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ECONOMIC DAMAGE LEVELS OF THE GREEN SHIELD BUG (*Palomena Prasina*, Hemiptera: Pentatomidae) IN TÜRKİYE HAZELNUT ORCHARDS

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Abstract: The green shield bug (GSB) (*Palomena prasina*, Hemiptera: Pentatomidae) is one of the most important pests of hazelnut in Turkish hazelnut orchards. This harmful insect causes serious yield and quality losses by feeding directly on fruits every year. Their feeding on hazelnut fruits may result in nut abortion (empty nuts) in early season and cause shriveled and corked kernels in kernel expansion period. Insect pest management must be decided by depending on insect population level in field according to integrated pest management concept. Economic injury level (EIL) and economic threshold (ET) are the main essential points that must be considered in decision for insect pest control. Thus, it can be possible to protect the natural environment from unnecessary pesticide applications and the growers from high production costs. Therefore, determining of economic decision levels for controlling pests is critical. This is especially important for hazelnuts, which are grown on hundreds of thousands of hectares of land in Türkiye, and for the GSB, a serious pest that requires a couple of chemical applications per year. The economic decision levels vary mainly due to insect species and their damage potential, crop value in the market and control costs which can change over years and countries. This study aimed to calculate the EIL and ET values for GSB control action in hazelnut orchards in Türkiye using new economic market data. Based on previous research, the authors calculated the yield loss caused by one individual of GSB in this study. Direct yield loss, as well as quality and quantity losses from damaged kernels, were calculated separately and then totaled. The data, including crop value and control costs necessary for calculation was updated from free market sources. In the calculation of EIL/ET, the most common formula (EIL= C/ VxbxK) was used. As a result, the economic threshold for a single insecticide application was determined to be3.8 insect/da (=0.1 ha) for K=1 value and 4.76 insect/da for K=0.8 value, for single insecticide application. When ET values were converted in traditional Turkish approach that is special for hazelnut orchards; ET values for K=1 and K=0.8 were 0.76 insect/ 10 "hazelnut "ocak" (traditional growing of hazelnut plants together) and 0.95 insect/ 10 "ocak" respectively. If 2 applications per year for GSB were considered, ET values were doubled up and calculated to be 7.6 and 9.47 insect/da for K=1 and K=0.8 value respectively, and thusly 1.52 and 1.9 insect/ 10 "ocak" for Türkiye. For practical reasons, the ET value for GSB was recommended as 10 insect/da and 2 insects/10 "ocak", for Türkiye, with consideration of 2 chemical applications and K= 0.8.

Keywords: Economic injury level, Economic threshold, Filbert, Insect, Pest, Control

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1. Introduction

Türkiye is the world's main hazelnut producer by a ratio of nearly 62%, producing 665.000 tons per year of in shell hazelnuts over an area of around 735.000 hectares. Türkiye also supplies 75% of the world's hazelnut demand. Hazelnut export earnings contribute significantly to the national economy and the livelihoods of 500.000 hazelnut producer families (Hekimoglu and Altindeger, 2019; Bars, 2021). Despite the fact that Türkiye is the world's primary hazelnut supplier by far, productivity per area is lower than some other hazelnut growing countries. In addition to insufficient and/or inappropriate agricultural practices, harmful mites and insects are among the most important factors causing yield and quality losses in hazelnut production in Türkiye (Tuncer and Ecevit, 1997). There are more than 10 important insect and mite species in Turkish hazelnut orchards. Some of them cause substantial damage every year, but others only in years with high populations. Some pests affect only yearly production and kernel quality, while others threaten the plant's health (Tuncer et al., 2005).

