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Significance of irrigation treatments and weather conditions on European corn borer appearance

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Abstract

Increased average air temperatures, winter temperatures, wind, amount of rainfalls and water shortages are climate factors that affect pest invasion. The aim of this study was to determine the effects of weather conditions on occurrence of European corn borer (ECB) (*Ostrinia nubilalis* Hubner) on different maize genotypes under three irrigation levels. This study was conducted at the Agricultural Institute in Osijek (Croatia) during three years period (2012 - 2014). Trials included three levels of irrigation (A1 – control, A2 60% - 100% water field capacity (WFC), A3 80% - 100% WFC) and four maize genotypes (OSSK: B1-596; B2-617; B3-602 and B4-552). At the end of each growing season ear weight (g), tunnel length (cm), ear shank damage (cm), number of larvae in maize stem, ear shank and total number of larvae were recorded. Unfavorable environmental conditions delayed ECB appearance for more than 10 days. In 2014, the lowest average air temperature in vegetation season (18.23°C) and the greatest amount of rainfalls (523.3 mm) were recorded, whereas intensity of ECB attack was the lowest compared to other two years. The highest air temperatures were recorded in 2012, in average 19.95°C while the rainfalls were 291.2 mm and ECB attack in this year was the highest. The lowest damage of plants was at the highest level of irrigation and hybrid B1 was the most susceptible to ECB. Although appearance of ECB was similar on tested variants, in all tested years, with increased air temperatures and an average rainfalls we can expect greater ECB potential to damage maize.

Keywords: *Ostrinia nubilalis*, irrigation, maize hybrids, temperature, rainfalls

Introduction

European corn borer (*Ostrinia nubilalis* Hubner) (ECB) is the most important pest of maize for many countries. ECB is polyphagus insect and feeds on over 220 plant species (Ponsard et al, 2004). In eastern Croatia, during period of 25 years (1971 – 1996) the average intensity of ECB attack was 37% (Ivezić and Raspudić, 1997) and in the last ten years, intensity of attack was between 90 and 100%. In eastern Croatia, ECB has two generations per year (Raspudić et al, 2013). Local optimal environmental conditions are in favor of a great population density of ECB in every year. Minimum temperature needed for development of ECB larvae is 11°C (Capinera, 2008). Intensity of ECB attack depends on many biotic and abiotic factors, while weather conditions are the most significant (Derozari et al, 1977). Insect are poikilotherm organisms and can't regulate its body temperature, so air temperature is main factor for their development. Climate change could affect geographic distribution of pests, extend the period of hibernation, may affect the changes in population growth, increased number of generations, prolonged development, some changes in interactions between pest and host plant and increase the risk of migratory species (Porter et al, 1991). According to Kocmankova et al (2009) higher temperatures can accelerate insect development, increase number of generations and population density. Stressful climatic conditions significantly affect ECB eggs and larvae mortality in early stages of development. Mortality of eggs and larvae is highest at low humidity during the first and second stage of ECB larvae and can reach up to 62% of the population (Lee 1988; Ross and Ostlie 1990). Moth flight activity is increased as well at higher relative humidity (Royer and McNeil, 1991). Amount of plant available water can be regulated with irrigation system while the air temperatures can not be influenced. Trends are to put as much as possible of agricultural area into the irrigation system and to ensure optimal conditions for plant development. Irrigation provides higher yield, better grain quality, increased ear length and number of kernels per ear (Grant et al, 1989; Josipović et al, 2007; Aydinsakir et al, 2013). Soil moisture deficiency have negative effect on leaf appearance and

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also delay silking phase (Cakir, 2004) and can result in a reduction od leaf area up to 33% and plant height up to 15% (Traore et al, 2000). Damages from the first generation of ECB are of less importance, while second generation of ECB can considerably damage plants and reduce maize yields, since it appears during maize pollination phase (Velasco et al, 2007). For suppression of ECB insecticides are commonly used (Blandino et al, 2008; Beres, 2010; Raspudić et al, 2013), good results are achieved with tolerant hybrids (Raspudić et al, 2003), genetically modified maize (Rice and Plicher 1998; Farino´s et al, 2004), and manipulation of sowing date (Pilcher and Rice, 2001; Blandino et al, 2008), respectively. ECB larvae prefer to feed on susceptible hybrids and they gain significantly more weight than larvae fed on tolerant hybrid (Davis et al, 1989; Kumar and Mihm, 1996). Differences between Croatian maize hybrids to ECB larvae feeding are published also by Augustinović et al (2005). Biological control of ECB has become important and different organisms such as fungi, bacteria, protozoa, wasps used for ECB control as well. The most important predator which occurs in natural conditions are wasps of the genus Trichogramma (Sarajlić et al, 2014). Effectiveness of this wasps depends on many factors including air temperatures and rainfalls (Gunie and Lauge, 1997). Manipulation of maize sowing date provides good protection from ECB and avoid negative impact on environment, this is also the cheapest method of maize protection. Late sowing increases chances for ECB attack beacuse plants are still suitable for larvae feeding and adults prefer deposit eggs on this plants to provide good nutrition for larvae. Study conducted in Spain compared the number of larvae and tunneling on ear and stalk 20 days after pollination and at harvest and proved that the greater ECB larvae activity and damage potential was during the maize pollination phase (Malvar et al, 2002; Velasco et al, 2004). According to Lisowicz et al (2005) when 50% - 80% intensity of ECB attack is observed yield losses are expected up to 20% - 30%, to maximum of 40% yield losses when 100% of plants are infected. Many researchers have tried to create models based on climatic factors in order to predict pests occurrence more precisely, monitor pests and apply appropriate control measures (Trnka et al, 2007; Maiorano et al, 2014). These models claim to predict development of pests under stressful environmental factors.

