Türk. entomol. derg., 2017, 41 (2): 207-218
DOI: http://dx.doi.org/10.16970/entoted.289663

ISSN 1010-6960
E-ISSN 2536-491X

Original article (Orijinal araştırma)

Khapra beetle (*Trogoderma granarium* Everts, 1898) in durum wheat (*Triticum durum* Desf): Impacts on some seed characteristics and marketing price

Makarnalık buğdayda (*Triticum* durum Desf) kapra böceği (*Trogoderma granarium* Everts, 1898): Bazı tane özellikleri ve pazarlama fiyatlarına etkileri

Fethiye ÖZBERK[1] İrfan ÖZBERK[2*] Abuzer YÜCEL[3] Ayhan ATLI[4] Duygu İZOL[3]

Summary

This study investigated the influence of khapra beetle (*Trogoderma granarium* Everts, 1898, Coleoptera: Dermestidae) on weight, grain quality and marketing price losses in various durum wheat cultivars stored in controlled conditions in laboratory of Faculty of Agriculture at Harran University. Experiment was conducted from 13 January to 4 September 2015. Durum wheat cultivars, Şahinbey, Diyarbakır-81, Zühre, Artuklu, Güney Yıldızı, Fırat-93, Aydın-93, Sarıçanak-98, Eyyübi and Altıntoprak-98, were infested by three different young larval stages. Three samples (80 g) of grain from each cultivar were put into 250-mL glass jars covered with the muslin cloth with the rubber bands and 5, 10 or 15 neonates khapra beetle larvae added. A randomized complete block design with 3 replicates was employed for grain weight losses and a split plot design with 4 replicates (purchasers) was employed for marketing price losses. Grain weight, marketing price and grain quality losses were recorded. The result revealed that geometric mean of weight loss was 4.075% in about 8 months. There were response differences between wheat cultivars against khapra beetle infestation. Except for Zeleny sedimentation, some of quality characteristics such as 1000 kernel weight (g), gluten (%) and gluten index (%) were affected negatively depending on increasing ratio of insect infestations. Geometric means of marketing prices reduced from 418 to 315 USD t^{-1} in 8 months. Marketing price loss was 103 USD t^{-1}. It was concluded that Fırat-93, Zühre and Altıntoprak-98 were the cultivars least affected by khapra beetle with less weight and marketing price losses.

Keywords: Durum wheat, khapra beetle damage, marketing price, weight and quality loss

Özet

Bu çalışmada laboratuvar koşullarında depolanmış bazı makarnalık buğday çeşitlerinde khapra böceği (*Trogoderma granarium* Everts, 1898, Coleoptera: Dermestidae)'nin yaptığı ağırlık, kalite ve pazarlama fiyatları kayıpları incelenmiştir. Çalışma Harran Üniversitesi, Ziraat Fakültesi, Tarla Bölümü Laboratuvarı'nda 13 Ocak- 4 Eylül 2015 tarihleri arasında yürütülmüştür. Şahinbey, Diyarbakır-81, Zühre, Artuklu, Güney Yıldızı, Fırat-93, Aydın-93, Sarıçanak-98, Eyyübi ve Altıntoprak-98 makarnalık buğday çeşitlerine genç larvalar üç farklı sayıda bulaştırılmıştır. Her bir çeşide ait 3 adet (80 gr) örnek içlerine 5,10 ve 15 adet genç khapra böceği larvası yerleştirilerek 250-mL'lik cam kavanozlara konulmuş ve ağzı lastik bantlı tülbent bezi ile örtülmüştür. Deneme ağırlık ve kalite kayıpları için tesadüf blokları deneme desenine göre üç tekerrürlü (larva seviyeleri) olarak yürütülmüştür. Pazarlama fiyatları için ise bölünmüş parseller (çeşitler ana parsel, larva bulaşma oranları alt parsel) deneme desenine göre 4 tekerrürlü (borsadaki alıcılar) olarak yürütülmüştür. Dane ağırlığı, pazarlama fiyatı ve dane kalite kayıpları kaydedilmiştir. Elde edilen sonuçlara göre 8 ayda tane ağırlık kayıplarının geometrik ortalaması %4.075 olmuştur. Çeşitler arasında khapra zararına karşı farklı tepki olduğu anlaşılmıştır. Zeleny sedimentasyon değeri dışında, 1000 dane ağırlığı (g), gluten (%) ve gluten indeks (%) değerleri larva bulaşma oranı arttıkça olumsuz yönde etkilenmiştir. 8 ayda khapra'ya bağlı pazarlama fiyatları 418 USD t^{-1}'dan 315 USD t^{-1}'a düşmüştür. Pazarlama fiyatı kaybı 103 USD t^{-1} olmuştur. Fırat-93, Zühre ve Altıntoprak-98 çeşitleri pazarlama fiyatı azalışı ve ağırlık kaybı yönünden khapra zararından en az etkilenen çeşitler olmuşlardır.