Stink bugs (Hemiptera: Pentatomidae) are one of the most important pests of hazelnut in Turkish hazelnut orchards as well as in other hazelnut-producing countries. These bugs damage hazelnuts during the growing season by feeding on hazelnut fruits and thereby significantly reduce the crop productivity and kernel quality of hazelnuts, thereby causing serious economic damage (Tavella and Gianetti, 2006; Hedstrom et al., 2014; Ak et al. 2018; Bosco et al., 2018; Ozdemir et al., 2021). More than 15 stink bug species (Hemiptera: Pentatomidae, Coreidae, and Acanthosomatidae) have been found in hazelnut orchards of different hazelnut countries, affecting the hazelnut production qualitatively and quantitatively (Tavella et al., 1997; Tavella et al., 2001; Tuncer et al., 2005; Ozdemir et al., 2022). Stink bugs' damage can result in fruit abortion during the early season, empty and gray–black nuts during the early nut development stage, shriveled kernels during the early kernel development stage, and corked kernels during the kernel expansion period (Kurt, 1975; Tavella et al., 2001; Tuncer et al., 2005; Saruhan and Tuncer, 2010; Hamidi et al., 2022). Their damage is usually unnoticed before harvest since fruit abortion and empty nuts without kernels are not linked with bug activity by most farmers. But after shelling the fruits in the factory, shriveled and corked kernels become very evident, especially the later damage type, which causes problem in exporting because of poor kernel quality (Tuncer et al., 2005). The population density of GSB can reach up to 50 insects/10 plants in some provinces in Türkiye (Saruhan and Tuncer, 2009). Corked kernels differ from healthy kernels in shape, taste, and color, and they lose significant economic value. Tuncer et al. (2005) reported that the corked kernel damage made by stink bugs in Turkish hazelnut orchards could reach up to 20%, with around 5% of the corked kernels as an average of a 5-year sampling from hazelnut factories after harvest. The percentage of corked kernels in hazelnut orchards caused by these bugs has been determined as 6.50, 3.16 and 9.82%, respectively, for 2014-2016, with an extensive sampling throughout Türkiye (Ak et al., 2018).

The most prevalent stink bug species affecting hazelnut production in Türkiye is the green shield bug (GSB) *Palomena prasina* L. (Hemiptera: Pentatomidae), with a density of nearly 85% of total stink bug population, and its population level is generally over the economic damage threshold (Tuncer et al., 2005). Despite the fact that GSB is a polyphagous pest that feeds on a variety of plants, economic damage to other crops is rare. The green shield bug produces one generation per year. Nymphs and adults feeds on hazelnut fruits from early May until harvest time in hazelnut orchards (Saruhan et al., 2022). Chemical application is the only option during bug feeding activity on fruits for control of this insect, and it is recommended to repeat it 2-3 times during the season. Many growers avoid applying the pesticides because of their cost, and in addition, they don't bear the cost of quality loss since they usually sell the hazelnut in shell. But in recent years, many hazelnut trading companies began to consider the kernel quality for price assessment during the buying process. As a result, growers are expected to adopt more chemical control measures in the coming years, in addition to the rising price of hazelnuts in the country. Implementing chemical control for GSB can ensure high productivity and quality in one aspect, but it also means higher control costs for growers and environmental costs for all communities, especially when such a large hazelnut area of the country considered. Hence, determining the action threshold for GSB control in hazelnut orchards becomes more critical.