The aim of this study was to determine how different irrigation levels effect on the occurrence of ECB on different maize hybrids with regard to the environmental conditions.

Materials and Methods

The experiment was set up on the experimental field at the Agricultural Institute in Osijek (45°33’27.11’’N, 18°40’6.52’’E) during three vegetation seasons: 2012, 2013, and 2014. Maize was sown in rotation with soybeans since 2000. Tested factors are shown in Table 1. Area of experimentally field was 0.5 ha. Basic plot was planted with two rows of maize 10 m long [maize hybrids, 14 m² (10 m x 2 rows x 0.7 m = 14 m²)]. Maize was sown at a row spacing of 70 cm. At the edge of each plot three rows of safety belt of maize was sown in order to avoid the impact of marginal rows (water, light source, unequal use of nutrients). One third of the nitrogen was applied in the autumn in the form of urea (46% N) along with the basic soil cultivation. Another third was added pre-sowing in the form of urea. Top-dressing was done twice with KAN (calcium-ammonium nitrate - 27% N). First top dressing was done in phase 6 - 8 leaves, and the other in phase 8 - 10 leaves. For monitoring ECB flight, light source (lamp) near the experiment site was used in a period between 19 h to 7 h, daily (May-September). Lamp was checked three times a week to determine beginning of the ECB flight. ECB flight was also monitored with pheromone traps (Phercon insect monitoring kit, Third Incorporated – USA). Three pheromone traps were installed on a metal stand of 1,8 m high. Pheromone traps were checked weekly. Appearance of ECB larvae and eggs was monitored twice a week during the growing season.

Table 1 - Tested factors in experiment.

Factor	A - Irrigation	B - Hybrid
Variant	A1 - natural rainfalls (control)	B1 - OSSK 596
		B2 - OSSK 613
	A2 - 60% - 100% WFC	B3 - OSSK 602
	A3 - 80% - 100% WFC	B4 - OSSK 552

WFC – water field capacity

Dissection of maize stalks was done in the beginning of September 2012 and 2013, while in 2014 dissection was done in October because of environmental conditions. From each variant of the experiment 10 maize plants were cut to determine damage from ECB larvae (total 1,080 plants). ECB feeding activity was evaluated according to several traits: EW - ear weight (g), TL – tunnel lenght (cm), LS – number of ECB larvae in maize stalk, LES – number of ECB larvae in ear shank, TNL – total number of larvae per maize plant, ESD – ear shank damage (cm). Climate data was collected by the State Hydrometeorological Service.

The data of ECB larvae injury was evaluated by analysis of variance using the SAS software (SAS Institute Inc, 2009) after normality data test. Log transformation (log (n+1)) was used to normalize the data. Least square means with the Tukey adjustment for multiple comparisons were then calculated and reported for significance at the 95% confidence level. Back transformation was done in order to see original values.

Results

Impact of weather conditions on ECB appearance

Environmental conditions during experimental years were different regarding rainfalls and temperature. Table 2 shows the values of mean air tempera-

Table 2 - Climatic parameters for tested years.

