GLOBAL JOURNAL OF BIO-SCIENCE AND BIOTECHNOLOGY

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BEE POLLINATION AND POLLINATOR FRIENDLY MANAGEMENT PRACTICES IN HIMACHAL HIMALAYA, INDIA

*Hem Raj & V.K. Mattu
G.B. Pant Memorial Govt. College Rampur Bsr., Shimla-172 001 (HP), India.
*Corresponding Authors' Email: suryahemraj@gmail.com

ABSTRACT
Himachal Pradesh is one of the major temperate fruit growing states of the country. Important temperate fruits grown in the state are apple, almond, cherry, peach, pear, plum and apricot. New research and development challenges to maintain horticultural productivity in mountain agro-economic systems have arisen due to diversification of agriculture and ever increasing human population. One among these several challenges is crop failure due to lack of pollination, which warrants a need for changed strategies and look for other possible inputs for increasing farm production. There are many factors responsible for the decline of insect pollinators, including the loss, degradation and fragmentation of habitat; introduced species; habitat disruption from grazing, mowing and fire; the use of pesticides (herbicides and insecticides); diseases and parasites, climate change and mono-cropping. The orchardists of Himachal Himalaya are well aware of the insect pollinators (especially bees) and their effect on crop productivity. Most of the fruit growers have observed that introduction of honeybee colonies in orchards at the time of flowering helped in fruit set and yield. But they came to know about this fact only a few years ago. The fruit growers are using both native *A. cerana* and exotic *A. mellifera* for pollination purposes but most of them have a preference for native *Apis cerana*. For the conservation of insect pollinators, orchardists are developing nesting and foraging sites in surroundings of orchards. Although, they are not concerned with modern techniques of pest control but spray pesticides in morning and non-blooming periods to reduce the hazardous effects of pesticides on friendly insects. The sustainable development of agriculture in 21st century will also necessitate a reorientation of present crop production technologies and a shift will be towards biologically based agriculture such as genetic engineering and biotechnology, increased photosynthetic efficiency, biological nitrogen fixation, efficient nitrogen uptake and biological cross pollination and these components will become necessary to increase food productivity.

KEY WORDS: Insect pollinators, Pollinators decline, bee pollination, Pollinator Friendly management practices, Himachal Himalaya.

INTRODUCTION

Although, human is the most superior over all organisms but insects are equally reigning this world. Insects are highest in number, largest in diversity of species and the most adapted individuals for every kind of habits and habitats on this earth. An entomologist only can know their economic and ecological importance. Pollinators provide an essential ecosystem service that contributes to the maintenance of biodiversity and ensures the survival of plant species including crop plants. Two types of pollinators occur in nature, which include abiotic pollinators such as wind, water and gravity and biotic pollinators such as insects, birds and various mammals. It has been estimated that over three quarters of the world's crops and over 80 percent of all flowering plants depend on animal pollinators, especially bees. Losey and Vaughan (2006) have estimated that the net value of insect services in the USA alone is of the order of $57 billion per year.

The technological advancement and tempering of nature by human activities has resulted global warming which affects the diversity and distribution of insect pollinators. For the conservation of insects, many growers in USA may already have habitat for native pollinators on or near their land. The availability of semi- natural or natural habitats significantly increases pollinator populations (Kremen *et al.,* 2004; Williams & Kremen, 2007). Marginal lands such as field edges, hedgerows, sub irrigated areas and drainage ditches mimic natural early successional habitat and can offer both nesting and foraging sites (Carvell, 2002). Woodlots, conservation areas, utility easements, farm roads and other untilled areas may also contain good habitat. Often, poor quality soils, unfit for crops, may be useful as pollinator habitat (Morandin and Winston, 2006). New research and development challenges to maintain horticultural productivity in mountain agro-economic systems have arisen due to diversification of agriculture and ever increasing human population. One among these several challenges is crop failure due to lack of pollination, which warrants a need for changed strategies and look for other possible inputs for increasing farm production. The sustainable development of agriculture in 21st century will also necessitate a reorientation of present crop production technologies and a shift will be towards biologically based agriculture such as genetic engineering and biotechnology, increased photosynthetic efficiency, biological nitrogen fixation, efficient nitrogen uptake and biological cross pollination and these components will become necessary to increase food productivity (Verma, 1992). In future, emphasis will be on full use of such underutilized resources which are eco-friendly also (Mattu, 2010). For the conservation of insect pollinators, we should know first the factors threatening the diversity and distribution of insects.