Anahtar sözcükler: Makarnalık buğday, khapra böceği zararı, pazarlama fiyatları, ağırlık ve kalite kaybı

[1] Harran University, Akçakale Vocational Collage, 63500 Şanlıurfa, Turkey
[2] Harran University, Agricultural Faculty, Field Crops Department, 63100 Şanlıurfa, Turkey
[3] Harran University, Agricultural Faculty, Plant Protection Department, 63100 Şanlıurfa, Turkey
[4] Harran University, Agricultural Faculty, Food Engineering Department, 63100 Şanlıurfa, Turkey
* Corresponding author (Sorumlu yazar) e-mail: ozberki@harran.edu.tr
Received (Alınış): 04.02.2017 Accepted (Kabul ediliş): 24.05.2017 Published Online (Çevrimiçi Yayın Tarihi): 28.06.2017

Introduction

Khapra beetle, *Trogoderma granarium* Everts, 1898 (Coleoptera: Dermestidae) (Munro, 1935), which is one of 115 *Trogoderma* species (Beal, 1982), is one of the most important stored-product pests ranked as one of the 100 worst severe species on earth (Lowe et al., 2000) and considered as an A_2 quarantine level organism by the EPPO (OEPP/EPPO, 1981) (Ahmedani et al., 2007). In Southeastern Anatolia, estimates of storage losses of food grains due to khapra beetle have been reported to vary greatly; 25-35% in 1963 (Kalkan, 1963) and 10% in 2000 (Ekmekçi & Ferizli, 2000). Similarly, in Pakistan khapra beetle damage varied from 4 to 10% (Huque et al., 1969), about 5% (Chaudhry, 1980), 5% (Ahmad, 1984), and from 3.5 to 25.5% (Irshad & Baloch, 1985). Average damage varied between 6 to 33% of stored grain in one season in India (Rahman et al., 1945). The worldwide stored grain loss average was estimated at 10% (Prevett, 1975) and 5% of this was due to insect damage (Esin, 1971). The great importance of this pest relies on its capacity to cause huge loss in stored grain through fast feeding and heating. Mature larvae have potential to withstand starvation for about 3 years. Furthermore, larvae have an ability to live on food with very low moisture content (Ahmedani et al., 2007). Khapra beetle larvae feed on wheat grain and as a result the nutritive quality of the wheat decreases, which lead to lower the marketing price (Ahmedani et al., 2009). Damage occurs in larval stage and adults feed only a little on the grains (Ahmedani et al., 2007) or do not feed at all (Freeman, 1980). Temperature and relative humidity (RH) are the two main physical factors that influence the population of khapra beetle (Cockerel et al., 1971). Larval development is not possible below 12ºC but may proceed at very low RH, for example at 25ºC and 2% RH. Development is most rapid in warm humid conditions, taking about 18 days at 35ºC and 73% RH, and under these conditions the number of larval molts is 4 for males and 5 for females (Hadaway, 1956).

The length of the youngest larva is 1.6-1.8 mm, body width is 0.25-0.30 mm with a tail longer than half of the whole body and tail is made up of quite lot hairs derived from on the last abdominal segment. Mature larva is about 6 mm long and 1.5 mm wide (OEPP/EPPO, 1981). Male pupae are smaller than female ones. The average lengths of males and females are 3.5 and 5 mm, respectively (OEPP/EPPO, 1981). Adults are oblong or oval shape and 1.6-3.0 mm long by 0.9-1.7 mm wide. Males are brown to black in color and the females are lighter in color. Female pupae are larger than male ones. The adults have short life span. The mated and unmated females can survive about 4-7 and 20-30 days respectively and males 7-12 days. They do not fly and can feed very little (Ahmedani et al., 2007). Once-mated females can lay about 60 eggs but more than twice mated females can lay up to 500 eggs.

The youngest larvae are unable to feed on whole grains and can survive eating only damaged grains, older larvae can feed on whole grains. The rate of increase at 33-37ºC is about 12.5 times per month (Anonymous, 2005). Khapra beetle has no special preference and can benefit from number of feed products including durum wheat (*Triticum durum* Desf.) (Jha, 2003). Grain quality decreases probably due to abolishment of specific nutrients. It can result in significant decreases in crude fat, total carbohydrates, sugars, protein nitrogen and true protein contents and increases in moisture, crude fiber and total protein at the infestation levels of 75% in wheat, maize and sorghum grains (Jood et al., 1993). Cast skins of khapra beetle may result in dermatitis (Pruthi & Singh, 1950), when the barbed hairs of larvae remain in the grain this may result in a serious hazard, if swallowed (Marison, 1925).

