Horticulture in India
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The wide range of climate and soil in India favours the growth of a large number of horticultural crops which play a unique role in India’s economy by improving the income of the people. The cultivation of horticultural crops is gaining importance due to the shrinking of lands and the need for leveraging and maximizing the output from limited land and water resources (Singh, 2009). Presently, horticultural crops occupy about 13% of India’s gross cropped area, producing 177.41 million metric tons (Horticulture annual report 2006–07). It is estimated that all the horticultural crops put together cover nearly 11.6 million hectares, with an annual production of 91 million tonnes.

Fruits form the major part of the total horticultural crops. India is the second largest producer of fruits and vegetables in the world (Horticulture annual report 2006–07). Total area of fruit and vegetable cultivation is estimated at 11.6 million hectares, which is 7% of total cropped area in the country. The commercial processing of fruits and vegetables is approximately 2.0%. Fruits and vegetables comprise an important part of our daily diet as they contain vitamins, minerals and chemicals called phytochemicals, which are the main source of nourishment and body building. They help to protect the body against disorders like diabetes, stroke, heart disease, some types of cancers and high blood pressure or hypertension (http://agriinfo.in/). Fruits and vegetables are processed into a variety of products such as juices and concentrates, pulp, canned and dehydrated products, jams and jellies, pickles, chutneys, and so on. So utmost care is required to protect them from calamities, and we need to find novel methods to increase the quality and quantity of their production (www.disr.gov.in/reportsittp-tedoagro).

A large array of fruits is grown in India, of which mango, banana, citrus, guava, grape, pineapple and apple are the major ones. Among the fruits, mango, the king of fruits, is an important seasonal fruit crop grown in the tropical and subtropical countries of the world (Abdullah and Shamsulaman, 2008), more so in the Indo-Pak continent (Talpur and Khuuro, 2003). It is known for over 6000 years and is indigenous even to Malay Archipelago (Butani, 1979). India is the largest producer of mango in the world, accounting for 52.63% of total mango production. The country produced 10.99 million tonnes of mangoes from an area of 1.23 million hectares (Negi, 1999). Though grown throughout India, the major mango growing states are Uttar Pradesh (24%), Andhra...
Pradesh (22.2%), Karnataka (12%), Bihar (8%), Gujarat (6%), Odisha (5%), West Bengal (4%), Tamil Nadu (3%), Maharashtra (3%), Jharkand (3%). Other states put together contribute 9% to the mango production (Chadha, 2003).

Mango (*Mangifera indica*) belongs to family Anacardiaceae. There are about 1000 mango varieties with approximately 30 commercial varieties like Alphonso, Banganapalli, Dashehari, Langra, Amrapalli, Mallika, Bangalora, Mulgoa, Neelum, Bombay Green, Himayuddin, Suvernarekha and so on (Pandey, 1998; Begum, 2013). It is known for its attractive colour, savouring smell, delicious taste and nutritive value and is liked and consumed by all. It contains sugars 10–20%; vitamins A, B, and C; iron; calcium; phosphorous; and small percentage of protein (Amur, 1986). But the yield is affected by many factors, mainly shortage of water, diseases like gummosis, anthracnose, powdery mildew, bacterial leaf spot, root rot, leaf blight, stem blight, malformation and so on. Yet another factor that negatively affects the vitality and yield of mango is the insect pests (Soomro, 1988).

There are about 400 insect pests attacking mango, affecting the fruit production and thereby causing great economic loss. The loss and havoc are caused mainly due to the insects belonging to the orders Hemipterans (mango leafhoppers, mealy bugs, scale insects), Coleopterans (weevils and stem borers), Dipterans (fruit flies), and Lepidopterans especially webber, slug, defoliators etc. (Tandon and Verghese, 1985; www.horticulture world.net). During the last one decade, the pest scenario has changed because of the increase in area and a paradigm shift in agronomic practices, like close planting, drip irrigation, regular pruning and so on. As a consequence, several insects are attaining major pest statuses in several fruit crops. It has hence becomes necessary to control them (Verghese and Jayanthi, 2001)

