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THE EFFECTS OF GLOBAL CLIMATE CHANGE ON 23

THE DIAMONDBACK MOTH, PLUTELLA XYLOSTELLA (LİNNAEUS, 1758) (LEPİDOPTERA: PLUTELLİDAE 16

) Ceren SARAN*1 Hanife GENÇ2 1Çanakkale Onsekiz Mart University, Faculty of Agriculture, Department of Agricultural Biotechnology, 17100, Çanakkale, Turkey. 2Çanakkale Onsekiz Mart University, Faculty of Agriculture, Department of Agricultural Biotechnology, 17100, Çanakkale, Turkey. Corresponding author e-mail: hgenc@comu.edu.tr

Abstract It is estimated **that** 26

the annual average temperature on Earth will be increased by 1°C until 2025, and this temperature increase will reach 3°C at the end of the century because of the glabal climate change. In addition to increasing CO2 level and heavy rainfall are seen as inevitable.

sources:

The diamondback moth, Plutella xylostella is originated from Europe **and the most** important **pest of** 9

Brassicaeous plants worldwide, distributed in different climatic conditions from the Himalayan Mountains to Ethiopia. P. xylostella survives in cold climates and resistant to insecticides and do not have a diapause. Additionally, it is caused 90% of product loss and 4-5 billions $ are spented annually for its management.

The objective of the **study is to examine the** effects of global **climate** 3

changes on Plutella xylostella. Plants secrete certain chemicals to attract natural enemies to inhibit insect herbivores. It has been observed that increasing CO_2 concentration weakens the plant response to effect the feeding of P. xylostella. Diadegma semiclausum is a parasitic wasp, belonging to Ichneumonidae family and parasites of the diamondback moth larvae however, it moves away from the environment as a result of the increasing temperatures. Physiology, phenology and geographical distribution of insects are effected by abiotic factors as well as biotic factors. It has been revealed that

exposure to high temperature **during the pupal stage** does **not** 20

effect the fecundity of adult but decreases the adult longevity. It has been determined that the fecundity and oviposition period of P. xylostella are negatively effected

at temperatures below 15 °C and above 25 °C , and **the** population reaches **the** 8

maximum level in these temperature ranges. Torrential rains, which are the result of

changes in the frequency and intensity of rainfall 3

beacuse of climate change, cause the extansion of the development period of P. xylostella. The unfavorable conditions resulted for the migration of P. xylostella to the suitable regions for its development and distribution. Increasing temperature in terrestrial areas may create suitable air currents that will allow the expansion of P. xylostella population towards the north. In Turkey, P. xylostella was first recorded in 1965 in collard fields in the Murgul district of Artvin. Later, it was detected in the cabbage fields in Erzurum in 1995 and recently reported in Çanakkale in 2018, after that distributioned everywhere Brassicaeous family are produced. Further studies are needed to reveal

the effects of climate change on the expansion **of pests and** 4

how they become native to invasive pests in worldwide. Keywords: Plutella xylostella, global climate change, diamondback moth, Lepidoptera 1. INTRODUCTION

The effects of global **climate change** have become **a** 24

reality accepted by all scientists in the world. Current estimate indicates an increase annually about 3°C by the end of the 21st century globally (Sharma, 2014). Additionally, the amount of CO_2 in the atmosphere will be about 540- 970 ppm by 2100 (

Bale et al., 2002). In addition, **due to** global **climate change** 22

(flood, drought, etc.) in the world, large increases are expected in extreme weather events (Kadıoğlu, 2001). Insects are cold blooded organisms that have a very superior position in the world in terms of their number of species. Arthropods can be used as an indicator of global climate change (Scherm et al., 2000). Body temperatures are almost the same as ambient temperature. Therefore, temperature is a crucial environmental issue affecting the phenology, distribution, development, survival, physiology, reproduction, adaptation and population of insects (Ögür and Tuncer, 2011). Natural enemies and other control methods are also important to control pest insects.

The diamondback moth is a serious pest of Brassicaeous plants **worldwide** (Talekar **and** 13

Shelton, 1993). It is known to be

originated from Europe (Hardy,1938) or South Africa (Kfir, 1998). The 10

diamondback moth, Plutella xylostella is distributed **in** 25

different climatic conditions from the Himalayan Mountains to Ethiopia (Ayalew and Ogol, 2006). In recent studies, it has been observed that management cost of the diamondback moth reaches 4-5 billion dollars. causing yield losses up to 90% in Brassicaeous fields where it is detected (Zalucki et al., 2012). The reasons why the cabbage leaf moth causes high levels of damage are listed as its

ability to adapt easily to different climatic **conditions, high** reproductive **ability** , 14
resistance **to**

many insecticides and

ability to migrate over long distances (Talekar **et al** 19

., 1985, Avcı and Özbek, 1995). It has been determined that it can migrate to 1000 km or more distances with the air flow caused by atmospheric pressure in Europe (Avcı and Özbek, 1995). Şekil 1. P. xylostella damage on cabbage (a) P.