Before making a control decision for a pest control program, some economic evaluations must be considered because economic decision levels are the keystone of insect pest management programs. Two main evaluations, the economic injury level (EIL) and the economic threshold (ET), which are closely related- are fundamental concepts in an integrated pest management (IPM) approach. The economic injury level is defined as "the lowest numbers of insects that will cause yield losses equal to the insect management costs" and expressed as the number of insects per unit area. The economic threshold is defined as "the pest density at which management action should be taken to prevent an increasing pest population from reaching the economic injury level" (Pedigo, 1996). The economic injury level is usually expressed as a pest density and is generally derived from insect and yield-loss relationships in field studies (Mumford and Knight, 1997). Simply, the value of crop loss caused by one insect can be estimated using the market value of crops, and then EIL is calculated by dividing control cost by the value of crop loss per area so that the smallest number of insects causing yield losses equals management cost. The calculation of ET can be a little complex, but in practical reason, many times the ET may be set equal to EIL or at some fixed point below it. In many studies, the relationship between the yield losses and the insect numbers in that field has been considered for the calculation of EIL for practical reasons (Pedigo, 1996; Mumford and Knight, 1997). Some insect damage and control cost parameters are used in EIL calculations. The damage caused by a single pest is critical data in calculation of EIL and ET, but it is also being by far the most difficult to calculate. The other main parameters are the market value of the crop and management costs needed in EIL calculations. Since economic levels are very dynamic and management costs (pesticide, labor, and amortization of equipment) and the market value of crop may vary due to years and countries, recalculation of EIL and ET values are needed over time (Pedigo, 1996). On the other hand, the evaluation of economic decision levels for some indirect pests may be difficult, while it is easier for direct pests (Mumford and Knight, 1997). Because of difficulties in determining EIL and ET for some pests in practice, nominal decision levels made by experts on related pest can be used (Pedigo, 1996).

The green shield bug is a direct pest on hazelnut, feeding on fruits directly. Therefore, the estimation of crop loss caused by one insect is considerably more applicable than that caused by many other indirect pest species, despite the fact that it is time consuming. Green shield bug damage potential on hazelnut has been quantified directly by field cage studies, and it was determined that GSB caused damage to 175 nuts per insect during the growing season, resulting in direct loss and a negative impact on nut quality (Saruhan and Tuncer, 2010). In this study, we aimed to calculate EIL and ET values by using injury potential determined before by the authors for GSB depending on the new economic data, including crop value and control costs such as pesticide prices, labor for applications, and other costs.

2. Materials and Methods

2.1. Damage Measurements for GSB

In this study, the yield loss caused by one GSB individual on hazelnut was derived and slightly changed from a previous study done (Saruhan, 2004) by one of the authors. The above-mentioned study used sleeve cages in hazelnut orchards to directly quantify GSB feeding damage because adults and nymphs of GSB feed on hazelnut fruits. In mentioned study; the experiments were carried out in a hazelnut orchard in Samsun in 2002-2003 by using 275 sleeve cages (175 cages for insects and 100 cages for control). After placing the nymphs and adults as pairs into 15-20 different sleeve cages for 15-day at each time of period during the fruit growing season (from May to mid-August), the insects were removed from the cages, and these cages were kept until harvest without insects. With nearly 15-day intervals, this procedure was repeated with different sleeves and insects until harvest, so the fruits in cages objected to insect feeding during the entire growing season. Some sleeve cages were kept without insects as control until harvest. At the harvest time, fruits from each cage were examined and evaluated according to different types of GSB damage on the fruits. Data on damage obtained from cages with insects were corrected for damage types that showed significant difference from control cages by using the Schneider-Orelli formula (Puntener, 1981). Some type of damages was needed to be corrected because they were also observed in control cages naturally but insect feeding increased these types of damages On the other hand corked kernel type of damage is only caused by insect feeding on kernels, not occurring in control cages (Saruhan and Tuncer, 2010) therefore it was not corrected. Consequently, it was determined that one individual of GSB damaged 175 fruits during the whole growing season, including all damage types. Early abortion, empty fruits, and shriveled kernel type of damage (produced the fruits without kernel or non-marketable kernels); therefore, the data for these damage types was considered a direct loss in the calculation. Because corked kernels caused solely by insect feeding do not completely lose their economic value but do lose some of their market value, the percent value loss of the kernels in the market was corrected prior to EIL and ET calculations. Preliminary EIL calculation had been attempted but was not published (Saruhan, 2004). In this study, the data was evaluated again by a slightly different method in order to calculate the damage of GSB.

