Environment and Ecology 40 (3D) : 1829—1837, July—September 2022
ISSN 0970-0420

Apple Pest Management under Climate Change Scenario in Dry Temperate Zone (Spiti) : Strategies, Prospects and Limitations

Sumit Vashisth, Upinder Sharma, Nidhish Gautam, Sudhir Verma

Received 6 April 2022, Accepted 13 July 2022, Published on 17 September 2022

ABSTRACT

Insect pests had a tremendous impact on fruit crops. The change in climatic conditions is a concede warning or hot line for fruit trees. Mean surface temperature in Himalayas rise by 1.5°C from 1982 to 2006 compared to a 0.6°C rise in the global mean temperature. Rise in temperature remains up to 0.2°C till 2000 m above mean sea level, while above 2000 m above mean sea level it often exceeds by 0.3°C. The impact of climate change in recent decades was seen on apple, shifting towards higher altitude in Himachal Pradesh. The earlier studies proved that due to increase in temperature and decrease in precipitation it resulted in expansion of apple growing region towards higher altitude especially in Spiti valley which was earlier considered too cold and dry zone and not suitable for apple cultivation. In addition to direct impact of climate change on apple production and productivity it has also accelerated infestation of some insect-pest which ultimately resulting in the yield losses. The high reproductive potential and higher generations turnover resulted from suitable climate change resulted in making wooly apple aphid and European red mite more pervasive in the Spiti valley of Himachal Pradesh. This poses a real challenge to develop an appropriate integrated pest management approach that is in accordance with existing farming system. The integrated pest management involves the compatible use of number of avoidable strategies to reduce the pest population with least damage to environment and ultimately leads to economic gains in this climate change scenario. The IPM is also an integral part of agriculture production system under which its primary aim is to manage the plant health rather than individual pest.

Keywords Apple, Global warming, Insect, Disease, Management.

Dr Sumit Vashisth[1]*, Dr Upinder Sharma[2], Dr Nidhish Gautam[3], Dr Sudhir Verma[4]
[1,2] Subject Matter Specialist (Soil Science), [3] Scientist (Vegetable Science), [4] Principal Scientist and Head
Dr. YS Parmar University of Horticulture and Forestry, RHRSS / Krishi Vigyan Kendra Lahaul and Spiti II at Tabo, Tabo, Himachal Pradesh 172 113, India
Email : sumitvashisth_hpau@yahoo.co.in
*Corresponding author

INTRODUCTION

Insects are cold-blooded organisms - the temperature of their body is approximately the same as that of the environment. Temperature, moisture and effect of CO_2 are the most important drivers in the climate change scenario which influences insect behaviour, distribution, development, survival and reproduction (Bale *et al.* 2002). Insect responses to environmental change are very interesting for understanding how agro-ecosystems will respond to climate change. Short-term temperature fluctuations can cause substantial stress on both pest species and their natural enemies, which have substantive influences on their interactions (Chidawanyika *et al.* 2012). Many insect species acts as pests of various crops, but they also play crucial beneficial roles as parasitoids and predators of key pest species. The change in an insect population's physiology, biochemistry, biogeography and population dynamics may occur among populations across their distribution, among the growing seasons and among crop types (Andrew and Hill 2017). Moreover rapid change in climate condition over the period of time in a region or area effect an insect population's response with different competitors, predators and parasitoids and impose costs at different life stages. Temperature fluctuations which directly linked with climate change affects insect biology of both pests and natural enemies in agro-ecosystems, including generation times, sex ratio, lifespan, fecundity, activity, distribution and survival (Duale 2005, Hance *et al.* 2007, Kalyebi *et al.* 2005, Liu *et al.* 1995, Sorribas *et al.* 2012). This also can influence the overall food production systems that can be at critical risk from the impacts of climate change (IPCC 2014).

All over the world, the research on effect of climatic change on pests and diseases of crops is inadequate. In India, there is very limited effort made in the area for any insect-pest or disease of any crop (Rao 2007, Chattopadhyay and Huda 2009). In India, we can expect that current insect-pests will extend their geographical ranges into new areas, and that a variety of new insect-pests will appear.

