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Study of yield gap in wheat caused by insects, case study Sunn pest (*Eurygaster integriceps* Puton)

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ABSTRACT: In order to achieve their maximum performance, agricultural plants must deal with factors limiting their growth and production, which involves costs for agricultural plants. These costs lead to a decrease in crop yield. Insects are also one of the factors that reduce the yield of crops. In this article, since there is no time to deal with all harmful insects on all crops, it will be discussed on a case-by-case basis about the yield gap caused by the sunn pest of wheat on wheat and barley plants. Wheat germ is the main insect that reduces the yield of wheat and barley. In order to estimate the damage caused by the sunn pest in the respective fields, various methods with various relationships have been used, and interesting results have been reported. The results of various researches that have been reviewed in this article show that the sunn pest causes damage to wheat between 3 and 8% on average, which is a significant amount. By accurately estimating sunn pest damage and providing suitable solutions to deal with sunn pest, this amount of damage can be reduced and turned into a harvestable product.

Key words: Insect, sunn pest, wheat and yield gap

INTRODUCTION

Sunn pest

Wheat germ is the most important pest of wheat and barley in Iran and the countries of the region. The importance of this pest is such that in ancient times it caused famine and death in the western and central regions of Iran. The population of this pest has decreased in the northern regions of Iran, the Caucasus countries and some other regions with Mediterranean climate, compared to the similar and competing species called *E.maura.*

The body length of this insect is between 13-9 mm and its body width is between 7-8 mm. The color of the body varies from yellow-gray to brownish-black and sometimes black is seen. Sunn pest has five stages.

The sunn pest is divided into two groups in terms of morphology:

1) A population of this insect that lives in natural habitats located at high altitudes and while feeding on non-agricultural plants, especially wheat, without making significant flights. It deals with reproduction.

This group has a small body size and their body length and width are 8.5-10 and 5.8-6 millimeters respectively.

2) The group that feeds on wheat and barley, especially those that attack the wheat fields, are larger and their body length and width are 8.9-8.2 and 6.6-7.2 mm, respectively.

The main causes of sunn pest population fluctuations are atmospheric factors, which cause two periods of boom and bust as follows:

1) Flooding years: If the weather is mild in spring and gradually warms up in summer and cool in autumn and sudden and severe temperature changes are seen in winter, in a few years suitable temperature and nutritional conditions will be created for sunn pest, which will lead to sunn pest outbreak and egg sunn pest.

2) Off years: If the weather in spring is cold and rainy and has a lot of weather changes, and the summer weather is moderate and has summer rains, the growth and development of wheat and sunn pest are not synchronized according to the weather factors, also if the weather is mild in autumn and the weather in winter is without snow and in late winter and early spring, the air temperature changes and the wind blows. During several years, the average egg-laying sunn pest has decreased every year, and the population tends towards extinction.

Sunn pest causes damage in three ways:

A) The damage of the mother sunn pest, which refers to the damage of male and female insects that fall in the fields after wintering in spring. At this stage, senesce by sucking the sap of the stem and young and green leaves and wheat sprouts, causing the plants to become weak, the leaves to become complicated and dry, and the clusters to turn white from the feeding place or the proboscis of senesce.

b) The damage of sunn pest nymphs, which feed on the leaves, stems and sap of soft wheat seeds for growth and appearance. The peak damage of sunn pest is related to the feeding of the developed nymphs such as the fourth and fifth age of the fruit, which causes the thinness and shriveling of the wheat grain.

c) Damage to the new generation of adult insects caused by the completion of nymph growth. If there is a delay in wheat harvesting, the highest damage will be in the sunn pest at this stage. At this time, the wheat ears are almost ripe and the crop is being harvested. Damage at this stage causes the bunche to rot, so the product should be harvested as soon as possible to avoid this type of damage. For this purpose, two-stage harvesting of wheat is suggested.