2.2. Calculation of Economic Decision Levels

Different but mostly similar methodologies are followed to calculate EIL and ET by researchers for practical reasons, although there are some others with theoretical approaches (Kranz, 1992). In this study, the method and formula (EIL= C/VxbxK) given by Pedigo (1996) were used for calculation. Economic data such as the market value of hazelnut and control costs for EIL and ET calculations were derived and used from open market sources for 2018-2022.

3. Results

The Damage potential of GSB, market value of hazelnut and control costs, including pesticide, labor, and amortization of pesticide application equipment are needed to calculate EIL and ET levels. All these determinants must be evaluated and used in the calculation according to the formula provided by Pedigo (1996) as follows in Equation 1:

$$EIL=C/VxIxDxK \qquad (1)$$

Where, V= market value per unit of produce (for example, $/kg), I= injury units per insect per production unit (for example, percent defoliation/insect/ha), D= damage per unit injury (for example, kg lost/ha/percent defoliation), C= cost of management per area (for example, $/ha), K= proportionate reduction in potential injury or damage (for example, 0.8 for 80%).

But, with some pests, particularly pierce-sucking insects, the separation of the *I* and *D* variables presents a problem. In those cases, a coefficient *b* represents the loss per insect substituted, and calculation formula changes as follows in Equation 2 (Pedigo, 1996):

$$EIL= C/VxbxK \qquad (2)$$

where, *b* = yield loss/ insect.

In this study, since GSB is a direct pest and yield loss per insect (*b*) was determined using sleeve cages in the field, later form of the formula was used in the calculation. But, here, the *b* coefficient was calculated from sleeve cages in which the insects fed on fruits during the growing season, instead of obtaining it from regression analyses of data by using experimental populations and measuring yield losses, as calculated in some studies.

3.1 Market Value of Hazelnut (V)

Of the primary factors, crop value (V) is one of the most variable, and it alone accounts for much of the change in EILs. The relationship between EIL and market value is inverse; as market value increases, EIL decreases and vice versa. As a general rule, estimates for EIL calculation are based on current or past records of crop value (Pedigo, 1996). Since hazelnut prices in the market usually fluctuate depending on years and yield per year, the mean of last five year's market value for in shell hazelnut was considered in the EIL/ET calculation for GSB in this study (Table 1). Following a five-year price evaluation of in-shell hazelnuts on the market, the market value in Türkiye was estimated at 3.3 $/kg and used in the EIL calculation.

Table 1. Market value of hazelnut in shell in last five years in Türkiye (Turkish Grain Board)

Year	Market value of hazelnut in shell ($/kg)
2018-2019	2.93
2019-2020	3.34
2020-2021	3.73
2021-2022	3.50
2022-2023	3.01
Mean market value of hazelnut in shell for five years= 3,30 $	

3.2. Management Costs (C)

Management costs include labor (pesticide application), used materials (insecticide), and equipment (insecticide application sprayer). Management costs also tend to be fluctuate over time, especially in developing countries that has high inflation like Türkiye. This fluctuation is generally caused by market inflation and labor costs, depending on economic improvement, but not crop value. The chemical control cost for GSB in hazelnut orchards was calculated in this study using variables gathered from the open market for two main insecticides registered on the market (Table 2). Recommended doses and prices of two registered insecticides on the market for GSB were used in the calculations. The daily labor cost for a pesticide applicator was estimated to be around 27 $ per day (equivalent to 500 TL per day in 2022), and one pesticide applicator can spray 10 da (equivalent to 1 ha) per day. For amortization of spraying equipment, a regular atomizer cost was obtained from the market and it is assumed that economic life of an atomizer is 10 years and that it is used in spraying 100 da/year by any grower.

3.3. Damage per Insect

In EIL calculations, estimating the loss per insect is by far the most difficult. Crude estimates of losses are usually obtained from field observation and experimentation on a crop at specific times, after which yield is measured and losses caused by insects are determined (Pedigo, 1996). Green shield bug damage potential (loss per insect) had been determined before by Saruhan (2004) through semi-field sleeve cage experiments in hazelnut orchards in 2002-2003.

