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CURRENT APPROACHES TO PREVENTION AND INTEGRATED PEST CONTROL ON MAIZE CROP IN THE CONTEXT OF CLIMATE CHANGE – MINI REVIEW

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Abstract: Maize is a staple crop that plays a key role in global food security. It is a primary source of food for millions of people and provides essential raw materials for various industries, including animal feed and biofuel production. However, maize cultivation faces increasing challenges in the 21st century, in particular the negative impact of climate change. As our planet undergoes rapid climate change, the agricultural sector must adapt to ensure consistent and sustainable maize production. One of the critical challenges posed by climate change is the proliferation of pests that threaten maize crops. Rising temperatures, changing rainfall patterns and shifting ecological balances create favorable conditions for pests, allowing them to develop and evolve at an alarming rate. These changes not only compromise the quality and quantity of maize crops, but also increase dependence on plant protection treatments, which can have harmful effects on the environment and human health.

Keywords: *climate change, integrated pest management, maize*

INTRODUCTION

The use of climate crop forecasting models to anticipate and extend agronomic decision-making under the influence of climate change has gained notoriety in recent years. Climate change adaptation strategies should be one component of an integrated strategy that considers all aspects of agricultural production. In addition, pest management strategies need to be designed to cope with regional climate change and its uncertainties. In this context, some available options include sensitivity analyses and combined results obtained by using climate change scenarios designed in conjunction with sensitivity analyses for a specific geographical area, covering a wide range of variable values. This approach may prove a useful tool to assist pest management staff in developing adaptation measures in the face of changing environmental conditions.

Anticipated climate change

Crop simulation models (CSMs) or crop models are computerized representations of crop growth, development and yield that are simulated using mathematical equations (Basso et al., 2013). These models were developed to simulate the risks associated with crop management options in the context of climate change and variation.

They perform simulations of plant growth, development and yield in response to water supply, temperature, solar radiation and nutrients. The models describe growth, development and yield processes at the field level, with daily resolution, and require site-specific and spatially uniform weather data as input (Zare et al., 2016). These models (Fig.1) are useful in further investigating the relationships between weather, climate and crop yield (Vučetić, 2006).

As with other crops, the main challenge influencing maize growth and development is changing weather patterns, which cause variations in yield over the season (Lin et al., 2017).