xylostella larva (b) and pupa (c) in the field Although more than 130 parasitoid species are known that are effective in different life stages of the cabbage leaf moth, Diadegma and Diadromus belonging to the order Hymenoptera, Microplitis and Cotesia belonging to the Braconidae family and Oomyzus from the Eulophidae family are effectively used in the biological control (Sarfraz, 2007). However, generally these natural enemies cannot prevent pests or control enough doing damages since they cannot adapt to the high migration ability of the cabbage leaf moth (Talekar and Shelton, 1993; Avcı and Özbek, 1995). P. xylostella was first recorded in 1965 in collard fields in the Murgul district of Artvin (Alkan,1965). It was detected in the cabbage fields in Erzurum in 1995 (Avcı and Özbek,1995). Recently reported in Çanakkale in 2018 after that distributioned everywhere Brassicaeous family are produced (Atay et al., 2019). Further studies are needed to reveal

the effects of climate change on the expansion **of pests and**	4

how they become native to invasive pests in the world.

In this study, the effects **of global climate change on**	3

Plutella xylostella were discussed. 2. RISING TEMPERATURE EFFECTS ON PLUTELLA XYLOSTELLA Temperature is an important enviromental factor affecting biological, ecological and evolutionary development of living organisms (Sorensen, 2010). Rising temperature usually reduces the durations of biological stages and increase the rate of development in insects such as plasticity. Accordingly, earlier emergence and population activity of insects in temperate regions are associated with them (Thomsen et al., 2015). The distribution of many species is partially related to temperature changes (Kocsis and Hufnagel, 2011). It was investigated the changes in distribution range and phenology of pest species due to increasing temperatures in Japan (Kiritani, 2006). It was reported that more than 50 butterfly species (bu türlerin adları olursa iyi olur) showed a northward expansion and 10 butterfly species (hangi türler belli mi) were migratory in the Nansei Islands between 1966- 1987. It was thought that

global warming may also **be responsible for the** decrease **in** P. **xylostella** population **and the increase in Helicoverpa armigera and Trichoplusia ni**	5

. (nerede ? hangi ülke Japonya mı başka çalışmadan mı alıntı öyle ise referans olmalı) Temperature is reported as an abiotic factor influencing insect reproduction. Marcioro and Foerster (2012), examined effects of 10-32.5°C temperatures on reproduction in the Plutella xylostella. It has been determined that the fecundity and oviposition period of P. xylostella are negatively effected by

below 15 °C and above 25 °C , and the **population**	21

reaches the maximum level in these temperature ranges. The effects of a high temperature of 40 ºC for 3, 4 or 5 hour durations were investigated on Plutella xylostella (Zhang et al., 2013). A high 40 ºC temperature had no harmful acute effects on biological properties such as mortality of life stages, mating success or mating duration, longevity and the number of laid eggs (fecundity), but reduced egg hatching about 21 % on the first and the second days of high temperature stress. It is reported that high temperature exposure expended pre-mating periods in adults. Only a day of high temperature can have harmfull effects on female reproduction, fecundity and

egg hatching and thereby influence the population dynamics of the **diamondback moth** 11

. For insects, exposure to high temperatures can have adverse effects on survival and reproduction. The effects of an average daily temperature of 30 °C were examined on the adult stage of P. xylostella (Zhang et al., 2015a). It was determined that longevity, oviposition period and fertility decreased due to heat stress experienced in the larval and pupal stages, even if P. xylostella was not exposed to heat stress in

the adult stage. Zhang et al . (2015b) investigated **the** survival rate **of** 18

P. xylostella when exposed to 40 ºC in different biological stages, and then the survival rate and reproductive status. As a result, it was observed that the 1st instar exposed to heat stress had the lowest survival level, while the 3rd instar was relatively more resistant. While exposure to high temperature in the egg and 1st instar did not affect survival in the next stage, it was observed to be effective for the 3rd instar. It has been determined that heat stress experienced in pupa and adult stages has more negative effects on reproduction than heat stress experienced in egg and larval stages. Ngowi et al. (2017) examined some biological characteristics and population dynamics of P. xylostella at 6 different temperature levels, as well as evaluated the differences between the climate change scenarios of 2013 and 2055. The effects of temperature on different biological stages were also investigated, and optimum development temperatures

for eggs, larvae and pupae were 6

determined as 32.5, 33.5 and 33˚C, respectively. It was observed that extreme temperatures increased mortality rates, and it was determined as 53.