Year	April	May	June	July	August	September	Vegetation season
			Temperature (°C)				
2012	12.5	16.9	22.5	24.8	24.1	189	19.95
2013	13.1	16.7	20.0	22.9	22.9	15.9	18.58
2014	13.2	16.1	20.5	21.8	20.8	17.0	18.23
Multi year Average	11.3	16.5	19,4	21.1	20.3	16.6	17.5
			Rainfalls (mm)				
2012	45.5	93.7	67.9	47.8	4.0	32.3	291.2
2013	44.9	119.0	63.2	36.5	32.9	129.0	425.5
2014	81.3	161.4	91.0	66.4	54.3	68.9	523.3
Multi year Average	54.1	58.9	83.5	66.6	59.6	51.8	374.5

(Source: Meteorological and Hydrological Service, Croatia)

tures and rainfalls per month during the vegetation season of maize. The highest average air temperatures were recorded in 2012 (19.95°C) while the total rainfalls were the lowest in the same year (291.2 mm). Years 2012 and 2013, were favorable for ECB appearance and development according to the environmental conditions. In 2013, there was a slight decrease of mean temperature during vegetation period for 1.37°C compared to 2012, while the rainfalls were higher for 134.3 mm. 2014 was extremely unfavorable for ECB. Temperatures were lower than in 2012 for 1.72°C and compared to 2013 for 0.35°C, respectively. In period of ECB laying eggs and larvae development, in 2014 temperatures were over 1°C lower compared to the year 2012.

Amount of rainfalls in 2014 was higher, compared to the other two years for 231.1 mm and 97.8 mm, respectively. In all tested years, temperatures were higher than in the multi-year average up to 2.4°C, while the rainfalls were higher in 2013 and 2014 for 51 mm and 148.8 mm, respectively and lower in 2012 for 83.3 mm.

Table 3 shows that the first-generation ECB females deposited eggs in the middle of June and second generation at the end of July, respectively. A year 2014 was unfavorable for this pest, since ECB occurrence was delayed for more than 10 days (for both generations) compared to the other two years. In 2013, both generations of ECB have occurred later than in 2012 although this year was also favorable for ECB attack. According to the agro climatic conditions, 2012 was the most suitable for ECB.

Irrigation effect on the ECB damage parameters

We compared effects of two levels of irrigation and control, on intensity of ECB attack. Average data for all years are compared in Table 4. Variant with highest level of irrigation (A3) had highest ear weight, and significantly differed for 36.8 g compared to the control (A1) and 15.88 g compared to the variant A2. Maize stalks in control variant had highest tunnel length, and statistically it was different compared to the variant with the highest level of irrigation. ECB larvae in maize stalks were statistically the most numerous in control variant, while plants in variant with highest irrigation level had the lowest number of larvae. Number of ECB larvae in ear shank did not differ significantly among the variants, and ranged from 0.13 to 0.79 larvae ear shank^{-1}. In 2012, statistically the highest ear weight was observed in variant with the highest irrigation level (Table 5). Ear weight in variant A2, compared to A1, was higher for 44.35 g and 74.73 g in A3, respectively. Significant differences for ear weight were observed between the irrigation variants, as well. The greatest tunnel length was determined in control variant (A1-77.65 cm), while in variant A2 it was lower for 8.14 cm and 28.55 cm in A3, respectively. All variants differed significantly for tunnel length. Statistically lowest number of larvae in stalks was observed in variant with the highest irrigation level. The number of ECB larvae per plant was the highest on A1 variant, but ear shank damage was higher on irrigation variants (A2 – 0.77 and A3 – 0.3 cm) compared to the control variant (A1). In 2013, variant with significantly highest yield was A3, in average ear weight had 32.74 g more than control variant (A1). The significantly the greatest tunnel length was recorded on control variant (A1), and it was 12.38 cm more than damage on A2 variant with the lowest damage. Total number of ECB larvae and ear shank damage were significantly highest on control variant (A1), compared to irrigation variants for larvae number, and variant with lower level of irrigation for ear shank damage. In 2014, total number of larvae per plant was statistically the most numerous in A2 variant. Other ECB damage parameters did not statistically differ in this year.

Table 3 - The appearance of eggs and larvae of ECB for each year.

	2012	2013	2014
		Eggs	
I generation	June 10	June 12	June 23
II generation	July 25	July 29	August 12
		Larvae	
I generation	June 19	June 21	July 5
II generation	August 5	August 10	August 21

Table 4 - Effect of irrigation on ECB potential to damage maize in all tested years.

			2012 – 2014			
Irrigation	EW	TL	LS	LES	TNL	ESD
A1	262.21c	37.96a	1.60a	0.79a	2.39a	1.45a
A2	284.93b	32.01ab	1.49ab	0.13a	1.62ab	1.42a
A3	300.81a	27.92b	1.30b	0.14a	1.44b	1.56a

Values marked with different letter in the same column are statistically different ($P < 0.05$). A1 – control, A2 – from 60% to 100% WFC, A3 – from 80% to 100% WFC; EW – ear weight, TL – tunnel length, LS – larvae in stalk, LES – larvae in ear shank, TNL – total number of larvae per plant, ESD – ear shank damage.

