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Insect species and their abundance in sunflower and soybean seeds in warehouses in the Çukurova Region, Türkiye

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ABSTRACT

Harmful insect species were investigated in soybean and sunflower seed samples mixed with weed seeds and stored for a short time in the open field in the Çukurova Region (Türkiye) including Adana, Mersin and Osmaniye Provinces in 2020. A total of 8 harmful insect species were found in the samples of stored soybean and sunflower seeds. Seeds of 12 weed species were detected in both soybean and sunflower seed samples. The red flour beetle, *Tribolium castaneum* (Herbsts, 1797) (Coleoptera: Tenebrionidae) was the major pest insect in both sunflower and soybean seeds. A few species of the rice weevil, *Sitophilus oryzae* (L. 1763) (Coleoptera: Curculionidae), which are the primary pest of stored cereals, were recorded under outdoor conditions. No insect feeding damage was observed on the seeds of both crops and also on the seeds of the weeds. Finally, the seeds of soybean and sunflower crops which were harvested and kept outside the warehouses, for a short time, were attacked by some stored pest insects particularly *Tribolium* spp. This issue may create a problem, in the case that harvested crops with insects are moved into the warehouse,which has suitable temperature and moisture for the pest insects to develop and multiply.

1. Introduction

Sunflower is one of the first plants that comes to mind when it comes to oilseeds in Türkiye, and it is grown for oil and snack foods. Sunflower meets 50% of the crude vegetable oil production in Türkiye (Semerci and Durmuş 2021). Although the amount of production has decreased slightly compared to the previous year, it has increased exponentially in the last 30 years (FAO 2021). The provinces where sunflower production is intense in Turkey are: Tekirdağ, Konya, Edirne, Kırklareli and Adana, these provinces meet 68% of the total production, and 2067004 tons of sunflower was produced in Türkiye in 2020 (Semerci and Durmuş 2021). Oil sunflower production reached 2.3 million tons in 2022. Total sunflower production was announced as 2.55 million tons. The estimation of the Turkish Statistical Institute for 2021, with an increase of 5.29 percent compared to the previous year (TÜIK 2022). The following are considered oilseed plants on a global scale; Soybean, sunflower, peanut, rapeseed, sesame, safflower, olive, maize, palm seed, coconut, oil flax and castor oil plants. When production amounts are taken into account, soybean, rapeseed, sunflower, peanut, cottonseed and palm kernel crops come first.

Soybean seeds contain 18-24% oil, 35-40% protein, and provide organic matter and nitrogen to the soil (Uçum and Korkut 2019). Soybean is the plant with the highest cultivation area and production amount among oilseed plants in the world. While oilseed production was carried out on 277 million hectares of land in the world in the 2017-2018 season, soybean production was carried out on 124 hectares of these areas and this accounted for 45% of the total oilseed cultivated areas. As of the 2017-2018 season, the total oilseed production in the world was 573 million 620 thousand tons, while soybean production was 336 million 820 thousand tons. Worldwide, the share of soybean production in the total production of oilseed plants was 61.1% (Uçum and Korkut 2019). In the 2018/19 season, soybean production in Türkiye reached 140 thousand tons, harvested from 328 thousand decares of land. In 2022, soybean production expanded to 2.415 tons. During this season, Adana Province accounted for approximately 64% of soybean production areas, while Mersin Province accounted for 28% (TUİK 2022).

Sunflower and soybean production statistics indicate that these two plant species contribute significantly to meeting the oil needs of Türkiyeand the world. As with other harvested oilseed crops, sunflower and soybean seeds are stored and evaluated in the market at the most appropriate time. Studies have been carried out on pest insects/mite species and their importance in mainly stored grains in Türkiye (Ekecan and Özgür 1990; Çankaya 1998; Mert 2012; Aydın 2011; Bağcı et al. 2014; Işıkber 2005; Işıkber et al. 2016; Özgen et al. 2018; Sekrane et al. 2022). Information about harmful arthropoda species in stored oilseeds is not clearly understood. However, in the review by Rajendran and Chavadevi (2004); 13 insect species were recorded in stored soybean seeds and 6 insect species in sunflower seeds, the most important among them: *Tribolium* spp. (Coleoptera: Tenebrionidae) and, together with *Ephestia cautella* (Walker, 1863) *Plodia interpunctella* (Hubner, 1813) (Lepidoptera: Pyralidae). White et al. (2011) reported that *Cryptolestes ferrugineus* (Stephens, 1831) (Coleoptera: Cucujidae) and

