Eco. Env. & Cons. 30 (1) : 2024; pp. (108-112)
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ISSN 0971–765X

DOI No.: http://doi.org/10.53550/EEC.2024.v30i01.020

Impact of Climate Change Variables on Thrips Complex in Horticultural Crops and their Management: An Overview

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(Received 5 September, 2023; Accepted 26 October, 2023)

ABSTRACT

The model predicted species range in respect of discrimination of suitable and unsuitable areas for its occurrence both in current and future climatic scenarios. The model provided a good fit for species distribution with a high value of area under the curve (0.957). The jackknife test indicated annual mean temperature and precipitation were found to be the most important bioclimatic variable in determining the distribution of *T. parvispinus*. High suitability areas were predicted in the countries wherever its occurrence was reported with high discrimination ability of suitable and unsuitable areas. Key distinguishing morphological characters of *T. parvispinus* were illustrated through high-resolution scanning electron microscopic images. The identity of the thrips causing wide spread damage in chilli is confirmed through morphological and molecular approaches. Key identifying characters were described through high resolution scanning electron microscopic images for accurate identification of the species. MaxEnt model identified high-suitability regions for the potential establishment of *T. parvispinus* in India and other parts of the world. This study facilitates forecasting of further spread and also suggests imposing strict domestic quarantine measures to curtail its establishment in the new areas. Changing climate can alter the growth and development of herbivorous insects by changing the host plants, including nutrient quality and defensive chemicals/metabolites. Particularly in C3 plants, high atmospheric CO2 levels enhance plant photosynthetic efficiency, and this often results in a change in leaf tissue quality, in particular the carbon-to-nitrogen ratio, thereby decreasing the nutritional quality for the herbivore. Effect of climate change is more in temperate insects which affect their range expansion, host enemy synchrony and interspecific competition. Thrips are the major pest in both temperate and tropical ecosystem. It is very evident that thrips is expanding its geographical and host range. Example, *Thrips parvispinus* which is native to Taiwan & Indonesia, now spread to allover the world. One of the reasons behind this is a climate change. It mainly affects the horticultural crops and causes huge loss. In this, review we are going to know about major horticultural pests and its response to climate change.

Key words : *Climate change, Horticultural crops*

Introduction

Climate change as defined by the Intergovernmental Panel on Climate Change (IPCC) is a change in the state of the climate that can be identified (*e.g.* using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer (Lenny *et al.,* 2007). Climate change is now unequivocally proven by and supported by hundreds of scientific studies and will likely impact all organisms. In some locations, climate change can potentially increase horticultural production but it is generally believed that widespread detrimental impacts are on horticultural production. These atmospheric changes can impact plant growth, production and water usage. The main cause for global climate change is the increasing concentration of CO_2. According to the "Keeling curve," the CO_2 concentration recorded at the Mauna Loa Observatory in Hawaii (USA) increased from about 315 to 395 ppm from 1958 to 2013, and recently passed 415 ppm. This increase has serious implications for global climate change and its impact on nature and horticulture.

The greenhouse gases (GHGs) that contribute most to global climate change from the worst to least bad are as follows: (1) H_2O—water vapor; (2) CO_2—carbon dioxide; (3) NH_4—methane; (4) N_2O—nitrous oxide; (5) O_3—ozone. Carbon dioxide is a less effective GHG than other, but the more evenly distributed global concentration is increasing steadily, and it is currently the GHG causing the most rapid global temperature rise. In some cases, increasing CO_2, temperature, humidity, and other greenhouse gases might be beneficial in regions where crop production is limited by cold temperatures. On the other hand, climate change could negatively impact agriculture in regions where climate conditions are currently good for production. Some possible climate change impacts on agriculture include (1) droughts (2) floods (3) faster phenological development (4) inadequate chilling requirements (5) pollination affected by rainfall and other extreme events (6) frost and chill damage (7) the spread of new insects and diseasesand (8) lower or higher yield and quality due to warming and water relations during summer.

Impact of Climate Change on Horticulture

The established commercial varieties of fruits, vegetables and flowers will perform poorly in an unpredictable manner due to the aberration of climate. Melting of ice cap in the Himalayan regions will reduce the chilling effect required for the flowering of many horticultural crops like Apple, Saffron, Rhododendron and Orchid *etc.* Commercial production of horticultural plants particularly grown under open field conditions will be severely affected. Due to high temperature physiological disorders of horticultural crops will be more pronounced *e.g.* Spongy tissue of mango, fruit cracking of litchi, flower and fruit abscission in solanaceous fruit vegetables, *etc.* Air pollution also significantly decreased the yield of several horticultural crops and increases the intensity of certain physiological disorder like the black tip of mango.

