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BIOLOGICAL CONSEQUENCES OF CLIMATE CHANGE ON ARTHROPOD BIODIVERSITY AND PEST MANAGEMENT

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Global warming and climate change will trigger major changes in geographical distribution and population dynamics of insect pests, insect – host pant interactions, activity and abundance of natural enemies, and efficacy of crop protection technologies. Changes in geographical distribution and incidence will affect both crop production and food security. Insect pests presently confined to tropical and subtropical regions will move to temperate regions along with a shift in the areas of production of their host plants, while distribution and relative abundance of some insect species vulnerable to high temperatures in the temperate regions may decrease as a result of global warming. The relative efficacy of pest control measures such as host-plant resistance, natural enemies, bio-pesticides, and synthetic chemicals is likely to change as a result of global warming and climate change. There is an urgent need to assess the efficacy of various pest management technologies under diverse environmental conditions, and develop appropriate strategies for pest management to mitigate the adverse effects of climate change.

INTRODUCTION

Insect pests cause an estimated annual loss of 13.6% globally, and the extent of losses in India has been estimated to be 17.5% (Dhaliwal et al. 2010). The pest associated losses likely to increase as a result of changes in crop diversity and climate change. *Climate change and climate variability will have major implication* for water availability forest cover, biodiversity, crop production, and food security (Fig. 1) Changes in rainfall pattern are of greater importance for agriculture than the annual changes in temperature, especially in regions where lack of rainfall may be a limiting factor for crop production. Geographical distribution of tropical and subtropical insect pests will extend along with shifts in the areas of production of their host plants, while distribution and relative abundance of some insect species vulnerable to high temperatures in the temperate regions may decrease. High mobility and rapid population growth will increase the extent of losses due to insect pests. Current estimates of changes in climate indicate an increase in global mean annual temperatures of 1°C by 2025, and 3°C by the end of the next century, and the date at which an equivalent doubling of CO_2 will be attained is estimated to be between 2025 and 2070, depending on the level of emission of greenhouse gasses (IPCC 1990; Crowley 2000) (Fig. 2). Mean annual temperature changes between 3 and 6°C are estimated to occur across Europe, with greatest increases occurring at high latitudes.

IMPACT ON GLOBAL WARMING ON ARTHROPOD DIVERSITY AND EXTINCTION OF SPECIES

Arthropods (insects, spiders, and mites) are the most diverse group of organisms, which can serve as useful indicators of the effect of global warming and climate change on different agro-ecosystems (Table 1). Arthropods are the most diverse component of terrestrial ecosystems and occupy a wide variety of functional niches and microhabitats (Kremen et al. 1993). Responses of arthropods to pollution depend on both temperature and precipitation in such a way that ecosystem-wide adverse effects are likely to increase under predicted climate change (Zvereva and Kozlov 2010). Consequences of temperature increases of 1 to 2°C will be comparable in magnitude to the currently seen climate change in the Antarctic (**Bokhorst et al. 2008**). Speciation takes between 100 and 1,000,000 years, providing between 10 and 10,000 new species per year, and 99.9% of all species that ever lived have become extinct. We are now living through the sixth extinction spasm, which is largely driven by human activities. The current extinction rates are 100 to 1,000 times greater than what has happened earlier. Nearly 45 and 275 species are going extinct everyday as a result of human activities (**Bokhorst et al. 2008**).

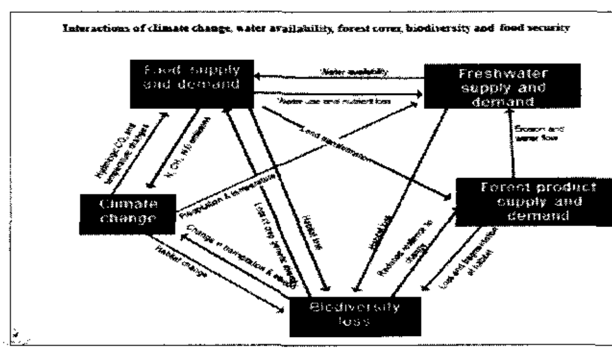

Fig. 1. Likely temperature increase over the next 100 years (Crowley 2000)