Relationship between performance and damage:

Insects, weeds, and plant pathogens have been observed to undoubtedly reduce crop yields. This article is in the sense that gradually with the increase in the number of pests, it is widely known that the yield of the products also decreases considerably. Modern agricultural science has recorded these losses for a long time and has also provided solutions to deal with pests. These concepts mean that agricultural products have been exposed to living stresses for thousands of years, and perhaps one of the reasons that we have not yet reached the potential of our agricultural products is the existence of these pests (21).

What is known beyond observation is the effect of living stressors on performance (21).

In a general equation, a picture of the black box situation of the damage of living stresses on the performance of agricultural plants has been designed (21).

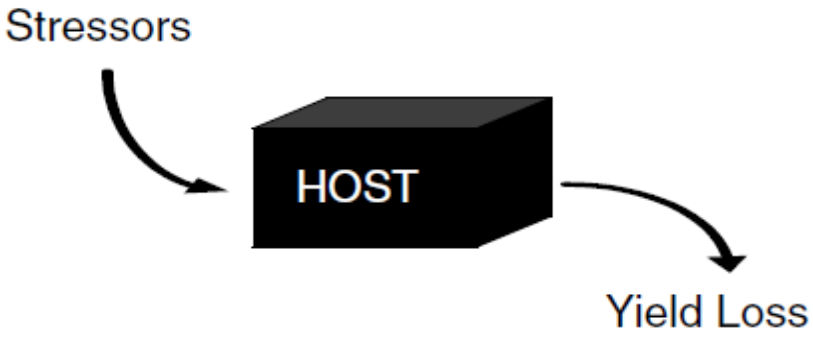

figure 1. Black box of pest damage on crops

In this plan, the pests approach the black box and feed on it. As a result, they reduce the final yield of agricultural products. Pest damage to crop yield has a curve that specifies the relationship between them (21).

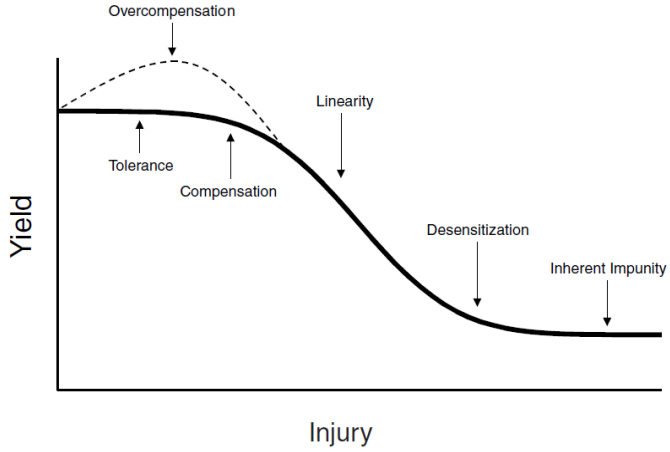

FIGURE 1.2 The damage curve.

figure 2. The curve of pest damage to crops yield gap due to sunn pest

The difference between the actual performance and the maximum achievable performance in the absence of limitations (potential conditions) is called the performance gap (Kochaki and Khajeh Hosseini, 2017). One of the basic problems of crop production in our country is the difference between the actual performance of farmers and the achievable performance. Therefore, it is very important to identify performance limiting factors and performance gaps (Torabi et al., 2019). In connection with determining the economic loss of the age of the mother and her nymphs, not much research has been done in Iran. According to Bahrami et al. (2011), Tanskali (1982) has shown that the economic loss level of overwintering plants depends on the vegetative stage of the plant. At the tillering stage, each age of mother per square meter reduces wheat yield by 30 kg/ha, while at the beginning of the emergence of spikes, the yield reduction is 80 kg/ha.