Tribolium castaneum (Herbsts, 1797) (Coleoptera: Tenebrionidae) species were quite common, especially in oilseeds and grains in the heated warehouses in Canada, and the cold tolerance of *Sitophilus granarius* (L. 1875) (Coleoptera: Curculionidae) and *P. interpunctella* were higher than the other two species.

Products intended for storage, including grains, legumes, and oilseeds, should be inspected to ensure that they are free from foreign objects and weed seeds. In the case of products that are contaminated with weed seeds, the moisture content can be high, creating ideal conditions for primary or secondary pests to proliferate quickly during storage (Rees 2004). For this purpose, the possible effects of crop seeds contaminated with weed seeds, stored for a short time on the abundance of insect species (number of individuals) was investigated in this study.

In stored products, harmful insects are generally the primary pests that directly damage the healthy grains and their larvae and/or adults mostly feed on the core (embryo) part of the grains. The secondary pests that feed on the grains that are destroyed by the feedings of the primary pest or for various reasons cause damage (Özgür 1984; Rees 2004). Studies with harmful insect species in stored products around the world have been carried out after the product is stored for a short or long term. While the main habitat of harmful insects in stored products is storage (eg *S. granarius*), some of them can live both outdoors and in warehouses (eg *Tribolium* spp.). In other words, such insects are transported to the warehouse with the products, multiply under suitable conditions and become harmful (Rees 2004). No study has been found yet of harmful insects or mite species in stored oilseeds in Türkiye. Before the product is put into storage, it is important to know whether the product has insects or mites and also weed seeds. In this study, insect species and their densities were investigated in sunflower and soybean seeds samples containing weed seeds and kept for a short time in the open field before being taken into the warehouses after post harvest.

2. Materials and methods

2.1. Samplings

Sunflower seeds samples were taken from bulk heaps, which were kept in the open area for about 10-15 days, between 21 July, and 28 August, 2020, before the harvest crops were stored (i.e seeds of both crops) in the warehouses or reinforced concrete horizontal warehouses in Çukurova Region, Türkiye. Sunflower seed heaps have a capacity of about 17 tons. Samples were taken from Ceyhan (38), Karaisalı (1), Sarıçam districts (9) in Adana Province; Kadirli district of Osmaniye (6); Tarsus district of Mersin Province (19). A total of 73 samples were obtained from 26 warehouses located in Adana (18), Mersin (5), and Osmaniye (3) for analysis in this study. The moisture content of the sunflower seeds varied between 8 and 10.5%. Soybean samples were taken from bulk piles, which were kept in the open area for about 10-15 days before the product was taken into the warehouses between September 15 and October 20 in 2020, similar to the collections of sunflower samples. Seeds of various soybean cultivars, including Arısoy, Asya, Lider, MonaSandoz 4240Blaze, AG3546, Planet, and Sonya, were collected and stored separately prior to analysis. The bulk capacities are on average 25 tons. Product grain moisture ranged from 12 to 14%. Soybean seed samples were taken from 19 warehouses from Adana, 8 from Mersin and 8 from Osmaniye, Ceyhan (8), Seyhan (14), Karataş (12), Yüregir (7), Kozan (9) Sarıçam (1); Osmaniye Province Kadirli district (15) and Mersin Province Tarsus district (34). Each soybean or sunflower sample (seeds) was taken randomly from the upper, middle and lower parts to represent the crop heap, with a total of 1 kg. A total of 100 samples were evaluated for identifications of the weed seeds and pest insects of the stored products.

