variations for investigated parameters, except for PBS. TE obtained from Akcin-91 and Kusmen-99 were not statistically different and higher than that of Local variety. Low threshing efficiency in Local chickpea variety mainly sourced from high unthreshed seeds percentage and total

Table 7: ANOVA results and significance of F values for percentage of broken seeds (PBS), unthreshed seeds (PUS), total seed losses (TSL), percentage of undamaged seeds (PUDS) and threshing efficiency (TE) of chickpea cultivars threshed by different beaters and concaves

Source of variations	df	F-values				
		PBS (%)	PUS (%)	TSL (%)	PUDS (%)	TE (%)
Replication	2	0.200	0.111	0.119	0.119	0.111
Beater (B)	2	9.012**	4.581*	3.045	3.045	4.581*
Concave (Co)	1	0.818	3.843	2.886	2.886	3.843
Cultivar (Cu)	2	1.717	6.520**	5.459**	5.459**	6.520**
B* Co	2	3.957*	0.065	0.018	0.018	0.065
B * Cu	4	2.141	0.652	0.840	0.840	0.652
Co * Cu	2	1.893	0.111	0.248	0.248	0.111
B * Co * Cu	4	1.597	0.716	0.830	0.830	0.716
Error	34					

*Significant at 5% probability level, **Significant at 1% probability level

Table 8: Means and Duncan's multiple range groups for percentage of broken seeds (PBS), unthreshed seeds (PUS), total seed losses (TSL), percentage of undamaged seeds (PUDS) and threshing efficiency (TE) of chickpea cultivars threshed by different beaters and concaves

Factors		PBS (%)	PUS (%)	TSL (%)	PUDS (%)	TE (%)
Beaters	Lama-toot	0.81b**	6.09a*	6.90	93.10	93.91b*
	Spike-toot	1.47a	2.27b	3.74	96.26	97.73a
	Wire loop	0.65b	3.65ab	4.30	95.70	96.35ab
Concaves	PVC	0.90	5.03	5.93	94.07	94.97
	Chrome	1.05	2.98	4.03	95.97	97.02
Cultivars	Akcin-91	0.83	2.65b**	3.48b**	96.52a**	97.36a**
	Kusmen-99	1.19	2.70b	3.89ab	96.11ab	97.30a
	Local	0.91	6.67a	7.58a	92.42b	93.33b

*Significant at 5% probability level, **Significant at 1% probability level

seed losses (Table 8), mainly because separation of the threshing unit was not adequate as Local chickpea variety consisted of a mixture of seeds in different size and shape. Koyuncu *et al*. (2007) found that the chickpea varieties varied significantly in threshing efficiency owing to the physical differences and mechanical specifications among varieties. There was negligible difference between beater-contrbeater combinations for specific energy consumption and power requirement. Obviously, the most appropriate beater-contrbeater combinations must be selected depending on the threshing efficiency of chickpea varieties.

Conclusions

Studies concluded that wire loop was the best one among all beaters for chickpea threshing due to minimal seed breakage, lowest invisible injury of the seeds accompanied with high field emergence and highest threshing efficiency. Any of PVC and chrome concave can be recommended for use in the threshing unit as these were not different from each other in their performance. Use of improved chickpea cultivars with high threshing efficiency is a prominent factor for minimizing threshing losses.

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