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Reducing the Damage Rate Caused by the Beetle Insect *Trogoderma Granarium* (Everts) (Coleoptera: Dermatecidae) in Stored Wheat Grains

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ABSTRACT
This study was conducted to determine how the wheat spike components can help in protecting or reducing the damage rate in stored wheat grains from the infection by the khapra beetle. Two types of sewn bags were used, polypropylene sutli bags and old jute bags, for storage. Several spike components (non-ground, ground remaining spike components and spike holder) of wheat plants were examined in protecting the stored wheat grains from the infestation of the khapra insect. The results showed that stored grains in the form of whole crops in bags of polypropylene sutli reduced the damage percentages in the third and second year of storage to the lowest levels 16.66% and 9.66%, compared to the control treatment that reached 50.66% and 20.66% respectively. While, the damage rate for storing grains in bags of old jute was 11.33% compared to the polypropylene sutli bags 8.77%. The smallest number of the insect skin sheddings was noticed in polypropylene sutli bags with 5.22 skins. The storage of grains with whole crop component in the third year has a great role in reducing the damage proportion to the lowest level (2.77%). The number of insect skin sheddings decreased to the lowest level (1.88 skin/bag) compared to the control treatment that reached 14.88 skin/bag. In conclusion, wheat spike components can play a great role in reducing the damage rate in stored grains in the polypropylene sutli bags against the khapra beetle.

KEYWORDS
Grains, Khapra, Spike Components, Wheat.

Introduction

Wheat *(Triticum, aestivum Linnaeus)* grain is one of the main food sources due to its richness in proteins, calories and carbohydrates and is a cheap source compared to other food sources (*1*). Wheat is also one of the most important crop that plays a strategic role in food security, as its grains are used in bread making that is indispensable in the countries of Asia and the Middle East (*2*). It also contains a high percentage of carbohydrates in addition to amounts of fats and vitamins B1, B2 and some mineral salts (*3*). Since wheat is mostly grown in a winter season, especially in the Middle East countries, it is considered a winter crop, even though it is consumed as a basic food source all through the year. Therefore, in the early ages, people needed to store their wheat grains to meet food requirements in seasons when the wheat crop was not cultivated, so our ancestors relied on keeping the whole spike components to store their grains (*4*). With the advancement of time, many methods have been used for storing wheat grains for longest duration with minimal losses resulting from the injury of pests in silo stores (*5*). The stored wheat grains are infected with many insect pests that cause a great damage to them (*6*), and the most important of these pests is *Trogoderma granarium,* which has been classified as one of the 100 most dangerous species in the world (*7*). This beetle has become a very destructive scourge of stored grains in hot and dry regions of the world (*8*), as it varies with the diversity of products (*7*). The larva is the most destructive stage of the insect, which can be populated even in the absence of food, whereas the adults live for two-three weeks (*9*), and they are able to produce one-nine generations per year depending on the temperature and humidity (*10*). The beetle consumes about 18 mg of grains per day, resulting in 14.8 mg of dust, skin sheddings, leather filaments and feces that damage the crop and causing infection to the workers and reducing germination rate of seeds intended for seeding (*11*).

Numerous methods were used to control this pest, such as chemical pesticides and physical methods. The chemical pesticides cause some health problems when the grains are used as a direct food for humans, while the physical methods are often costly, (*12-14*). The residues of pesticides in the grains prompted the use of plants to control the insects that infest the stored grains (*15*). Also, the use of residues of plants, plant extracts and essential oils can reduce the toxicity of the remaining pesticides in the stored grains and their products (*16*), as well as the use of aromatic plants (*17*). The aim of this paper was to examine the use of spike components (awns (Al-safa), Al-canabah, and spike holder) of wheat plants to protect the stored wheat grains in two type of bags from the infestation of the

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khapra insect.