Turkey is one of the most important grain producing countries of world, especially for wheat where it is classified in the top-ten countries globally (FAO Stat, 2009). Southeastern Anatolia is considered to be the durum wheat belt of Turkey. Around the 35% of total durum wheat production is grown in the Southeastern Anatolia (Özberk et al., 2005; 2006). Temperate cereal acreage in the region is about 2 million ha representing 15-17% of total area of Turkey. Total wheat acreage is 1,152,500 ha and annual production is 2,045,990 t. Major growing sites are Şanlıurfa and Diyarbakır Provinces (Özberk et al., 2005). Turkey harbors many species of storage pests due to its suitable climate (Ekmekçi & Ferizli, 2000). *Trogoderma granarium* can reach high infestation rates in wheat samples in Şanlıurfa Province (Işıkber et al., 2014). Grading factors such as the presence of sunn pest (*Eurygaster integriceps* Puton, 1881) damaged kernels in the durum wheat seed lots, presence of red bread wheat kernels, vitreousness

and starchy kernels are major downgrading factors in the region. Some visual characteristics such as 1000 kernel weights and hectoliter weights are also referred by local purchasers (Özberk et al., 2006). The effects of khapra beetle damaged kernels onto marketing prices have not been studied previously. This study investigated the effects of khapra beetle on some seed quality characteristics and the impacts on marketing prices in durum wheat. Cultivar differences were also assessed.

Material and Methods

Widely grown durum wheat cultivars, Şahinbey, Diyarbakır-81, Zühre, Artuklu, Güney Yıldızı, Fırat-93, Aydın-93, Sarıçanak-98, Eyyübi and Altıntoprak-98, were appraised against three different infestation densities (5, 10 and 15 neonate larvae jar^{-1}) of khapra beetle in the laboratory of the Faculty of Agriculture of Harran University, Şanlıurfa, Turkey from February to September of 2015. Some seed characteristics and losses in grain weight and marketing prices were scored periodically. Grain samples in glass jars subjected to khapra beetle infestation in the laboratory were presented to the randomly selected grain purchaser and marketing prices offers were scored. A randomized complete block design with 10 entries and 3 replicates (i.e., 5, 10 and 15 neonate larvae jar^{-1}) was employed for weight loss and some seed characteristics. A split plot design was employed for marketing price losses. Where, the cultivars and three larval infestation densities were assigned to main and subplots respectively. Purchasers in local commodity market were employed as replicates. Grain samples of durum wheat cultivars were received from GAP International Agriculture Research and Training Center in neighboring Diyarbakır Province. Grain samples were treated by high temperature (5 h at 45ºC) to abolish the possibility of previous infestation. RH after this treatment was about 10% for all entries. Three samples (80 g) of wheat grain from each cultivar were put into 250 mL glass jars covered with the muslin cloth with the rubber bands and 5, 10 or 15 neonate khapra beetle larvae added. Thousand kernel weights (Uluöz, 1965), Zeleny sedimentation (AACC, 2000; method 56-60), delayed sedimentation (Greenway et al., 1965), gluten (%) and gluten index (%) (AACC, 2000; method 38-12A) were scored initially and at the end of experiment. Khapra larvae were collected from the wheat storage house of the Plant Protection Department of the Provincial Extension Service in Şanlıurfa. The jars were put in an incubator under semi-storage house conditions in summer at 30±2ºC, 55±5% RH. The infested grains in each jar were subjected to sieving to isolate the grain dust, exuviate and other residues formed due to the khapra beetle infestation. All live larvae and pupae in jars were put aside and reintroduced to the jar after weighing. Weight losses were scored five times during the period of incubation between 13 January and 4 September 2015. In the same period, marketing price estimates were scored 3 times in local commodity market. JMP-5 statistical software was employed for analysis of variance. A stability analysis called rank (Huehn, 1990) was also performed to detect the less affected cultivars for both weight and market price and losses.

