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Orijinal araştırma (Original article)

Economic threshold revision of the Sunn Pest (*Eurygaster integriceps* Put.) (Hemiptera: Scutelleridae) on wheat in Southeastern Anatolia Region

Güneydoğu Anadolu Bölgesi'nde Süne (*Eurygaster integriceps* Put.) (Hemiptera: Scutelleridae)' nin ekonomik zarar eşiğinin revizyonu

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Summary

The Sunn Pest is the most important insect pest wheat and barley in Turkey. In order to revise the economic threshold (ET) for the pest, the average plant number, kernel number in each spike, nymphs and new-generation adults (NGAs) density, and the percent kernel damage caused by nymphs plus NGAs in per square meter were determined in wheat fields sampled. Studies were conducted in 20 insecticide-free bread and durum wheat fields which have at least 5 da. in Diyarbakir province from 2004 to 2008. The binary logistic regression was used to signify the effect of spikes, kernels, nymphs and new-generation adults (NGAs) density, and kernel damage on ET. At the end of the study, average plant per m^2, kernels in each spike, over ed adult density, nymph plus new-generation adult density, and percent kernel damages were between 173.7 and 910.0 11.0 and 41.4, 0.7 and 3.7 per m^2, 5.7 and 114 per m^2, and 0.4 and 55.4%, respectively. The yield lost caused by feeding of OWAs and kernel damage due to feeding of nymph plus NGAs ranged from -89.1 to 145.3 g/m^2. There was no correlation between yields from sprayed and unsprayed fields. The sedimentation values were between 8 and 35, and 9 and 50 for Zeleny and incubated sedimentations, respectively. Economic damage threshold for South East Anatolia Region were around 8, 10, and 12 nymphs plus NGAs per square meter, when plant number is between 350- 460 in per square meter, constant kernel number in each spike (average 26), 3.5% kernel damage tolerance limit. Hovever these numbers could be higher or lower depending on plant number, number kernels of spike and number of nymphs in m^2.

Key words: Economic threshold, kernel damage, sunn pest, wheat, Southeastern Anatolia Region

Özet

Süne Türkiye'de buğday ve arpanın en önemli zararlısıdır. Sünenin ekonomik zarar eşiğini revize etmek amacıyla yapılan bu çalışmada buğday alanlarında, metre karedeki ortalama bitki sayısı, başaktaki tane sayısı, nimf ve yeni nesil ergin yoğunluğu ile bunlardan kaynaklanan tanelerdeki yüzde ağırlık kaybı belirlenmiştir. Çalışmalar Diyarbakır ilinde kimyasal uygulanmamış ve en az 5 dekarlık olan 20 ekmeklik ve makarnalık çeşitlerde 2004-2008 yılları arasında yürütülmüştür. Nimf ve yeni nesil ergin yoğunluğu ile başaktaki tane sayısı ve tanelerde meydana getirdiği ekonomik zarar eşiğini belirlemek için çok değişkenli regresyon analizi kullanılmıştır. Çalışma sonucunda, ortalama bitki sayısı (m^2), başaktaki tane sayısı ve kışlamış ergin, nimf ve yeni nesil ergin yoğunluğu sırasıyla 173.7 ile 910.0, 11.0 ile 41.4, 0.7 ile 3.7, 5.7 ile 114 adet (m^2) olarak belirlenmiştir. Kışlamış ergin ile nimf +yeni nesil erginlerden kaynaklanan ürün kaybı -89.1 ile 145.3 g/m^2 olarak belirlenmiş ve ilaçlı ile ilaçsız parseller arasında bir ilişki bulunamamıştır. Çeşitlerde normal sedim değerleri 8-35, beklemeli sedim değerleri ise 9-50 aralığında bulunmuştur. Güneydoğu Anadolu Bölgesi'ne özgü ekonomik zarar eşiği, bir m^2'de ortalama 350- 460 bitki, 26 adet tane ve kabul edilebilir %3.5 emgi sınırında m^2'de 8, 10, 12 aralığında belirlenmiştir. Belirlenen eşik değerleri m^2'de bitki sayısı, başaktaki tane sayısı ve nimf yoğunluğuna göre değişkenlik gösterebilir.

Anahtar sözcükler: Ekonomik zarar eşiği, tane zararı, süne, buğday, Güneydoğu Anadolu Bölgesi

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Introduction

Wheat, *Triticum aestivum* L. (Poaceae) is grown on about 9 million ha. area annually with the production of approximately 20 million tons in Turkey (Anonymous, 2008). This crop is an important basic food consumed mostly as bread in the country. It provides a substantial component of the human diet; cereal (mostly wheat) products provide 53 and 66% of the per capita dietary supply of calories and protein, respectively (Anonymous, 1980). It is also consumed as animal food and used to make various processed foods in the industry. The country exports about 10% of wheat production. The South Eastern Region of the country represents 13 and 8% of wheat acreage and production, respectively (Anonymous, 2008).

The Sunn Pest, *Eurygaster integriceps* Put. (Hemiptera: Scutelleridae), is a very damaging insect pest of wheat and barley in Turkey (Lodos, 1982). Overwintered adults (OWAs) of the sunn pest attack the leaves and stems of young, succulent wheat and barley plants, causing them to wither and die prior to spike formation. They also feed the base of the spike during the early growing period resulting in whitish spikes without kernels, producing white spikes. Yield losses by this pest are estimated at 50-90% on wheat and 20-30% on barley. In addition to the direct yield reduction, the pest injects digestive enzymes during the feeding, causing reduction in the baking quality of the dough. Even if as little as 2-3% of the grain has been fed on, the entire grain lot may be rendered as unacceptable for baking purposes because of poor quality flour (Lodos, 1982).

This pest was first reported in the South Anatolia Region of Turkey in 1927 and there have been many outbreaks ever since. Detailed studies on the sunn pest begun in the 1950s in Turkey (Şimsek, 1998). The government managed sunn pest control from 1927 to 2001 while an integrated pest management (IPM) approach was adopted. Sunn Pest management was changed from aerial application to ground spraying, shifting responsibility to farmers. Currently, ground sprays are conducted on 1-2 million ha area annually (Anonymous, 2004). Government provides technical support and farmers are applying insecticides with their own equipment with the help of qualified technical consultants.