Material and Methods

At the harvest time, wheat spikes were collected from local wheat variety (Abu-Ghraib 3) in Basrah province at the end of May 2016, the wheat spikes were isolated, and treated as the following:

Types of Storage Bags

Two types of bags were used, polypropylene sutli bags (made from synthetic polyethylene) and old jute bags (made from plant (Jute) fibers). Both types of bags were of the size 15x20 cm and they were used after being sewn.

Storage Methods of Wheat Crop

Storing the Whole Spike Components. The whole spike components were stored in the bags mentioned above filling with 20 spikes per bag with three replicates. The bags of control treatment were filled with 50 grams of wheat grains isolated from the spikes. Then, the bags were stored in laboratory to be examined for a period of three years, calculating the damage percentage, the number of insect skin sheddings and the live larvae of *T. granarium*.

Storing the Wheat Grains with Residues of Crop. At a harvest time, grains from mature wheat heads were individually collected, cautiously pulled off, combined and air-dried, the remaining ear components (awns (Al-safa), Al-canabah, and spike holder) were collected separately. The grains were stored with the spike components in the following two methods using polypropylene sutli bags.

First: Storing the wheat grains with non-ground remaining spike components: a 5 g of spike residues were combined with 50 g of wheat grains in a polypropylene sutli bag at a rate of 3 bags as replications and keeping the fourth bag as a control treatment without residues. Second: Storing the wheat grains with ground remaining spike components: the remaining spike components were ground separately. A 5 g of the ground residues were added at a rate of 5 g / 50 g of wheat grains separately. The remaining spike components and grains were stored at a laboratory in pouch from May 2016 to the end of May 2019 with annual examination in May and the following characteristics were recorded:

Damage Percentage

The damage percentage was obtained by calculating the number of affected (crushed) grains from the fifty wheat grains chosen randomly from the four bags of each treatment separately.

Percentage of Damage = Number of Affected Grain / Total Number of grains* 100

The Skin Sheddings of Larvae

The number of skin present in the bags for each treatment was calculated after emptying the contents of each bag onto a white sheet separately.

Live Larvae

The live larvae were calculated for each treatment after emptying the bag contents also onto a white sheet separately.

Statistical Analysis

Variance analysis was implemented by means of the statistical program SPSS ver. 21.0 software to define the statistical differences ($p < 0.05$) among the methods of grain storages (with non-ground and ground remaining spike components) using two type of bags.

Results

Storing the Whole Spike Components

Damaging Rate caused by the Khapra Beetle T. granarium. The results showed that the highest rate of damage was noticed in the third year 38.91%, which was significantly ($p < 0.05$) different from the second year 16.49% compared to the rate of damage in the first year 0.5%. The treatment of old jute bags showed the highest rate of damage 11.33% compared to the polypropylene sutli 8.77 %. While, storing the wheat grains with the whole spike components reduced the percentage of damage to the lowest level 16.66 and 9.66% with polypropylene sutli bags compared to the control treatment 50.66 and 20.66%, respectively. In the first year for

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all treatments, there was no damage percentage in the two type of bags, except the control treatment in the old jute bag that reached 0.22%, as shown in **Figure 1**.