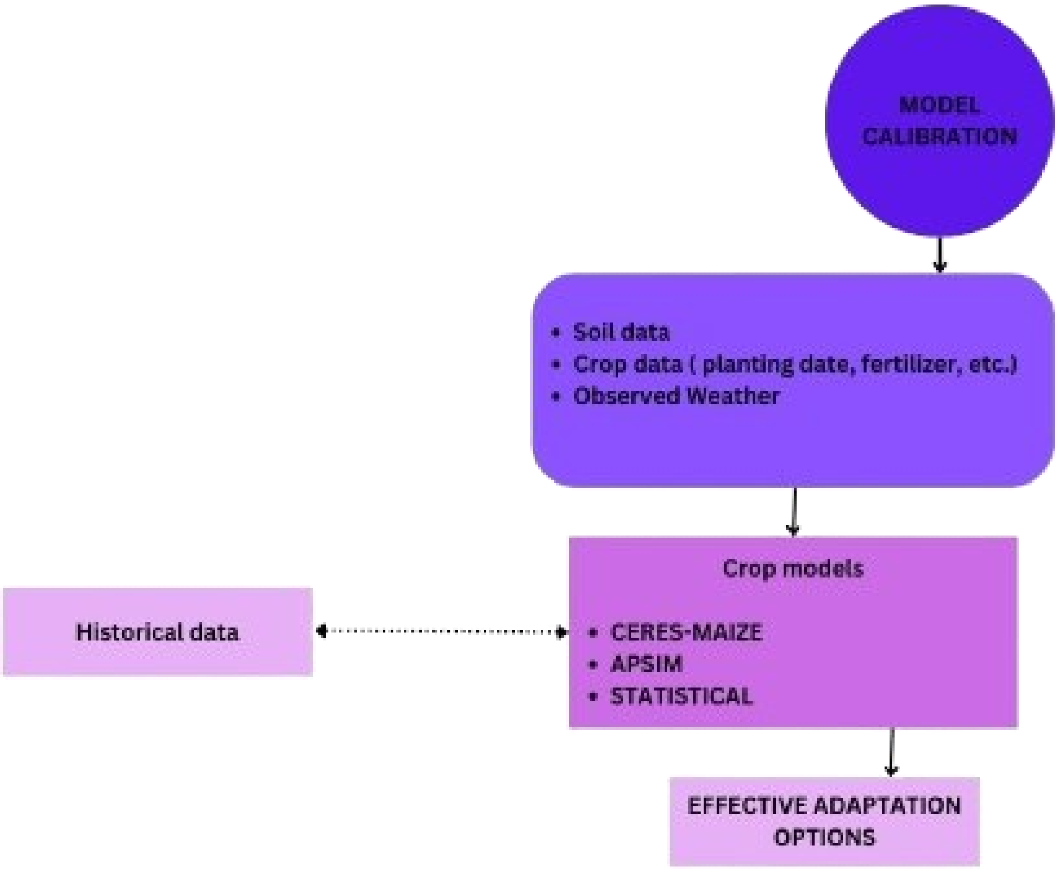

Figure 1. The Impact of Climate Change on Corn Yield Using Statistical Production Simulation Models. Source: Chisanga et al., (2017).

Other impacting factors include variable soil properties, agronomic crop management practices such as planting, fertilizer application, tillage, etc. (Tesfaye et al., 2018). Climate models, combined with species-specific environmental requirements, can be an effective tool for projecting possible global changes. By modelling pest risk in conjunction with host plant responses to climate change, the ability to predict the evolution of an insect infestation can be improved (Raza et. al., 2014). The crop models due to rising global temperature predict minor changes in world agricultural production as a result of the negative impact of climate change in the tropics and most developing countries, and these are offset by gains in temperate in industrial countries. Moderate warming of 1 and 2°C for wheat, maize, and rice in tropical countries would lead to the reduction of crop yields significantly. Temperature increases have multiple effects on crop growth, development and yield depending on the crop growth stage. Higher temperatures usually accelerate rates of crop development and this results in a shortened growing period, and typically but not always in lower crop yields. For example, temperature thresholds of 32 to 36°C for a few hours around flowering may strongly affect floret mortality/spikelet fertility, resulting in reduced yield that is dependent on the frequency and intensity of the stress - as has been reported for wheat, groundnut, sunflower, maize and rice.

Crop yields are most sensitive to heat stress at lowering and grain filling stages. Furthermore, a small temperature increase occurring at flowering and grain filling stages affect the crop, and this is not included in crop simulation model (Chisanga, 2017).

Effects of climate change on pests

Temperature increases associated with climate change could lead to the following effects:

(a) expansion of geographic range;
(b) increased winter survival rate;
(c) changes in population growth rate;
(d) increased number of generations;
(e) extended growing season;
(f) changes in crop-pest synchrony;
(g) changes in species interactions;
(h) increased risk of invasion by invasive pests.

Pest risk assessment

Pest risk analysis is an assessment of the likelihood of introduction and spread of a pest and the magnitude of the potential economic consequences in a given area, based on biological, scientific and economic evidence. This assessment can identify potential management options that reduce the risk to an acceptable level. It can also be used to set phytosanitary regulations. It is important to note that climate change has a significant impact on pest biology and epidemiology, which requires increased pest risk analysis activities at national, regional and international level. Climate change aspects also need to be integrated into plant health risk assessment (Lopian, 2018).