MATERIALS & METHODS

Himachal Pradesh is one of the major temperate fruit growing states of the country. Important temperate fruits grown in the state are apple, almond, cherry, peach, pear, plum and apricot. Temperate fruits popularly known as 'Hill fruits' are grown in Himachal Pradesh at an altitude of 1200 meters or above. These fruits have low to medium heat requirements and can resist the intensive winter cold. However, Himalayan ecosystem has sustained the hill communities from times immemorial and these communities have developed some traditional conservation and management practices, which in turn needs to be documented and evaluated for ecosystem based approach for effective manipulation of insect pollinators. Therefore, there is a need to conduct detailed and extensive studies on conservation and management of insect pollinators for efficient and effective manipulation of their services.

The data prepared for the present study is primary as well as of secondary nature. The primary data was collected by a questionnaire from the orchardists. The secondary data was collected from different agencies like Directorate of Horticulture and Directorate of Industries Govt. of Himachal Pradesh, Khadi and Village Industries Commission (KVIC) and Central Bee Research and Training Institute (CBRTI), Pune. Elaborate interactions were made with the district and state level officials of beekeeping department of Govt. of Himachal Pradesh.

Most of the questions were regarding pollination issues and effect on temperate fruit productivity of hill ecosystem. The questionnaire was pre-tested on 10 % of sample size respondents in Arki, Deothi, Shilaroo and Matiana areas of Himachal Pradesh. As a result of the pre-testing necessary revision of the questionnaire was done and the revised questionnaire was administered to the orchardists, who were purposely selected on the basis of following aspects: firstly who had orchard, secondly who practiced management of pollinators in their orchards.

RESULTS & DISCUSSION

Farmers' Perception of Pollination Practices

In the present studies, it has been concluded that in Himachal Himalaya, farmers had divided the crops into agricultural and horticultural crops. 31% of the landholdings were under agriculture and 69% were under horticultural crops. Major agricultural crops grown by farmers were: wheat, maize, rice, barley, potatoes and beans. Apple was the main cash crop for most of the households in Himachal Himalaya, while other important fruit crops were plum, almond, cherry, peach and other fruits. The main variety of apple is Royal Delicious, followed by Red Delicious and other varieties like Golden Spur, Vance Delicious, Red Spur, Star Crimson Gold and Red Chief. The main pollinizer variety preferred is Golden Delicious, followed by Red Gold and other varieties. Most of the fruit growers in Himachal Himalaya were aware that introduction of honeybee colonies in orchards at the time of flowering helped in fruit set and yield. But they came to know about this fact only a few years ago. The fruit growers are using both native *A. cerana* and exotic *A. mellifera* for pollination purposes but most of them have a preference for native *Apis cerana*.

TABLE 1: Farmer's awareness about pollinating insects (Surveyed farmers' percentage of responses)

	Farmers' response (%)	Remarks
Insects observed in orchards	90	About 36% of farmers said they had seen insects in their orchards, but apart from honeybees and bumble bees, they were all pests
Types of insects seen on fruit crops		
Honeybees	92	There is moderate to high use of pesticides in the hills and still large natural population of insects
Bumblebees	34	
Syrphids	13	
Butterflies	76	
Other insects	36	
Natural insect pollinators sufficient for crop pollination?		
Yes	73	
No	15	
DNK	12	
Natural insect pollination declining?		
Yes	73	
No	9	
DNK	18	
Pollination in own orchards adequate?		
Yes	62	
No	13	
DNK	25	