In this study, damage per insect value of GSB on hazelnut was recalculated on an individual insect basis from the mentioned study in order to use it in our calculations. Damage types including “light brown and shrunken at the bottom”, “gray-black nuts without kernels”, empty nuts, shriveled kernels, and corked kernels caused by GSB were considered to calculate damage per insect Because some types of damage occurred in control cages as well, with the exception of corked kernels, the damage values for insect cages were corrected by the Schneider-Orelli formula according to the control if there was a significant difference. If there was no difference between insect and control cages for any type of injury in each year, that injury type was not included in the calculations. Afterwards, mean values of damage per insect were calculated using the result of both years for each damage type.

It was calculated that the mean total direct yield loss (no kernel or no marketable kernel) was 165.01 nuts/insect and corked kernels (quality and quantity loss) was 104.2 per insect (Table 3). Quantitative loss was also calculated for corked kernels using the mean weights of kernels from sleeve cages with insect and control cages. Normal kernel weights, without insect damage were, 0.96, 1.23 and 0.97 gr for çakıldak, palaz and tombul hazelnut cultivars respectively (mean value =1.05 gr/kernel). Corked kernel weight values for these 3 cultivars were 0.79, 0.96, and 0.82 gr (mean value =0.86 gr/corked kernel. As a result, the quantity loss of corked kernels was calculated as follows in Equation 3.

$$\text{Quantity loss ratio of corked kernels} = \frac{\text{Mean normal kernel weight(gr)} - \text{mean corked kernel weight(gr)}}{\text{Mean normal kernel weight (gr) X 100}} \quad (3)$$

Quantity loss ratio of corked kernels = 1.05-0.86/1.05 x 100 = 18%.

Table 2. Chemical control cost parameters for green shield bug management in hazelnut orchards (2022)

Costs for insecticide application	Registered insecticide-I	Registered insecticide-II
	120 g/l Indoxacarb + 12 g/l Beta-cyfluthrin	218 g/l Acetamiprid + 37 g/l Emamectin Benzoate
Recommended dose/da	50 ml/da	50 ml/da
Price/unit	16.13 $	14.78 $
Pesticide cost/da	2.02 $	2.96 $
Labor cost/da	2.7 $	2.7 $
Equipment amortization cost/da	0.5 $	0.5 $
Fuel cost /da	0.5 $	0.5 $
Total cost/da	5.72 $	6.66 $
Average cost/da for single application	6.19 $/da	
Average cost/da for two applications	12.38 $	

Table 3. Different damage types of GSB on hazelnut fruits in sleeve cages (after data corrected with control by Schneider-Orelli formula, the data was modified and recalculated from Saruhan, 2004)

Years	No.of fruits/damage type				
	Light brown and shrunken at the bottom	Gray-black nuts without kernels	Empty nuts	Shriveled kernels	Corked kernels (kernel/insect)
2002	111.5	-	74.85	-	139.5
2003	71.27	21.35	30.68	20.34	68.96
Mean	91.39	10.68	52.77	10.17	104.2
	Total direct yield loss: 91.39+10.68+52.77+10.17= 165.01 nuts				Quality and quantity loss= 104.2 kernels

3.4. Economic Injury Level and Economic Threshold

In this study, *b* value was assessed by using direct quantification through measurements of damage from sleeve cages with insect during growing season (Equation 4).

$$EIL= C/ Vx\ b\ x\ K \quad (4)$$

where *b* = yield loss/ insect. This formula provided by Pedigo (1996) was modified so that direct nut loss and corked kernel damage caused by GSB were separated, yield loss = direct yield loss + quality and quantity loss of corked kernels (b = b1 + b2), as written in Equation 5:

$$EIL= C/ V\ x\ (b1+b2)\ x\ K \quad (5)$$

3.4.1. Calculation of b value

b1= direct yield loss, was calculated as 165.01 nut/insect above (3.3), meaning nut loss without any marketable kernel.