Amongst different agro-ecosystems in India, the mountain ecosystem is one of the most vulnerable ecosystems and presently facing the challenges created due to variability in precipitation, increasing aridity, unexpected storms, frost and warmer winter seasons. A mountain ecosystem also plays an important role in ecological sustainability by acting as repository of water in forms of glaciers from where many rivers and streams are formed. About 24% of the earth's terrestrial surface is occupied by the mountain ecosystem which harbors diverse natural resources and prosperous biomass (Messerli and Ives 1997). Mountain ecosystem have a comparative advantage over plains for off-season vegetable production, cultivation of temperate and tropical fruits, medicinal plants, production of high value cash crops, flower production, virus/disease free planting material or seed production.

Agriculture is the major and foremost occupation of the people of the Himalayan states of India accounting to 53.8 m ha land under cultivation and contributing 45% of total regional income (Partap 2011). Farmers of Indian Himalayan region grow mainly fruit crops, including pomes (apple and pear) and stone fruits (peach, plums, apricot and cherry) in considerable quantity (Ghosh 1999), however apple has the preference overall other horticultural crops (Kala 2007). There are 7500 known cultivars of apple in world and India ranks seventh with average yield of about 7.24 tonnes per hectare (Thamaraikannan *et al.* 2010). In Himachal Pradesh apples are grown at altitude ranging from 1200 m to 3500 m above sea level (Deodhar *et al.* 2007). Area under apple in India has increased from 400 ha in 1950-51 to 99564 ha in 2009-10 (Anonymous 2006, 2012). In Himachal Pradesh, the area under apple has increased from 400 ha in 1950–51 to 3,025 ha in 1960– 61 (Mohan 2017), 99,564 ha in 2009–10 and 114144 in 2019-20 (Directorate of Horticulture, Shimla, https://hds.hp.gov.in/Generalpage With Template. aspx ? key = (FACTKEY0001). Though the production of apple in state has steadily increased by bringing more areas into apple farming but the productivity has declined (Awasthi *et al.* 2001). However, apple being highly sensitive to adversities of climate, a decline has been seen in the productivity of the apple (Wani 2019). Spiti valley (Cold desert/dry temperate zone) in trans Himalayan region of India, which was considered unsuitable for apple cultivation a few decades ago, is now witnessing flourishing apple

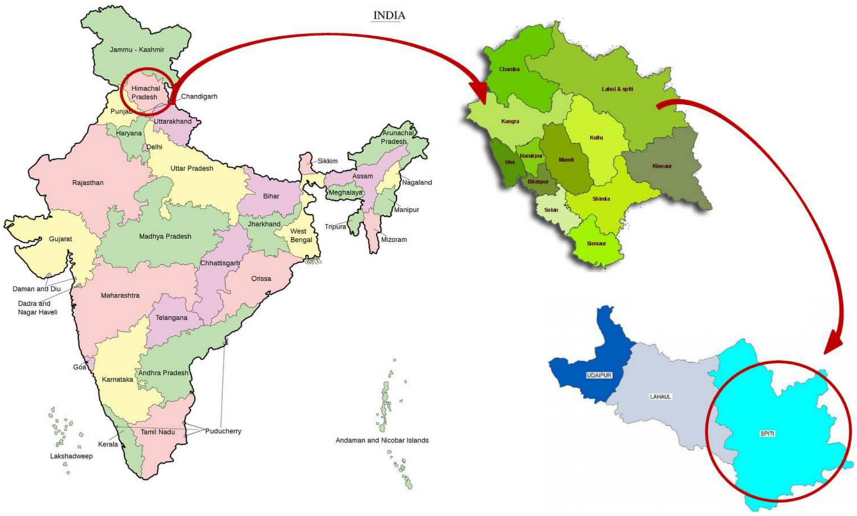

Fig. 1. Location of Spiti, Himachal Pradesh, India.

orchards (Partap and Partap 2004). On an average, every year, 60000 apple saplings (enough to cover 120 hectares) are being planted (Chauhan *et al.* 2004) and the early-planted orchards are now in production stage in Spiti of Himachal Pradesh. The quality of produce is rated best in the market and almost entire produce is being exported to Gulf and south East Asia region. This climate changes act as a new opportunity for farmers of this region due to rising temperature in the valley. But simultaneously, Spiti region being locked territory with changing climate has chances of being suffered seriously by infiltrated insect pests.