Results and Discussion

Weight losses

Weight losses for all entries under study were scored on 2 and 23 February, 6 April, 16 June and 4 September 2015. Individual analysis of variance indicated the presence of significant cultivar response against khapra beetle infestation ($F = 24.78^{***}$, $P < 0.001$; $F = 12.47^{***}$, $P < 0.001$; $F = 4.94^{**}$, $P < 0.01$; $F = 4.22^{**}$, $P < 0.01$; and $F = 4.91^{**}$, $P < 0.01$ respectively). Geometric grand mean of weight loss was 4.075% in about 8 months. There were no significant differences among replicates (i.e., larval infestation levels) until the last two scoring dates. The effects of larval infestation levels were found to be significant in last two scoring dates ($F = 4.32^{*}$, $P < 0.05$ and $F = 21.36^{***}$, $P < 0.001$ respectively). Weight loss increased with increasing initial infestation level (Table 1). A rank stability analysis for weight loss occurred after 8 months of artificial infestation by khapra beetle larvae (Figure 1) showed that Fırat-93, Zühre and Altıntoprak-98 were the cultivars least affected, whereas Artuklu and Sarıçanak-98 were the most susceptible cultivars. These results confirmed the previous findings of Ahmad et al. (1986) and Navarro et al. (1978), who reported a high degree of positive correlation between infestation levels and weight loss. Khattak et al. (2000) studied on the effect of khapra beetle infestation employing twelve wheat lines and also found that correlation between progeny development vs. damage and weight loss

was positive and highly significant (P<0.01). Their results matched those of Syed et al. (2006), in which they evaluated the losses caused by khapra beetle to various wheat cultivars. Results of Ahmedani et al. (2011) revealed that increasing infestation levels resulted in significant increase in progeny development, weight loss and weight of frass, the number of broken and insect damaged grains. In general, the insects tend to develop more slowly on khapra beetle resistant wheat cultivars. It is known that there have been several studies about the resistance mechanism of wheat grains against khapra beetle but inheritance of the factors controlling resistance have scarcely been studied (Dobie, 1991).

Table 1. Means and LSD groups of cultivars and larval infestation levels for the weight losses from 80 g of initial sample weight on five consecutive dates

	Scoring dates				
Cultivars Name	02.02.2015	23.02.2015	06.04.2015	16.04.2015	04.09.2015
Şahinbey	78.88 a	78.71 a	78.62 a	77.06 a	68.29 bc
Diyarbakır-81	78.80 b	78.69 a	78.58 a	73.67 b	67.48 bc
Zühre	78.72 c	78.68 a	78.54 a	78.18 a	74.49 a
Artuklu	78.78 b	78.60 ab	78.49 a	77.01 a	71.57 abc
Güney Yıldızı	78.69 cd	78.56 b	78.47 a	77.34 a	67.03 bc
Fırat-93	78.81 b	78.69 a	78.64 a	78.70 a	76.12 a
Aydın-93	78.78 b	78.66 ab	78.52 a	76.23 ab	69.43 bc
Sarıçanak-98	78.65 de	78.38 c	78.23 b	77.81 a	76.01 a
Eyyübi	78.60 e	78.29 c	78.25 b	76.39 ab	66.95 c
Altıntoprak-98	78.89 a	78.65 ab	78.50 a	77.36 a	71.82 ab
Larval intensity (LI)					
5	78.78 a	78.61 a	78.52 a	77.92 a	74.23 a
10	78.75 a	78.60 a	78.49 a	77.17 ab	72.25 a
15	78.75 a	78.56 a	78.43 a	75.83 b	66.27 b
Statistical significance for some sources of variation and some descriptive statistics					
F (Cultivars)	24.78**	12.47**	4.94**	2.22 ^{ns}	4.91**
F (Larval intensity)	2.45^{ns}	1.15^{ns}	1.74^{ns}	4.32*	21.39**
Grand mean	78.76	78.59	78.48	76.97	70.92
Standard deviation (SD)	0.033	0.07	0.11	1.61	2.84
LSD	0.046	0.10	0.15	2.28	4.02
CV%	0.4	0.80	0.13	2.09	4.00

ns, not significant, *significant at P <0.05, **significant at P <0.01,
difference between the means with same letter in a column is not significant.

