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Crop Loss Assessment of *Lixus incanescens* Boh. (Coleoptera: Curculionidae) on Sugar Beet, *Beta Vulgaris L.*

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Abstract

Sugar beet weevil, *Lixus incanescens* Boh., is one of the most important pests of sugar beet in many parts of Iran and neighbor countries. The leaf and petioles of sugar beet are attacked by adults and larvae. The economic losses due to *L. incanescens* damage have not been estimated in Iran. Moreover, chemical application is currently the conventional control method. Therefore, it was necessary to assess crop losses. This project was done in a sugar beet field during 2006 and 2007 in Tehran (Iran) using fenvalerate EC20% (1 L/ha). The number of infested petioles in 50 plants was counted in treated and untreated plots once a month until the harvesting time. Then, the weight (kg), sugar content (%), sugar extraction coefficient (%) and white sugar content (%) of roots were measured. The results showed that in both years, there was significant difference between the mean number of infested petioles in each plant in treated (0.47 ± 0.03 and 0.047 ± 0.003 in first and second years, respectively) and untreated (6.53 ± 0.33 and 4.82 ± 0.52 in first and second years, respectively) plots. But, there were not significant differences regarding the indices including weight, sugar content, sugar extraction coefficient and white sugar content. The cost-benefit ratio was 2.65- 3.7, when the field had an average of 5-6 infested petioles per plant.

Keywords: Chemical control, Crop loss Assessment, *Lixus incanescens*, Sugar beet**.**

1. Introduction

Sugar beet weevil, *Lixus incanescens* Boh., is the major pest of sugar beet. It has been reported from many parts of Iran and other countries like south of Ukraine, east south of Russia, Caucasia, Kazakhstan, Turkmenistan and Turkey (Davatchi and Kheyri, 1960; Aleeva, 1953). It has three generations per year in Iran. The leaf and petiole of sugar beet are attacked by adults and larvae of *L. incanescens*. The adults prefer plants which have well developed four to six leaves and feed on petioles and new leaves. The larvae attack the petiole of sugar beet and petiole vessels are torn and broken. In each petiole, 1 to 10 larvae can be found. The damage reduces leaf green area, root weight and nutrient movement rate in plants. As Ocete *et al.* (1994) reported, the larvae can cause up to 75% root weight loss. Adults hibernate under plant debris and stones. Severe damage happens in the second generation in August. The percentage of damage is related to date of planting. Hence damage in early-planted sugar beet is less than late-planted ones (Parvizi and Javanmoghadam, 1988). It also feeds on common purslane (*Poryulaca oleraceae* L.), common orache (*Atriplex patula* L.), common goosefoot (*Chenopodium album* L.), *Amaranthus retroflexus*, *Salsola kali* and *Atriplex hortensis*. So, destroying the host weeds can reduce its population (Kheyri, 1966; Parvizi and Javanmoghadam, 1988). It was a key pest in Turkmenistan during 1970-1973 (Gold *et al.*, 2004) and in 1983 in south west of Romania (Manole, 1990). Also, it is one of the most important pests of sugar beet fields in Uzbekistan (Rashidov and Khasanov, 2003).

Assessment of crop losses was investigated for several pests and diseases (Hills *et al*., 1980; Shane and Teng, 1983; Campbell *et al*., 1998; Hull, 2007). There are several methods for estimating crop losses by insect pests. In the direct method, actual crop losses are measured in the field. In the indirect methods, crop losses are estimated by relation between insect density or damage symptoms and yield index (Walker, 1991 a), e.g. the relation of number and length of holes caused by stem borers and yield index (Walker, 1991 b).

The most precise method of estimating crop losses is through direct measurement of actual losses. Crop loss can be defined as the difference between the potential yield (the yield that would have been obtained in the absence of the pest and the actual yield (De Groote *et al.,* 2001).