In these trans-Himalayan zones, mainly in Spiti (Fig. 1) the area under apple cultivation is increasing every year however with a very little pace because of several reasons like very low temperature, less precipitation, poor soil conditions, water scarcity, gravels and stones. But due to changing climate scenario (rise in temperature) in Himalayas the apple cultivation is shifting from lower elevated areas towards these higher altitudes. In many areas of Spiti the land under traditional coarse grains were replaced by apple farming and more area is bringing under apple cultivation due to its more economic benefits.

Over the last decade, Apple growing is often thought as a major success story in the trans Himalayan region, but with the passage of time there is a steady decline in apple productivity, both in yield and in quality of fruit which is affected by several factors including poor structure and nutritional status of the soil, poor quality of planting material such as root stock which are susceptible to various diseases and pests, poor planting practices such as inappropriate spacing and practice of deep planting, thus burying the scion union and promoting scion rooting, poor tree training and pruning, affecting light penetration, the physiological condition of trees, and insufficient pollination and fertilization due to lack of pollinating insects and inclement weather conditions (Partap and Partap 2004).

Strategies and prospects

Since the early 2000s, average temperature in the Himalayan Mountains has increased by about 1°C, which is around four times the global average (http://www.robertscribbler.wordpress.com). Temperature increases are more during winter and autumn than during summer, and it clearly increases with rise in altitude. Analysis of the data (Liu and Chen 2000) indicates that decadal temperature rise remains up to 0.2°C till 2000 m altitude; while above 2000 m it often exceeds 0.3°C. These changes have been noticed across different regions of the Himalaya. Analysis of data of the last two decades of major apple-growing areas (Shimla, Kullu, Lahaul and Spiti) indicates that minimum temperature is decreasing per year from November to April, whereas maximum temperature has been showing an increasing trend from November to April (Bhagat *et al.* 2009).

Pest management is as old as agriculture. Farmers used different tactics and practices to overcome the pest problems. Scientific and compatible integration of all these tactics against a pest species to manage pest population or damage below threshold levels is integrated management. Traditionally, farmers of Himalayan region also use different locally available materials or tactics for pest management. In general, this indigenous knowledge is unique to give culture or society and fully based on local-level decision-making over time (Singh and Tyagi 2014). However, in the present context of genetic architecture of the pest, possibility of their faster movement due to increased human movement, availability of host over a long period of time and alternate hosts at different altitudes, all of these traditional practices may not be effective to tackle pest problems. But, an established scientific base of this indigenous knowledge may offer effective management of problem and effortless adoptability among the society as well (Chandola *et al.* 2011). Spiti is geographically isolated in combination with the absence of indigenous *Malus* species restricted the establishment of fruit pests. However, with the transportation of infested planting material from traditional apple growing areas/uncertified nursery providers, inoculums of insect pests like Wooly Apple Aphid (*Eriosoma lanigerum* Hausmann), phytophagous mites (*Panonychus ulmi* Koch. and *Tetranchus urticae* Koch.), Indian gypsy moth caterpillar (*Lymantria* spp.), apple fruit moth (*Argyresthia conjugella*), defoliating beetles were accidently introduced and in the absence of diversity of natural enemies these pests have developed effectively. Gautam *et al.* (2013) reported that due to high spring temperature, it resulted in higher reproduction rate and increased pest population. Insect-pest infestation showed a hypothesized positive functional relationship with crop vulnerability which indicated that vulnerability of crop increased with increased insect-pests infestation in the crop and vice-versa (Chand *et al.* 2018). IPM uses all the possible and available techniques like resistant varieties, cultural, physical, mechanical and biological tactics of pest suppression. Keeping in view the status of mountain farmers and fragile agro-ecosystem of Himalayas, adoption of eco-friendly control measures is also the need of the hour. Besides, the strategies would also support overall productivity of the system in a sustainable manner. The essence of integrated approach is minimal and judicious use of chemical pesticides in combination with all available methodologies to keep away the pest or maintain the population below economic injury levels. Its success relies on availability of relevant technologies, their appropriate combinations, dynamic extension, stakeholder's participation and large-scale adoption.