They are either maintaining honey bee colonies or hiring them during flowering period from government agencies or private beekeepers for pollination purposes. Despite the overall success in promoting honeybees as pollinators the survey indicated that some of the farmers are still not aware regarding the potential role of honeybee pollination in enhancing fruit yield. They were also not properly trained regarding the potential role of honeybees in pollination that enhances fruit yield. They were also not properly trained regarding the number and time of placement of bee colonies in the orchards. In Himachal Himalaya, many farmers had knowledge regarding the local bee flora and they agreed that they had sufficient availability of honey plant resources like mustard, pear, apple, plum, peach, almond, rose and bottle brush. They practiced beekeeping as a part time or whole time job and

were engaged in this venture for the last many years. Commercial beekeepers stressed on the role of honeybees as honey producers than pollinators of horticultural crops. Most of the farmers also earned extra income from honey and other bee products besides using them for pollination purposes. The farmers had knowledge regarding different aspects of honey production, processing and marketing like constituents of honey, nutritional value, different type of honey containers used for honey storage, honey processing, marketing problems etc. But only some farmers were acquainted with different pests, predators and diseases of honeybees and their remedial measures. The following tables 1to 10 represent the farmers' perception of pollination practices in Himachal Himalaya.

TABLE 2: Type of bee species reared and preferred by fruit growers

	% of responses
Type of bees reared	
Apis cerana F.	40.50
Apis mellifera L.	55.50
Both	4.00
Preference for bee species	
Apis cerana F.	52.10
Apis mellifera L.	38.00
Both	9.90

TABLE 3: Apple cultivation by surveyed households/orchardists

Main variety pollinated	% of responses
Royal Delicious	95
Red Delicious	3
Other varieties (included Golden Spur, Vance Delicious, Red Spur, Richard, Star Crimson, Crimson Gold and Red (Chief)	2
Main pollinizer variety	
Golden Delicious	37
Red Gold	30
Other varieties (included Tydeman's Early Worcester, Commercial, Jonathan and Crab	33

TABLE 4: Problems in apple productivity

	% of responses
Apple productivity	
Increasing	13
Decreasing	77
No change	10
Cost of production	
Increasing	85
No change	15
Factors affecting apple productivity	
Change in climate	79
Diseases and pest attacks	15
Lack of pollination	85

TABLE 5: Reasons for rearing honeybees throughout the year

Reasons	% of responses
Professional beekeeper	13.20
Pollination purpose	65.30
Experimenting apiculture	1.50
Honey production	13.20
For honey production and pollination (both)	6.80

TABLE 6: Measures to protect bees against adverse environmental conditions/diseases/Pests/Predators

Measures	% of responses
Extra feeding by sugar	16.45
Covering with gunny bags	11.52
Separate the boxes when diseases occurred	23.35
Controlled the diseases by fungicides	2.10
Using miticides, antivirons	6.20
Using medicines (streptomycine, tetramycine, formic acid etc.)	7.20
Kept the hive in warm places	8.10
Do not know how to protect	13.15
Used antibiotics	11.93

TABLE 7: Number and time of spray of pesticides

		% age of responses
a.	Number of pesticide spray per season	
	3-4	10
	4-5	8
	6-7	15
	9-10	67
b.	Period of spray	
	Non-flowering	61.10
	Flowering	30.90
	Both	8.00
c.	Time of spray	
	Morning	52.20
	Afternoon	29.80
	Evening	18.00

TABLE 8: Remedial measures for the protection of bee from sprays

	% age of responses
Putting mud at the mouth of box	12.80
Covering the boxes	19.10
Closing the doors of hives	34.40
Mild insecticides	14.50
Put the hives after spray	19.20