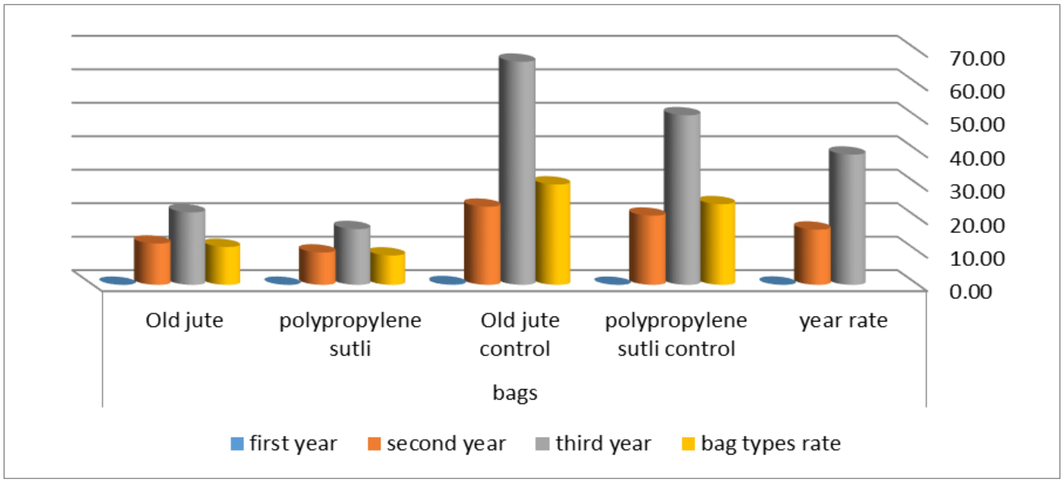

Fig. 1. The effect of storing methods of whole crops on the damage percentage from the khapra beetle infection. Ls.d: year 3.45, Bag types 3.45, interaction 5.97

The Effect of Stored Wheat Grains in Whole Crops on the Skin Sheddings of the Khapra Insect T. granarium. The highest number of larval skin sheddings was recorded in the old jute bags with a rate of 8.78 skin/bag, compared to the polypropylene sutli bags with 5.22 skin/bag. The highest number of skins were recorded in the first, second and third years when the control treatment with the old jute bags reached 0.3, 11 and 39.66 skin/bag, respectively. While, the lowest number of skin sheddings were noticed in the treatment of whole crop for the three years, especially when using polypropylene sutli bags that reached 0.00, 0.6, and 9.66 skin / bag, respectively as shown in **Figure 2**.

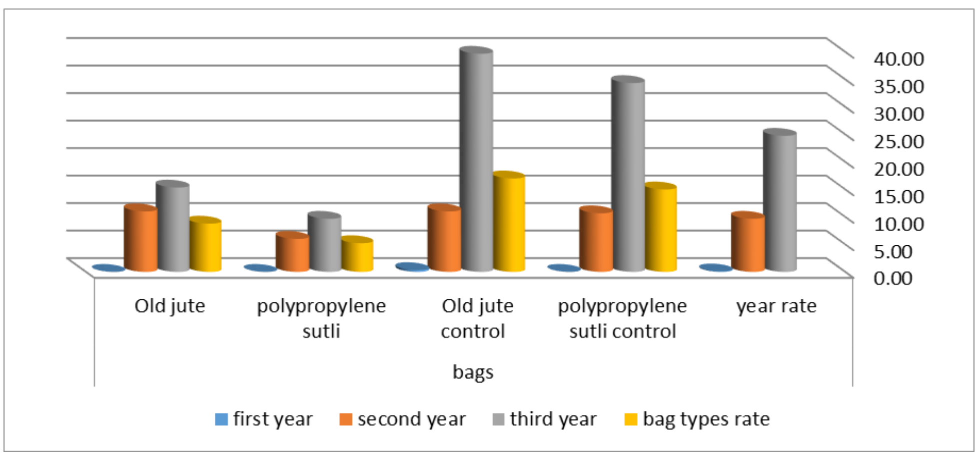

Fig. 2. The effect of stored wheat grains in whole crops on the number of skin sheddings of the khapra beetle. Ls.d: year 8.72, Bag type NS, interaction NS

The Effect of Stored Wheat Grains in Whole Crops on the Live Larvae of Khapra T. granarium. The highest number of live larvae of the khapra beetle was recorded in the treatment to old jute and polypropylene sutli bags with 17.99 and 14.33 larvae / bag, respectively. Whereas, the lowest number was present in the stored grains with the whole crop in the polypropylene sutli and old jute bags with 0.22 and 1.22 larvae/bag, respectively. The live larvae did not appear in the first and second years, along with the whole crop in the polypropylene sutli bags as shown in **Figure 3**.