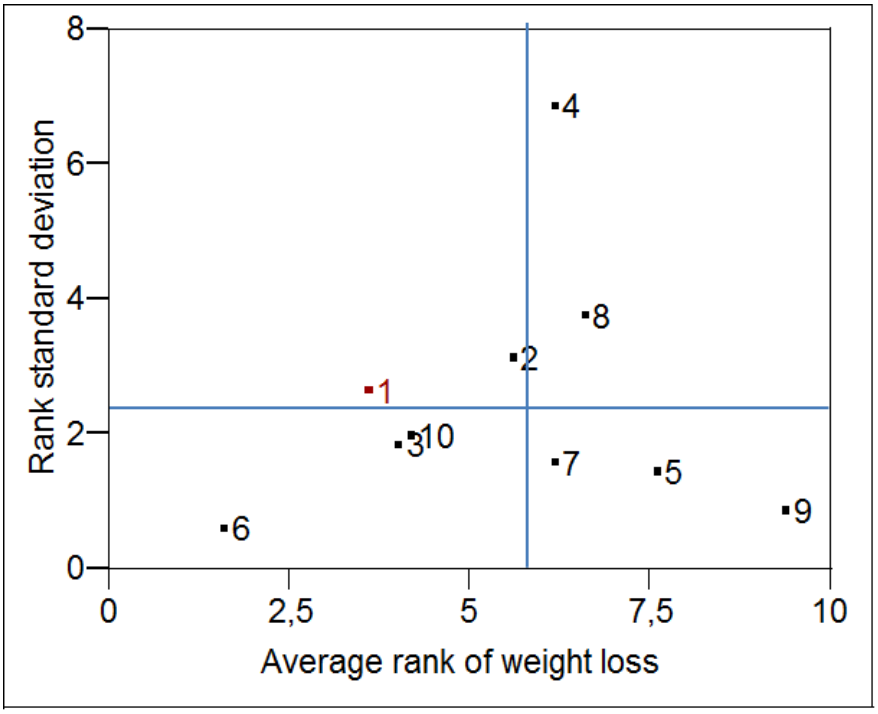

Figure 1. Ranks stability analysis for weight losses of varieties under study (1. Şahinbey, 2. Diyarbakır-81, 3. Zühre, 4. Artuklu, 5. Güney Yıldızı, 6. Fırat-93, 7. Aydın-93, 8. Sarıçanak-98, 9. Eyyubi, 10. Altıntoprak-98).

Grain quality assessment

Thousand kernel weights as one of most affecting grading factor on market price were first assessed on 18 May 2015. Thousand healthy grains and thousand randomly selected grains from glass jars of each entry with different levels of infestation were taken and weighed. An analysis of variance was performed and the means with LSD groups are given in Table 2. The overall mean 1000 kernel weight for healthy grains was 46.19 g whereas for the randomly chosen grains it was 42.21 g. An average of 3.98 g decrease was observed due to khapra beetle larvae damage. Altıntoprak-98, Güney Yıldızı and Şahinbey cultivars exhibited minimum kernel weight loss of 2.90, 2.63 and 3.46 g, respectively. Grain samples of entries with different infestation levels were selected (not adequate for replication) and tested for Zeleny and delayed Zeleny sedimentation tests at the end of study (Table 2). Zeleny sedimentation values ranged between 11 and 19 indicating weakness of durum wheat for this characteristic and the presence of some difference among cultivars. Delayed sedimentation was employed to detected sunn pest damage of grains. Results showed that only Sarıçanak-98 was suffered from sunn pest damage. It also proved to exhibit maximum kernel weight losses. There might be a correlation between susceptibility to sunn pest and khapra beetle damage due to the relatively soft grain structure. Gluten was also tested for all entries (not adequate for replication). Wet gluten ranged from 33 to 48% showing strong nature of durum wheat and the presence of genuine differences among the cultivars. Gluten index values were also scored for all entries under study. There was very high variation among entries with the lowest one of 3.38% and the highest one of 86.95% (Table 2). Eyyübi, Zühre and Altıntoprak-98 gave the highest three ranks with 86.95, 83.86 and 80.90%, respectively. Sarıçanak-98, Diyarbakır-81 and Şahinbey generated the extremely low values with 3.38, 4.60 and 5.10%, respectively. Those low values were attributed to khapra beetle damage totally. Grain quality may downgrade due to reduction of specific nutrients. Significant decreases in crude fat, total carbohydrates, sugars, protein nitrogen and true protein contents and increase in moisture, crude fiber and total protein occurred at the infestation level of 75% by khapra beetle in wheat, maize and sorghum grains (Jood & Kapoor, 1993; Jood et al., 1993; 1996). Starch content decreased at the 50% infestation level (Jood et al., 1993). Severe infestations of grains by khapra beetle may result in unpalatable or unmarketable products for human consumption.