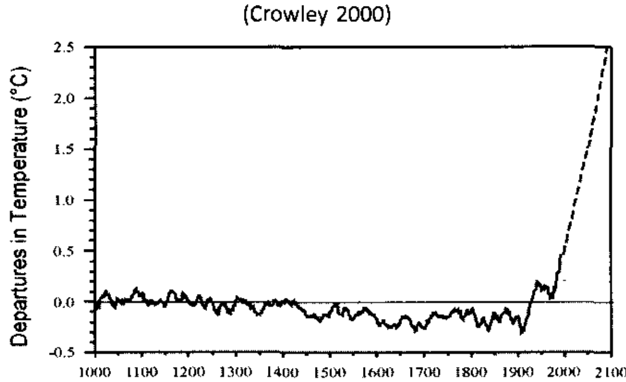

Table 1. Species diversity among different groups of organisms.

Organisms	Number of species
Viruses, algae, protozoa, etc..	80,000
Bacteria	4,000
Fungi	72,000
Plants	270,000
Animals: Invertebrates (insects)	1,360,000
Animals: Vertebrates	48,500
Total	**1,834,500**

EFFECT ON GEOGRAPHIC DISTRIBUTION AND POPULATION DYNAMICS OF INSECT PESTS

Low temperatures are often more important than high temperatures in determining geographical distribution of insect pests. Increasing temperatures may result in a greater ability to overwinter in insect species limited by low temperatures at higher latitudes, extending their geographical range (EPA 1989; Hill and Dymock 1989). Spatial shifts in distribution of crops under changing climatic conditions will also influence the distribution of insect pests in a geographical region (Parry and Carter 1989). However, whether or not an insect pest would move with a crop into a new habitat will depend on other environmental conditions such as the presence of overwintering sites, soil type, and moisture e.g., populations of the corn earworm (*Heliothis zea* (Boddie) in the North America might move to higher latitudes/altitudes, leading to greater damage in maize and other crops (EPA 1989). For all the insect species, higher temperatures, below the species' upper threshold limit, will result in faster development, resulting in rapid increase of pest populations as the time to reproductive maturity is reduced. In addition to the direct effects of temperature changes on development rates, increases in food quality due to plant stress may result in dramatic increases in growth of insect pest populations, while the growth of certain insect pests may be adversely affected (Maffei et al. 2007). Pest outbreaks are more likely to occur with stressed plant's as a result of weakening of plants' defensive system, and thus, increasing the level of susceptibility to insect pests. Global warming will lead to earlier infestation by *Helicoverpa armigera* (Hub.) in North India (Sharma 2010), resulting in increased crop loss. An increase of 1 and 2°C in temperature will cause northward shifts in the potential distribution of the European corn borer, *Ostrinia nubilalis* (Hub.) of up to 1,220 km, with an additional generation in nearly all regions where it is currently known to occur (Porter et al. 1991). Overwintering of insect pests will increase as a result of climate change, producing larger spring populations as a base for a build-up in numbers in the following season. Many insects such as *Helicoverpa* spp. are migratory, and therefore, may be well adapted to exploit new opportunities by moving rapidly into new areas as a result of climate change (Sharma 2005).

EFFECTS ON POLLINATORS

Altered profiles of pollinators/scavengers

- Extinction, and or emergence of new pollinators/scavengers
- Changes in composition of pollinators
- Asynchrony in pollinator activity and plant phenology
- Landscape changes due to change in pollinators and scavengers

EFFECTS OF CLIMATE CHANGE ON PEST MANAGEMENT

Effects on expression of resistance to insect pests. Host plant resistance to insects is one of the most environmental friendly components of pest management. However, climate change may alter the interactions between the insect pests and their host plants (Sharma et al. 2012b). Resistance to sorghum midge, observed in India, breaks down under high humidity and moderate temperatures in Kenya (Sharma et al. 1999). There will be increased impact on insect pests which benefit from reduced host defenses as a result of the stress caused by the lack of adaptation to sub-optimal climatic conditions. Problems with new insect pests will occur if climatic changes favor the introduction of non-resistant crops or cultivars. The introduction of new crops and cultivars to take advantage of the new environmental conditions is one of the adaptive methods suggested as a possible response to climate change (Parry and Carter 1989).