Contemporary and methods for combating common, weeds, and pests. Preventive measures

The most effective approach to preventing and limiting the international spread of pests through trade and transport is to regulate them through phytosanitary measures and ensure that best agricultural practices are applied to reduce the incidence of pests to a minimum (Fig. 2). According to studies by Carvajal-Yepes et al. (2019) and Giovani et al. (2020), phytosanitary import legislation is the first line of defence in preventing international spread. The objective of a phytosanitary regulatory system for importation is to prevent or limit the introduction of regulated pests via imported commodities, other regulated articles and passengers. This phytosanitary regulatory system for importation is typically composed of two components: a regulatory framework consisting of phytosanitary legislation, regulations and procedures, and an official service. Under preventive measures, treatments are implemented in response to known problems. Preventive approaches include hybrid selection, crop rotations, changing row spacing, adjusting plant density, using cover crops, using weed-free seed, preventing weed reproduction, using pest traps and selecting the date of maturity to avoid pest problems. Other possible cultural tactics include eliminating alternative hosts or locations that may favour pests and pathogens, such as cleaning field edges or waterways, and applying proper hygiene measures, such as cleaning agricultural ploughing and harvesting machinery when moving from field to field (Deneke, 2016).

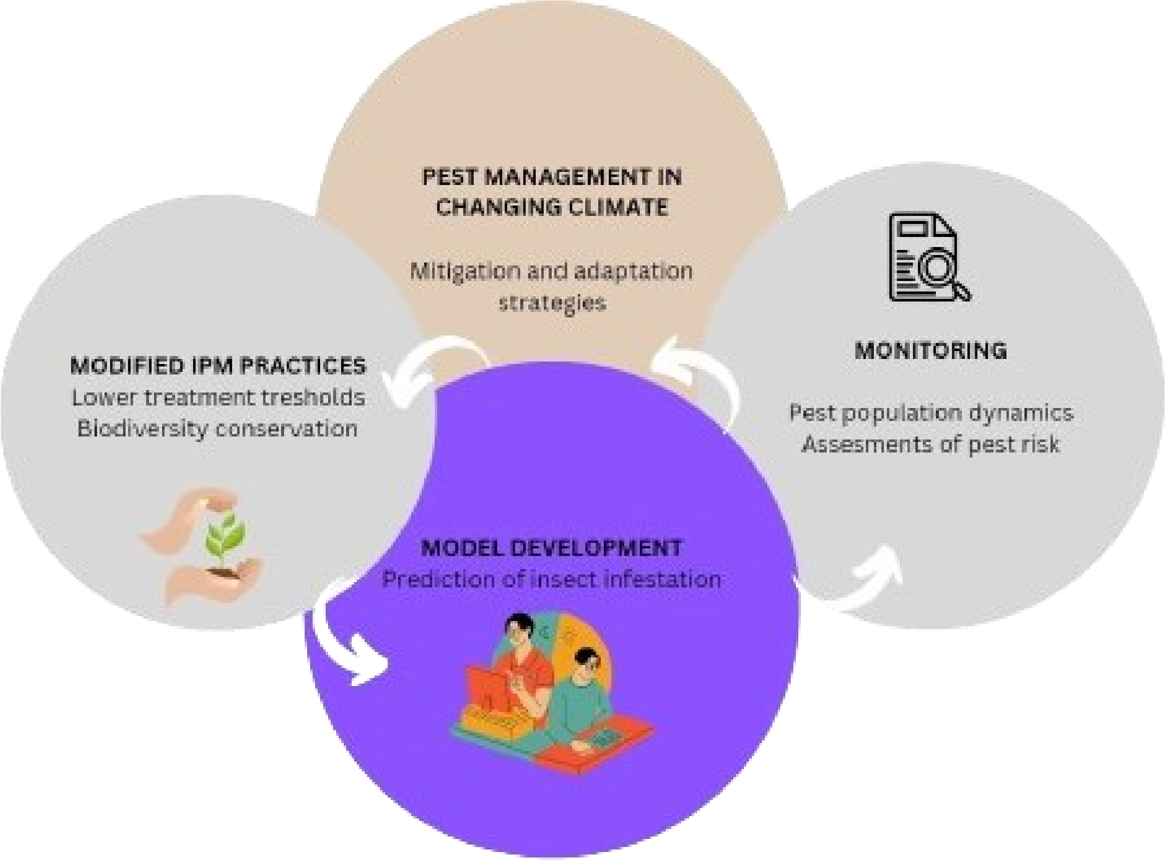

Figure 2. Monitoring Climate and Pest Populations and the Use of Forecasting Tools Based on Models. Source: Skendžić et al., (2021).