Effect of maize genotype on ECB damage parameters

In Table 6, average data for all years regarding genotypic diversity of maize hybrids for all ECB damage parameters is represented. B3 hybrid had significantly the greatest ear weight, 29.62 g more than hybrid B4 with the lowest ear weight, but hybrid B4 had significantly the lowest tunnel length, 8.82 cm less than B1 hybrid with the greatest tunnel length. Number of ECB larvae was also significantly the highest on hybrid B1, 0.63 higher than on B4 hybrid with the significantly lowest number of larvae in stalk. The greatest number of larvae in ear shank was on the hybrid B4 as well as the total number of larvae per plant, although the damage of ear shank was the largest on hybrid B1 and 0.62 cm more than on B4 hybrid with the lowest damage. In 2012, no statistically significant differences were observed for ear weight, however B2 hybrid had the highest ear weight, for 24.47 g higher compared to B4 hybrid with the lowest ear weight (Table 7). Hybrid B1 had significantly the greatest tunnel length and 22.27 cm larger compared to B4 tunnel length where the lowest damage was recorded. Hybrid B1 also had significantly the highest number of ECB larvae in maize stem and ear shank. Total number of larvae per plant was significantly higher on the B1 hybrid for 1.02 larvae when compared to hybrid B4 with the lowest number of larvae. Ear shank damage was significantly the highest on hybrid B1, and significantly the lowest on hybrid B4.

In 2013, the highest ear weight was achieved on the hybrid B3, higher for 30.29 g compared to the hybrid B4, but statistically differences were not determined. Significantly, the greatest tunnel length was recorded on the B1 hybrid, while in this year hybrid B2 had significantly the lowest damage, and similar results were obtained for number of larvae in maize stalks. However, number of larvae in ear shank was significantly the highest on B4 hybrid. The largest damage of ear shank had hybrid B1 and it was 0.42 cm more compared to the B4. In 2014, hybrid B1 had significantly the highest ear weight, which was higher for 47.36 g more than on hybrid B4. Tunnel length was significantly the lowest on hybrid B4, compared to other hybrids. Total number of ECB larvae was significantly the highest on B1 and significantly the lowest on B4 hybrid. Significant differences for ear shank damage was observed between hybrids B2 and B4. Intensity of ECB attack was 100% for all hybrids in 2012 and 2013, however in 2014, only 45.55 to 57.40% of maize plants were infested with ECB.

Discussion

According to the Croatian Bureau of Statistics (2015) in the last ten years, two years with the lowest average maize yield were 2007 (4.9 t ha^{-1}) and 2012 (4.3 t ha^{-1}) in Croatia. In these two years 100% attack of ECB recorded. Both years were dry, with

Table 5 - Effect of irrigation on ECB potential to damage maize for each year.

			2012			
Irrigation	EW	TL	LS	LES	TNL	ESD
A1	231.90c	77.65a	2.78a	0.08a	2.86a	1.85b
A2	276.25b	69.51b	2.55a	0.13a	2.68a	2.62a
A3	306.63a	49.10c	2.13b	0.13a	2.26b	2.15b
			2013			
	EW	TL	LS	LES	TNL	ESD
A1	260.84b	36.33a	1.93a	2.29a	4.22a	2.28a
A2	278.72ab	23.95b	1.89a	0.22b	2.11b	1.35b
A3	293.58a	32.31a	1.90a	0.27b	2.17b	2.33a
			2014			
	EW	TL	LS	LES	TNL	ESD
A1	296.93a	2.77a	0.09a	0.02a	0.11ab	0.30a
A2	302.82a	2.78a	0.13a	0.03a	0.16a	0.30a
A3	302.34a	2.52a	0.08a	0.02a	0.10b	0.23a

Values marked with different letter in the same column are statistically different ($P < 0.05$).A1 – control, A2 – from 60 to 100% WFC, A3 – from 80 to 100% WFC; EW – ear weight, TL – tunnel length, LS – larvae in stalk, LES – larvae in ear shank, TNL – total number of larvae per plant, ESD – ear shank damage.

Table 6 -Effect of hybrid on ECB potential to damage maize in all tested years.