2.2. Detection of seeds of weed species in sunflower and soybean seed samples

The samples were brought to the Weed Science Laboratory, Department of Plant Protection, Çukurova University, and then the crop seeds, i.e. soybean and sunflower seeds, and weed seeds were separated by eye under a large table magnifier with LED light using forceps and spatulas. The separated weed seeds were compared with the seed samples from the seed collection in the herbarium under the DMSZ7P stereo-binocular microscope with aninternal camera, and the same ones were grouped together.

Weed seeds were identified by comparison with the previously identified weed seeds, and also by using different identification keys (Hanf 1990; Meyer and Effenberger 2010; Parkinson et al. 2013; Uygur et al. 2020; ISMA 2022). However, those whose identifications were unclear, were germinated in the growing cabinets and their development was followed until the fruiting period.

2.3. Detection of insects from sunflower and soybean seed samples

During the analysis of sunflower and soybean samples containing weed seeds, the weed seeds were sorted and counted by species, for each 1 kg sample. Each sunflower or soybean sample was first evaluated in terms of weed seeds, and the sample was taken back into the same polyethylene plastic bags without deteriorating its properties. The bags were again examined in terms of harmful/beneficial insects in the entomology laboratory in the same department. For this purpose, the samples were passed through a 10 mesh sieve, and the insect samples falling under the sieve were collected with the help of a wet-tipped No. 2 fine brush and stored in plastic tubes (1.8 cc) containing 70% ethyl alcohol for later evaluations of the collected specimens. Specimens were recorded by counting at the species level under the stereo-binocular microscope. Mostly adults of insect species were recorded from the samples. A few larvae belonging to the genus *Tribolium* were also found. Harmful mites and also beneficial insect/mite individuals could not be detected in the stored products.

The identification of the adult insects found in the sunflower and soybean seed samples was carried out by comparing them with the previously identified insect species stored in the Entomology Laboratory of the Plant Protection Department at the Faculty of Agriculture in Çukurova University. In addition, Özgür (1984)'s lecture note (Practical Identification Key) and the identification key of harmful insects in stored products published by Rees (2004) were used for the identification of insects under the stereo-binocular microscope with X 45 magnifications. Insect identifications at species level were carried out by the senior author.

2.4. Evaluation of data

Within the goal of this current study, weed seeds were identified at the species level and their densities were not evaluated. In addition, no insect damage was observed in weed seeds in each sample material. Insect species and densities in sunflower and soybean samples mixed with the weed seeds were

recorded in the Excel file. Samples (different sunflower and soybean samples) taken from different or the same warehouses from each region on different dates were not evaluated at the variety level. The individual numbers of the insect species collected at different dates were combined and the total number of individuals and also the frequency of occurrence (%) of the species according to the region (districts) were given. By combining regions and warehouses and varieties (sunflower and soybean) sampling dates, the percentages of insect species in total adult individuals were tabulated separately according to sunflower and soybean products. The proportion (%) of a species in adult individuals was found by dividing the number of that species in the total population by the total number of adult population and multiplying by the constant of 100 according to (Karman 1971). In the sunflower and soybean samples taken from the crops harvested and stored in the open area for a short time in heaps, damage rates (%) were not given, since there was no insect damage to the grains.

3. Results and Discussion

3.1. Weed species in sunflower and soybean seed samples

The main or potentially harmful weed species, mixed with the sunflower or soybean seed samples are given in Table 1. In the study, a total of 49 weed species in sunflower seed samples, and 25 weed species in soybean seed samples were found during the harvest in the sampling locations. The most common weed species mixed with the soybean seeds were jute (*Corchorus olitorius*), redroot pigweed (*Amaranthus retroflexus*), field muskmelon (*Cucumis melo* var. *agrestis*). Along with sunflower seeds, lamb's-quarters (*Chenepodium album*), johnson grass (*Sorghum halepense*), redroot pigweed (*Amaranthus retroflexus*) were found extensively.

