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Dynamics of pesticides under changing climatic scenario

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Pesticide consumption is ever increasing in spite of many concerns pertaining to human health and hazards. Also, biodiversity on the globe is being affected by the pesticide left over in the environment. The journey of synthetic pesticide started with the introduction of DDT, and now we have more than 1055 different pesticides in our arsenal to combat pests and diseases in crop fields to secure foods for 7.8 billion population. The growth of pesticide usage is significant and it was estimated to be around 3.5 million tonnes by 2020. Many countries are restricting the use of pesticides in agriculture including China, where pesticide consumption is at maximum. In India, many non-proprietary pesticides are going to be phased out in coming years. However, these efforts could not minimize the overall global pesticide consumption because of increasing pest pressure on agricultural crops. Many factors are involved in the growth of pest pressure; climate change is among them.

Each element of climate change influences the growth of biological members of an ecosystem. As per the IPCC definition of climate change, major parameters are the rise of global temperature, the elevation of carbon dioxide concentration in the atmosphere, erratic rainfall, and change in radiation (Bloomfield et al. 2006; Jackson et al. 2011; Noyes et al. 2009; Rosenzweig et al. 2001; Scherm 2004). These changes have direct and/or indirect impact on the living organisms in an agricultural ecosystem, including crops and their associated pests. In general, the increase in temperature and carbon dioxide favors the photosynthetic activity, in consequence the plant growth. It will influence all the pests, i.e., weeds, pathogen, and insects either way.

Differential growth pattern in crops and weeds is expected due to climate change and it may have more repercussions on weed management in general. But, the effects of climate change on the dynamics of crop–weed interactions are likely to vary by region and crop type. As the crop–weed interactions are influenced by various biotic and abiotic factors, localized changes in these factors may alter the balance either side. Changes in carbon dioxide level and temperature are likely to influence weeds significantly and that would affect crop–weed balance or lead to weed invasion. Research output has been shown that a higher level of CO_2 concentration can stimulate the growth and development of hundreds of plant species significantly (Kimball and Idso 1983; Semenov et al. 1993; Sage 1995). Plants vary in their response to CO_2 because of differential photosynthetic pathways, i.e., C_3 and C_4. The differential response by C_3 and C_4 plants to higher CO_2 is specifically relevant to crop–weed competition because most of the crops are C_3 plants and most of the weeds are C_4 plants. In

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general, most of the studies related to crop–weed competition concluded that where the photosynthetic pathway is the same, weed growth is favored upon enhancement in CO_2 concentration. Therefore, C_3 weeds like *Phalaris minor* and *Avena ludoviciana* in wheat (C_3) would aggravate with the increase in CO_2 due to climate change.

Climate change projections propose a 2.4–6.4 °C increase of global temperature by the end of the twenty-first century (IPCC 2007). With the increase of mean temperature, weeds following the evolutionary mechanisms expand their range into new areas. Under high temperature, plants with C_4 photosynthesis pathway have a competitive advantage over C_3 plants (Yin and Struik 2008) and weeds mostly belong to the first group. Also, an increased risk for the introduction of invasive weeds from the adjacent territories is expected in changing climate. By virtue of their competitive ability, alien weeds may heavily disturb the existing plant biodiversity of that region, as it has been seen in the case of *Parthenium* in South and Southeast Asia.

Almost all the studies indicate that both crops and weeds respond to climate change, but the balance will tilt toward weeds since they are naturally evolved with better adaptation strategies. Weeds have more competitive advantages over most crops both in biotic and abiotic stresses due to their physiological plasticity and superior interspecific genetic variation.

The impact of climate change on the insect–host plant relationship is a complex conundrum. It is not possible to generalize the impact of climate change on the insect genera as a whole. The response of each species of insect toward climate change is very much distinctive. Therefore, it will be wiser to assess the impact of climate change on each insect pest in crop production. But changes in temperature level might influence insect incubation period and extension of vector transmission season. Climate change promotes distribution and abundance of insect pests, and thus it all favors insects compared to crops.

Plant diseases are mainly affected by temperature, rainfall, humidity, and radiation (Patterson et al. 1999). Etiology of any plant disease suggests that proliferation of fungi and bacteria is governed by wet conditions as it promotes germination, spread, and activity of spores. Changes in rainfall dynamics cause the dispersal of diseases. However, warm and dry conditions can positively influence plant resistance, resulting in a reduced fungicide requirement. Nevertheless, an increased plant disease coupled with physiological plant stress is expected to enhance host susceptibility and thus pesticide dependency.

In this situation of global warming, it is now apparent that the pest and disease pressure on crop is going to be aggravated. To combat this pressure, we have to depend on a comprehensive module of plant protection practices, of which pesticides will be the major component. For the obvious reason, the consumption of pesticides will be more. It will be a complicated situation for pesticides too due to the elevated CO_2 and temperature, erratic rainfall, and higher intensity of sunshine. Their efficacy will be impacted in a changing climate situation.

Pertaining to pesticide efficacy, there was a general belief that some pesticides impart more toxicity to insect pests at a higher temperature (Noyes et al. 2009; Noyes and Lema 2015). However, it was found in a recent study by de Beeck et al. (2017) that at a higher temperature chlorpyrifos degraded more causing less mortality and less oxidative damage to insect pest. This is obvious due to the higher rate of hydrolysis of organophosphate pesticides at a higher temperature (Hooper et al. 2013). Pesticides, which undergo hydrolysis in aqueous phase, are mostly temperature dependent as found in organophosphates, carbamates, synthetic pyrethroids, and sulfonylureas. Some pesticides undergo extensive photodegradation under more sunshine. An increased temperature also favors the volatilization loss of pesticides (Otieno et al. 2013). Changes in intensity and seasonality of rainfall and temperature do have impact on pesticides but it may not be generalized. The microbial activities in soil will also increase with the rise of temperature and moisture status. Therefore, the rate of degradation of pesticides caused by soil microbes will be escalated. Therefore, under the global warming situation, the higher dissipation of pesticides and climatic adaptation of pests will probably cause repeated use of pesticides at a higher application rate. Balancing the use of resources will be key to minimize the negative impact.

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