	2012 – 2014					
Hybrid	EW	TL	LS	LES	TNL	ESD
B1	291.01a	39.46a	1.86a	0.16a	2.02a	1.74a
B2	285.89ab	31.11ab	1.51b	0.15a	1.66b	1.52a
B3	293.07a	30.88b	1.44bc	0.13a	1.57b	1.64a
B4	263.45b	30.64b	1.23c	1.03a	2.26b	1.12b

Values marked with different letter in the same column are statistically different ($P < 0.05$). B1- OSSK 596, B2 – OSSK 617, B3 – OSSK 602, B4 – OSSK 552. EW – ear weight, TL – tunnel length, LS – larvae in stalk, LES – larvae in ear shank, TNL – total number larvae per plant, ESD – ear shank damage.

small amount of rainfall and high temperatures. Controversy, in our investigation, year 2014 was with excessive rains, and total amount of rainfalls during growing period was 523.3 mm and average temperatures 18.23°C, while intensity of ECB attack was below 50% and maize yield achieved were over 8 t ha^{-1}. Weather conditions in investigated years (2012 – 2014) were significantly different for amount and distribution of rainfalls which greatly influence ECB occurrence and pest potential to damage plants. A year 2012 had the highest average temperature from June to August when this pest occurs. Compared to 2014, temperatures in June 2012 were higher for 2°C, in July for 3°C, and in August for 3.5°C. Besides high ECB attack, this climatic stress could have impact on maize yield (Kovačević et al, 2007). Yield reduction to more than 20%, when local mean temperature increases of greater than 3.5° are reported by Thornton et al (2010). In 2014, temperatures were lower, while rainfalls were increased compared to the previous two years and such weather conditions caused longer ECB development period, weaker attack and less plant damage. The impact of climate change on biology of ECB was reported by many scientists (Beck and Apple, 1961; Matteson and Decker, 1961; Showers et al, 1978; Beck, 1983; Trnka et al, 2007). Great amount of rainfalls resulted eggs rinse and less plant damage. Compared to the multi-year temperature average, it is evident a raise of temperature in investigated years while rainfalls were unequally distributed, so in general years were dry with very short periods optimal for ECB development. As result of climate change, primarily temperature increase cause the appearance of a new (third in our conditions) ECB generation (Porter et al, 1991). In a 3-years study, in Italy, Coppolini (1979) calculated the accumulated thermal units for the first and second ECB generations, and created a forecasting model required to predict ECB emergence and insect development. However, Cagan et al (2000) reported accumulation of thermal units during the whole year is not responsible for the development of the ECB second generation in Poland. Unfavorable environmental conditions, low nighttime temperatures, heavy rain and wind are an important mortality factor. Excessive amount of rainfalls cause eggs rinse, larvae death, difficult moth flights and oviposition. Under unfavorable conditions for oviposition ECB moths aggregate to the edge of maize fields to mate, they remain there and do not oviposit (Showers et al, 1976, 1980). However, according to Barlow et al (1963) positive effects of rainfalls are larger compared to negative consequences. They proved that rainfalls favorably affect ECB reproduction. To achieve maximum reproductive power, they need constant source of drinking water and even short lack of drinking water briefly after emerging larvae may reduce reproduction rate two to five times. According to their research moist spring with frequent and heavy rainfalls caused longer life and greater fertility of ECB females, and can cause relatively large population of second generation of ECB. Similar results were obtained by Kira et al (1969), which pointed to the importance of the availability of water for 24 hours for good eggs and larvae development. Young larvae are extremely sensitive to the desiccation.

ECB moth flight begin at the end of May and last until August. Warm nights with sufficient humidity are optimal for oviposition and increase the pest potential to damage the plants. Pilcher and Rice (2001) tested three different sowing dates and report between 50 and 100% deposited first generation eggs on early sown plants and 40-65% from second generation on later sown maize. Dillehay et al (2004) also reports association of higher ECB infestations with delayed planting dates. In Croatia, first generation of ECB moths appear earliest at the end of May but a year with large amounts of rainfall and lower temperature delayed the occurrence and development up to 15 days. Average plant damage in dry years was 60-70 cm plant^{-1}, while in rainy years average damage was about 3 cm plant^{-1}. In 2012, tunnel length was in average 50% greater for all hybrids, compared to 2013. In 2012 and 2014, one larvae of ECB damaged maize plant more than 20 cm in average (2012 - 24.97; 2014 - 22.5) while average damage in 2013 perone ECB larvae was 10.87 cm. Maximum tunnel length in 2012 and 2014 was higher up 17% compared to average in that years and in 2013 was 12%.

Yield losses may be caused due physiological disorder by larvae or mechanically during harvest. According to Klenke et al (1986) losses caused by physiological disorder were 25.9% and during harvest 2.8%. Losses incurred during maize harvest had no significant effect on yield and it is considered that some other genetic factors have greater influence on yield. Bohn et al (1999) report yield reduction on com-

Table 7 - Effect of hybrids on ECB potential to damage maize for each year.