b2 (quality and quantity loss of corked kernels) = corked kernels from GSB feeding have still got market value, even at reduced prices. In the calculation of b2, 25% of market value loss from corked kernels was assumed, plus 18% of weight loss from corked kernels. The number of corked kernels per insect was calculated above as 104.2

In this case;

b2= the number of corked kernels/insect x weight loss induce for corked kernels x ratio of market value loss (%)

b2= 104.2 x 1.18 x 0.25= 30.74 nut loss/insect,

Indices 1.18 for *b2* to add 18% weight loss to the total corked kernel loss were used.

b (Total loss) = *b1* (direct yield loss) + *b2* (quality and quantity loss of corked kernels). In our case;

b= 165.01 + 30.74 = 195.75 hazelnut fruit/ insect.

It was estimated that 1 kg hazelnut in shell consists of almost 535 hazelnut fruits, as a mean of the three main cultivars (çakıldak, palaz and tombul) of Türkiye (Demir, 2004). In this case, the yield loss in kilograms can be calculated as follows:

Yield loss in kg= 195.75/535= 0.37 kg hazelnut in shell loss / insect.

3.4.2. Calculations of EIL and ET (If K value is considered =1)

Here K value (amount of damage avoided because of control action) was considered as equal to 1. Using determinants calculated, EIL can be determined as follows:

EIL= 6.19 $ (cost/da) / 3.3 $ (market value/kg) x 0.37 kg (loss/insect) x 1= 5.07 insect / da

Traditionally ET is given per 10 “ocak” (ocak= a group of plants planted together) and there are almost 50 “ocak” in one decare area, as a mean in Türkiye. It means 10 “ocak” is nearly 0.2 decare. In this case; EIL can be expressed for Türkiye as follows:

EIL = 5.07 insect per da x 0.2 da= 1.01 insect / 10 “ocak”

We can use EIL as our “action levels (=ET)” or we may choose to set ET at levels conservatively below the EIL, say at 75 percent of EIL (Pedigo, 1996);

ET=5.07 x 0.75= 3.80 insect/ da, or

ET=1.01 x 0.75= 0.76 insect/ 10 “ocak”, for Türkiye.

EILs values are calculated as 10.14 insect/da and 2.03 insect/10 "ocak", and ETs are values 7.6 insect/ da and 1.52 insect / 10 “ocak”, if two insecticide applications are made per growing season (Table 4).

Table 4. Economic decision levels for Green shield bug on hazelnut were calculated for Türkiye

No.of chemical application/season	Economic decision	K-value	Insect/da	Insect/10 “ocak”
Single spray	EIL	1	5.07	1.01
		0.8	6.34	1.27
	ET	1	3.80	0.76
		0.8	4.76	0.95
Two spray	EIL	1	10.14	2.03
		0.8	12.63	2.53
	ET	1	7.6	1.52
		0.8	9.47	1.9

3.4.3. Calculation of EIL and ET (If K value is considered =0.8)

K value (amount of damage avoided because of control action) can be considered equal to 1 in some cases, but it is often hard to determine the real effectiveness of control action in the field. Therefore, we assumed here as another option that K value is equal to 0.8 (80% damage avoided because of control action). In this case;

EIL= 6.19 / 3.3 x 0.37x0.8= 6.34 insect /da

EIL = 6.34 insect /da x 0.2 da= 1.27 insect/ 10 “ocak”

ET= 6.34 x 0.75= 4.76 insect/ da, or

ET=1.27 x 0.75= 0.95 insect/ 10 “ocak”,

EILs values are calculated as 12.63 insect/da and 2.53 insect/10 "ocak", and ETs are values 9.47 insect/ da and 1.9 insect / 10 “ocak”, if two insecticide applications are made per growing season (Table 4).