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A reliable analytical frame for plant health decision making is essential. Cost-benefit analysis provides such a frame, typically by projecting a stream of predicted costs and benefits for managing options, expressed in financial terms, and setting present values on these streams. Further detailed analysis may deliberate the distribution of benefits in time and space, risk attitudes can be combined, and non-monetized elements can be integrated. The aim is to provide an obvious and objective frame in which managing options can be compared on common economic criteria (Mumford *et al*., 2000).

Cost-benefit analysis is an organized frame to analyze the efficiency of projects, programs, policies or regulations. It can be used to improve the quality of public policy decisions by recognizing all the costs and benefits of a policy, and evaluating them using as a metric a monetary measure of the aggregate change in individual well-being resulting from the policy (Boardman *et al*., 1996). Cost-benefit analysis is based on the economic theories of prosperity and can be used to assess how rare resources should be assigned to the avoidance and control of pests and unwanted species in the agricultural part.

Sugar beet weevil has become a key pest in Iran. Farmers apply insecticides a lot against this pest because all stages except adults develop in the petiole, and adults emerge gradually. The objectives of this study were a) to assess the crop losses and b) to determine the cost- benefit ratio to finally reduce application of insecticides.

2. Materials and Methods

The project was done in an unsprayed sugar beet field (2 ha) during 2006 and 2007 in Tehran, Iran. Distance between rows was 50 cm. Sugar beets (variety Universe) were planted at a distance of 25 cm from each other. The field was irrigated by a center pivot sprinkler. Percentage of damaged plants (plants with symptoms on their leaves and petioles) was calculated. Because, damaged plant percentage depended on *L. incanescens* abundance. Then, 15 plots, each including five 15-m rows, were selected. The middle row of each plot was selected for sampling. Each row had 50 sugar beet plants. Six plots were treated once every two weeks by fenvalerate EC20% (1L/ha). The rest of the plots were not treated (considered as check).

2.1. Sampling Method of Crop Loss Assessment

The number of infested petioles in 50 plants was counted once per month (The initial sampling showed that variation in infested petioles was significant during a month) until the harvesting time. Then, the tubers of the middle row of each plot were collected separately and transferred to the laboratory of Sugar Beet Seed Institute in Karaj, Iran. The samples were weighed after washing. A cossette was prepared using all 50 glands of each row (van der Poel *et al*., 1998). Sugar content (%), sugar extraction coefficient (%) and white sugar content (%) of roots were measured (Kunz, 2004).

2.2. Cost-Benefit Ratio Calculation

Cost- benefit ratio was calculated by the following formula (Ponnusamy, 2003):

$$\frac{\text{Treated benefit (\$) - Untreated benefit (\$)}}{\text{Cost of Protection}}$$

Cost of protection must be calculated. Cost of protection ($) is sum of insecticide cost ($), labour cost ($), sprayer rent cost ($), and crop loss compensation ($).

In Iran sugar factories buy sugar beet on a basis of sugar content using by the following formula (Sheikholeslami, 2003):

$$\text{Value of Sugar Beet (\$)} = \frac{\text{Sugar content (\%) - 3}}{13 \times \text{price (\$)}}$$

'Sugar content' as a grade is measured in sugar factories. Here, the average grade in each treatment was calculated. The value '3' is the rate of yield loss or rate of sugar is not extractible. The value '13' is the minimum acceptable grade that lower than it, is not purchased.

'Price' is value of sugar beet per kilogram that is determined annually by the Agricultural Ministry. Price of sugar beet was 4.6 cent per kg during the two years of our research.

After calculating income per one kilogram, the average gland weight of 50 plants was multiplied by the average number of sugar beet plants per hectare (100000 plants), then the total income was calculated per hectare.

