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Seasonal Incidence and Population Dynamics of Insect Pests of Maize under Changing Climatic Conditions

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Maize (*Zea mays* L.) ranks among the most widely cultivated cereal crops globally and contributes significantly to food security, livestock production, and industrial development. India is one of the leading producers of maize, with cultivation extending across diverse agro-climatic regions. Despite improvements in varieties and crop management, insect pests remain one of the major constraints limiting maize productivity. Climate change has emerged as an important driver influencing agricultural ecosystems. According to the Intergovernmental Panel on Climate Change (IPCC, 2023), global temperatures continue to rise, accompanied by changes in rainfall distribution, increased frequency of extreme weather events, and elevated atmospheric carbon dioxide concentrations. These changes directly and indirectly affect insect biology, including survival, reproduction, development, migration, and host utilization. Insects are ectothermic organisms whose physiological activities are highly dependent on environmental temperature. Even slight changes in climatic conditions may significantly influence pest outbreaks. Consequently, several maize insect pests have expanded their geographical range, increased their seasonal abundance, and developed multiple generations within a single cropping season. Understanding these ecological changes is essential for designing adaptive pest management strategies under changing climatic scenarios.

Major Insect Pests of Maize

Maize is attacked by numerous insect species throughout its growth stages. The most economically important pests include:Fall armyworm (*Spodoptera frugiperda*), Stem borers (*Chilo partellus*, *Sesamia inferens*), Shoot fly (*Atherigona spp.*), Corn aphid (*Rhopalosiphum maidis*), Maize leafhopper (*Cicadulina mbila*), Pink stem borer (*Sesamia inferens*), Armyworms and cutworms. Among these, fall armyworm has become one of the most destructive invasive pests worldwide since its introduction into Asia and Africa.

Seasonal Incidence of Maize Insect Pests

Seasonal incidence refers to the occurrence and abundance of insect populations during different crop growth stages and seasons. Pest incidence varies depending on weather conditions, cropping pattern, host availability, and natural enemy populations.

Stem borers generally infest maize during the early vegetative stage, causing dead hearts and stem tunneling. Their population usually increases during warm and humid conditions with temperatures ranging from 25–30°C.The fall armyworm attacks maize from seedling emergence to tasseling. Peak infestation commonly occurs during vegetative growth when moderate temperature and high relative humidity prevail. Continuous cultivation of maize throughout the year has enabled this pest to survive across seasons. Corn aphids generally appear during reproductive stages under relatively cool and dry weather. Their populations often increase rapidly under moderate temperatures and decline during heavy rainfall due to washing off of colonies. Shoot fly infestation is usually higher during delayed sowing and dry environmental conditions. Young seedlings remain highly susceptible during the first three weeks after emergence.

Influence of Climate Change on Population Dynamics

Climate change has significantly altered the population dynamics of maize insect pests through several mechanisms.

Rising Temperature: Temperature directly regulates insect metabolism and developmental rate. Increased temperatures generally shorten the life cycle of insects, enabling more generations within a cropping season. Studies have shown that higher temperatures accelerate egg hatching, larval development, and adult reproduction in many lepidopteran pests. However, extremely high temperatures exceeding the thermal tolerance of insects may reduce survival, although many pest species demonstrate remarkable adaptability through behavioral and physiological adjustments.

Changing Rainfall Pattern: Rainfall influences insect populations through its effects on host plant growth and pest survival. Moderate rainfall creates favorable humidity for pest multiplication, whereas excessive rainfall may physically remove eggs, larvae, and aphid colonies. Erratic monsoon patterns often result in asynchronous crop establishment, providing continuous host availability and facilitating pest persistence over extended periods.

Relative Humidity: Relative humidity affects egg viability, larval survival, and adult longevity. High humidity generally favors stem borers, armyworms, and fall armyworm development, while prolonged dry conditions may suppress certain fungal pathogens that naturally regulate pest populations.

Elevated Carbon Dioxide: Increasing atmospheric carbon dioxide alters plant physiology by modifying leaf chemistry and nutrient composition. Reduced nitrogen concentration in plant tissues may encourage insects to consume greater quantities of foliage to meet nutritional requirements, potentially increasing crop damage.

Population Dynamics of Major Maize Pests

Population dynamics describe fluctuations in insect populations over time due to interactions among climatic conditions, host plants, natural enemies, and agricultural practices. The fall armyworm exhibits remarkable reproductive potential, with females capable of laying over 1,000 eggs during their lifespan under favorable conditions. Warmer climates accelerate population buildup, allowing multiple overlapping generations each year. Stem borer populations are closely associated with temperature accumulation measured as degree days. Early sowing often reduces infestation because crop growth escapes the peak emergence of larvae. Aphid populations frequently increase rapidly under mild temperatures (20–25°C) with low rainfall. These insects also act as vectors of viral diseases, increasing indirect crop losses.

Natural enemies, including parasitoids, predators, spiders, lacewings, ladybird beetles, and entomopathogenic fungi, play an important role in regulating pest populations. Climate change may disrupt the synchronization between pests and their natural enemies, reducing biological control efficiency.

Implications for Integrated Pest Management

Integrated Pest Management (IPM) strategies to ensure sustainable maize production. An effective IPM approach begins with timely sowing, which helps the crop escape periods of peak pest activity and reduces the risk of severe infestations. Regular field scouting, supported by pheromone trap monitoring, enables early detection of pest populations and facilitates timely management decisions. Conservation of natural enemies such as parasitoids, predators, and pollinators should be encouraged through the judicious use of insecticides, thereby enhancing biological regulation of pest populations. The cultivation of resistant or tolerant maize hybrids further strengthens crop resilience against major insect pests. Biological control agents, including *Trichogramma* spp., *Telenomus remus*, and entomopathogenic fungi, offer environmentally safe alternatives for suppressing pest populations. Chemical control should be implemented only when pest populations exceed the economic threshold level, with preference given to selective insecticides that minimize adverse effects on beneficial organisms. Additionally, weather-based pest forecasting systems that utilize temperature, relative humidity, and rainfall data can improve the accuracy of predicting pest outbreaks and support timely interventions. The integration of advanced technologies such as remote sensing, artificial intelligence (AI), and Geographic Information Systems (GIS) further enhances real-time pest surveillance, risk assessment, and decision-making. Collectively, these climate-smart IPM strategies improve pest management efficiency, reduce environmental contamination, delay the development of insecticide resistance, and contribute to the long-term sustainability of maize production under changing climatic conditions.

Future Research Priorities

Future research should focus on developing predictive models integrating climate projections with insect phenology. Long-term monitoring of pest populations across agro-climatic zones will improve forecasting accuracy. Genomic studies may identify adaptive mechanisms enabling insects to tolerate changing climates, while advances in digital agriculture can facilitate early warning systems for farmers. Strengthening ecological research on natural enemies under variable climatic conditions will also support sustainable pest management.

Conclusion

Changing climatic conditions have significantly influenced the seasonal incidence and population dynamics of insect pests affecting maize. Rising temperatures, altered rainfall patterns, increased humidity variability, and elevated atmospheric carbon dioxide collectively contribute to greater pest survival, faster reproduction, geographical expansion, and more frequent outbreaks. Among the major pests, the fall armyworm has emerged as a particularly serious threat under warm climatic conditions. Effective management requires continuous surveillance, weather-based forecasting, conservation of natural enemies, resistant cultivars, and integrated pest management practices tailored to local agro-ecological conditions.