Components of IPM

The integrated pest management involves the simultaneous use of a number of available strategies of reducing the population of pest with least damage to environment and ultimately having economic gains. The pest is thus a part of agro-ecosystem and one has to manage the plant health rather than the individual pest. The strategy thus start with the host and comprises selection of genetically superior and resistant genotypes, adoption of cultural practices resulting in reduced population of pests, preserving and promoting the activities of natural antagonists and predators with minimum use of pesticides and wherever absolutely necessary.

IPM programs are based on information obtained by sampling and monitoring and this information is used to make decision.

Surveillance : Pest surveillance is an important component of a decision-making system. Estimates of some pests can be obtained directly by counting the number of insects or mites on a number of leaves and terminals. Some insects are however, active only at night and difficult to observe. In such cases, other devices like light traps, can be used. Similarly, it is important to know the population of beneficial insects like *Aphelinus mali*, *Chysoperla carnea,* coccinelids (*Coccinella septempuctata* and *Hippodamia variegate*), predatory mites (*Amblyseius fallacies*, *Zetzellia mali*, *Balaustium* spp.), syrphid flies, which are helpful in IPM. Indirect methods of counting include the use of pheromone traps, sticky cards/bands. The monitoring has to be continued during the season to decide the levels of insecticidal spray. This helps in assessment of level of infestations, type of damage, economic importance. Thereby estimating the threshold levels, this in turn helps in choice of management technique to be imposed for economic benefits.

Resistant varieties : Use of resistant cultivars or rootstocks of MM series or M25 (MM106 and M9 have shown considerable resistance against wooly apple aphid root infestation). Three apple resistance genes Er1, Er2 and Er3 to wooly apple aphid (prevailing in Northern Spy, Robusta 5 and Aotea, respectively) have been identified and selectively incorporated in rootstocks. Attempts have been made to evolve the strategy of pyramiding these genes to give a durable resistance to wooly apple aphid (Sandanayaka *et al.* 2003) and new rootstocks exhibiting resistance to disease and wooly apple aphids are being developed (eg. Elite Geneva series rootstocks, like Geneva TM 202, CG 4202, CG 6210). Resistant varieties have immense ecological and biological advantages like minimal use of pesticides, survival of natural enemies, protection of environment, reduces extent of crop loss. Most importantly, adoption of resistant varieties is an easy and effective and low-cost method of pest management.

Cultural control : The extent of damage of different pests can be minimized by slight modifications of different cultural practices. For example, use of pest free planting material, field sanitation, removal of water-shoots and suckers, removal and destruction of infested plant parts, covering the pruning cuts, cracks, crevices, wounds with paste. Removal of suckers at the base of tree trunk, it reduces the favorable establishment site for wooly apple aphid. Avoid plantation of orchard in sandy soils. Judicious and split application of fertilizers, especially nitrogenous fertilizers avoids different pests and diseases.

Light and pheromone traps : The target specificity of pheromone traps makes them eco-friendly alternative against some economically important pest species. Insect traps have been found useful in mass trapping of target insect pests, especially whitegrubs (defoliating beetles) and borers, a major menace to hill agriculture due to rainfed cultivation.