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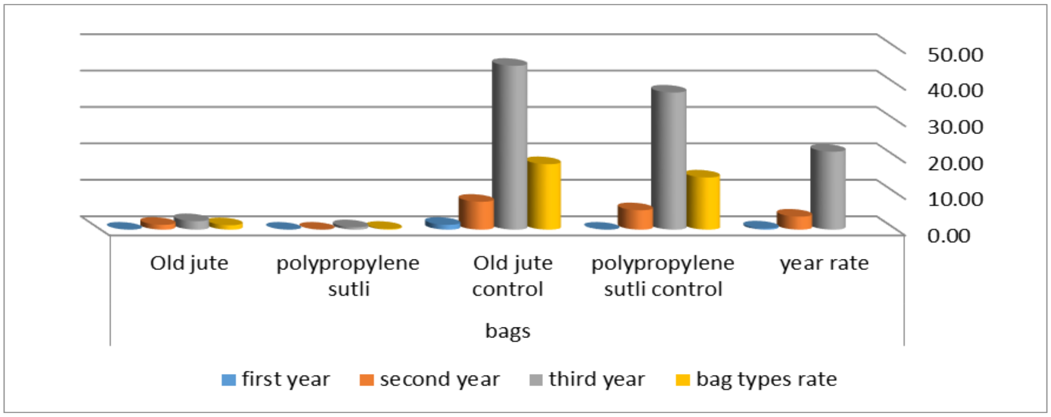

Fig. 3. The effect of stored wheat grains in whole crops on the number of live and dead larvae of the khapra beetle. Ls.d: year 4.79, Bag types NS, interaction NS

Storage of Wheat Grains with Residues without the Whole Spikes

The Damage Rate of Khapra Insect T. granarium. Storing the wheat grains with their spike components reduced the percentage of damage in the stored grains to the lowest level in the treatment of Al-cannaba and awns components 2.22 and 2.72% respectively, compared to the spike holder and the control treatments that reached 7.44 and 23.27%, respectively. The shape of spike remaining, whether it was crushed or not crushed did not show significant differences in reducing the damage. The damage percentage was limited in the third year, which did not differ significantly from the second year for the two grain storage treatments (cannaba and safa) that had not exceeded 7% compared to the treatments of control and grain storage with spike holder 66.66 and 19.33%, respectively. While, no noticeable damaging percentage was found in the first year of storage compared to the control treatment 2.66% as shown in **Figure 4.**