3.2. Insect species in sunflower and soybean seed samples

A total of 8 harmful insect species were found in the samples of stored soybean seeds, these are: *Lasioderma serricorne* (Fabricius, 1792) (Coleoptera: Anobiidae), *Sitophilus oryzae* (L. 1763) (Coleoptera: Curculionidae), *Cryptolestes turcicus* (Grouvelle, 1876) (Coleoptera: Laemophloeidae), *Carpophilus dimidiatus* (Fabricius, 1792) (Coleoptera: Nitidulidae), *Oryzaephilus surinamensis* (L. 1758) Coleoptera: Silvanidae), *Tribolium castaneum* (Herbsts, 1797) and *Tribolium confusum* Jacquelin du Val, 1863 (Coleoptera: Tenebrionidae) and *Liposcelis entomophila* (Enderlein, 1907) (Psocoptera: Lipocelidae) (Table 2). The most common (57%) species in the soybean seed samples and the highest prevalence (47.01%) in total adults was *T. castaneum*. This species was followed by *O. surinamensis* with a rate of 49% in samples and 28.80% in total individuals. Both species are polyphagous secondary pests of cereals and feed on many stored products. *Sitophilus oryzae*, which is the primary pest of cereals, was found in very low numbers in the samples, and it occurred rarely. The frequency of the other insect species in the samples and their rate in the total individuals were quite low.

Table 1. Weed species and their presence in sunflower and soybean seed samples in 2020

Family	Weed species	Sunflower	Soybean
Amaranthaceae	Redroot pigweed (*Amaranthus retroflexus* L.)	-[a]	+
	Lamb's-quarters (*Chenopodium album* L.)	-	+
Apiaceae	Wild carrot (*Daucus carota* L.)	+	
Asteraceae	Yellow starthistle (*Centaurea solstitialis* L.)	+	-
	Common cocklebur (*Xanthium strumarium* L.)	+	+
Boraginaceae	Common heliotrope (*Heliotropium europaeum* L.)	+	-
Brassicaceae	Wild radish (*Raphanus raphanistrum* L.)	+	-
	Wild mustard (*Sinapis arvensis* L.)	+	-
Convolvulaceae	Field bindweed (*Convolvulus arvensis* L.)	+	-
	Morning glory species (*Ipomoea hederacea* (L.) Jacquin, *Ipomoea triloba* L.)	-	+
Cucurbitaceae	Field muskmelon (*Cucumis melo* var. *agrestis* Naudin.)	-	+
Cyperaceae	Purple nutsedge (*Cyperus rotundus* L.)	-	+
Euphorbiaceae	Nodding spurge (*Euphorbia nutans* Lag.)	+	
Malvaceae	Jute (*Corchorus olitorius* L.)	+	+
	Venice mallow (*Hibiscus trionum* L.)	+	+
Poaceae	Sterile wild oat (*Avena sterilis* L.)	+	
	Barnyardgrass species (*Echinochloa colona* (L.) Link, *Echinochloa crus-galli* (L.) P. Beauv.)	-	+
	Common barley (*Hordeum vulgare* L.)	+	
	Johnson grass (*Sorghum halepense* (L.) Pers.)	-	+
Portulacaceae	Common purslane (*Portulaca oleracea* L.)	-	+
Solanaceae	Black nightshade (*Solanum nigrum* L.)	-	+

[a](-): not found, (+): found.

Table 2. Sample number of insect species found in soybean seeds, number of adults, and percentages of species in total adults in 2020

Insect species	Number of samples found	Frequency (%) in samples	No of individuals	Percentage of adults
Coleoptera				
Anobiidae				
Lasioderma serricorne	3	3	6	1.63
Curculionidae				
Sitophilus oryzae	3	3	4	1.08
Laemophloeidae				
Cryptolestes turcicus	3	3	3	0.82
Nitidulidae				
Carpophilus dimidiatus	35	35	72	19.56
Silvanidae				
Oryzaephilus surinamensis	49	49	106	28.80
Tenebrionidae				
Tribolium castaneum	57	57	173	47.01
Tribolium confusum	3	3	3	0.82
Psocoptera				
Lipocelidae				
Liposcelis entomophila	1	1	1	0.28