Table 2. Means and LSD groups of 1000 kernel weights and the means of some quality characteristics of cultivars scored on various dates

Cultivars Name	Scoring dates					
	18.06.2015	18.06.2015	04.09.2015	04.09.2015	04.09.2015	04.09.2015
	1000 kernel weight in healthy grains (g)	1000 kernel weight in khapra beetle damaged grains (g)	Zeleny sedimentation in khapra beetle damaged grains (mL)	Zeleny sedimentation (Delay) in khapra beetle damaged grains (mL)	Gluten in khapra beetle damaged grains (%)	Gluten index in khapra beetle damaged grains (%)
Şahinbey	50.56 a	47.10 a	16	22	39.00	5.10
Diyarbakır-81	47.33 b	43.76 bc	16	16	43.00	4.60
Zühre	43.10 cd	39.46 ef	11	20	43.50	83.86
Artuklu	46.53 b	42.46 cd	13	18	40.00	29.95
Guney Yıldızı	42.66 d	39.83 e	19	18	40.35	61.55
Fırat-93	50.53 a	45.53 ab	11	19	41.00	37.85
Aydın-93	43.01 cd	37.96 f	15	23	48.00	6.95
Sarıçanak-98	45.60 bcd	41.26 de	16	12	44.00	3.38
Eyyübi	45.70 bc	40.55 e	14	18	33.00	86.95
Altıntoprak-98	47.20 b	44.30 bc	15	21	37.00	80.90
Statistical significance of some source of variation and some descriptive characteristics						
F (Cultivars)	8.11**	22.30**				
F (Larval intensity)	1.26^{ns}	0.26^{ns}				
Grand Mean	46.21	42.22				
Standard deviation (SD)	1.73	1.07				
LSD	2.44	1.51				
CV%	3.74	2.53				

ns, not significant, *significant at P <0.05, **significant at P <0.01, difference between the means with same letter in a column is not significant.

Market price

Market price estimates of all entries with three infestation levels were received by presenting grain samples in glass jars in local commodity market on 2 February, 16 June and 4 September 2015 respectively. Table 3 shows the statistical significance of various sources of variation and the LSD groups of means of market prices (Table 3). By the end of study, khapra beetle damage was quite high and Fırat-93, Sarıçanak-98 and Altıntoprak-98 received the highest market prices with 0.28, 0.24 and 0.22 USD kg^{-1} (0.82, 0.72 and 0.67 TL kg^{-1}), respectively. There were genuine differences among the market prices offered by local purchasers. Personal preferences of purchasers also affected market prices significantly. Larval infestation levels also affected market prices where the increasing amount of larval infestations reduced market prices significantly. Cultivar x larval infestation levels interactions were also examined and increasing amount of larval infestation resulted in lower market prices. Fırat-93 and Altıntoprak-98 were found to be the highest market price offered irrespective to larval infestation levels for all scoring dates (Table 4). Sarıçanak-98 seemed to be susceptible to khapra beetle damage initially. However, later on it recovered and was found to be less affected by khapra beetle. A rank stability analysis (Figure 2) indicated that Altıntoprak-98 and Zühre were the highest ranking with lowest SDs. Fırat-93 was also the highest-ranking cultivar with highest SD. Figure 3 shows the overall mean of market price for all entries received above given dates of study. Commodity market ceiling and base market prices for undamaged durum wheat grains are also shown.

It was evident that decreases in market price for all entries were due to khapra beetle damage rather than seasonal price fluctuations. Geometric mean of overall market price was 0.301 USD kg^{-1} for 8-month period. This resulted in a 117 USD t^{-1} income loss in the period (i.e., 418 USD initial market price - 301 USD average market price for 8 months). This could be even worse when market prices at the beginning and the end of study were taken into consideration with a 202 USD t^{-1} loss (i.e., 418 USD initial market price - 206 USD average market price for 8 months) .The pests of stored cereal and products are estimated a 10% weight loss annually in Turkey and khapra beetle damage dominates in the Southeastern Anatolia (Yücel, 1988; Işıkber et al., 2004). This damage to durum wheat grains caused by khapra beetle seems to be huge. In December 2016, stock wheat statistics obtained from Turkish Grain Board (TMO, 2016) and the purchasers from local commodity markets and some farmers in Şanlıurfa and neighboring provinces such as Diyarbakır, Mardin, Adıyaman and Gaziantep showed that there was a total stock of 483,000 t of durum wheat. A given amount of stock durum wheat is usually kept from harvest in June until the end of December. When the market prices go up, stored wheat is sold at the end of year. Khapra beetle management by aluminum phosphide fumigation for stored grain is normally practiced when grain is infested. However, it is reported that at least 5% khapra beetle damage always occurs irrespective to khapra beetle management between harvest in June and December. This equates to 24,150 t of wheat. Taking into account for average market price of khapra beetle damage grains in duration of this study (117 USD t^{-1}), the average income loss builds up; 2,825,550 USD (i.e., 24,150 t x 117 USD t^{-1}) for nearly 6-7 months. It could reach a maximum income loss of 4,878,300 USD (i.e., 24,150 t x 202 USD t^{-1}) when the market prices differences at the beginning and end of the study are taken into consideration. Consequently, Zühre, Fırat-93 and Altıntoprak-98 were the cultivars least affected by khapra beetle infestation for weight, market price and grain quality losses. Whereas Şahinbey, Diyarbakır-81, Artuklu, Güney Yıldızı, Aydın-93, Sarıçanak-98 and Eyyübi were moderate or susceptible to khapra beetle infestation for above given characteristics. Resistance mechanism of grains against khapra beetle must become a research focus, but control measures for stored products should not be neglected.