Hybrid	EW	TL	LS	LES	TNL	ESD
			2012			
B1	266.94a	79.21a	3.02a	0.17ab	3.19a	2.74a
B2	284.48a	62.95b	2.54b	0.18a	2.72a	2.17ab
B3	275.04a	62.63b	2.33bc	0.09bc	2.42b	2.49a
B4	260.01a	56.94b	2.11c	0.06c	2.17b	1.51b
			2013			
	EW	TL	LS	LES	TNL	ESD
B1	287.13a	35.93a	2.40a	0.26b	2.66a	2.14a
B2	276.02a	27.01b	1.85b	0.23b	2.08b	2.00a
B3	289.07a	27.26b	1.86b	0.26b	2.12b	2.13a
B4	258.78a	33.32a	1.53c	3.00a	4.53b	1.72a
			2014			
	EW	TL	LS	LES	TNL	ESD
B1	318.97a	3.21a	0.13a	0.03a	0.16a	0.33ab
B2	297.19b	3.29a	0.11ab	0.03a	0.14ab	0.39a
B3	315.10ab	2.70a	0.11ab	0.03a	0.14ab	0.30ab
B4	271.61c	1.61b	0.04b	0.02a	0.06b	0.10b

Values marked with different letter in the same column are statistically different ($P < 0.05$). B1- OSSK 596, B2 – OSSK 617, B3 – OSSK 602, B4 – OSSK 552. EW – ear weight, TL – tunnel length, LS – larvae in stalk, LES – larvae in ear shank, TNL – total number larvae per plant, ESD – ear shank damage.

mercial hybrids of 0.28% for every 1% plant damage and 6.05% for each larvae per maize plant.

The highest yield was achieved on B3 hybrid, while the lowest was recorded on B4, respectively. According to all ECB damage parameters B4 hybrid had least damage from larvae and B1 was the most sensitive with the greatest damage. Similar results are reported in Croatia (Raspudić et al, 2003; Raspudić et al, 2010). Many published results prove positive effect of irrigation on maize yield (Maqsood et al, 2003; Cakir 2004; Josipović et al, 2007). Splitko et al (2014) investigated 83 hybrids and conclude that lack of water in soil extend period between tasseling and silking and reduce number of kernels per ear which means with higher water content in soil ear weight will be increased. For all tested parameters of ECB damage, the greatest damage found on control variant of irrigation (A1) compared to A3 variant where infestation was significantly the lowest. Although the results show a higher level of attack on non-irrigated variant many other researchers found greater damage on variants with higher level of water (Huberty and Denno, 2004). Some researchers found non or small differences between irrigated and deficit water supply on ECB feeding environment (Ellsworth et al, 1992). The reason could be because water deficit stress can increase sugar content in maize genotypes (Aydinsakir et al, 2013). In dry 2012 damage was largest, while the lowest damage was in wet 2014, so in dry years maize should be irrigated because the proportion of infected plants on irrigated areas is lowered by 37% compared to those which did not have a sufficient amount of water while at the same irrigated variants achieved increased yields up to 25%.

This study proves that rise in temperature with low humidity as a consequence of climate change, brings to the 100% infestation of maize plants and yield loss on all tested hybrids. This fact is showing minor importance of natural enemies and other biotic factors in the field that may interfere with ECB attack.

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References

Augustinović Z, Raspudić E, Ivezić M, Brmež M, Andreata-Koren M, Ivanek-Martinčić M, Samobor V, 2005. Influence of European corn borer (*Ostrinia nubilalis* Hübner) on corn hybrids in north-west and eastern Croatia. Agriculture 11(2): 24-29

Aydinsakir K, Erdal S, Buyuktas D, Bastug R, Toker R, 2013. The influence of regular deficit irrigation application on water use, yield and quality components of two corn (*Zea mays* L.) genotypes. Agric Water Manage 128: 65-71

Barlow CA, Wressell HB, Driscoll GR, 1963. Some factors determing the size of infestation of the European corn borer, *Ostrinia nubilalis* (Hubner) (Pyralidae: Lepidoptera). Can J Zool 41: 963-970

Beck SD, Apple JW, 1961. Effects of Temperature and Photoperiod on Voltinism of Geographical Populations of the European Corn Borer, *Pyrausta nubilalis*. Can J Zool 54(3): 550 – 558

Beck SD, 1983. Thermal and thermoperiodic effects on larval development and diapause in the European corn borer, *Ostrinia nubilalis*. J Insect Physiol 29(1): 107–112

Beres PK, 2010. Harmfulness and effects of chemical control of *Ostrinia nubilalis* Hbn. on sweet corn

(*Zea mays var. saccharata*) in Rzeszów region. Acta Sci Pol Agric 9: 5-15

Blandino M, Saladini MA, Reyneri A, Vanara F, Alma A, 2008. The influence of sowing date and insecticide treatments on *Ostrinia nubilalis* (Hubner) damage and fumonisin contamination in maize kernels. Maydica 53: 199-206