Similar to the soybean samples, a total of 8 insect species were recorded in the sunflower samples (Table 3). The same species were found in sunflower seeds, with the exception of *L. serricorne*. *Rhyzopertha dominica* (F., 1792) (Coleoptera: Bostrychidae) was detected in the sunflower samples in Table 3. Similar to the soybean samples, the most common (67%) in total adults and most abundant (621 individuals) insect species in the sunflower samples was *T. castaneum*. Unlike soybean samples, *T. confusum* was collected in relatively higher numbers (50 individuals) in the sunflower samples, constituting 6.03% of the total individuals, compared to its numbers found in the soybean samples. *Liposcelis entomophila* individuals were also noted in the sunflower samples, with a rate of 8.20% in total adults.

3.3. Abundance of insect species in samples of soybeans and sunflowers by districts

The total number of individuals belonging to different insect species according to districts level in sunflower samples are shown in Table 4. The highest number of insects collected was found in Ceyhan (472 individuals), followed by Tarsus (200 individuals). Similar to the soybean samplings, *T. castaneum* was recorded in higher numbers than other insect species in all districts. This species was mostly collected from the Ceyhan (342 individuals) and Tarsus (164 individuals). The reasons for the higher concentration of insects in both districts may be related to the higher sunflower production in these districts and thus, the higher number of sunflower seeds coming to the warehouses, and therefore the higher number of samples taken.

The rates of insect species found in the soybean samples according to sampling locations are shown in the Table 5. The most insects were detected in Tarsus (147 adult individuals). This was followed by the Seyhan (60 individuals) and Kadirli. *Tribolum castaneum* was detected in all districts except Sarıçam. This species was mostly recorded in Seyhan (43 individuals) and Tarsus (58 individuals). *Oryzaephilus surinamensis* (53 individuals) and *C. dimitatus* (29 individuals) were found mostly in Tarsus. The numbers of the other species detected were lower compared to the districts and their number varied from 1 to 3 individuals. The higher number of individuals in Tarsus and Seyhan districts may be related to taking more samples from these districts.

In this study, secondary harmful species, mostly *Tribolium* spp. and *O. surinamensis* individuals were collected. Adult individuals of *Sitophylus oryzae*, which are the primary pests of cereals (wheat and corn seeds) and are a common occurrence in high numbers (Işıkber et al. 2005; Mert 2012; Er et al. 2016; Yetkin 2021), were recorded in very low numbers. This issue may indicate that the main habitat of this pest insect species is warehouses , even if it is capable of living in the open areas neighboring the warehouses. In this study, the higher number of *T. castaneum* compared to *T. confusum* in both the sunflower and soybean seed samples may be due to the ecological demands of this species, in other words, the high temperature demand of *T. castaneun* (Rees 2004). There were high densities of this species in the open area around the warehouses, where grains are stored in Adana therefore, hidden places should be investigated carefully for pest insects of stored products, particularly for flour beetles (*Tribolium* spp.). Although *Tribolium* spp. are of secondary importance in stored grains, if the product moisture is high, it can also be fed and reproduce quickly in healthy grains. Işıkber et al. (2016), in the study that they conducted on the stored corns in three different geographical locations:- South Türkiye (Adana, Mersin and Kahramanmaraş Provinces), Southeast (Şanlıurfa Province) and Central Anatolia (Konya Province) inTürkiye , they reported that *T. castaneum* (40%) and *S. oryzae* (40%) had the highest prevalence in the Southern Anatolian Region. Another reason for the widespread and high occurrence of *T. castaneum* in the open field, may be related to the fact that this species develops very high resistance to the phosphine gases in the Southern Provinces of Türkiye (Adana, Hatay, Kahramanmaraş, Mersin and Osmaniye) (Doğanay 2019). Similar to *Tribolium* species, *O. surinamensis* is a species of secondary importance in cereals, and it is a major problem especially in stored oilseeds (eg peanuts) (Rees 2004). *Tribolium castaneum* and *O. surinamensis* prefer stored grains and oilseeds, and they also cause toxigenic fungi infestations on the stored products, such as *Aspergillus* species, which infect insect's body parts and in their feces, and are thus spread in warehouses (Howe 1965; Rao et al. 2010; Tucker et al. 2014).