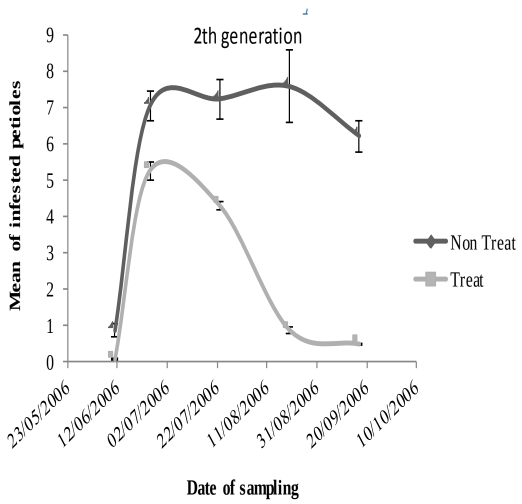
2.3. Statistical Analysis

Data were analyzed using SAS Var. 9.1 (SAS Institute Inc., Cary, NC). Means were compared by T-test (PROC TTEST). Correlation between traits such as infested petioles and indexes (sugar content, sugar extraction coefficient, white sugar content and weight) was estimated (PROC UNIVARIATE, PROC CORR).

3. Results

3.1. Comparison between means number of infested petioles in treated and untreated plots

In both years, the highest mean number of infested petioles was observed in August, during which, the second generation emerges (Figure 1).



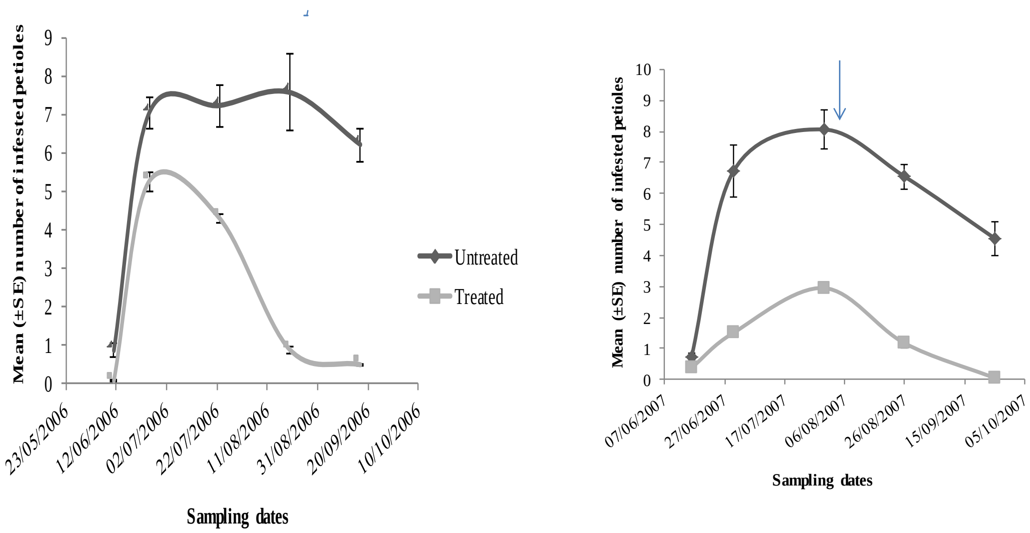


Figure 1. Mean (± SE) number of infested petioles at different sampling dates in (up) 2006 and (down) 2007. The arrows indicate the start date of the second generation.

Results showed that in both years, there was a significant difference between the mean number of infested petioles in each plant in treated and untreated plots (2006: T= 18.36, DF(7,5), *P*<0.0001) (2007:, T= 9.09, DF(7,5), *P*<0.0001). However differences were not significant in the indices including sugar content (2006, T= -2.23, DF(7,5), *P*>0.0517) (2007, T= -2.22, DF(7,5) *P*>0.0464) sugar extraction coefficient (2006, T= -1.62, DF(7,5), *P*>0.1311) (2007, T= -1.34, DF(7,5), *P*>0.2047) white sugar content (2006, T= -1.73, DF(7,5) *P*>0.1090) (2007, T= -2.02, DF(7,5), *P*>0.0666) and weight (2006, T= -0.87, DF(7,5) *P*>0.4109) (2007, T= 1.14, DF(7,5), P>0.2897). Table 1 shows the mean of infected petioles and indexes in treated and untreated plots in 2006- 2007.