The area sprayed in South Eastern Turkey was about 400,000 ha in 2008 (more than the 40% of total wheat acreage in the region), covering a large proportion of the region form Şırnak to Adıyaman Provinces, under IPM framework. One of the key factors affecting the success of IPM programs is economic threshold (ET). The economic threshold used for sunn pest control was established about 40 years ago in the region and country (Yüksel, 1968). There is a need to revise the ET because of changes in climatic conditions, wheat varieties used, agronomical practices, and crop diversity. The purpose of this study was to determine plants (spikes), nymphs and new-generation adults (NGAs) density, and kernel damage caused by nymphs plus NGAs in wheat fields to redefine the ET for the Sunn Pest in the region.

Materials and Methods

1. Field studies

The study was conducted in 20 insecticide-free bread and durum wheat fields which have 5 da. in the various districts of Diyarbakır province in southeastern of Turkey during 2004-2008. There were 18 fields of bread wheat and two fields of durum wheat. An area of 0.2 ha beside the trial fields was kept as treated control. This area was sprayed with alpha-cypermethrin weekly until harvest. Eight bread and one durum wheat varieties were used. Variety was not held constant over all fields and not all fields were used in the study years.

When the migration of adults from overwinter sites to cereal fields ended, weekly surveys of plant, adult, and nymph density begun in each field by using a 0.25 m^2 frame. A total of 12 frames tossed randomly in each field sampled, and OWAs, nymphs, and NGAs were counted in each frame. At the harvest, the spikes in the frames were evaluated to estimate the yield and use in ET calculations. The results of counts were multiplied by 4 while presented.

Just before harvest, spikes in fields with and without insecticide applications were counted and all plants in each frame were cut and put in a paper bag separately, and brought to laboratory. In the laboratory, spikes were dried and threshed, and the kernels cleaned. The kernels from each frame were weighed to determine yield per field. The mean yield from 12-0.25 m^2 was used to estimate the yield per ha for each sprayed or unsprayed field. Then kernels from all 12 frames were combined and 1-kg of kernels was taken from this combined kernel for each field. From this sample, 100 kernels, up to 10 times, (total = 1.000 kernels) were randomly selected. These sub-samples were checked under the dissecting microscope and damaged and undamaged kernels were evaluated individually (Dörtbudak, 1974) to determine percent kernel damage, 1.000-damaged and healthy kernel weight, and percent weight loss.

2. Sedimentation test

The kernels combined from 12 sampling frames from each trial fields, except for the ones in 2004, were also used for the Zeleny and incubated sedimentation test (Anonymous, 1994) to evaluate the sunn pest damage on wheat quality. All milling of wheat was conducted at 23°C and 60% relative humidity. Wheat samples were cleaned and tempered overnight to optimum moisture, as described by Williams et al. (1988). Tempered wheat was milled using Buhler laboratory mill type MLU-202 (Uzwil, Switzerland), with break roll gaps adjusted to B2 = 1.2/1000 cm, B3 = 0.8/1000 cm, C1 = 1.2/1000 cm and C3 = 0.8/1000 cm. Medium hard soft-wheat clothing was used for. Buhler Bran finisher MLU-302 (Uzwil, Switzerland) was used to extract “bran flour”, which was combined with all six flour streams. Then the following reagents were prepared;

1. Dissolve 0.04 g bromophenol blue in 10 liter demineralized water (reagent A).

2. Dilute 250 ml of lactic acid to 1 liter demineralized water (store for 3 weeks).

3. Mix thoroughly 180 ml of lactic acid solution with 200 ml isopropyl alcohol (2-Propanol), and demineralized water to make 1 liter (reagent B). Let stand 48 hour before using. The method involved weighing 3.2 g of sieved flour [using UDY cyclone mill, (Fort Collins, Colorado) and 100 mesh sieve], which is transferred to a 100-ml stoppered measuring cylinder. Timing is started and 50 ml reagent (A) is added and shaken 12 times. The cylinder is placed on a mixing rack and mixed until total elapsed time is 5 min. The cylinder is removed from the mixing rack and 25 ml of reagent (B) is added and mixed for another 5 min. The cylinder is removed and let stand for exactly 5 min (Total time from start is 15 min.). The volume of sediment is read in ml. It is read again two hours later as incubated sedimentation value.

3. Statistical analysis

Logistic Regression Analysis is a method used when a dependent variable has a categorical form and also when an independent variable is constant or in a categorical form. In order to analyze the influence of each explanatory variable on the dependent variable, which is a dichotomous variable, the binary logistic regression is used as a method (Maddala, 1983; Field, 2000; Grene, 2000; Gujarati, 2003; Özdamar, 2004). It was used in order to signify the factors affecting the sunn pest economic threshold of 3.5% kernel damage in our research. Two different binary logistic regressions were applied for dependent variables such as the kernel damage rate under the economic threshold (3.5%) (y=0), or the kernel damage rate over the economic threshold (3.5%) (y=1). Dependent variables were assumed as the number of nymphs plus new generation adults of sunn pest, the number of spike in per square meter, and the number of kernels per spike. We thought, currently the change of these factors was to reaction of economic threshold of sunn pest in 3.5% kernel damage level.

The relationship between the predictor variable and expectation of response variables is not a linear function in logistic regression; instead the logistic regression function is used, which is the logit transformation of the probability of occurrence of Prob (y=1) (Field, 2000).

Where; Prob (y=1) is once again the probability of the event, α is the Y intercept, βs are regression coefficients, and Xs are a set of predictors. α and βs are typically estimated by the maximum likelihood (ML) method.

Results

The yield loss caused by overwintered adults, nymphs, and new-generation adults

The yield loss caused by overwintered adults, nymphs, and new-generation adults are shown in Table 1.

Table 1.Average spike (plant) per square meter, kernel in each spike, overwintered adult density, nymph plus new-generation adult density, and percent kernel damage in various wheat varieties and localities, Diyarbakır, 2004-2008.