This resulted in the development of a number of control strategies including the use of pesticides which is one of the main strategies followed (Verghese, 2001). Heavy use of chemical insecticides has resulted in increased expenditure, reduction in pollinators (Verghese and Tandon, 1990), reduction in populations of natural predators and parasitoids of other insect pests and enhanced resilience on insecticides that also lead to
the development of biotypes and eventually environmental pollution (Kim et al., 2001; Peng and Christain, 2005). So emphasis has been to develop environmental-friendly control strategies, culminating in Integrated Pest Management (IPM). IPM is an effective and environmentally sensitive approach to pest management that relies on a combination of practices, and it uses current, comprehensive information on the life cycle of pests and their interaction with environment. In combination with the available pest control methods, this information is used to manage pest damage by synergising the most economical means with the least possible hazard to people, property and impact on the environment.

IPM is a system that primarily takes into account the milieu and the population dynamics of the species under consideration and uses appropriate techniques and methods in a compatible manner in order to restrict the pest population to less than the threshold of economic damage. Application of such a method mandates not only a thorough knowledge of the pests' biology but also its market goals (Pena et al., 2002). IPM is a sustainable approach to managing pests by combining biological, cultural, mechanical and chemical tools in a way that minimizes economic, health and environmental risks. IPM is a dynamic and constantly evolving approach to crop protection in which all the suitable management tactics and available surveillance and forecasting information are utilized to develop holistic management programmes as part of a sustainable crop production technologies. The success of IPM depends on prevention, monitoring and timely intervention with need-based pesticide, with preference to bio-pesticides over chemical pesticides (Singh et al., 2005).

Some eco-friendly control strategies include the use of bio control agents, conserving naturally occurring entomopathogenic and natural enemies by organic means, host plant resistance that deters the breeding of pests on hosts, use of biopesticides, etc. The use of bio-agents like predators, parasitoids and entomopathogens are gaining importance as a component of IPM, as fruit crops provide a stable environment and bio-agents find it as more favourable environment (Mani, 2001).
Further the host plant resistance to insect pest has become one of the most important component of the IPM. The use of insect-resistant crop varieties is economically, ecologically and environmentally advantageous. This results in economic benefits by saving crop yields from loss to insect pests and fiscal saving by not applying insecticides when susceptible varieties are used. Plant resistance is specific to type and affects only the target pest. Plant resistance can be brought about by understanding the diversity of insect pests in different locations which in turn enables habitat management and conservation strategies compatible with plant resistance against insects in breeding and management programmes.

The main disadvantage of relying solely on host plant resistance is the possible development of new insect biotypes particularly where there are high levels of resistance. Some examples of biotype development that have led to severe problems are the *Nilaparvata lugens* on rice in the Philippines and the chestnut gall wasp *Dryocosmus kuriphilus* in Japan (Shimura, 1972).

An effective ecology-based management is necessary to bring about an effective IPM strategy. Prime prerequisite of ecological management is the correct identification of the pest, knowledge about its biology and continuous monitoring/surveillance throughout the year. Ecological management comprises ecological modelling, biosystematic, biodiversity and geographical distribution and therefore ecological management is crucial to IPM decision making. Ecology-based IPM (EBIPM) should have a focused road map on the ecological concepts with specific priorities that are designed with consumer needs and implementation. The specific goal should be to focus on decreasing the economic and environmental risks, to generate ecological knowledge base for the multitude of cropping systems, environments and pest complexes constituting global agriculture which has long-term collaboration with farmers (Koul and Cuperus, 2007).

Ecological modelling is a methodological key skill in modern environmental research. It is an important tool for investigating dynamic behaviour patterns in populations, trophic interactions and behavioural ecology. However, the ecological patterns that reflect population oscillation trends are often not clearly visible without analytical instruments.
such as ecological models. Thus, ecological modelling plays a fundamental role in
describing demographic processes that are important for population dynamics. They
allow integrating information from different disciplines as well as analysing, interpreting
and understanding field observations. This provides basis for the development of tools for
management support and policy options in fields such as conservation of biodiversity,
sustainable use of natural resources, disease control or adaptations to impacts of climate
change (Leipzig and Schandau, 2008)

Taxonomy deals with the correct identification of the pest (Kapoor, 1998). Identification
can be done at field level using simple taxonomic keys so that pests can be identified up
to the genera level, and later in the laboratory they can be identified up to the species
level using taxonomic keys or molecular systematicss.