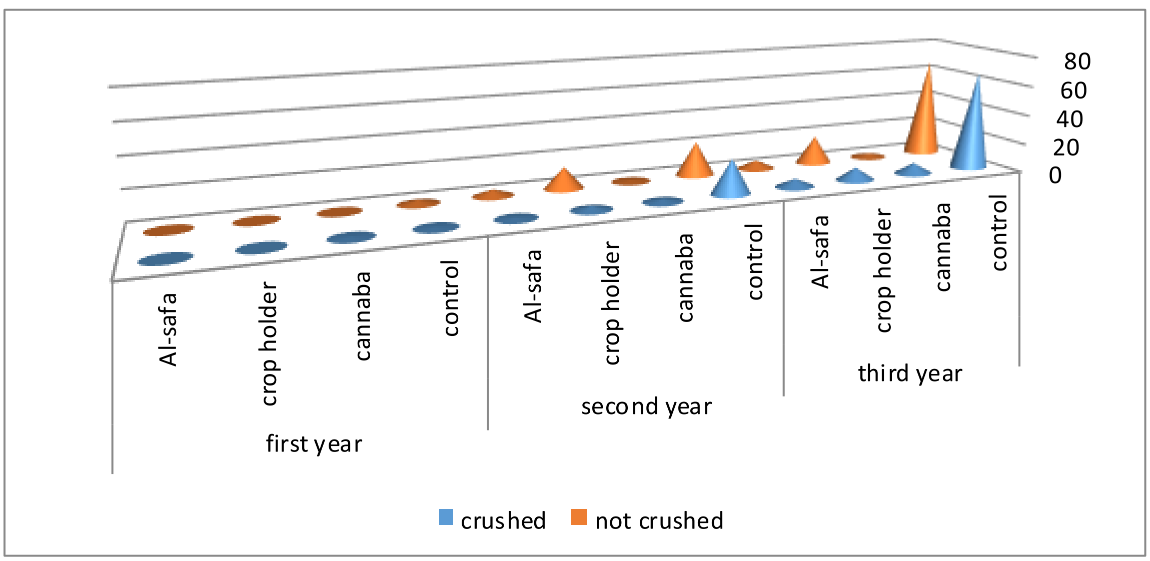

Fig. 4. The effect of crop component residues on the damage percentage resulting from the khapra beetle. L.s.d: components 4.061, interaction 7.034, the form of wheat 2.872.

The Effect of Crop Components on the Skin Sheddings of Khapra Larvae T. granarium. The spike component had a great role in reducing the number of skin sheddings to the lowest level 1.88 scraping skins /bag, compared to the control treatment 14.88% skin /bag. Whereas, the remaining spike components, whether they were ground or not, showed a significant ($p < 0.05$) difference. Also, the number of skins was not significant and not differed in the third and second years. The highest number was 6.66 skin /bag in the treatment of spike holder, compared to the control treatment in the same year with 32 skin /bag. While, the highest number was noticed in the second year with 5.33 skin /bag in the treatment of non-crushed Al-safa, compared to the treatment of control of the same year, which was

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10.66 skin/bag as shown in **Figure 5**.

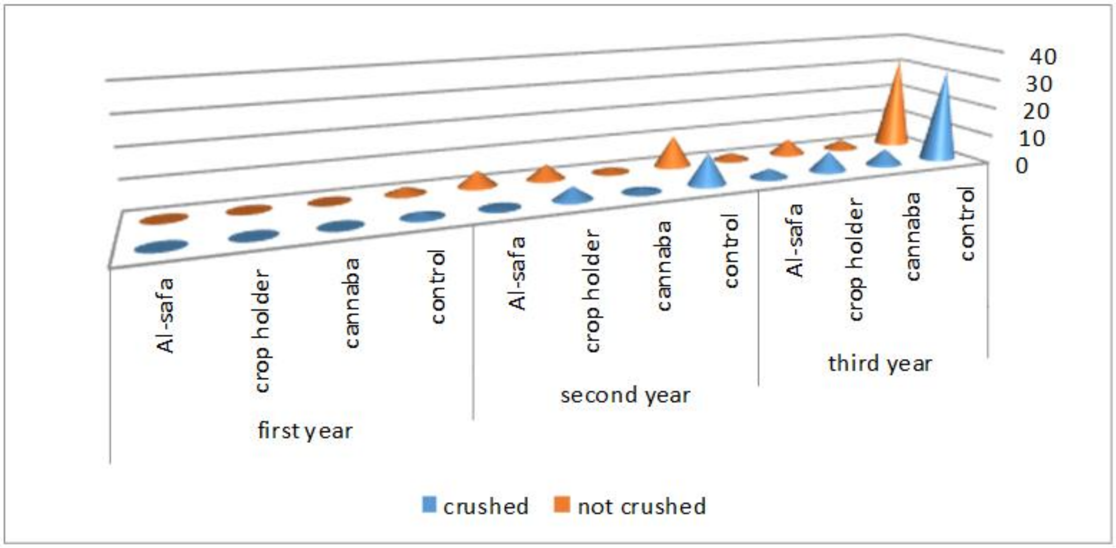

Fig. 5. The effect of crop components on the number of skin sheddings of the khapra beetle. L.s.d: residues components use 2.92, interaction 5.07, the form of wheat 2.07.