Effect of Thrips in horticulture

Among the 5,500 (or more) well-described species of thrips (Thysanoptera: Thripidae) worldwide, nearly 1% are known as economically important pests. Owing to their polyphagous nature (ability to feed on multiple plants) and damage potential to nursery and greenhouse production, thrips inflict millions of dollars in loss annually. Thrips can reduce yield and/or the aesthetic or economic value of plants directly by causing feeding and egg laying injury, and indirectly by transmitting plant-damaging viruses to their hosts. Their small size (1–2 mm), tendency to hide in tiny spaces (cracks/crevices), high reproductive rate, and ability to survive in a wide range of climatic conditions help explain their significant representation on invasive pest lists of many countries. Recent Invasive thrips, *Thrips parvispinus* Karny reported in India, causing a widespread severe infestation in more than 0.4 million ha of chilli (*Capsicum annum* L.) growing areas. Thrips infestations can greatly impact regional and international trade of plant materials and products, due to the quarantine risks and damage associated with several species in the order.

Effect of Climate change on thrips

Climate change factors can lead to both direct and indirect effects on key agricultural thrips species. Direct effects include the rate of thrips development, reproduction, distribution, migration/ dispersal and adaptation to the new environment. Alternatively, indirect effects include host-plant interactions, natural enemies and insect relations.

Impact on Host metabolism

Comparative transcriptome analysis studies combined with corresponding phenotypic changes revealed the molecular mechanism of interaction between *F. occidentalis* and *P. vulgaris* under e CO_2. Inferred from the results, e CO_2 had different degrees of inhibition to the defense responses caused by thrips infestation in *P. vulgaris* leaf sap based on nutrients, plant hormones and secondary metabolites, making *P. vulgaris* leaves less resistant to thrips under e CO_2 compared to ambient CO_2 (a CO_2). Besides, the contents of glucose, trehalose, triglycerides and free fatty acids in *F. occidentalis* adults increased significantly after feeding on the *P. vulgaris* leaf sap with significantly increased soluble sugars content under e CO_2, which might lead to glucolipid metabolic disorders and increased food intake of *F. occidentalis* adults. The results indicated that decreased plant defence of *P. vulgaris* and increased food intake of *F. occidentalis* adults were combined to aggravate the thrips damage under e CO_2, providing a theoretical basis for the future occurrence trend of thrips under e CO_2.

Impact on dispersal and distribution

Climate change factors, primarily changes in temperature, can influence dispersal in thrips species. Insects are poikilotherms, in that their physiology is highly influenced by temperature. Insect flight has been shown to be influenced by increases in temperature with the flight muscles becoming more efficient and moving more rapidly (Machin *et al.*, 1962). Coupled with the fact that temperature directly influences metabolic rates, insects will, therefore, be able to fly faster and further at higher temperatures which can influence their dispersal (capabilities and the extent to which they will be distributed) within a region.

Impact on Growth and Development

Elevated CO_2 increased the contents of total amino acids, soluble sugar and soluble protein in host plant *P. vulgaris*. Resulted shortened the pre-adult duration (PAD) and longevity of *F. occidentalis*, lowered their survival rate and increased the weight and fecundity. PAD was positively correlated with the expression levels of br, Krh-1, JHEH and EIP in *F. occidentalis* larvae. The longevity of *F. occidentalis* female adults was negatively correlated with JHEH, but positively correlated with ER and EIP. The fecundity of *F. occidentalis* female adults was negatively correlated with ER and Vg, but positively correlated with JHEH. And also they have demonstrated that elevated CO_2 could enhance the nutrient quality of host plants and, therefore, accelerate the development and reproduction of *F. occidentalis*, which is regulated by JH, MH and Vg. (Qian *et al.*, 2019)

Impact on Gene Expression and Enzyme activity

Gene expression and enzyme activity of superoxide dismutase (SOD), peroxidase (POD), and glutathione-S-transferase (GST) in *F. occidentalis* studied to notice the effect of temperature. SOD, POD and GST enzyme activity increased significantly at 35–37^{o}C but declined as the temperature increased to 41^{o}C. In a time course study at 35 ^{o}C, SOD, POD and GST activities were significantly elevated at 0.5, 1 and 2 h in comparison to the control at 26^{o}C. Expression patterns were evaluated for the three antioxidant genes under high and low-temperature stress. In a time course study at –4^{o}C, SOD, POD and GST expression peaked at 1 h and declined at 2 h of exposure. In contrast, when transcription was monitored at 35 C, expression was lowest at 1 h and increased at 2 h. The results provide data that will be useful in deciphering the role of antioxidant enzymes in the adaptation *of F. occidentalis* to climate change (Yuvan *et al.*, 2021).

Impact on thrips reproduction

Changes in temperature are predicted to exert the greatest influence on thrips reproduction. However, other environmental factors such as humidity can influence the life parameters of thrips. Humidity changes can lead to an increase in the number of eggs laid by a species and larvae may emerge earlier than usual, generational time will be reduced and pest numbers can be increased. Many thrips species can sexually reproduce which increases genetic variation within the progeny and enables the population to be more adaptive to environmental changes. Asexually reproducing thrips species are able to quickly increase population numbers and can thus bring about damaging effects to crops over very short time periods. Climate change effects that promote thrips' reproduction such as temperature increases and suitable humidity conditions will enable thrips to have a more devastating effect on cultivated crops.