4. Discussion and Conclusion

The green shield bug is one of the most important pests of hazelnut in some hazelnut growing countries, such as Türkiye and Italy. This insect pest is abundant in hazelnut orchards during the nut development in season. Therefore, it affects yield seriously as well as kernel quality. Corked kernels, in particular, are the main source of complaints from Turkish hazelnut importers because poor quality of the kernels affects the confectionary products that use hazelnut kernels.

For both reasons- crop yield and quality- proper management of GSB in hazelnut orchards is critical. Unfortunately, chemical control is the only viable option for dealing with this insect. Therefore, the growers currently must rely on chemical control to prevent the damage caused by GSB. In hazelnut orchards, 2-3 applications for GSB are recommended in a year (Anonymous, 2017). Using pesticides incurs additional costs for growers as well as environmental costs for the community. In the IPM concept for agricultural pests, decision-making for chemical control is an essential step to reduce the mentioned costs. For this reason, EIL and ET decision levels are calculated and used to take a control action for any pest. EIL/ET are dynamic action levels and may change due to the market value of the crop and control costs over time. The main critical data that is very important in EIL/ET calculations based on experiments is the damage potential of insects which may vary less overtime. Since damage assessment of any insect in the field to calculate EIL/ET levels is mostly hard, time consuming, and costly, these attempts are very limited with some agricultural pests. Moreover, GSB is a serious pest only in few hazelnut producing countries, so there is only one preliminary attempt (unpublished, Saruhan, 2004) for EIL/ET study about it yet. In this study, the data regarding damage per insect was derived and recalculated from mentioned study.

Currently, in Türkiye the nominal ET accepted for GSB in practice is 1 insect / 10 “ocak” (Anonymous, 2017). For a single insecticide application, ET was calculated to be 3.8 insects per day (0.1 ha) for K = 1 and 4.76 insects per day (0.8 ha) for K = 0.8 in this study. When ET values were converted into the traditional Turkish unit that is special for hazelnut orchards; ET values for K=1 and K=0.8 were 0.76 and 0.95 insect per 10 “ocak”, respectively. ET values were naturally doubled when two chemical applications for GSB per year were considered. Here we found that for a single insecticide application, the ET value is about 1 insect/ 10 “ocak” (for K=0.8), similar to the nominal threshold that is currently used in practice.

We propose that two chemical applications in a year and the K= 0.8 option are more realistic approaches to determining the ET value of GSB for the following reasons: Tuncer et al. (2009) found from field experiments on stink bugs that one chemical application was not satisfactory to reduce corked kernel damage, but two applications produced 60-80% effectiveness in the field. Moreover, this insect is very migratory, so it can travel among host plants and orchards, and the damaging period can extend up to three months in hazelnut orchards. On the other hand, hazelnut growing areas are usually rainy, and this can affect the success of chemical control. In fact, another application for GSB is advised in late May to prevent early season losses, but this application time overlaps with the hazelnut weevil control period (that is the key pest of hazelnut in Türkiye and chemical control is made for it) and is rarely used.

Therefore, considering two chemical applications and 80% effectiveness in control (K=0.8) for calculating the ET value for GSB is a more practical approach. Therefore, we recommend the ET value for GSB as 9.47 insect/ da, about 10 insect/da and 1.9 insect/ 10 “ocak” about 2 insect/10 “ocak”, for Türkiye.

Author Contributions

The percentage of the author(s) contributions is present below. All authors reviewed and approved final version of the manuscript.

	İ. S.	M. K. T	C.T.
C	30	30	40
D	30	30	40
S	30	20	50
DCP	60	20	20
DAI	20	40	40
L	20	30	50
W	30	30	40
CR	30	30	40
SR	30	30	40
PM	70	00	30
FA	70	00	30

C=Concept, D= design, S= supervision, DCP= data collection and/or processing, DAI= data analysis and/or interpretation, L= literature search, W= writing, CR= critical review, SR= submission and revision, PM= project management, FA= funding acquisition.

Conflict of Interest

The authors declared that there is no conflict of interest.

Ethical Consideration

Ethics committee approval was not required for this study because of there was no study on animals or humans.

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