Year	Locality	Wheat variety	Spike No. / m²	Kernel No. / spike	OW adult / m²	Nimph + NGA/m²	Kernel damage (%)
2004	Bereketli	Fırat 93	497.3	26.4	2.3	64	6.6
2004	Bereketli	Bezostaja	592.7	30.6	1.0	8.0	0.4
2004	Bereketli	Svevo	476.7	20.0	3.7	114	55.4
2004	Çakırbağ	Dariel 1	848.0	37.1	2.0	15.0	2.6
2004	Çakırbağ	Dariel 2	910.0	41.4	1.3	12.0	0.6
2005	Alabal	Pehlivan	557.0	32.8	1.0	5.7	1.7
2005	Halkapınar	Svevo	453.7	31.8	1.7	22.7	4.6
2006	Gömmetaş	Pehlivan	485.0	27.2	1.7	15.0	3.0
2006	Sarıçanak	Nurkent	573.0	27.8	1.3	17.3	4.3
2006	Güleçoba	Bezostya	564.0	26.0	1.3	24.3	5.7
2007	Sarıçanak	Cumhuriyet 75	415.3	24.0	1.7	11.3	3.0
2007	Alibardak	Svevo	528.3	25.0	1.7	18.3	3.2
2007	Alibardak	Basribey	433.3	34.0	1.0	10.3	1.5
2007	Çeltikaltı	Nurkent	523.0	22.0	1.3	10.0	2.5
2007	Sarıçanak	Pehlivan	454.3	30.0	1.3	11.3	2.3
2008	Sarıçanak	Basribey	501.0	26.0	0.7	11.0	1.7
2008	Sarıçanak	Cemre	173.7	11.0	1.0	9.7	31.3
2008	Sarıçanak	Cumhuriyet 75	296.7	11.0	1.7	18.7	14.1
2008	Sarıçanak	Nurkent	398.7	21.0	1.7	20.0	6.9
2008	Sarıçanak	Pehlivan	453.0	21.0	2.0	16.3	11.1

Average plant number (spike) per square meter, kernel number in each spike, overwintered adult density, nymph plus new-generation adult density, and percent kernel damages were between 173.7 and 910.0, 11.0 and 41.4, 0.7 and 3.7 per m2, 5.7 and 114 per m2, and 0.4 and 55.4%, respectively, during 2004-2008 (Table 1).

The yield lost caused by white spike and stem damage due to feeding of OWAs, and kernel damage due to feeding of nymph plus new-generation adults ranged from -89.1 (more yield in unsprayed plot) to 145.3 g/m² (Table 2).

Table 2. Average spike, yield, and yield difference per square meter in sprayed and unsprayed plots in various wheat varieties, Diyarbakır, 2004-2008.

Year	Wheat variety	Nimph+ NGA / m²	Spike number / m² (Sprayed plot)	Spike number / m² (Unsprayed plot)	Yield (g) / m² (Sprayed plot) (A)	Yield (g) / m² (Unsprayed plot) (B)	Yield difference (g) (A – B)
2007	Basribey	10.3	387.0	433.3	343.6	333.4	10.2
2008	Basribey	11.3	485.7	501.0	346.1	406.6	-60.5
2004	Bezostaja	8.0	602.7	592.7	814.5	803.9	10.6
2006	Bezostya	24.3	636.0	564.0	671.0	525.7	145.3
2008	Cemre	9.7	300.3	173.0	59.2	46.9	12.3
2007	Cumhuriyet 75	11.3	509.7	415.3	500.2	391.6	108.6
2008	Cumhuriyet 75	18.7	347.7	296.7	126.1	86.6	39.5
2004	Dariel 1	12.0	844.0	848.0	1.083	1.088	-5.0
2004	Dariel 2	15.0	932.3	910.0	1.554	1.519	25.0
2004	Fırat 93	64.0	504.0	497.3	637.1	625.1	12.0
2007	Nurkent	10.0	500.3	523.0	326.0	294.5	31.5
2008	Nurkent	20.0	410.3	398.7	289.1	248.1	41.1
2006	Nurkent	17.3	645.7	573.0	471.3	504.1	-32.8
2005	Pehlivan	5.7	647.0	557.0	748.4	707.7	40.7
2006	Pehlivan	15.0	479.7	485.0	533.9	406.4	127.5
2007	Pehlivan	11.3	515.7	454.4	522.6	443.5	79.1
2008	Pehlivan	16.3	475.7	453.0	314.7	324.2	-9.5
2004	Svevo	114	480.7	476.7	380.7	339.4	41.3
2005	Svevo	22.7	473.3	453.7	466.1	481.0	-44.5
2007	Svevo	18.3	499.7	528.3	406.3	495.4	-89.1

The yield values in some unsprayed fields were greater than sprayed ones for Svevo, Pehlivan, Nurkent, Dariel 1, and Basribey varieties. There were no correlations between yields from sprayed and unsprayed fields. This was because of big differences between spike numbers in sprayed and unsprayed fields due to various seed amount used and cultural practices under different farm conditions where trials conducted.

In 2004, the feeding of nymph plus NGAs on kernels at the density of 8, 12, 15, 64, and 114 per square meter resulted in 0.6, 1.0, 1.8, 16.6, and 36.9% weight loss in kernels for the varieties of Bezostaja, Dariel 1, Dariel 2, Fırat 93, and Svevo varieties (Table 3).

The spike number and kernel number each spike ranged from 476.7 to 910 and from 20 to 41.4 per square meter, respectively (Table 1). The weight loss averaged 4.1% for Pehlivan variety at 5.7 nymph plus NGAs per square meter, 557 spikes per square meter, and 32.8 kernels each spike densities, respectively and 8% for Svevo variety at 22.7 nymph plus NGAs per square meter, 453.7 spikes per square meter, 31.8 kernels each spike densities, respectively in 2005. Sunn Pest caused 5.1, 8.7, and 5.5% yield loss for Pehlivan, Nurkent, and Bezostya varieties at 15, 17.3, and 24.3 nymph plus NGAs per square meter, 485, 573, and 564 spikes per square meter, and 27.2, 27.8, and 26 kernels each spike densities, respectively, in 2006. Weight losses in kernels were between 3.8 and 24.3% at the 9.7 to 20.0 nymph plus new-generation adult density per square meter, respectively in 2007-2008 (Table 1 and 3).