To explore the mechanism by which high temperatures suppress the growth of WFT populations, as well as the effects of multiple heat treatments on WFT, they recorded the duration of development and survival of immature WFT, and the sex ratio (female/male) and fecundity of F1, F2, F3 and F4 adult females that developed after a single heat shock, and those of F2 offspring after a double heat shock. they also recorded the longevity and ovarian structure of adult females of the treated generation (P) and their F1, F2 and F3 offspring after a single heat shock. In addition, they determined whether the effects of a heat shock on second-instar nymphs and adults differed. The results indicate that exposure of the parental generation to 41 °C or 45 °C for 2 h significantly prolonged the duration of development, reduced survival of immature WFT and altered the sex ratio (female/male), longevity and fertility of their adult female offspring. The effects of a heat shock of 41 °C persisted for two generations, whilst the effect of a heat shock of 45 °C persisted for three generations. In addition, double heat shocks had more pronounced effects than a single heat shock. Heat shock administered to second-instar nymphs resulted in a decrease in the number of ovarioles, whilst a heat shock administered to adults resulted in ovariole deformity. The maternal effects of heat shock in terms of the biological parameters of WFT, structure and number of ovarioles, are critical in determining the suppression of the growth at high temperatures of WFT populations (Sun *et al.*, 2019).

Impact on thrips abundance

Among the environmental factors studied, temperature had the strongest influence on the population dynamics and abundance of this thrips species. Temperature increases associated with climate change will extend growing seasons, extend the availability of hosts, and serve to facilitate an increase in pest numbers. It has also been suggested based on global climate models that the greatest temperature changes in the future will be in the winter (Bergant *et al.,* 2005).

Impact on the Host range of thrips

The polyphagous nature of thrips defines their host range and the number of plants on which they can feed, reproduce and survive. Oftentimes, pest thrips introduced into a new region on a single plant species, become established on native flora and later extend their host range by affecting new plant species in that area. The future climatic environment as influenced by climate change factors with an increase in CO_2 concentrations is projected to favor the proliferation of C3 weed species; C4 weeds could also benefit but with a slower response. However, studies have shown that a simultaneous increase in both CO_2 and temperature could favor C4 weeds (Porter *et al.,* 2019). This could increase host availability for thrips as they are known to emigrate from earlier flowering crops and wild hosts including weeds to a crop.

Impact of climate change on host plant resistance

Elevated CO_2 can alter plant resistance against insect herbivores. This study investigated the effect of elevated CO_2 on the callose synthesis involved in the resistance of *Phaseolus vulgaris* against *Frankliniella occidentalis*, which is one of the most important invasive insect pests worldwide. Elevated CO_2 elevated the silver damage, callose deposition, and the expression level of CalS3 and CalS10 genes involved in callose synthase (CalS) in thrips-infested bean leaves, while reducing PR2 gene expression related to the hydrolysis of callose. In addition, both infestation by thrips and mechanical damage increased the callose deposition in leaves and induced CalS and β-1,3-glucanases (BG) expression at both transcriptional and translational levels. Under ambient CO_2, callose content in the mechanically damaged plants (MDPs) and thrips-infested plants (TIPs) was positively correlated with CalS activity and the expression level of CalS3 and CalS10; BG activity was positively correlated with PR2 gene expression. Under elevated CO_2, callose content in MDPs and TIPs was negatively correlated with BG activity which also negatively correlated with the expression level of CalS10 and PR2. *F. occidentalis* feeding can induce callose synthesis and deposition in *P. vulgaris* leaves, especially under elevated CO_2. Specifically, genes associated with CalS defense are up-regulated, while the expression level of PR2 gene is downregulated. These results suggest that elevated CO_2 can modulate callose synthesis leading to a higher level of resistance in host plants against thrips infestation (Qian *et al.*, 2021)

Future Predictions and Models

The model predicted species range in respect of discrimination of suitable and unsuitable areas for its occurrence both in current and future climatic scenarios. The model provided a good fit for species distribution with a high value of area under the curve (0.957). The jackknife test indicated annual mean temperature and precipitation were found to be the most important bioclimatic variable in determining the distribution of *T. parvispinus*. High suitability areas were predicted in the countries wherever its occurrence was reported with high discrimination ability of suitable and unsuitable areas. Key distinguishing morphological characters of *T. parvispinus* were illustrated through high-resolution scanning electron microscopic images. The identity of the thrips causing wide spread damage in chilli is confirmed through morphological and molecular approaches. Key identifying characters were described through high resolution scanning electron microscopic images for accurate identification of the species. MaxEnt model identified high-suitability regions for the potential establishment of *T. parvispinus* in India and other parts of the world. This study facilitates forecasting of further spread and also suggests imposing strict domestic quarantine measures to curtail its establishment in the new areas.

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