Results showed that, when the number of infested petiole increased, sugar content decreased (2006: rs = -0.6733, *P*= 0.0083; 2007: rs= -0.6811, *P*= 0.0073). On the other hand, sugar contents between treated and untreated plots were not different.

Table 1. Mean (± SE) number of infested petioles and the indices including sugar content, white sugar content, sugar extraction coefficient and weight in treated and untreated plots in 2006- 2007.

Treatments	Infested petioles/plant		Sugar content/plant (%)		Sugar extraction coefficient /plant (%)		White sugar content/plant (%)		Weight/plant (Kg)	
	1st year	2nd year	1st year	2nd year	1st year	2nd year	1st year	2nd year	1st year	2nd year
Treated	0.47±0.03	0.047±0.003	14.57±0.09	16.41±0.27	80.28±0.43	74.11±0.73	11.70±0.14	12.18±0.30	1.47±0.02	1.12±0.03
Untreated	6.53±0.33	4.82±0.52	14.04±0.21	15.64±0.23	78.87±0.67	72.70±0.73	11.11±0.27	11.33±0.28	1.37±0.11	1.28±0.13

Number of infested petioles was negatively correlated with sugar extraction coefficient (2006: rs= -0.6835, *P*= 0.0070; 2007: rs= -0.3827, *P*= 0.1768) and white sugar content (2006: rs= -0.7011, *P*= 0.0052; 2007: rs= -0.6239, *P*= 0.0171). The amount of impurities and sugar molasses had positive correlation with infestation rate.

This study showed direct relation between the number of infested petioles and root weight in two years (2006: rs= -0.2706, *P*=0.3494; 2007: rs=0.5201, *P*= 0.0566).

3.2. Cost- Benefit Ratio Calculation

Cost-benefit assessment shows (tables 2 and 3) when all plants of the farm are infested with *L. incanescens* and infection mean rate is 5-6 petiole per plant, insecticide application can increase yield, sugar content percentage and benefit while reducing damage.

Table 2. Calculation process of income rate per hectare.

Year of experiment	1st year		2nd year	
Treatments	Treated	Untreated	Treated	Untreated
Mean sugar content (%)	14.57	14.04	16.41	15.64
Income rate of selling 1 kg sugar beet ($)	0.041	0.039	0.047	0.045
Mean weight of 50 plants (Kg)	73.63	68.72	56.42	54.52
Mean plant weight per hectare	147260	137440	112840	109040
Income rate per hectare ($)	6028.82	5369.09	5354.37	4876.92

Table 3. Calculation of cost-benefit ratio between treated and untreated plots in 2006- 2007.

Main factors in calculation	First year		Second year	
	Treated	Untreated	Treated	Untreated
Chemical control cost ($/ha)	180	-	180	-
Income of selling sugar beet ($/ha)	6028.82	5369.09	5354.37	4876.92
Benefit ($/ha)	479.73		477.45	
Cost Benefit ratio	3.7		2.65	

4. Discussion

Sugar beet has two growth stages: 1) from germination to tuber formation, and 2) sugar production in tubers. Incidence of pests and diseases in the second growth stage may reduce sugar content and storage in tubers. The reduction of green area of sugar beet fields by pests may also decrease sugar storage in roots. Moreover, sugar content depends on different factors such as depth of plowing, seeding date, time and amount of nitrogen fertilizers, planting density per hectare, shoot appear, pests and diseases incidence, incomplete crown beater and delay in harvest and transferring to factory (Amini, 1988).

The amount of sugar content and impurities such as potassium, sodium, and harmful nitrogen in sugar beet tubers are the main factors in quality assessment (Smith *et al.*, 1977). The quality of crop increases with high rate of sugar content and low rate of impurities, because impurities prevent crystallization of sucrose and decrease efficacy of extracted sugar and increase the amount of molasses in the factory (Eck *et al.*, 1990; Dunham and Clark, 1992; Kerr and Leaman, 1997).