Table 3. Insect species found in sunflower seed samples, number of adults, and percentages of species in total adults

Species	Number of samples found	Frequency (%) in samples	No of individuals	Percentage of adults
Coleoptera				
Bostrychidae				
Rhyzopertha dominica	1	1	1	0.12
Curculionidae				
Sitophilus oryzae	5	5	7	0.85
Laemophloeidae				
Cryptolestes turcicus	10	10	10	1.20
Nitidulidae				
Carpophilus dimitatus	17	17	30	3.62
Silvanidae				
Oryzaephilus surinamensis	26	26	42	5.01
Tenebrionidae				
Tribolium castaneum	67	67	621	74.91
Tribolium confusum	29	29	50	6.03
Psocoptera				
Lipocelidae				
Liposcelis entomophila	20	20	68	8.20

Table 4. Number of adult individuals of insect species in soybean seeds by districts in 2020

Insect species	Ceyhan	Kadirli	Karataş	Kozan	Sarıçam	Seyhan	Tarsus	Yüreğir	Total
Lasioderma serricorne	0	1	0	0	0	2	3	0	6
Sitophilus oryzae	0	0	2	0	0	0	2	0	4
Cryptolestes turcicus	0	1	0	1	0	0	1	0	3
Carpophilus dimidiatus	2	15	3	12	4	7	29	0	72
Oryzaephilus surinamensis	1	12	17	1	0	17	53	5	106
Tribolium castaneum	5	31	13	8	0	43	58	15	173
Tribolium confusum	0	0	1	0	0	1	1	0	3
Liposcelis entomophila	0	0	0	1	0	0	0	0	1
Total	8	60	36	23	4	70	147	20	368

Table 5. Number of adult individuals of insect species found in sunflower seeds by districts in 2020

Insect Species	Ceyhan	Kadirli	Karaisalı	Kozan	Tarsus	Sarıçam	Total
Rhyzopertha dominica	1	0	0	0	0	0	1
Sitophilus oryzae	1	0	0	1	3	2	7
Cryptolestes turcicus	4	0	0	3	3	0	10
Carpophilus dimidiatus	20	0	0	6	3	1	30
Oryzaephilus surinamensis	35	0	0	1	5	1	42
Tribolium castaneum	342	41	15	30	164	29	621
Tribolium confusum	33	1	0	1	12	3	50
Liposcelis entomophila	36	2	2	3	10	15	68
Total	472	44	17	45	200	51	829

No damage caused by the insects identified was observed in the soybean, sunflower and weed seeds. This may be related to the short-term storage in the open area. However, weed seeds being together with harvested crops may increase crop moisture (Rees 2004). Because during the harvest period, only the moisture situation in the seeds of these cultivated plants is taken into account.

4. Conclusions

In this study, soybean and sunflowers seeds stored outdoor as heaps for a short time (approximately 15 days) in the open areas of the sampled warehouses before being stored were attacked by the various harmful insects living both in the open area, and in the warehouses. With this study, it was concluded that insects, defined as secondary pests in particular *Tribolium* spp. and *O. surinamensis*, which are transported to the warehouse with the products from outside, may cause damage as much as insect attacks inside the warehouses. Weed seeds coexisting with soybean or sunflower seeds may increase crop moisture and thus, cause the proliferation of the pests, and thus, increased damage. In this case, it is suggested that it is important not to leave the harvested crop seeds in the open area, even for a short time, before it is taken into storage, in terms of preventing the attacks of harmful outdoor insects such as the red flour beetles and the sawtoothed grain beetles. Moreover, it is recommended to spray the products for preventive purposes before storing them.

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