Table 3. The weight loss in kernels caused by nymphs and new-generation adults in various wheat varieties, Diyarbakır, 2004-2008.

Year	Wheat variety	Damaged kernels inthousand kernels	Kernel Damage (%)	Nimph + NGA / m²	Damaged thousand kernel weight (g)	Undamaged thousand kernel weight (g)	Weight difference (g)	Weight loss in kernels (%)
2004	Svevo	554	55.4	114	22.4	35.5	13.1	36.9
2004	Fırat 93	66	6.6	64.0	39.7	47.6	7.9	16.6
2004	Dariel 2	6	0.6	15.0	39.7	40.1	0.4	1.0
2004	Dariel 1	26	2.6	12.0	33.97	34.6	0.6	1.8
2004	Bezostaja	4	0.4	8.0	43.93	44.21	0.3	0.6
2005	Svevo	46	4.6	22.7	37.0	40.0	3.0	7.5
2005	Pehlivan	17	1.7	5.7	42.2	44.0	1.8	4.1
2006	Bezostaja	57	5.7	24.3	36.1	38.2	2.1	5.5
2006	Nurkent	69	6.9	17.3	29.3	32.1	2.8	8.7
2006	Pehlivan	30	3.0	15.0	33.8	35.6	1.8	5.1
2007	Svevo	32	3.2	18.3	37.5	40.2	2.7	6.7
2007	Cum. 75	30	3.0	11.3	39.8	41.8	2.0	4.8
2007	Pehlivan	23	2.3	11.3	32.8	34.3	1.5	4.4
2007	Basribey	15	1.5	10.3	22.8	23.7	0.9	3.8
2007	Nurkent	43	4.3	10.0	34.4	36.0	1.6	4.4
2008	Nurkent	25	2.5	20.0	25.3	26.8	1.5	5.6
2008	Cum. 75	141	14.1	18.7	25.9	34.2	8.3	24.3
2008	Pehlivan	111	11.1	16.3	34.6	37.6	3.0	8.0
2008	Basribey	17	1.7	11.3	31.6	32.9	1.3	4.0
2008	Cemre	313	31.3	9.7	23.5	30.3	6.8	22.4

Quality loss in wheat kernels caused by nymphs plus new-generation adults of the Sunn Pest

Some technical properties of various wheat varieties worked on are shown in Table 4. The results of the sedimentation tests for kernels from sprayed (zero kernel damage) and unsprayed fields in our research are summarized in Table 4. The sedimentation values were between 8 and 35, and 9 and 50 for Zeleny and incubated sedimentations, respectively. The lowest value (8) obtained on durum wheat variety of Svevo while the highest one (50) obtained on bread wheat varieties of Nurkent and Cemre at sprayed fields (Table 4). Zeleny sedimentation value for healthy kernels of Basribey variety (No. 1, Table 4) was 29 and it increased to 39 after incubating 2 hours while it was 26 for damaged kernels with 1.7% which did not increase after 2 hours. For sample, No. 2 of Basribey, Zeleny sedimentation was 33 and 34 for healthy and damaged kernels (1.5%), which became 38 and 35 after 2 hours, respectively. Baking quality of dough of this variety was not affected at 1.5 and 1.7% kernel damages because incubated sedimentation values did decrease, even they increased incrementally (Table 4). Incubated sedimentation of Bezostya variety (No. 3, Table 4) with 5.7% damaged kernel lowered to 15 which was about 1/3 of the one for healthy kernels, affecting the baking quality of dough negatively. It appears that Pehlivan varieties No. 11 and 12 tolerated damaged kernels up to 2.5 and 3%, respectively, as it reflected with their sedimentation values of 25 and 26. However, incubated sedimentation for this variety dropped about 3 folds compared to healthy kernels at the 11.1% kernel damage (Table 4).

Table 4. Some technological properties of various wheat varieties, Diyarbakır, 2004-2008

o.	Wheat variety	No. nymphs+ NGA/ m²	Kernel Damage (%)	Thousand kernel weight (g)	Hectoliter weight (g)	Zeleny Sedim.	Incubated Sedim. (2 hours)
1	Basribey (Damaged)	11.0	1.7	30.2	80.0	26	26
	Basribey (Undamaged)	0	0	30.2	80.8	29	39
2	Basribey (Damaged)	10.3	1.5	23.1	72.1	34	35
	Basribey (Undamaged)	0	0	23.7	73.3	33	38
3	Bezostaja (Damaged)	24.3	5.7	32.0	75.4	27	15
	Bezostaja (Undamaged)	0	0	32.1	76.1	31	46
4	Cemre (Damaged)	9.7	31.3	27.9	70.0	23	10
	Cemre (Undamaged)	0	0	28.9	75.6	35	50
5	Cumhuriyet 75 (Damaged)	18.7	14.1	31.1	78.9	27	9
	Cumhuriyet 75 (Undamaged)	0	0	27.6	76.3	33	43
6	Cumhuriyet 75 (Damaged)	11.3	3	41	77.2	16	21
	Cumhuriyet 75 (Undamaged)	0	0	41.8	79.1	19	22
7	Nurkent (Damaged)	20	6.9	29.6	77.2	32	10
	Nurkent (Undamaged)	0	0	29.0	79.1	34	50
8	Nurkent (Damaged)	10	2.5	25.9	72.9	24	22
	Nurkent (Undamaged)	0	0	26.8	73.2	24	30
9	Nurkent (Damaged)	17.3	4.3	24.3	73.9	21	14
	Nurkent (Undamaged)	0	0	29.9	75.8	22	29
10	Pehlivan (Damaged)	16.3	11.1	34.7	78.9	26	10
	Pehlivan (Undamaged)	0	0	35.9	77.2	27	34
11	Pehlivan (Damaged)	11.3	2.3	33.6	76.8	28	26
	Pehlivan (Undamaged)	0	0	34.3	77.2	22	33
12	Pehlivan (Damaged)	15	3	28.9	70.8	25	25
	Pehlivan (Undamaged)	0	0	33.0	76.1	26	32
13	Pehlivan (Damaged)	5.7	1.7	36.4	80	26	32
	Pehlivan (Undamaged)		0	37.6	80.1	25	32
14	Svevo (Damaged)	18.3	3.2	38.7	79.4	10	12
	Svevo (Undamaged)	0	0	40.2	82.5	8	14
15	Svevo (Damaged)	22.7	4.6	31.4	78.5	30	11
	Svevo (Undamaged)	0	0	31.6	79.0	35	39

The nymph plus NGAs densities (the ETs) that cause the kernel damage that ruins dough quality at various spike (plant) numbers per square meter and constant kernel number in each spike (Average 26) at various yield levels are given in Table 5.