Adaptation and mitigation approaches and strategies for pest management in a changing climate

The most commonly mentioned strategies include modifying integrated pest management practices, monitoring climate and pest populations, and using model-based forecasting tools (Raza et al., 2014).

Integrated pest management is not new, but has gained interest as growers seek to reduce production costs while risk reduction of pest resistance to chemical and biological agents. IPM activities can include crop rotation, early harvesting, rotating pest control mechanisms, adjusting plant dates and populations, mechanical cultivation, applying appropriate fertilizers, using disease or insect resistant plant varieties, risk reduction of errors in applying chemical treatments and using biological control agents. Decisions on the need for control measures must be based on the most modern tools, such as forecasting methods and scientifically validated thresholds. Direct pest control tools are a last resort when intolerable economic losses cannot be prevented by indirect measures (Boller et al., 2004). FAO recommends a two-pronged strategy based on global and regional action and, above all, significant investment in improving existing early detection and control systems. Essentially, growers and researchers are designing IPM strategies to reduce negative environmental impacts while maximizing crop yields and economic returns (www.fao.org). Many IPM programs have focused on extensive knowledge-based decisions on how many pests can be tolerated before economic losses occur, known as economic thresholds or action thresholds. Environmental factors, such as drought stress, affect crop protection recommendations. When a crop suffers from drought stress, it is less able to cope with the additional stress caused by herbivorous insects, which can slightly reduce the economic threshold (Lamichhane et al., 2015).

Chemical control practices

Crop protection strategies vary across European regions due to distinct challenges posed by pests, weeds, and diseases. Predominantly, pesticides, including seed treatments, are the primary means of control across all regions. Herbicides constitute the primary component of the pesticide arsenal in every region, followed by insecticides, commonly administered through seed treatments or soil/foliar applications during high infestations. Fungicides are utilized as seed treatments or foliar depending on the infection level of the crop. Nevertheless, inequality in weed species, pest and disease diversity, and abundance among different European areas may complicate the implementation of low-dose substance options in certain countries.

Cultural control practices

In systems incorporating maize into rotation, the selection of rotational crop(s) emerges as a crucial determinant for managing pests, weeds, and diseases across all regions. A judicious choice of the rotational crop can be a strategic approach, prioritizing crops with positive agronomic impacts, such as disease tolerance or weed competitiveness, as opposed to market/price oriented crop choices.

The predominant method for controlling *Ostrinia nubilalis* (Hübner, 1796) involves crop resistance through Bt maize (GMO). Regrettably, the European Commission has granted authorization for only three new genetically modified (GM) varieties and renewed approvals for two others intended for food and animal feed, making this technology unavailable to the majority of farmers. Practices such as early sowing or delaying maize cultivation are deemed significant in combating *Fusarium* spp. and pests. Additionally, plant nutrition management is currently employed for controlling *Cochliobolus* spp., *Setosphaeria* spp., *Fusarium* spp., and weeds.

Mechanical control practices

Major (ploughing) and minor tillage currently play significant roles in disease control involving practices such as burying maize residues through inversion ploughing to reduce the survival of fungal pathogens, as well as weed management in various regions. In areas affected by *O. nubilalis*, major tillage is a prevalent practice for pest control, addressing concerns related to *Diabrotica virgifera* (LeConte, 1868) and wireworms, particularly in the south-western and southern regions of Europe. Conversely, minor tillage is recognized as an effective measure against *O. nubilalis* in the south-western region. In the central-eastern region, the removal or incorporation of crop residues into the soil is predominantly employed to combat *Fusarium* spp. related diseases and *O. nubilalis* larvae.