Table 3. Means and LSD groups of marketing prices (Krş kg^{-1}) for all varieties in various days of study

Cultivars Name	Scoring dates					
	02.02.2015		16.06.2015		04.09.2015	
Şahinbey	101.63	bc	86.79	ef	63.75	c
Diyarbakır-81	100.75	ef	87.38	cd	55.79	de
Zühre	101.71	bc	87.75	bc	64.17	c
Artuklu	101.38	bcd	87.75	bc	52.42	e
Güney Yıldızı	101.48	bcd	86.92	de	58.88	d
Fırat-93	101.33	cde	87.96	b	82.33	a
Aydın-93	100.26	g	86.20	f	52.92	e
Sarıçanak-98	100.58	ef	87.30	cde	72.42	b
Eyyübi	102.13	ab	86.83	de	43.33	f
Altıntoprak-98	102.97	a	88.71	a	66.58	c
Larval intensity						
5	101.68	a	87.84	a	62.19	a
10	101.52	a	87.68	a	61.73	a
15	101.07	b	86.58	b	60.46	a
Purchasers						
1	101.49	a	87.30	b	62.82	a
2	101.61	a	87.65	a	62.08	a
3	101.74	a	87.58	ab	59.22	b
4	100.83	b	86.92	c	61.72	a
	242.4 Krş= 1 $USD		274.3 Krş = 1 $USD		297.0 Krş = 1 $USD	
Statistical significance of some sources of variation and some descriptive statistics						
F (Cultivars)	8.59**		14.21**		81.25**	
F (Larval intensity)	4.62*		44.64**		2.10^{ns}	
F (Purchasers)	5.71*		7.88**		4.11*	
Grand Mean	101.42		87.36		61.46	
Standard deviation (SD)	0.93		0.65		3.90	
LSD	1.10		0.77		4.60	
CV%	0.92		0.74		6.34	

ns, not significant, *significant at P <0.05, **significant at P <0.01,
difference between the means with same letter in a column is not significant.

Table 4. Means (US cents kg^{-1}) and LSD groups of market price of cultivar x larval intensities interactions for all cultivars scored on various dates in local commodity market

Scoring date: 02.02.2015

Larval intensity	Cultivars Name																			
	Şahinbey		Diyarbakır-81		Zühre		Artuklu		Guney Yıldızı		Fırat-93		Aydın-93		Sarıçanak-98		Eyyübi		Altıntoprak-98	
5	42.02	cde	41.71	defg	42.43	abc	42.12	bcd	41.61	defgh	41.87	def	41.87	def	41.71	defg	41.35	fghi	103.50	a
10	41.92	cde	41.71	defg	41.66	defgh	41.81	def	41.94	cde	41.97	cde	41.35	fghi	41.15	hi	42.43	abc	103.80	a
15	41.85	def	41.25	ghi	41.76	defg	41.50	efgh	42.00	cde	41.56	efgh	40.84	i	41.61	defgh	42.60	ab	101.62	cde

F (cultivar x larvae): 4.01**
**significant at P < 0.01, difference between the means with same letter is not significant.

Scoring date: 16.06.2015

Larval intensity	Cultivars Name																			
	Şahinbey		Diyarbakır-81		Zühre		Artuklu		Guney Yıldızı		Fırat-93		Aydın-93		Sarıçanak-98		Eyyübi		Altıntoprak-98	
5	31.94	cdefg	31.76	efgh	32.12	bcd	32.17	bc	31.94	cdefg	32.17	bc	31.53	hij	31.99	cdef	31.35	j	32.62	a
10	31.62	ghij	31.80	defgh	32.17	bc	32.00	cde	31.71	efghi	32.39	ab	31.80	defgh	31.99	cdef	31.94	cdefg	32.71	a
15	31.35	j	31.99	cdef	31.66	fghij	31.76	efgh	31.39	ij	31.62	ghij	30.98	k	31.48	hij	31.62	fghij	31.66	fghij

F (cultivar x larvae): 4.05**
**significant at P < 0.01, difference between the means with same letter is not significant.