Biological control : The beneficial organisms like predators, parasitoids, antagonists and pathogens are the natural limiting factors of given pests and diseases contributing to maintain the pest population to certain levels in any ecosystem. Promoting the activities of these natural enemies can avoid the use of other pest management practices as they can manage the pest below threshold levels, if favorable conditions exist. Before spraying, clip the twigs having aphids parasitized by *Aphelinus mali,* which lacks wooly strands and look like black mummies. Tie these twigs containing mummified aphids without exit holes with unsprayed trees supporting Wooly Apple Aphid population to enhance parasitoid activity. Rahman and Khan (1941) have reported the successful biological control of wooly apple aphid in Kullu valley of Himachal Pradesh with release of *Aphelinus mali* (Hald.). Beside, most of the biocontrol agents are compatible with other tactics of pest management thereby providing an eco-friendly and sustainable pest management.

Botanicals : Plant derived pesticides have their say in eco-friendly management of pests. Neem based products have been used effectively in pest management programs against a variety of insect pests.

Chemical control : It is a key tool and last line of defence in pest management programs especially when pest populations are above economic threshold levels. In an emergency, it is the sole option. However, judicious and need based application of target specific pesticides are recommended in IPM. Use of indiscriminate or broad-spectrum chemical control is avoided to facilitate survival of natural enemies. Don't spray summer oils in combination with sulfur or sulfur based pesticides as well as during drought and high humid conditions as it may cause phytotoxicity and fruit injury.

New concepts are emerging for suppression of insect pests by using irradiance reflective material eg. Micronized mica applied on host plants to repel insects. Color sticky traps (ultramarine yellow and emerald green) are good to monitor the aphid migration and settlement on stone fruits (Dhawan *et al.* 2013). The preliminary initiatives of IPM against different pests chiefly focused on combination or sequential applications of pesticides with different modes of actions. Keeping in view, the consumer awareness against chemical pesticides and eco-friendly biological services provided by natural enemies the pesticide biased IPM was tuned towards eco-friendly bio-intensive IPM (BIPM) practices.

Limitations

The observed climatic trends over northwestern Himalayas showed a significant increase in mean and maximum temperature over time period of 1951-2010 (Rathore *et al.* 2013). Adverse impact of climate change in Western Himalayas on apple producing areas and productivity is being reported in recent decades (Rana *et al*. 2009, Chaudhary and Bawa 2011, Basannagari and Kala 2013). Changes in temperature will alter the timing of diurnal activity patterns of different groups of insects (Young 1982), changes in inter-specific interactions could also alter the effectiveness of natural enemies for pest management (Hill and Dymock 1989).

Earlier apple orchards of Himachal Pradesh, India were found to be free from the attack of phytophagous mite, thereafter the attack of European red mite, *Panonychus ulmi* was found in an apple orchard in Kullu during 1992. Later on the infestation spread to other districts like Shimla, Mandi and Kullu and become a regular pest of apple (Kakkar 2003). Similarly in recent past decade it has become a major pest of apple in dry temperate zone during dry and hot spell of season. The irrevocable climate change in the form of unstable monsoons, long dry spells, etc., directly affects two most important agricultural inputs viz., water and temperature ultimately affecting productivity (Allison *et al.* 2011). It also indirectly affects agriculture by influencing the frequency of incidence and infestation intensity of pests (Ninan and Bedamatta 2012, Deschenes and Greenstone 2006).

Climate change resulting in increased temperature could impact crop pest populations in several complex ways. Researchers have shown that increased temperatures can potentially affect insect survival, development, geographic range and population size. Insects that spend important parts of their life histories in the soil may be more gradually affected by temperature changes than those that are above ground simply because soil provides an insulating medium that will tend to buffer temperature changes more than the air (Bale *et al.* 2002).

An increase in extreme climate events, changes in abiotic factors are expected to magnify pest pressure on agricultural systems through :

Range expansion of existing pests and invasion by new pests : Insect species diversity per unit area tends to decrease with higher latitude and altitude (Andrew and Hughes 2005), meaning that rising temperatures could result in more insect species attacking more hosts in temperate climates (Bale 2002). Climate change will have a major effect on geographic distribution of insect-pests and low temperatures are often more important than high temperatures in determining geographical distribution of insect-pests.