Modified cultural practices

Using early detection methods such as pheromone traps, smart traps, and video hyperspectral imaging holds significant promise as an advanced practice within Integrated Pest Management (IPM) for addressing pests and weeds. While biological control is not currently implemented on a large scale, utilizing *Trichogramma* spp. presents an advanced solution for managing *O.nubilalis*, even in non-Bt maize fields, and *Helicoverpa armigera* (Hübner, 1808). The conservation of wild flora or the establishment of flowering or grass strips along field margins to provide food and overwintering sites for natural enemies is steadily gaining attraction to farmers.

Breeding efforts have been successful in the development of high-yielding maize hybrids that are highly resistant to *Fusarium* spp. (Stuthman et al., 2007), or inbred lines with elevated resistance to *O. nubilalis* stalk tunnelling (Willmot et al., 2005). Innovative early detection methods of pests, weeds and diseases have been developed, although not extensively implemented, using pheromone traps or acoustic detection technique (detecting insects by species specific sounds) for pests (Johnson et al., 2007), specific molecular markers and real-time PCR detection techniques for fungal, bacterial and virus diseases (Ratti et al., 2004) and robotic platforms for weed population mapping in the field (Bak and Jakobsen, 2004). However, the implementation cost of this tool is often high (i.e. synthetic pheromones for mating disruption and their application) due to the small and specialized market for such products (Cook et al., 2007).

The use of pheromones and allelochemicals is an important method by which insects perceive their environment. They play a significant role in various IPM techniques such as biological control, mating disruption, monitoring and trapping (Heuskin et al., 2011). As the climate warms and the microclimate becomes more variable, it is anticipated that the use of pheromones and allelochemicals in their current form will become less effective and may require a synergist or other adjuvant to reduce their volatility under high temperature conditions (Andrew et al. 2017). In addition, some biopesticides based on viruses, fungi, bacteria and entomopathogenic nematodes are highly susceptible to environmental changes. An increase in temperature and a decrease in relative humidity may make some of these management techniques less effective, and a similar outcome is expected for synthetic insecticides (Nihal, 2020). In this context, the focus should be on the development of new pest management strategies and possible new formulations of insecticides as well as attractants and repellents.

CONCLUSIONS

The adaptive capacity of agricultural production systems will depend on several biological, economic, and sociological factors. The ability of local communities to adapt their pest management practices will depend on their physical, social and financial resources (Sutherst et al., 2011). With climate change and the acceleration of global trade, uncertainties and frequency of occurrence of existing and new pests will increase. Increasing the ability to adapt rapidly to disturbances and climatic changes will therefore become all the more important (Barzman et al., 2015). There is an urgent need to better understand the effects of global warming on the performance of many synthetic insecticides, their persistence in nature, and also the development of resistance to certain insecticides in pest populations. (Vadez et. al., 2012). Therefore, it is necessary to consider the use of effective biological control agents or the introduction of pest-resistant crop varieties obtained through conventional genetic technologies or genetic engineering (Gomez-Zavaglia et. al., 2020). Specific and compatible components of control (such as pest and weed control, nutrient management strategies and proper use of techniques) need to be identified through practical research and farmer involvement (Cairns et. al., 2012).

A long-term financial commitment is essential to fully understand the impacts of ongoing climate change and the risk associated with pests. For this reason, it is crucial to select 'significant impact areas' (climate-sensitive production areas) for the implementation of long-term research activities. In addition, national governments should direct investments towards strengthening national surveillance systems and related structures in order to be able to react quickly to possible biological invasions.

Current pest control strategies such as detection, forecasting, physical control, chemical control and biological control can be intensified to cope with climate change. (Heeb et. al., 2019).

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