Table 5. Economic thresholds (ET) (No. nimph / m²) of the sunn pest for the kernel damages of %5, %4, %3.5 and %3 at different spike No. and kernel No. in each spike.

Spike No. / m² (173-910)	Kernel No. / spike (17-34)	Yield / ha (kg) (174-825)	ET for %2 kernel damage	ET for %3 kernel damage	ET for %3.5 kernel damage	ET for %4 kernel damage	ET for %5 kernel damage
350	26	324	5	8	8	10	11
360	26	333	6	9	9	11	12
370	26	342	6	9	9	11	12
380	26	352	6	9	9	12	13
390	26	361	6	10	10	12	13
400	26	370	7	10	10	13	14
410	26	380	7	11	10	13	14
420	26	389	7	11	11	14	15
430	26	398	8	12	11	14	15
440	26	407	8	12	12	14	16
450	26	417	8	12	12	15	17
460	26	426	8	13	12	15	17
470	26	435	9	13	13	16	18
480	26	444	9	14	13	16	19
490	26	454	9	14	13	17	19
500	26	463	9	14	14	17	20
510	26	472	10	15	14	18	20
520	26	482	10	15	14	18	21
530	26	491	10	16	15	19	21
540	26	500	11	16	15	19	21
550	26	509	11	16	15	19	22

For the wheat producer who has lower or higher yield, the separate tables of ETs can be established for various kernel number each spike at different damage levels. The ETs were around 7, 9, and 12 nymph plus NGAs per square meter at about 3,000, 3,500, and 4,000 kg / ha yield levels, respectively (Table 5). Very different ETs could be calculated using our equations at various yield levels as we reached 1 and 26 nymph plus NGAs per square meter for 3% kernel damage at 1,740 and 8,250 kg / ha yield level, respectively.

Discussion

The yield loss caused by overwintered adults, nymphs, and new-generation adults.

As shown in Table 1, nymph plus new-generation adult density in trial fields were usually over 10 for the study in general, which is practical ET in the country. In 2004, the 0.6% kernel damage on Dariel 2 variety was fairly low compared to nymph plus new-generation adult density of 12, which is over the practical ET. This indicates that high plant density and kernel numbers (910 and 41.4 for Dariel 2) on spike increase wheat tolerance to the sunn pest. Contrary of the latter was seen on Cemre variety which had 31.3% kernel damage at 9.7 nymph plus NGAs and 173.7 spikes per square meter in 2008 when there was drought.

Svevo durum wheat variety sustained the highest sunn pest density in the trials in 2004, 2005, and 2007 with 114, 22.7, and 18.3 nymph plus NGAs per square meter, respectively (Table 1). This showed that this durum wheat variety was preferred by the sunn pest among the other bread wheat varieties around. This may be because of the variety's trait or some other reasons. Therefore, we think that studies should be focused to this variety and other some durum wheat varieties sown commonly in the region.

Kılıç et al. (1973) stated that kernel damage caused by the sunn pest was 15% and yield loss was 1,531 kg/ha at the density of 32.6 nymph plus NGAs per square meter in South Eastern Turkey. It was indicated that 10 nymph and NGAs of the sunn pest per square meter resulted in 7% kernel damage (Kılıç, 1976) in the same region. We found that 14.1% kernel damage and 23.4% yield loss occurred on Cumhuriyet 75 variety at the density of 18.7 nymph plus NGAs per square meter. Özkan et al. (2009) indicated that kernel damages in Bezostaja and Pehlivan varieties were different at the similar sunn pest density in field studies in the Central Anatolian Region. Apparently these results are varies from each other. This is attributed to differences between the varieties containing different traits and the changes in ecological conditions.

There was no homogeneity between the average spike numbers of sprayed and unsprayed fields (Table 2). This was attributed to the nonhomogeneous in the application of seeds and fertilizers used, land structure, and cultural management tactics in trial field of grower conditions. For example, kernel weight per square meter was 9.5 g heavier in unsprayed field which had 453 spikes per square meter (less than sprayed one) than sprayed field which had 475.7 spikes per square meter. Therefore, the comments on the yield loss due to the Sunn Pest damage in the field trials under farmer conditions may not be dependable. We think that the trials for this purpose should be conducted under controlled conditions. Özkan et al. (2009) conducted a similar research under controlled conditions and they stated that kernel damage caused by the Sunn Pest is much more important than yield loss which may fluctuate limited amount under unfavorable climatic conditions. They concluded that yield loss was 60 to 380 kg / ha at the density of 3 to 38.7 nymph plus NGAs per square meter and 0.5 to 9.7% kernel damages.

The weight loss in kernels was the lowest with 0.6% in Bezostaya variety at 0.4% kernel damage and the highest with 36.9% in Svevo variety at 55.4% kernel damage. Yüksel (1968) stated that weight loss in damaged kernels was low of being 5% kernel damage and it increased after that. This finding was in accordance with our data (Table 3).

Quality loss in wheat kernels caused by nymphs plus new-generation adults of the sunn pest.

Wheat and flour quality is expressed by a variety of chemical and physical properties of dough (Pyler, 1988). Wheat's bread making potential is derived largely from the quantity and quality of its protein. Protein quantity is influenced by environmental factors such as climate, soil, growing practices, and pest damages while the quality of the protein is genetically determined. In wheat varieties that are grown under comparable environmental conditions, a high quality wheat will produce good bread over a fairly broad range of protein levels while a poor quality wheat will yield relatively low quality bread even at high protein contents (Atlı, 1999; Hruskova & Famera, 2003).