Methods of estimating the yield gap due to sunn pest and their results

The methods used to estimate the damage due to sunn pest have been different in some cases and various results have been obtained. For example, Qanadha et al. (2012) conducted a research on the evaluation of the resistance of wheat genotypes according to age. In this research, in order to determine the damage caused by the mother's sunn pest, it was decided to build chicken net cages in the form of a cylinder with a diameter of 40 cm and a height of 120 cm. These cages were installed in

the farm with a net covered with fine mesh in the middle of the above nets. To protect the cages against the wind, 150 cm long wooden sticks, as well as net cages with clamps, were firmly hammered into the ground. The rest of the cotton net on top of the cage was tied with thread to the wood in the middle of the cage. Each cage was randomly installed on 4 wheat plants. The ages were weighed with a sensitive scale before release. After the second day of release, in order to keep the number of sunn pest constant, the cages were inspected and if the number decreased, re-release was done. The freed adults were fed from the aerial parts of the plant for 14 days, after this period, the sunn pest of each experimental unit were re-weighed and the amount of weight gain of the male and female sunn pest was recorded. To determine the damage, nymphs of age 3 and 4 were used. In order to prevent natural contamination of the control plants in the field, possible nymphs were collected every day, then the sunn pest nymphs were collected from the surface of the ground and the number of clusters, biomass, number of seeds per cluster and weight of 1000 seeds were determined. Then, in order to determine the percentage of seed senescence from the seeds of plants treated with Puresen, three samples of 100 were randomly selected and the number of senescent seeds was counted. The aging percentage was determined by dividing the number of aged seeds into 100 seeds and then averaging them. The results of this research showed that the weight of 1000 grains was significantly reduced in both conditions as a result of mother sen and pure sen nutrition compared to the control. In this study, the average senescence percentage of durum wheat is lower than the average senescence percentage of bread wheat. but this difference was not significant. Durum wheat showed less leaf damage and spike damage than bread wheat.

Bahrami et al. (2001) by examining the level of economic loss of sunn pest in rainfed fields of Kermanshah province by determining the number of sunn pest with the help of half square meter boxes and determining the level of economic loss using the equation EHL = P = C/V.I.D.K where C = cost Pest management (Rials per hectare), V = price in Rials of each unit of produced product (Rials per hectare), I = unit of damage by each mother sunn pest per unit area (for example, the number of central buds dried by each sunn pest per hectare), D = damage per each unit of damage (amount of crop in kg/ha lost per dried central sprout) and K = a coefficient for the percentage of the crop not preserved by the fight. If 100% of the pest is controlled and all the crop is preserved, it will be 1 K- and it is removed from the above equation. If 80% of the damage can be prevented with full control of the pest, it will be K = 0.8. In this study, K is assumed equal to 0.8. They found that the density of mother sunn pest in 25 farms during two years was 3.3 and on average Each sunn pest was able to damage 61 buds and cause them to dry. The number of dried spikes by each sunn pest was 12.2. The amount of yield reduction for each sunn pest per square meter was estimated to be 126 kg per hectare. The level of economic loss per mother's sunn pest in the three investigated regions was 1.3 in the first year, 1.65 in the second year, and an average of 1.5 mother's sunn pest per square meter. The average density of nymphs and new generations in selected farms was estimated to be 30. On average, each nymph and sunn pest of the new generation aged 0.5% and 0.7% of the seeds at the time of harvest. The level of economic loss of nymphs in the above stages was estimated as 2.4 and 2.8 per square meter, respectively.

In the comprehensive sunn pest plan, the yield reduction per mother sunn pest in dry conditions is 43.8 kilograms and the level of economic loss is estimated to be 1.8 per square meter (Anonymous, 1377). According to Rezabeighi's research (1379), each sunn pest of mother in irrigated fields causes damage of 1/3 gram (about 30 kilograms per hectare) and the level of economic loss is about 3 per square meter.