Insect - host plant interactions will change in response to the effects of CO_2 on nutritional quality and secondary metabolites of the host plants. Increased levels of CO_2 will enhance plant growth, but may also increase the damage caused by some phytophagous insects (Coviella and Trumble 1999). The effects of increased atmospheric CO_2 on herbivory will not only be species-specific, but also specific to each insect-plant system. Increased CO_2 may also cause a slight decrease in nitrogen-based defenses (e.g., alkaloids) and a slight increase in carbon-based defenses (e.g., tannins). Lower foliar nitrogen due to CO_2 causes an increase in food consumption by the herbivores up to 40%, while unusually severe drought increases the damage by insect species such as spotted stem borer, *Chilo partellus* (Swin.) in sorghum (Sharma et al. 2005).

Effect on effectiveness of transgenic crops. Environmental factors such as soil moisture, soil fertility, and temperature have strong influence on the expression of *Bt* toxins in transgenic plants (Sachs et al. 1998). Cotton bollworm, *Heliothis virescens* (F.) destroyed *Bt* cottons due to high temperatures in Texas, USA (Kaiser 1996). Similarly, *H. armigera* destroyed the cotton crop in the second half of the growing season in Australia because of reduced production of *Bt* toxins in the transgenic crops. Possible causes for the failure of insect control may be: inadequate production of the toxin protein, effect of environment on transgene expression, locally resistant insect populations, and development of resistance due to inadequate management (Sharma and Ortiz 2000). It is therefore important to understand the effects of climate change on the efficacy of transgenic plants for pest management.

Activity and abundance of natural enemies. Relationships between insect pests and their natural enemies will change as a result of global warming, resulting in both increases and decreases in the status of individual pest species. Changes in temperature will also alter the timing of diurnal activity patterns of different groups of insects, and changes in interspecific interactions could also alter the effectiveness of natural enemies for pest management (Hill and Dymock 1989). Quantifying the effect of climate change on the activity and effectiveness of natural enemies will be a major concern in future pest management programs. The majority of insects are benign to agro-ecosystems, and there is much evidence to suggest that this is due to population control through interspecific interactions among insect pests and their natural enemies (pathogens, parasites, and predators). Oriental armyworm, *Mythimna separata* (Walk.) populations increase during extended periods of drought (which is detrimental to the natural enemies), followed by heavy rainfall (Sharma et al. 2002). Aphid abundance increases with an increase in CO_2 and temperature, however, the parasitism rates remain unchanged in elevated CO_2. Temperature not only affects the rate of insect development, but also has a profound effect on fecundity and sex ratio of parasitoids (Dhillon and Sharma 2009). The interactions between insect pests and their natural enemies need to be studied carefully to devise appropriate methods for using natural enemies in pest management.

Bio-pesticides and synthetic insecticides. There will be an increased variability in insect damage as a result of climate change. Higher temperatures will make dry seasons drier, and conversely, may increase the amount and intensity of rainfall, making wet seasons wetter than at present. Current sensitivities on environmental pollution, human health hazards, and pest resurgence are a consequence of improper use of synthetic insecticides (Sharma 2012a). Natural plant products, entomopathogenic viruses, fungi, bacteria, and nematodes, and synthetic pesticides are highly sensitive to the environment. Increase in temperatures and UV radiation, and a decrease in relative humidity may render many of these control tactics to be less effective, and such an effect will be more pronounced on natural plant products and the biopesticides. Therefore, there is a need to develop appropriate strategies for pest management that will be effective under situations of global warming in future. Farmers will need a set of pest control strategies that can produce sustainable yields under climatic change.

CONCLUSIONS

The relationship between the inputs costs and the resulting benefits will change as a result of changes in insect-plant interactions. This will have a major bearing on economic thresholds, as greater variability in climate will result in variable impact of pest damage on crop production. Increased temperatures and UV radiation, and low relative humidity may render many of these control tactics to be less effective, and therefore, there is a need to address these issues on an urgent basis for sustainable crop production and food security.

REFERENCES

Bokhorst, S., Huiskes, A., Convey, P., van Bodegom, P.M., and Aerts, R. 2008. Climate change effects on soil arthropod communities from the Falkland Islands and the Maritime Antarctic. *Soil Biology and Biochemistry* 40: 1547-1556.

Coviella, C.E. and Trumble, J.T. 1999. Effects of elevated atmospheric carbon dioxide on insect-plant interactions. *Conservation Biology* 13: 700-712.

Crowley, T.J. 2000. Causes of climate change over the past 1000 years. *Science* 289: 270-277.