Accelerated pest development leading to more pest cycles per season : Temperature can affect insect physiology and development directly or indirectly. It has been estimated that with an increase of 2°C temperature, insects might experience one to five additional life-cycles per season (Yamamura and Kiritani 1998). Natural enemy and host insect populations may respond differently to changes in temperature. Parasitism could be reduced if host populations emerge and pass through vulnerable life stages before parasitoids emerge. Hosts may pass though vulnerable life stages more quickly at higher temperatures, reducing the opportunity for parasitism. The rising temperature directly affects the biology and physiology by shortening the life cycle and increasing number of generations which aggravate the pest problems (Hulle *et al.* 2008).

Disruption of the temporal and geographical synchronization of pests and beneficial insects that increase risks of pest outbreaks : Based on evidence developed by studying the fossil record some researchers conclude that the diversity of insect species and the intensity of their feeding have increased historically with increasing temperature.

At higher temperatures, aphids have been shown to be less responsive to the aphid alarm pheromone they release when under attack by insect predators and parasitoids – resulting in the potential for greater predation (Awmack *et al.* 1997). Natural selection will tend to increase synchrony between hosts and parasitoids, asynchrony may occur if host and parasitoids respond differentially to change in weather conditions (Heong *et al.* 1995). The relationship between pests and predators can be profoundly affected by temperature i.e. effects of parasitoids can be encouraged or discouraged by increase in temperature. Below 11°C the aphid reproduction rate exceeds the rate at which *Coccinella septumpunctata* can consume it and above 11°C the situation is reversed (Harrington *et al.* 2001). Precipitation – whether optimal, excessive or insufficient, is a key variable affecting crop-pest interaction. It was observed that rainfall kept a significant check on the nymphal movement of Wooly Apple Aphid, even under favorable conditions (Bhardwaj *et al.* 1995). Similarly due to the less precipitation in Trans Himalayas the wooly apple aphid population generally increases with sharp progression during the month of July.

Increased damage potential from invasive alien species : 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), and sudden outbreaks of insect pests can wipe out certain crop species, and also encourage the invasion by exotic species (Kannan and James 2009). Some plant species may be unable to follow the climate change, resulting in extinction of species that are specific to particular hosts (Thomas *et al.* 2004).

CONCLUSION

Incidence of insect pest and diseases on apple crops are generally considered as the indicators of climate change. Apple orchards are constantly threatened by pests and diseases, and the production depends on effective pest and disease control measures. Pest management is an obvious event of agricultural production system to sustain productivity. Proper maintenance of orchard health by resorting to timely application of horticultural practices, especially balanced and need based fertilizer application, is the key role for good fruit production. Routine inspection of the orchard and mechanical destruction (hand picking, use of traps and sticky materials) of pests feeding in groups like gypsy moth larvae also helps in reducing the pest incidence. Wherever, biological control is integrated with other methods of control, use of insecticides has to be minimized and make in such a compatible and careful manner that the population of natural enemies present, do not get decimated. Quantifying the effect of climate change on the activity and effectiveness of natural enemies for pest management will be a major concern in future pest management programs.

The relationship between the crop protection costs and the resulting benefits will change as results of global warming and climate change. This will have a major bearing on economic thresholds, as greater variability in climate will result in variable impact of pest damage on crop yields. Increased temperature, UV radiation and low relative humidity may render many of these control tactics to be less effective and therefore, there is a need to :

Predict and map trends of potential changes in geographical distribution, and interpretation how climate changes will affect development, incidence, and population dynamics of insect-pests.

Understand the influence of global warming and climate change on species diversity and cropping patterns, and their influence on the abundance of insect-pests and their natural enemies.

Understand the changes in expression of resistance to insect-pests, and identify stable sources of resistance, and pyramid the resistance genes in commercial cultivars.

Assess the efficacy of various pest management technologies under diverse environmental conditions, and develop appropriate strategies for pest management to mitigate the effects of climate change.

Climate change might change the population dynamics of insect pests differently in different agro-ecosystem and ecological zones. Therefore, there is a need to take a concerted look at the likely effects of climate change on crop protection and devise appropriate measures to mitigate the effects of climate change on food security.

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