Bohn M, Kreps RC, Klein D, Melchinger AE, 1999. Damage and Grain Yield Losses Caused by European Corn Borer (Lepidoptera: Pyralidae) in Early Maturing European Maize Hybrids. J Econ Entomol 92(3): 723-731

Cagan L, Sobota G, Gabrys B, Kania C, 2000. Voltinism of the European corn borer *Ostrinia nubilalis* Hbn. In Poland. Plant Prot Sci 36(4): 201-2013

Cakir R, 2004. Effect of water stress at different development stages on vegetative and reproductive growth of corn. Field Crops Res 89(1): 1–16

Capinera JL, 2008. Encyclopedia of Entomology. Springer Science & Business Media 1374-1376

Coppolino F, 1979. Temperature and adult emergence of *Ostrinia nubilalis* Hb. in the Bergamo. Redia 62: 85 – 94

Davis FM, Seong SN, Williams PW, 1989. Mechanisms of Resistance in Corn to Leaf Feeding by Southwestern Corn Borer and European Corn Borer (Lepidoptera: Pyralidae). J Econ Entomol 82 (3): 919-922

Derozari MB, Showers WB, Shaw RH, 1977. Environment and the Sexual Activity of the European Corn Borer. Environ Entomol 6(5): 657-665

Dillehay BL, Roth GW, Calvin DD, Kratochvil RJ, Kuldau GA, Hyde JA, 2004. Performance of Bt Corn Hybrids, their Near Isolines, and Leading Corn Hybrids in Pennsylvania and Maryland. Agron J 96: 818-824

Ellsworth PC, Bradley JR, Kennedy GG, Patterson RP, Stinner RE, 1992. Irrigation effects on European corn borer - maize water relations. Entomol Exp Appl 64: 11–21

Farinos GP, De La Poza M, Hernandez-Crespo P, Ortego F, Castanera P, 2004. Resistance monitoring of field populations of the corn borers Sesamia nonagrioides and *Ostrinia nubilalis* after 5 years of Bt maize cultivation in Spain. Entomol Exp Appl 110: 23–30

Grant RF, Jackson BS, Kiniry JR, Arkin GF, 1989. Water Deficit Timing Effects on Yield Components in Maize. Agron J, 81: 61-65

Gunie G, Lauge G, 1997. Effects of high temperatures recorded during diapause completion of *Trichogramma brassicae prepupae* (Hym: Trichogrammatidae), on the treated generation and its progeny. Entomophaga 42: 329–336

Huberty AF, Denno RF, 2004. Plant water stress and its consequences for herbivorous insects: a new synthesis. Ecology 85: 1383–1398

Ivezić M, Raspudić E, 1997. Intensity of attack of the corn borer (*Ostrinia nubilalis* Hubner) on the territory of Baranja in the period 1971-1990. Nat Croat 6(1): 137-142

Josipović M, Jambrović A, Plavšić H, Liović I, Šoštarić J, 2007. Responses of grain composition traits to high plant density in irrigated maize hybrids. Cereal Res Commun 35(2): 549-550

Kira MT, Guthrie WD, Huggans JL, 1969. Effect of drinking water on production of egg by the European corn borer. J Econ Entomol 62: 1366-1368

Klenke JR, Russell WA, Guthrie WD, 1986. Grain Yield Reduction Caused by Second Generation European Corn Borer in BS9 Corn Synthetic. Crop Sci 26(5): 859-863

Kocmánková E, Trnka M, Juroch J, Dubrovský M, Semerádová D, Možný M, Žalud Z, 2009. Impact of Climate Change on the Occurrence and Activity of Harmful Organisms. Plant Prot Sci 45 (Special Issue): 48–52

Kovačević V, 2007. Precipitation and temperatures influences on maize yield in eastern Croatia. Maydica 52: 301-305

Kumar K, Mihm JA, 1996. Resistance in maize hybrids and inbreds to first-generation southwestern corn borer, *Diatraea grandiosella* (Dyar) and sugarcane borer, *Diatraea saccharalis* Fabricius. Crop Prot 15(3): 311-317

Lee DA, 1988. Factors affecting mortality of the european corn borer, *Ostrinia nubilalis* (Hubner), in Alberta. Can Entomol 120(10): 841-853

Lisowicz F, Tekiela A, Bereś P, 2005. Threats corn from pests. Agro Serwis: 50-57

Malvar RA, Revilla P, Velasco ME, Ordas A, 2002. Insect damage to sweet corn hybrids in the south Atlantic European coast. J Am Soc Hortic Sci 127: 693-696