Dhaliwal, G.S., Jindal, V., and Dhawan, A.K. 2010. Insect pest problems and crop losses: Changing trends. *Indian Journal of Ecology* 37: 1-7.

Dhillon, M.K. and Sharma, H.C. 2009. Temperature influences the performance and effectiveness of field and laboratory strains of the ichneumonid parasitoid, *Campoletis chlorideae*. *BioControl* 54: 743-750.

Environment Protection Agency (EPA). 1989. *The potential Effects of Global Climate Change on the United States*. Vol 2: National Studies. Review of the Report to Congress, US Environmental Protection Agency, Washington DC, 261 pp.

Hill, M.G. and Dymock, J.J. 1989. *Impact of Climate Change: Agricultural/Horticultural Systems*. DSIR Entomology Division Submission to the New Zealand Climate Change Program. Auckland, New Zealand: Department of Scientific and Industrial Research. 16 pp.

IPCC. 1990. *The Potential Impacts of Climate Change on Agriculture and Forestry*. Intergovernmental Panel on Climate Change. Geneva and Nairobi, Kenya: World Meteorological Organization and UN Environment Program. 55 pp.

Kaiser, J. 1996. Pests overwhelm Bt cotton crop. *Nature* 273: 423.

Kremen, C., Colwell, R.K., Erwin, T.L., Murphy, D.D., Noss, R.F., and Sanjayan, M.A. 1993. Terrestrial arthropod assemblages: Their use in conservation planning. *Conservation Biology* 7: 796-808.

Maffei, M.E., Mithofer, A., and Boland, W. 2007. Insects feeding on plants: Rapid signals and responses proceeding induction of phytochemical release. *Phytochemistry* 68: 2946-2959.

Parry, M.L. and Carter, T.R. 1989. An assessment of the effects of climatic change on agriculture. *Climatic Change* 15: 95-116.

Porter, J.H., Parry, M.L., and Carter, T.R. 1991. The potential effects of climate change on agricultural insect pests. *Agricultural and Forest Meteorology* 57: 221-240.

Sachs, E.S., Benedict, J.H., Stelly, D.M., Taylor, J.F., Altman, D.W., Berberich, S.A., and Davis, S.K. 1998. Expression and segregation of genes encoding Cry1A insecticidal proteins in cotton. *Crop Science* 38: 1-11.

Sharma, H.C. (ed.). 2005. Heliothis/Helicoverpa *Management: Emerging Trends and Strategies for Future Research*. New Delhi, India: Oxford & IBH, and Science Publishers, USA. 469 pp.

Sharma, H.C. 2010. Effect of climate change on IPM in grain legumes. In: *5th International Food Legumes Research Conference (IFLRC V), and the 7th European Conference on Grain Legumes (AEP VII)*, 26 – 30 th April 2010, Anatalaya, Turkey.

Sharma, H.C. 2012a. Climate change effects on activity and abundance of insects: Implications for Crop Protection and Food Security. In: *Combating Climate Change: An Agricultural Perspective* (Kang, M.S. and Banga, S.S, eds.). Taylor and Francis, Boca Raton, Florida, USA.

Sharma, H.C. 2012b. Effect of global warming on insect – host plant – environment interactions. In: *24th International Congress of Entomology*, 19-24 Aug 2012, Daegu, South Korea.

Sharma, H.C. and Ortiz, R. 2000. Transgenics, pest management, and the environment. *Current Science* 79: 421-437.

Sharma, H.C., Dhillon, M.K., Kibuka, J., and Mukuru, S.Z. 2005. Plant defense responses to sorghum spotted stem borer, *Chilo partellus* under irrigated and drought conditions. *International Sorghum and Millets Newsletter* 46: 49-52.

Sharma, H.C., Mukuru, S.Z., Manyasa, E., and Were, J. 1999. Breakdown of resistance to sorghum midge, *Stenodiplosis sorghicola*. *Euphytica* 109:131-140.

Sharma, H.C., Sullivan, D.J., and Bhatnagar, V.S. 2002. Population dynamics of the Oriental armyworm, *Mythimna separata* (Walker) (Lepidoptera: Noctuidae) in South-Central India. *Crop Protection* 21: 721-732.

Zvereva, E.L. and Kozlov, M.V. 2010.Responses of terrestrial arthropods to air pollution: a meta-analysis. *Environmental Science Pollution Research International* 17: 297-311.