Scoring date: 04.09.2015

Larval intensity	Cultivars Name																			
	Şahinbey		Diyarbakır-81		Zühre		Artuklu		Guney Yıldızı		Fırat-93		Aydın-93		Sarıçanak-98		Eyyübi		Altıntoprak-98	
5	22.97	g	23.52	fg	27.44	bc	19.69	hi	24.36	efg	28.40	ab	18.85	hij	26.72	bcd	13.97	n	29.46	a
10	25.58	cde	18.68	ij	20.62	h	17.34	jkl	20.62	h	29.46	a	17.92	ijk	27.98	ab	18.01	ijk	18.77	hij
15	15.82	lmn	14.14	mn	16.75	kl	15.90	lm	14.47	mn	25.29	def	18.68	ij	18.43	ijk	11.78	o	19.02	hij

F (cultivar x larvae): 47.42**
**significant at P < 0.01, difference between the means with same letter is not significant.

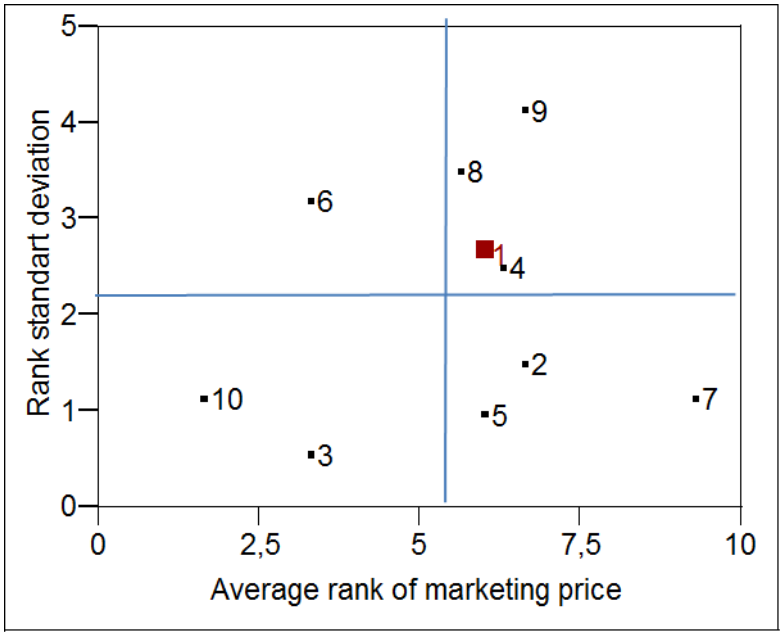

Figure 2. Rank stability analysis for marketing price losses of varieties under study (1. Şahinbey, 2. Diyarbakır-81, 3. Zühre, 4. Artuklu, 5. Güney Yıldızı, 6. Fırat-93, 7. Aydın-93, 8. Sarıçanak-98, 9. Eyyübi, 10. Altıntoprak-98).

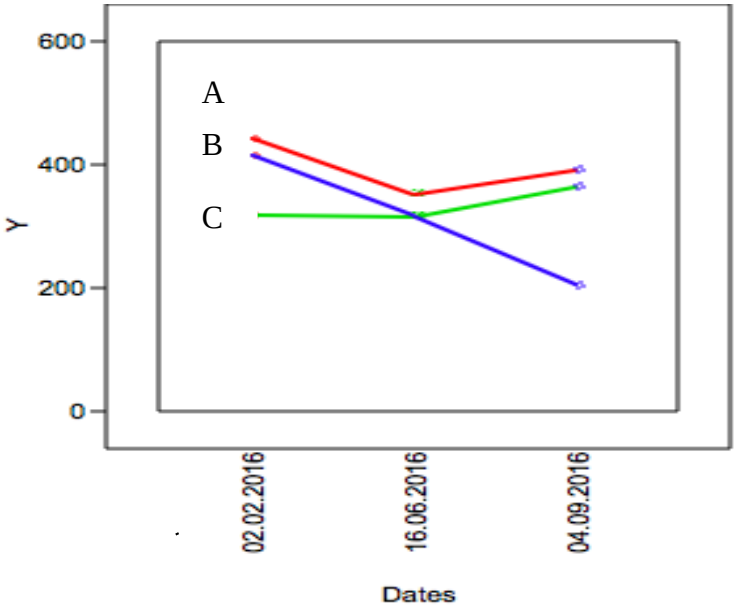

Figure 3. Local commodity market base, ceiling prices and market price of khapra beetle damaging grains.

A: Ceiling price for undamaged grains in the commodity market (USD t^{-1})
B: Base price for undamaged grains in the commodity market (USD t^{-1})
C: Average price for khapra beetle damaged grains in the commodity market (USD t^{-1})

Acknowledgments

Many thanks to the purchasers in local commodity market for their help in market price estimates and laboratory technician, Kübra AYIKGÖZ for laboratory analysis.

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