One way to measure the quality loss of wheat dough caused by the activity of enzymes which are injected by the sunn pest is Zeleny and incubated sedimentation tests (Atlı et al., 1988; Atlı, 1999; Haramein et al., 2004). The sedimentation value drops when sunn pest damage in kernels increases. It increases in incubated sedimentation compared to Zeleny sedimentation for undamaged kernels whereas it drops in incubated sedimentation for damaged kernels (Egesel et al., 2009). For sedimentation, Zeleny sedimentation values between 5 and 15 are considered as weak, 16 and 24 as medium, 25 and 30 as good, and over 30 as very good (Elgün et al., 2002).

It seems the wheat varieties in this study tolerate the sunn pest's kernel damage up to 3% and they lose their baking quality above this level of damage. Incubated sedimentation values for the varieties with less than 3% kernel damage were between 21 and 35, which are at medium to very good quality. Kernel damage that ruins the dough quality varies among countries and studies. In Bulgaria, Gospodinov et al. (1975) found that it was 4% for *E. integriceps* and 6% for *E. maura, E. austriaca,* and *Aelia acuminata* in a research on 63 wheat varieties. In the same country, Gatsova and Kontev (1981) stated that acceptable kernel damage was 3% for wheat varieties with low quality flour and 5-6% for wheat varieties with good quality flour. Shurovenkov et al. (1985) indicated that kernel damage above 7% ruined the dough quality in Russia. Atlı (1987) figured out that kernel damage that deteriorates dough quality was 3% for wheat varieties with protein less than 11.4% and 5% for wheat varieties with protein more than 11.4% in Thrace Region, Turkey. It is stated that the quality of dough made from wheat with over 5% Sunn Pest damage was ruined in a research conducted in Southern Cyprus in 1990 and 1991 (Josephides, 1993) and kernel damage ranged from 2% to 44% during this study. Aden et al. (2004) stated that if kernels damages were over 5% during kernel formation period, wheat lose bread quality. Özkan et al. (2009) found out that kernel damages were between 0.5 and 3.8 and kernel damages over 3% ruined the dough quality for Bezostaja and Pehlivan varieties in field plots 2004 and 2005 in Central Anatolia Region, Turkey. Some of these results corresponds our findings in this research. It is apparent that kernel damage tolerance varies depending on insect species, wheat type (Durum or bread wheat), wheat variety, and ecological conditions

Tolerance limit for damaged kernels of *Eurygaster* spp. and *Aelia* spp. species was 6% which was dropped to 5% in Turkey in 2003. This limit of 5% was applied in private sector and Government for a while until when it was decreased to 4% in 2005. It is applied as 3.5% since 2007 after stock exchanges for cereals had active role for wheat trade. There is no specific item for *Eurygaster* spp. and *Aelia* spp. damages in EU legislation of 824/2000 EC which was adopted in the framework of EU harmonization in the country. The kernels damaged by pests are in the group of defective kernels. The weight of defective kernels should not exceed 7% of total weight in the batch.

The ET for Sunn Pest is defined as a population density of nymphs or nymph plus NGAs or OWAs per square meter which cause kernel damage that ruins the baking quality of dough. Spraying against OWAs was conducted in the limited areas for a while until 1995 in Turkey too. Later it was changed to be able to have the advantage of adult and egg parasitism of the Sunn Pest which may be affected by early insecticide applications against OWAs.

There are many studies to define ET for the Sunn Pest to decide pesticide applications, about which we need to discuss to be able to evaluate our results. Pavlov (1975) suggested to apply insecticide against the Sunn Pest when nymphs were over 20 per square meter if wheat plants (spikes) were 600-700 per square meter. This suggested ET was quite similar to the ET we obtained in our research, which was 21-23 nymphs per square at 600-650 spikes per square meter for 3% kernel damage. Starostin and Galkina (1976) stated that ET should be 10 nymphs/m² against third instars at low population density and 15 nymphs/m² against first-second instars at high population density.

Semyanov et al. (1981) in Kazakistan and Stavraki (1982) in Greece suggested that ET for *E. integriceps* could be 10 nymphs per meter square against second instars, which was practical ET applied most parts of Turkey. Areshnikov et al. (1987) in Ukraine stated that spraying against only overwintered sunn pest adults was not enough and there was a need of a second spraying against second to third instars at the beginning of kernel formation period at the density of 4-6 nymphs per square meter.

In a 5 year study conducted in Romania, Mustatea (1976) mentioned that the ET for *Eurygaster* and *Aelia* species were 10 nymphs per square meter. The yield loss caused by 2-3 OWAs per square meter and their nymphs could be tolerated if plant number is between 400-500 per square meter. Whereas Popov (1998) in the same country stated that the ET would be 5 nymphs per square meter for wheat for consumption purposes as bread and 3 nymphs at seed production fields and it varies depending on growth stage of wheat, climatic conditions, usage purpose of yield, and pest density. On the other hand, Lazarov et al. (1969) emphasized that 2 OWAs per square meter could cause important damage and chemical applications were needed at the density of 2 fourth-fifth instars plus new-generation adults. Haramein et al. (2004) found out that 7 nymphs plus NGAs per square meter in Iran and 10 nymphs plus NGAs per square meter in Turkey did not reduce the baking quality of wheat dough. Sheikh & Rahbi (1996) expressed that ET for the Sunn Pest was 5-10 nymphs at the flowering stage, 5-6 nymphs after flowering in Syria.

In Turkey, there are considerable researches on ET for the sunn pest. Kılıç (1988) and Şimşek (1998) stated that sprays applications for the sunn pest could be directed to mainly first-third instars. The fields where the overwintered adult density is over 0.8 per square meter should be kept under check and sprays should be started for first-third instars and continued for nymph plus NGAs if the density exceeds 10 nymphs or nymph plus new-generation adults. Canhilal et al. (2005) indicated that the ET for the sunn pest was 8.1 and 9.2 nymphs for bread and durum wheat varieties, respectively in South Eastern Turkey. Özkan et al. (2009) found out that the tolerance limit for kernel damage was 3.5% against *Eurygaster maura* in a research conducted Central Anatolian Region of Turkey in 1997-2008. The ET was 6-8 nymphs, which could be changed depending on spike number per square meter and kernel number each spike.