The second generation of *L. incanescens* causes severe damage because this period is synchronized with sugar storage in the roots which is so important in sugar beet development. So, if active leaves decrease, it can reduce sugar storage. Then sugar content percentage and value of sugar beet would be dropped. Results of the present study demonstrated that when the number of infested petioles with *L. incanescens* increased, sugar content, sugar extraction coefficient and white sugar content decreased however root weight did not change. As Jadidi *et al.* (2010) indicated, the main effect of defoliation stage was significant on quality traits of sugar beet such as sugar content, white sugar content and sugar extraction coefficient, but its effect on quantity traits such as root yield was not significant. However, different levels of defoliation affected both quality and quantitative traits of sugar beet. Different experiments on defoliation showed that defoliation in early spring had negligible effect on yield loss, but defoliation in the summer causes more yield reduction (Dunning and Winder, 1972; Jones *et al.*, 1955).

Stallknecht and Gilbertson (2000) stated that date and severity of defoliation, are more important than the sugar beet stage of growth, regarding reduction of root yield and sucrose content of sugar beet.

Parvizi and Javanmoghadam, (1988) compared percentage of plant infestation to *L. incanescens* in different dates of planting and different generations of pest. They showed that percentage of plant infestation was higher in late-planted fields than early-planted fields in all three generations. So, the mean percentage of plant infestation in the second generation in the late-planted fields (%46.25) was almost double of early-planted fields (29.25%). Arbabtafti *et al.* (2008) found that if there were five to six infested petioles per plant, which is equivalent to 20% infestation per square meter, spraying could be done. The economic injury level for other defoliator pests of sugar beet such as armyworm, beet webworm, variegated cutworm and grasshoppers were estimated about 25% of damaged leaves (DiFonzo *et al.*, 2006). Lilly and Harper (1962) indicated that sugar beet could recover from light to moderate defoliation with little or no decrease in yields of roots and sugar. It showed that insect infestation causing 25% or less defoliation of beets resulted in no economic importance. During late June, July, and early August pests should be controlled if the beets were defoliated 50% or more. Even when the leaves have been defoliated to 75% it was still possible to obtain a reasonably healthy crop.

Throughout this study, the cost-benefit ratio was calculated 2.65- 3.7. If it is above 1, chemical application can be economic. Results of the present study were similar to the results of experiments conducted in England and India. It was calculated for some pests like Colorado beetle which is a serious pest of potatoes in many countries but has never become established in England because of peripheral English climate for pest. Climate change might make Colorado beetle a greater hazard in future. The benefit- cost ratio of the current policy of elimination and suppression is estimated at 7.5 : 1, and the Net Social Benefit at 3.35 million pounds (Mumford *et al.*, 2000). *Thrips palmi* also has an extensive range of crop plants but it is only a threat to protected crops in England. The benefit-cost ratio was estimated at 7.4 : 1 and the Net Social Benefit was 2.2 million pounds (Mumford *et al.*, 2000). Tobacco Whitefly has more than 500 plants which it is known to eat but in the English climate it is a potential pest of only protected crops. The Benefit-Cost ratio was 3.1 : 1 and the Net Social Benefit was 11.1 million pounds

(Mumford *et al.*, 2000). In assessment of neem-based insecticide, in controlling the ear head bug on rice, high cost benefit ratio was obtained from the treatment plot (2.74) compared to control plot (2.55). These results showed that application of neem-based insecticide (Azadirachtin 0.03%) at 500 ml/ha decreased the occurrence of ear head bug and increased the grain yield of rice and thus offer an appropriate approach to pest management (Ponnusamy, 2003).

Sugar beet weevil decreases sugar content, sugar extraction coefficient and white sugar content. Sugar content percentage has a key role in acceptance and rejection or determining price of sugar beet crop. Therefore, it is necessary to manage this pest. So when there was 20% infestation per square meter, spraying would be done.

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