According to Bahrami's studies (1377) quoted by Reza Beigi and Rajabi (?), each sunn pest of mother damages an average of 61 central buds and 12.2 spikes in dry conditions, and the level of economic

loss is 1.6 sunn pest of mother per square meter, and also He estimated the aging of seeds per nymph to be about 0.6% at the time of harvest of dry wheat and 3-4 nymphs per square meter. Rezabeighi (1379) has estimated the level of economic loss of nymphs at an average of 2.8 per square meter. This amount is 5.3 and 6.7 in Rashid and Sardari cultivars, respectively, and 11.8 and 9.6 in Plateau and Golestan cultivars, which are more tolerant. Nouri (2012) has estimated the level of economic loss of nymphs in wet conditions at 11-12 nymphs per square meter.
Rezabeighi (2013) obtained the following results by estimating the quantitative and qualitative losses of wheat and barley in different regions of the country with the help of the following equations:
Product unit value (Rials) kg / Pest management cost (Rials) per hectare = Profitability limit of the fight
Average number of sunn pest per square meter / average yield reduction = yield reduction per sunn pest of mother
Product reduction per sunn pest / profitability limit = level of economic loss

Maternal sunn pest in wet and dry wheat fields and dry and wet barley fields respectively with a density of 2.13, 2.7, 2.37 and 2.1 pieces per square meter, respectively, yield reduction equivalent to 92, 248, 25.7 and 107 kg/m ha, but this reduction in yield was significant at the 5% level and no statistically significant difference was seen between the experimental treatments (farms with the activity of the mother and nymphs and control farms without the activity of the mother and nymphs). The reduction of yield for each sunn pest of mother in dry wheat, wet wheat, wet barley and wet fields was 43.8, 91.8, 10.8 and 50.9 kg per hectare, respectively. According to Rajabi et al.'s report in 2001 (cited by Reza Beigi, 2003), a mother's sunn pest caused a decrease of 90 to 110 kg of crop efficiency per hectare. The level of economic loss of maternal sunn pest was estimated as 1.8, 0.8, 7.5 and 1.6 female sunn pest per square meter for dry and irrigated wheat and dry and irrigated barley fields respectively. If the grain aging percentage is 2%, the level of economic loss of purees for dry and irrigated wheat fields was estimated as 3.4 and 2.5 grains per square meter, and if the grain aging percentage is 3%, the level The economic loss of nymphs was estimated to be 5.4 and 8.2 per square meter for dry and irrigated wheat fields.
Nouri et al. (2012) by evaluating the quantitative damsunn pest sunn pest using Alvand and Zarin cultivars and different mother sunn pest populations with the number of 0, 2, 4, 6, 8, 10, 12, 15, 17 and 20 per square meter and measuring The characteristics of the number of central buds and damaged spikes, the weight of 1000 seeds and yield reduction, with the help of the following equations, the following results will be obtained:

$DS= IT.Y_s$ $I_t= (IS+I_h)/N_s$
It= the number of central buds and dried spikes by each mother sunn pest per square meter
Ih = number of dried spikes per square meter Is = number of dried central buds per square meter
Ns = number of maternal sunn pest left per square meter DS = reduction of yield by each maternal sunn pest (grams per square meter)
Ys = average yield of each spike (grams)
The average yield reduction in different groups for each mother sunn pest in Alvand variety 123.5, 80.03, 53.5, 50.94, 45.50, 38.66, 41.98, 38.28 and 40.87 kilograms It was 83/55, 68/10, 50/67, 40/43, 41/80, 41/26, 42/53, 43/19, 46/18 per hectare per hectare. The relationship between pest density and yield reduction was linear, and the correlation between the number of central buds and damaged spikes, and the percentage of yield reduction in Alvand and Zarin cultivars with the abundance of insects in full sunn pest wheat was positive and significant at the 1% probability level.

The comparison of the average number of central bud and damaged spike showed (Figure 1) the treatments related to the density of 17 and 20 wheat senes per square meter with the averages of 1.706 and 1.763 compared to the control were at the highest level.