The ET determined in Turkey and out of Turkey varies greatly by ranging from 2 to 20 nymphs per square meter. This difference depends on socio-economic needs of the country, usage purpose of wheat, phenological stage of wheat, growth stage of the sunn pest, and tolerance limit for kernel damage in the country. In this study, the ET determined in South Eastern Turkey conditions is dynamic, which can be changed by parameters (Nymph plus NGAs per square meter, spike number per square meter and kernel number each spike) that are determined by climatic conditions in different years. In this research, if we accept the kernel damage limit as 3%, the ET is 6 nymph plus new-generation adults per square meter at 2780 kg/ha, 8 nymphs at 3240 kg/ha, 10 nymphs at 3700 kg/ha, and 12 nymphs at 4170 kg/ha (Table 5). The ET of 6 nymph plus new-generation adults per square meter at 2780 kg/ha is lower than 8-9 nymphs at 2,000-2,500 kg/ha suggested by Canhilal et al. (2005).

The ET was applied as 10 nymphs per square meter for many years regardless of the region, wheat type and variety until 2010 when it was reduced to 7-8 where the yield was around 2500 kg / ha as suggested by Canhilal et al. (2005). In our region, with the exception of extreme conditions (drought or excessive rain fall), the ET should be 10 nymphs per square meter when plant number is 400 at 3.5% kernel damage tolerance limit and it could be higher or lower depending on plant number (Table 5) as it went up to 20 nymphs when there was 600-700 plants in Pavlov's research (1975).

Acceptable kernel damage depends on insect species, wheat type (Durum or bread wheat), wheat variety, the protein quality and quantity of wheat in the studies conducted in and out of the country. We believe that this is an important issue and ET studies should be conducted with common wheat varieties on variety base country-wide starting in South Eastern Turkey to determine kernel tolerance limit. This will help us to determine economic thresholds based on wheat variety. In addition to resistant wheat varieties should be determined against to sunn pest damage and disseminated in the region, research studies aimed to forecasting and warning system at the control of sunn pest must be improved. In these studies, the varieties with high quality proteins should be prioritized.

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References

Aden, A., H. Mazid Gül, A. Majid, H.M. & M. El-Bouhssini, 2004. "Analysis of policies on integrated pest managment on Sunn Pest in İran, Syria and Turkey, 6". In proceedings, Second International Conference of Sunn Pest, July 19-22, 2004, Aleppo, Syria, ICARDA, Aleppo, Syria.

Anonymous, 1980. Buğdaydan Ekmeğe. T.M.M.O.B. Yayınları No 26/3. 336 page. (In Turkish)

Anonymous, 1994. Determination of the Sedimentation Value (According to Zeleny) as an Approximate Measure of Baking Quality. In: http://www.icc.or.at/standard_methods/116.1

Anonymous, 2004. Zirai Mücadele Teknik Talimatları. Koruma ve Kontrol Genel Müdürlüğü, Tarım ve Köyişleri Bakanlığı, Ankara, 291 s.

Anonymous, 2008. TÜİK Tarımsal Yapı, Üretim, Fiyat, Değer 2006. Türkiye İstatistik Matbaası, Ankara, Nisan 2008.

Areshnikov, B.A., I.M.G. Kostyukiovsk & D.M.Feshchin, 1987. How to optimize control of the sunn pest. Zashchita Rastenii-Moskva, 5: 22-25.

Atlı, A., 1987. Trakya Bölgesi buğdaylarında görülen süne emgi şikayeti üzerine toplanan numunelerde yapılan kalite çalışmaları Raporu: 1-19.

Atlı, A., N. Koçak, H. Köksal, B. Aktan, E. Karababa, A. Dağ, T. Tuncer, B. Dikmen & Ş. Özkan, 1998. Süne (*Eurygaster* spp.) ve kımıl (*Aelia* spp.) zararı görmüş tanelerin ekmeklik buğday kalitesine etkileri.Tarla Bitkileri Merkez Araş. Ens.Yayınları, 1988/2, Ankara, 23 s.

Atlı, A., 1999. "Buğday ve ürünleri kalitesi, 498-506". Hububat Sempozyumu (8-11 Haziran 1999), Konya.

Canhilal, R., H. Kütük, A. D. Kanat, M. İslamoğlu, J.F. Haramein & M. El-Bouhssini, 2005. Economic threshold for the Sunn Pest (*Eurygaster integriceps* Put.) (Hem: Scutelleridae) on wheat in Southeastern Turkey. J. Agric. Urban Entomol. 22(3-4): 191-204.

Dörtbudak, Y., 1974. Investigation on *Eurygaster* species; identification, distribution and population densities in the Southeast Anatolia. General Directorate of Plant Protection and Agricultural Quarantine Research Trace Series, Ministry of Food-Agriculture and Livestock Farm, Ankara, 40 p.

Egesel, C.Ö., F. Kahrıman, S.Tayyar, & H. Baytekin, 2009. Ekmeklik buğdayda un kalite özellikleri ile dane veriminin karşılıklı etkişimleri ve uygun çeşit seçimi. Anadolu Tarım Bilimleri Dergisi, 24(2):76-83 (In Turkish).

Elgün, A., Z. Ertugay, M. Certal & H.G. Kotancılar, 2002. Tahıl ve Ürünlerinde Analitik Kalite Kontrolü ve Laboratuvar Uygulama Klavuzu. Atatürk Üniversitesi Yayın No: 867, Ziraat Fakültesi Yayın No: 335, Ders Kitapları Serisi No: 82, 238 s.

Field, A., 2000. Discovering statistics using SPSS for Windows. Chapter 5, pp 163-204, London, Sage Publication.

Gatsova, V. & K. H. Kontev, 1981. Effects of damage by *Eurygaster integriceps* on the baking quality flour of recommended wheat varietes. Rasteniv'dni-Nauki, 18 (4): 33-43.

Gospodinov, G.T. & I. Atanasova, 1975. Investigations on the technological qualities of wheat damaged by sunn pests. Rasteniv'dni-Nauki. 12(5): 109-117.