3%, 70.0% and 52.4% for eggs, **larvae and pupae, respectively** 6

. It was reported that the reproduction rate reached the highest level at 20 ºC. According to the 2055 model, it is predicted that there will be a decrease in the increase of the diamondback moth population at medium and low altitudes. If the expected scenario is realized, it is estimated that the population will decrease at high altitudes and the damage to the diamondback moth will decrease. Diadegma semiclausum is a Hymenopteran parasitoid that has been successfully used in biological control of Plutella xyostella in some regions (Furlong et al., 2013). It was examined the relative thermal requirements and temperature tolerance of Diadegma semiclausum and Plutella xylostella (Furlong and Zalucki, 2017). It has been determined that the optimum temperature required for the development of D. semiclausum is much lower than that of P. xylostella. This suggests that increasing global temperatures will negatively affect host-parasitoid interactions. Machekano et al. (2018) examined the thermal tolerance of another P. xylostella parasitoid, Cotesia vestalis. The results showed that Cotesia vestalis had lower thermal tolerance and heat resistance time than P. xylostella, and parasitoid survival rate was lower at lethal heat levels. Bahar et al. (2012) similarly reported that Diadegma insulare had a lower survival rate than P. xylostella under the influence of increasing temperature. It is concluded that this superiority of P. xylostella is due to its genetic structure (Lee, 2013). It has been reported that this large genome, which has the ability to process and respond to differences in the environment, with an extra 1412 unique genes, provides an advantage (Lee, 2013). A study was conducted to determine the morphological damage in the wing veins of P. xylostella caused by heat stress and the primary mechanism between insecticide resistance and adaptation. The results showed that the insecticide resistant P. xylostella exhibited a significant disadvantage against heat stress. Morphologically more damage was detected in the wing veins due to the heat stress of diamondback moth resistant to chlorpyrifos, an insecticide. In addition, it has been revealed that the expression of hsp genes in insects struggling with environmental stresses and the expression of genes related to apoptosis will cause much more apoptosis (Zhang et al., 2015). 3. EFFECTS OF INCREASING CO2 CONCENTRATION ON PLUTELLA XYLOSTELLA Changes in CO2 concentration effect plant physiology (Sallas et al., 2003). In relation to this situation, it is predicted that the host-parasitoid relationship will also be effected (Vuorinen et al., 2004). In a study, using FACE technology (free air gas concentration enrichment), an atmosphere model was created similar to the increase in CO2 and O2, which is the result of global climate change. It is reported that 57 % more insect damage was observed in soybeans due to increased CO2 concentration, and insecticide was used for pest management and prolongation of the experiment (Petzoldt and Seaman, 2007; Ögür and Tuncer, 2011). Several plant species are protected themselves by producing volatile compounds which were attracted

the natural enemies of herbivores. The effects of elevated atmospheric CO2 2

concentration were tested for the indirect defense mechanism, physiological properties for the white cabbage (Vuorinen et al., 2004).

The generalist predator Podisus **maculiventris** distinguished **between the odors of intact and** 2 **P. xylostella damaged plants** which are **grown at ambient CO2 concentration** , like better **the odor of the damaged plants. The specialist parasitoid** Cotesia **plutellae** choose **the odor of damaged plants**

at ambient CO_2 but did not detect damaged cv Lennox plants grown at elevated CO_2. The reports suggest that elevated atmospheric CO_2 concentration reduced the plant response caused by feeding and thereby guide to confusion of signaling 1

. Himanen et al. (2009) investigated the effects of biogenic volatile compound signals on the host-parasitoid relationship between P. xylostella and Cotesia vestalis in the presence of CO_2 and O_3, which cause high atmospheric pollution, on the oilseed crop rapeseed, Brassica napus. Although

low feeding damage was observed **in** herbivorous- **resistant plants** , it **was** 7

observed that it was attracted

C. vestalis females to their **host** P. xylostella **damaged plants** 7

. However, in the presence of high O_3 concentration, signaling to the parasitoid was found to be disfunctional in plants with low damage. 4. EFFECTS OF HEAVY RAINFALL ON PLUTELLA XYLOSTELLA As a result of global warming, it is estimated that the average precipitation and its intensity will increase on the earth's surface, but there will be drought in some regions. Although, the amount of precipitation falling on the earth's surface has increased by 1% in the last century. Most of this precipitation was in the northern hemisphere (Samways, 2005; Ögür and Tuncer, 2011). Physiology, phenology and geographical distribution of insects are effected by abiotic factors as well as biotic factors.

Some insects are sensitive to precipitation and die **or** move away **from** the plant in **heavy rains** 12

(Harrington ve ark., 2001). It is thought that precipitation will be as effective on parasitoids, hosts and diseases as temperatures. For example, it is predicted that fungal pathogens of insects will increase in areas with high humidity and decrease in areas that are arid (Petzoldt and Seaman, 2007; Ögür and Tuncer, 2011). The

changes in the duration and intensity of rainfall events are 3

predicted under anthropogenic global warming. When disturbed, P. xylostella larvae secrete a silky thread and hang on the leaf, clinging to it. However, heavy rains can prevent this behaviour (Kobori and Amano 2003). 5. CONCLUSIONS Due to global climate change, it is inevitable that the temperature and CO_2 concentration will increase and an unstable precipitation regime is inevitable. The negative impact of the agricultural ecosystem from this situation will lead to changes in increasing human population and resulting food needs in the future. Considering the studies carried out, global

climate change will cause crucial **changes in arthropod diversity, geographical distribution** 17

, population dynamics, host-parasitoid relationship, pest management and cost. It has been observed that Lepidopteran insects, which prefer mild conditions for optimum development, tend to migrate towards higher latitudes and altitudes. Increasing temperature in terrestrial areas may create suitable air currents that will allow the expansion of P. xylostella population towards the north. ACKNEWLEDGEMENTS

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