The Effect of Crop Components on the Live Larvae of Khapra Beetle T. granarium. The spike components also had a role in reducing the number of live larvae to the lowest level 0.44 larvae /bag in the treatment of awns, which differed significantly from the control treatment 4.94 larvae /bag. While, the crushed and non-crushed components had no significant ($p < 0.05$) difference in reducing the number of live larvae among the treatments. The number of larvae also decreased to the lowest level 0 larvae / bag in the third year for the treatments of spike holders, non-crushed Al-cannaba and the crushed Al- safa compared to the control treatment with 7 larvae /bag as shown in **Figure 6**.

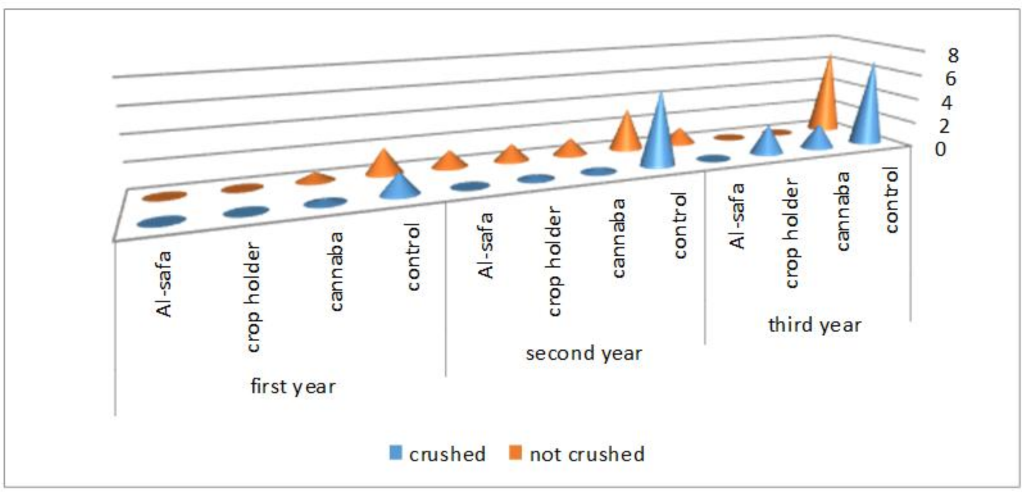

Fig. 6. The effect of crop components on the number of live larvae of the khapra beetle. L.s.d: components 3.27, interaction 5.664, the form of wheat 2.312

Discussion

The rate of damage by larvae in the polypropylene sutli bags was low 8.77% compared to the old jute bags 11.33%. This damage was significant from year to year, but its rate was lower as compared to the stored wheat grains with whole spikes in the polypropylene sutli bags that reached 16.66 and 9.66 % in the third and second years, respectively. This rate differed significantly from the storage of grains with the whole spikes in the old jute bags 21.66 and 12.33% for both the third and second year, respectively. While, the highest rate was recorded in the storing

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grains in the old jute bags 66.66 and 23.33% for the third and second year, respectively. The reason may be attributed to the effect of polypropylene sutli bags in reducing the damage caused by the insect larvae. The effects of polypropylene sutli bags may be due to the nature of threads from which the bags were woven. As the polypropylene sutli bags are synthetic strands in comparison to the old jute bags that are natural plant fibers and the range of pores in the threads of one bag as the ventilation is greater in the old jute bags. As storing the crop completely reduced the damage percentage in grains and maintained the rate of damage to be in the least level, compared to the grain storage without the whole crop or its residues that may be attributed to the role of crop components in protecting the grains from the khapra insect. These findings are in consistent with the results of Al-Juburi, et al. (*18*), who indicated that storing grains with the whole crop protects them from injury by the khapra beetle. The infection in our study had not exceeded 7%, which may be attributed to the physical nature of whole crop, as we noticed that the crusts provided morphological protection to the crop and worked as a natural barrier to prevent the penetration of beetles down to the grains. A similar explanation was given by Dent (*13*), who reported the role of crusts in providing natural barrier against such pests. Also, the resistance of rice grains to infestation with stored grain pests has been attributed to the physical state of the crop (*19*). The lack feeding of beetles on grains with the presence of crop components can be due to the presence of repellent or anti-feeding components (cannabah and awns, crushed and not crushed) (*20*).