Greene, W.H., 2000. Econometric Analysis. 4th edition, Upper Saddle River, New Jersey: Prentice-Hall, 758 p.

Gujarati, D.N., 2003. Basic Econometrics. Fourth Edition, McGraw-Hill Higher Education, Published by McGraw-HiII/lrwin, a business unit of The McGraw-Hili Companies, Inc. 1221 Avenue of the Americas, New York, NY, 10020. C, 979 p.

Haramein, J.F., M.El-Bouhssini, M.A. Mafi, R. Canhilal & H. Kütük, 2004. "The impact of Sunn Pest density in wheat fields on grain and flour quality, 17". In proceedings, Second International Conference of Sunn Pest: 181-186, July 19-22, Aleppo, Syria, ICARDA. Printed in Beirut, Lebanon.

Hruskova, M. & O. Famera, 2003. Prediction of wheat and flour Zeleny sedimentation value using NIR technique. Czech Journal Food Science. 21: 91–96.

Josephides, C. M., 1993. Infestation of cyprus durum wheat by suni-bug and its effect on the physical dough properties. Technical Bulletin Cyprus Agricultural Research Institute, no. 156: 8 pp. [CAB Abstr. 93-7/95]

Kılıç, A.U., A. Çatalpınar, N. Adıgüzel, Y. Dörtbudak, & S. Çavdaroğlu, 1973. Investigation on distribution, biology, epidemiology and chemical control of Sunn Pest (*Eurygaster integriceps* Put.) in the Southeast Anatolia region of Turkey. Annual Report of the Plant Protection Research Institute, Report No. A- 106.602, Diyarbakır, 121p.

Kılıç, A.U., 1976. The biology and control of *Eurygaster integriceps* Put. Meeting on Cereal Ccrops, June 1-4, 1976, Ankara. (In Turkish)

Kılıç, A.U., 1988. Türkiye'de süne (*Eurygaster integriceps* Put.) mücadelesinin esasları. 1. Uluslararası Süne Sempozyumu (13-17 Haziran 1988), Tekirdağ.

Lazarov, A., S. Grigorov, V. Popov, V. Bogradov, D. Abaciev, H. Kontev, H. Kayzatov, H.Gospodinov, H. Fitanov & D. Duçevski, 1969. Investigation on biyo-ecology and control of species harmful on creals in Scutelleridae ve Pentatomidae (Hem.) in Bulgaria, 144p.

Lodos, N., 1982. Turkey Entomology 2. General, Practical and Faunistic. Ege Üniversitesi Ziraat Fakültesi Yayınları No. 429, Ege Üniversitesi Matbaası Bornova-Izmir, 591 p (in Turkish).

Maddala, G.S., 1983. Limited-Dependent and Qualitative Variables in Econometrics. Cambridge University Press.

Mustatea, D., 1976. The cereal bugs (*Eurygaster* spp. and *Aelia* spp.) in Romania. The papers of the 5 th Interbalcanic Plant Protection Conference probleme de Protectia Plantelor 4:175-184.

Özdamar, K., 2004. Paket Programlar İle İstatistiki Veri Analizi-1. Genişletilmiş Beşinci Baskı. Kaan Kitabevi, Eskişehir. (In Turkish).

Özkan, M. &N. Babaroğlu, 2009. Orta Anadolu Bölgesi'nde Avrupa Sünesi (*Eurygaster maura* L.)'nin neden olduğu ürün kayıpları ve ekonomik zarar eşiği üzerinde araştırmalar. Tagem Yayınlanmamış Araştırma Projesi, 59 s. (In Turkish)

Pavlov, I.F., 1975. Agrotechnical measures for control of *Eurygaster integriceps* [Cereal pests]. Zashch Rast. Journal (5): 16-19.

Popov, C., 1998. Controlling Sunn Pest in Romania and integrated Sunn Pest management. First Workshop Report (6-9 January 1998), Ankara, 165 p.

Pyler, E.J., 1988. Baking Science and Technology. 3rd ed. Sosland Publ. Comp., Kansas City, Missouri, US: 357–377.

Semyanov, V.P., A.T.Tilmenbaev, S. Z. Beksultanov & A.T.Sarbaev, 1981. The main elements of integrated control of the sunn pest in Kazakhistan. Noveishiedostizheniya-sel'skokhozyaistvennoi-entomologii-po-materialam-Ush-sezdaVEO-Vilnyus, 9-13-oktyabrya-1979-g, 184-186

Sheikh, K. & M.A. Rahbi, 1996. Sunn Pest and their control in the Near East. FAO Plant Production and Protection.pp.138-165.

Shurovenkov, Y.U.B., Ermakov, A.V., Boiko, N.I., Mikhailova, N.A. & M.A. Volodichev, 1985. Grain condition and the Sunn Pest. Zashchita Rastenii, 8:8-9.

Starostin, S.P. & R.G. Galkina, 1976. Effects of dates control of nymphs of the noxius pentatomid on its dynamics of numbers and injuriousness the wheat grains. Zashchity Rastenii, 45: 30-34.

Stavraki, H.G., 1982. Study on the biology and ecology of wheat pests of the family Pentatomidae in the central Greece. Annales-de-I'Institut-Phytopathologique-Benaki, 13(2): 213-232.

Şimşek, Z., 1998. "Türkiye'de süne (*Eurygaster* spp.) mücadelesinin genel durumu, dünü, bugünü, 51-62". Entegre Süne Mücadelesi. I. Workshop Raporu (6-9 Ocak 1998). Ankara.

Yüksel, M., 1968. Güney ve Güneydoğu Anadolu'da Süne (*Eurygaster integriceps* Put.)'nin Yayılışı, Biyolojisi, Ekolojisi, Epidemiolojisi ve Zararı Üzerinde Araştırmalar. T.C. Tarım Bakanlığı Zirai Müc. ve Kar. Gn. Md. Yayınları No: 46 Teknik Bülten, Yenidesen Matbaası, Ankara, 255p.

Williams, P.C., F. J. El-Haramein, H. Nakkoul, & S. Rihawi, 1988. Crop Quality Evaluation Methods and Guidelines. Technical Manual No. 14. ICARDA, Aleppo, Syria, 145 p.