Biodiversity accounts for richness and evenness of all the species present in a
community. There are various indices to estimate species richness. These indices are
mathematical measures of a species in a community. They not only provide more
information about community composition and species richness (i.e. number of species
present in a particular area) but also take into account the relative abundances of different
species (Southwood and Henderson, 2000).

Geographical distribution is the manner in which insects are organized within a given
area. Understanding the geographical distribution of a species helps us to know if an
exotic species or cryptic species occur. Studying geographical distribution of a species is
considered a predictive tool for invasiveness (Strauss et al., 2006).

Broadly ecological studies include the knowledge about the biology of the species,
continuous monitoring/surveillance throughout the year, association studies, population
dynamics, potential damage to hosts and development of prediction models. This
provides knowledge about the current pests and crop situation and is helpful in selecting
the best possible combinations of the pest management methods. Thus, hoppers coupled
with measures compatible with environmental variables were taken holistically.
Leafhoppers form an important component of the insect fauna of many categories of plants including vegetables and fruits, cereals and grain crops, forest trees and grasslands. These insects have high economic significance due to their habit of breeding in enormous numbers under suitable ecological conditions (Fatema, 2001). They cause considerable damage to the crops and reduce their yield by the habit of sucking sap from leaves and flowers, puncturing the under surface of the leaves during feeding and oviposition, obstructing photosynthesis besides transmitting bacterial and viral disease etc.

There are about 20 species of mango leafhoppers that attack mango (Viraktamath, 1989; Dalvi et al., 1992), of which 6 species of leafhoppers are common, which are *Idioscopus nitidulus* Walker, *I. nagpurensis* Pruthi, *I. clypealis* Lethierry, *Amritodus brevistylus* Viraktamath, *A. atkinsoni* Lethierry and *Amrasca splendens* Ghauri (Tandon et al., 1988; Reddy and Dinesh, 2005) causing up to 20–100% loss (Sohi and Sohi, 1990). *Idioscopus nitidulus* and *A. brevistylus* feed and breed on both shoots and inflorescence unlike *I. clypealis* and *I. nagpurensis*, which breed only on inflorescence, while *A. splendens* feeds and breeds on fresh shoots (Verghese and Devi, 2011).

Mango leafhoppers were chosen for this study because leafhoppers are considered as the major constraint among the pests, especially during flowering period and mango is one of the important fruits. They belong to the order Hemiptera and family Cicadellidae. It is a large family of bugs, second in abundance to the Aphididae. They are slender, small insects usually with tapering antennae. Most species are restricted in their choice of hosts but some are polyphagous (Hill, 2008)

In mango, the hopper activity coincides with maximum emergence of inflorescence and new shoots (Zagade and Chaudhari, 2010). Both adults and nymphs suck and desap the inflorescence and shoots causing them to wither (Nachiappan and Bhaskaran, 1983; Verghese, 2001). As a result of sap-feeding, leafhoppers excrete honey dew on to the flowers and leaves on which sooty mold develops. This is reported to affect the photosynthetic activity of the trees (Verghese and Jayanthi, 2001; Peng and Chirstian, 2005). Though mango leafhoppers have several natural enemies (Singh, 1993), insecticidal control has been the only viable strategy. Therefore, insecticides like
imidacloprid, lambda cyhalothrin or azadirachtin have been recommended (Verghese, 2000).

As of now, only chemical control is available for hopper management (Verghese, 2000). However, due to the health hazardous and the environmental degrading nature of the insecticides, there is a need for a sound ecological-based management to optimise the use of pesticides on a need based basis. There is a systemic abyss in our understanding of the species complex and distribution (spatial and temporal). The role of off-season brood in the population dynamics of leafhopper is a vital link that needs to be understood. Hence, through faunistic survey and ecological modelling, these aspects can be understood. Apart from the ecological studies, the biochemical effect of feeding by the mango leafhoppers on the inflorescence and on the fruit will be assessed. It is expected that the hopper dynamics, biodiversity, effects of biotic (tree phenology) and abiotic effects and species complex will form a sound ecological basis on which IPM strategies can be developed in future for sound management of mango leafhoppers.