The treatment of polypropylene sutli bags filled with the whole crop showed a few alienation skins 9.66 skin /bag, compared to the control treatment with 34.33 skin /bag. This finding may be reflected the biological behavior and activity of larvae on the whole crop, especially on the polypropylene sutli bags. The role of such bags as inhibitors confirmed by the presence of a few live larvae, which were differed significantly from the two treatments for both old jute and polypropylene sutli bags in the third year. As a result, it can be concluded from the above that crop components have a great role in protecting wheat grains in the storage from the injury of the khapra insect larvae due to the apparent composition of the crop with the presence of awns. Similarly, Acreman and Dixon (*21*) reported that the spikes of wheat varieties that contain awns are resistant to infestation with aphids. Also, it may be attributed to the anti-insecticidal properties of these compositions that are repellent or lethal and anti-feeding (*18*). The compound (Azadirachtin) extracted from the seeds of the neem plant inhibits the growth and reproduction of the khapra beetle (*22*). Many phytochemicals that have an active role in expelling and inhibiting the growth of beetle insects, including phenylprponoid and 4-allylanisole in pine (*23*).

The decrease in damage percentage in the storing grains with crop components (canabah and awns, crushed and not crushed) was limited to 7% in the second and third years, compared to the control treatment 22.33 and 66.66% for the same years respectively. This indicates that the crop components have a great role in reducing the damage caused by the insect larvae at the ends of the second and third year. From this finding, it can be concluded that the presence of crop components with stored wheat grains might carry repellent, inhibiting or anti-feeding to the insect larvae, which reduce the damage cause. Al-Juburi et al. (*18*), clarified that the presence of crusts on grains reduces the proportion of damaged grains by 15% compared to their absence 26% for 13 weeks. While, removing the crusts increases injury and the presence of grains for all wheat varieties does not exceed the infection rate to 37% when stored as the whole crop. The crop residues (crushed or not crushed) have not showed a difference in the effect that may have been found in any case would lead to the same role (repellent, deadly, or anti-feeding). Just as, the decrease in skin alienations with the presence of remaining crop and the decrease in the number of live larvae to the level of zero larvae / bag at the third year compared to the control. The residues (crushed or not crushed) indicated that the efficiency of remaining residues of crops (canabah, awns and the spike holders) in reducing/inhibiting the growth or preventing the feeding of larvae. Such residues gave protection to grains with the advance of storage period for the third year. This may be attributed to the nature of these components in terms of natural composition and physical and chemical properties. Al-Juburi et al. (*18*), stated that the crop scaling extract reduced the damage from 35% to 26%, and the percentage of damaged grains increased with storage time and the damage percentage was significant after 4 months of storage. A 20 plant species have been tested to reduce the damage caused by rice weevil field in storage (*24*), and many plants may have used their essential oils as an alternative source for protecting form the storage pests (*8*). In other words, when plants do not use their oils in prevention the level of damage may ranges from 6% to 33 in one year and may reach 73% (*25*). The use of methanol crop scale extract provides protection to grains for a period of more than 15 months (*18*). The protection of stored grains by crop scales for possession anti-insect pests, such as the repellent, anti-nutritional, or killer action, the treatment of khapra beetle larvae with extracts of Aaron plant *Hypericum*, Citrus plant *Citrullus*, and figilas plant *Diplotaxis* inhibits the growth of the larval role (*14*).

Conclusions

Storing the whole wheat crop completely reduced the damage percentage in grains and maintained the rate of damage to be in the least level as compared to the grain storage without the whole crop or its residues. This reflects the role of crop components in protecting the grains from the khapra insect. In other words, the presence of crop components with stored wheat grains might carry repellent, inhibiting or anti-feeding to the insect larvae, which reduce the damage cause.

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