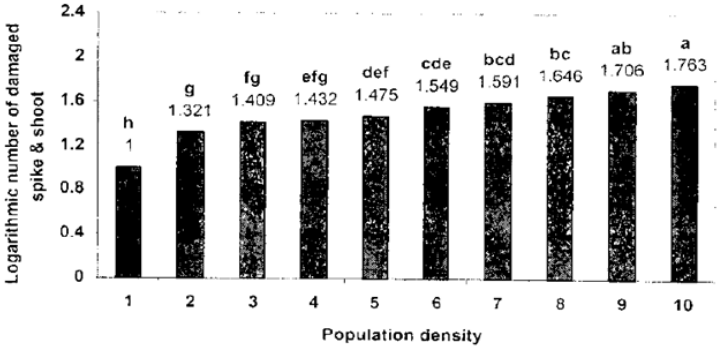

Figure 1- Comparison of the average number of damaged central bud and spike by different groups of mother age

The comparison of the averages of the observed yield reduction percentages showed (Figure 2) that the treatments related to the abundance of 17 and 20 wheat senes per square meter with the averages of 3.18 and 3.44 compared to the control were at the highest level.

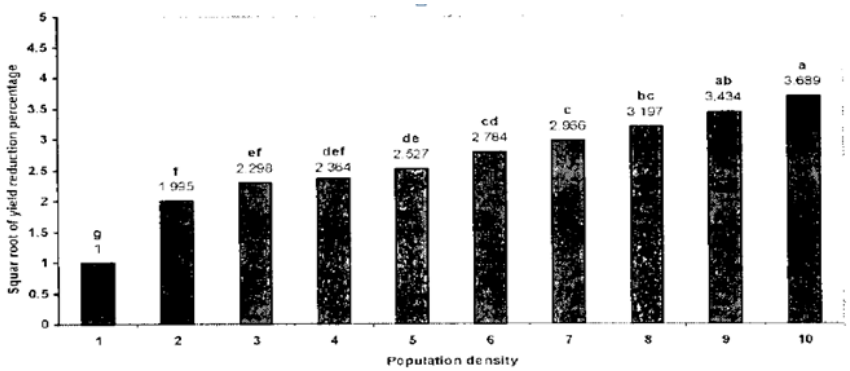

Figure 2- Comparison of the mean percentage of yield reduction by different groups of maternal sunn pest

Table 1- The level of economic or soft losses of fighting against wheat senescence in Iran's wheat fields (http://www.iranwheat.ir/introduction/Pests/wheat%20pests.htm**)**

Farm conditions		Threshold to figh against mother's sun pest)number in squar meters(	Threshold to figh against nymph's sun pest)number in squar meters
Cultivation type	Yield		
Dryland	Lower than 2 ton.ha^{-1}	1	3-4
	Higher than 2 ton.ha^{-1}	3	4-5

Irrigated	Lower than 3 ton.ha^{-1}	3	4-5
	Higher than 3 ton.ha^{-1}	4-5	6-7
	Falat, Navid and Azad cultivars	6-7	8-9

In the research conducted by Sengol et al. (2012) on the effect of marginal cultivation on the damage of sunn pest on durum wheat, to measure the density of nymphs, he counted the nymphs inside the frame using a 50x50 cm square at the milky stage. A total of 4 frames were randomly used in each plot. The percentage of seeds damaged by wheat senescence was determined by considering five hundred seeds in each plot after harvest and counting the damaged seeds by wheat senescence. Then, the data was analyzed and the results were interpreted. The results showed that nymphs caused 8% damage to the final wheat product and marginal cultivation had no effect on its control, but with earlier cultivation of durum wheat, it is possible to get a higher yield from the damage of the nymphs sunn pest was maintained and a higher yield was obtained.