Maqsood SU, Farooq M, Hussain S, Habib A, 2003. Effect of Planting Patterns and different Irrigation Levels on Yield Component of Maize (*Zea mays* L.). Int J Agric Biol 5(1): 64-66

Matteson JW, Decker GC, 1965. Development of the European corn borer at controlled constant and variable temperatures. J Econ Entomol 58(2): 344-349

Pilcher CD, Rice ME, 2001. Effect of Planting Dates and *Bacillus thuringiensis* Corn on the Population Dynamics of European Corn Borer (Lepidoptera: Crambidae). J Econ Entomol 94(3):730-742

Ponsard S, Bethenod MT, Bontemps A, Pe´lozuelo L, Souqual MC, Bourguet D, 2004. Carbon stable isotopes: a tool for studying the mating, oviposition, and spatial distribution of races of European corn borer, *Ostrinia nubilalis*, among host plants in the field. Can J Zool 82: 1177– 1185

Porter JH, Parry ML, Carter TR, 1991. The potential effects of climatic change on agricultural insect pests. Agric For Meteorol 57 (1-3): 221-240

Raspudić E, Ivezić M, Brmež M, 2003. Larval tunneling of European corn borer (*Ostrinia nubilalis* Hubner) on OS corn hybrids. Zbornik predavanj in

referatov 6. Slovenskega Posvetovanje o Varstvu Rastlin: 526-530
Raspudić E, Ivezić M, Brmež M, Majić I, Sarajlić A, 2010. Intensity of European corn borer (*Ostrinia nubilalis* Hubner) attack in maize monoculture and rotation systems. 45th Croatian and 5th International Symposium of Agriculture, Opatija. 901-905
Raspudić E, Sarajlić A, Ivezić M, Majić I, Brmež M, Gumze A, 2013. Efficiency of the chemical treatment against the European corn borer in seed maize production. Agriculture 19(1): 11-15
Rice ME, Plicher CD, 1998. Potential benefits and limitations of transgenic Bt corn for management of the European corn borer (Lepidoptera: Crambidae). Am Entomol 44: 75–78
Ross SE, Ostlie KR, 1990. Dispersal and Survival of Early Instars of European Corn Borer (Lepidoptera: Pyralidae) in Field Corn. J Econ Entomol 83(3): 831-836
Royer L, McNeil JN, 1991. Changes in calling behaviour and mating success in the European corn borer (*Ostrinia nubilalis*), caused by relative humidity. Entomol Exp Appl 61: 131-138
Sarajlić A, Raspudić E, Majić I, Ivezić M, Brmež M, Josipović M, 2014. Efficasy of natural population of Trichogramma wasps against European corn borer in field maize. Agriculture 20(2): 18-22
Showers WB, De Rozari MB, Reed GL, Shaw RH, 1978. Temperature-Related Climatic Effects on Survivorship of the European Corn Borer. Environ Entomol 7(5): 717-723
Schowers WB, Berry EC, Von Kaster L, 1980. Management of second generation European corn borer by controlling moths outside the corn field. J Econ Entomol 73: 88-91
Spitkó T, Nagy Z, Tóthné ZZ, Halmos G, Bányai J, Marton CL, 2014. Effect of drought on yield components of maize hybrids (*Zea mays* L). Maydica 59: 161-169
Statistical Yearbook of the Republic of Croatia, The State Bureau for Statistics, http://www.dzs.hr/Hrv_Eng/ljetopis/2015/sljh2015.pdf (Data accessed: 05.07.2016)
Thornton PK, Jones PG, Alagarswamy G, Andresen J, Herrero M, 2010. Adapting to climate change: agricultural system and household impacts in East Africa Agric Syst 103: 73-82
Traore SB, Carlson RE, Pilcher CD, Rice ME, 2000. Bt and non-Bt maize growth and development as affected by temperature and drought stress. Agron J 92: 1027–1035
Trnka M, Muška M, Semerádová D, Dubrovský M, Kocmánková E, Žalud Z, 2007. European Corn Borer life stage model: Regional estimates of pest development and spatial distribution under present and future climate. Ecol Modell 207 (2 – 4): 61 – 84
Velasco P, Revilla P, Cartea ME, Ordas A, Malvar RA, 2004. Resistance of early maturing sweet corn varieties to damage caused by *Sesamia nonagrioides* (Lepidoptera: Noctuidae). J Econ Entomol 97: 1432-1437
Velasco P, Revilla P, Monetti L, Butron A, Ordas A, Malvar RA, 2007. Corn borers (Lepidoptera: Noctuidae; Crambidae) in Northwestern Spain: population dynamics and distribution. Maydica 52: 195-203