The results of a survey conducted in Isfahan province

The investigations conducted by the author in Isfahan and the conversation with the head of the pest and plant disease research department and also with the head of the plant protection department of the province, no field research has been done to determine the damage of pests quantitatively on crops, only the damage estimation has been done on the sunn pest. It is known that this also has problems in some cases, so it is not possible to investigate the effect of pests on the reduction of performance and the difference between the actual performance and the performance that can be achieved. This research is done on the amount of sunn pest damage and only on the basis of the pest damage (sunn pest) and in irrigated and dry wheat cultivation. A limited number of pests have been investigated in master's and doctorate theses, mostly in research field conditions. Therefore, according to the available information, there is no pest damage on all crops, at least in Isfahan province. The research results of theses are usually one year old, considering that pests are greatly affected by climatic conditions. Even these investigations have been done in different areas, and maybe the conditions of the experiment are not compatible with many areas of Isfahan province.

How to estimate pest damage: Usually, after planting a crop in the field, the cultivated land is divided into two equal parts at a suitable distance. The pest is allowed to grow on the plant. Based on the type of pest, characteristics are evaluated, for example, the density of the pest, the percentage of dried buds, etc. Pests will reduce the yield in any case, but what The number of pests on crops causes damage, and the damage threshold depends on various factors. Environmental temperature changes, drought, pest wintering conditions, presence of host, agricultural management and...

The presence of the pest in more than one square meter causes economic damage, so calculating the damage threshold is very important.

Calculation of the economic loss level of pests:

The first method:

The average cost of pest control management per hectare (Rials)

The unit value of the product in kilo grams (Rials) / the cost of pest control management per hectare (Rials) = the profitability limit of the fight

Average number of pests per square meter/average yield reduction=product reduction per pest

Product reduction per pest / profitability limit = (EIL) level of economic loss

Economic Injury level=EIL

Gain Threshold=GT

The level of economic loss is based on the number of pests per square meter. Therefore, if the number of pests per square meter in the farm exceeds the level of economic loss, there should be a fight.

The second method:

The method of Bahrami et al. (2012) which was explained earlier.

Table 2: Average yield, performance in the fields of leading farmers and performance in the research fields of wheat cultivars in Isfahan province, 2009-2019

Cultivar of wheat	Farmer fields ($kg.ha^{-1}$)	Research fields ($kg.ha^{-1}$)	Average of yiel ($kg.ha^{-1}$)
Sepahan	9000	10000	4000
Pishgam	9500	10500	4000
Alvand	9500	9200	3600

Due to the absence of a control farm to make a simple comparison, based on the available information in the crop year of 2009-2009, as a rule, we should not have a decrease in yield regarding the sunn pest. It shows the sunn pest in time. Therefore, in the crop year of 2009-2009, the difference between the yield by leading farmers, which is five tons in temperate regions and six tons in cold regions, should be due to other factors that reduce production, including plant nutrition. Weeds, up to the mine of healthy seeds, estimation of the reported cultivation area compared to the actual cultivation area, proper irrigation, non-observance of proper planting date and crop management which plays a very important role.

Analytical report of the Provincial Plant Protection Department

The decrease in the area under cultivation compared to last year due to the drought, the harvestable area decreased compared to last year. The decrease in temperature in March caused a delay in the shedding of sunn pest in hot areas of the province and created a good opportunity to fight senescence in some way. In some of the desert cities, the fight against the nymph reached its minimum. However, in the central areas, due to the fact that after the fall in late Farudin and the beginning of May, the weather conditions were not suitable for fighting, the fight against the mother's sunn pest was done less and the fight against the nymph was done more. At the same time, due to the warm weather during the last crop year, the cold areas of the province, where the sunn pest did not reach the sunn pest of fighting, including the city of Feridan, Feridounshahr, there was a significant increase in the number of pests, and in these areas, for the first time this year, hip fighting was carried out.

The causes of non-participation of some farmers in the fight against grain sunn pest in 1989-90

1- The reduction of rainfall and drought and the indecision of the farmers who did not bear the additional cost of spraying made the care networks face a challenge to fight this year.

2- Due to the small size of the plots, the owners usually do not actively participate in the struggle and take a lot of time from the care networks..

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