TABLE 9: Major constraints in bee keeping

	% of responses
Non-availability of flora throughout the year	29.30
Heavy snow fall	22.60
Lack of latest knowledge	16.50
Lack of labour	14.90
Habit of bee to leave the hive	11.00
No knowledge about medicine	4.70

TABLE 10: Institutional Support

a.	Financial assistance from the government	% of responses	Remarks
	Yes	38.30	
	No	58.50	
	DNK	3.20	
b.	Sources from where financial assistance obtained		
	Department of Khadi Village and Industry	15.20	
	Department of Horticulture	23.40	
	Beekeeping farm	17.70	
	DNK	43.70	
c.	Desired institutional support		
	Training in orchards management and beekeeping	83	Training in orchards management, improved methods of beekeeping and pollination management using honey bees
	Financial support	49	To buy farm equipments and for planting materials
	Increasing awareness	61	Support towards increases awareness of technical aspects of pollination including honey bee pollination

Although, most of the farmers wanted to have financial support for different horticultural practices and training purposes, only some of the farmers got financial assistance from government agencies like Department of Horticulture. But most of them did not know resources from where to get the financial support. They preferred to be trained in orchard management technology and beekeeping practices. There were different types of constraints faced by beekeepers regarding the beekeeping practices which included non availability of bee flora throughout the year, heavy snowfall, shortage of labour, habit of absconding of bees and poor knowledge about medicines.

Pollinator Friendly Management Practices

In higher belt of Himachal Himalaya, off-season vegetables and fruits provide the comparative advantage to the farmers. As a result, the focus of mountain agriculture is shifting from traditional cereal crops farming to high value cash crops and the cultivation of such crops as apples, almonds, pear, peaches, plums and cherries and off-season vegetables, both for local and export markets is increasing. One of the methods of enhancing crop productivity is through managing pollination of crops using friendly insects, which in the process of searching for food perform this useful service to farmers. It has been

estimated that over three quarters of the world's crops and over 80 percent of all flowering plants depend on animal pollinators, especially bees. Different kinds of insect pollinators such as bees, flies, beetles, butterflies, moths and wasps are important pollinators of many crops. Among insects, bees are more effective pollinators than other insects because, unlike other insects, they are social and collect nectar and pollen not only to satisfy their own needs but to feed their young; their body hairs help transfer pollen from one flower to another; they show flower constancy and move from one flower to another of the same species; and many species can be reared and managed for pollination.

In recent years there is a world-wide decline in pollinator populations and diversity. The factors causing this decline could be the decline in the habitat, with the accompanying decrease in their food (nectar and pollen) supplies as a result of decline in pristine areas, land use changes, increase in monoculture-dominated agriculture and negative impacts of modern agricultural interventions e.g. use of chemical fertilizers and pesticides. Earlier, farmers used to grow a variety of crops, plants, which bloomed during different months of the year and provided food and shelter for a number of natural insect pollinators and hence the pollination problem never existed. Mono-cropping also requires pesticide use to control various pests and diseases. Thus, it not only reduced the diversity of food sources of pollinator but also led to the killing of many pollinators due to pesticides. The insecticides have contributed to the extermination of both the diversity and abundance of pollinating insects. Changes in climate might also be affecting insect numbers.

In Himachal Himalayas, honeybees are being used for apple pollination. Here, some farmers keep their own honeybee colonies while others rent them from the Department of Horticulture or from the private beekeepers. The fruit growers are using both native *A. cerana* and exotic *A. mellifera* for pollination purposes but most of them have a preference for native *Apis cerana*. However, *Apis mellifera* is the main bee species made available to farmers from government institution and private beekeepers for pollination purpose. A number of pollination entrepreneurs (beekeepers who rent honeybee colonies for crop pollination) have now started up in the state to complement the official services. In addition to increasing the number of insect pollinators by renting colonies of honeybees, some farmers are trying to save the populations of existing pollinators by making judicious use of carefully selected, less toxic pesticides and spraying outside the flowering period of apple. Pesticides are posing a lot of problems to pollinators and affecting their population. In Himachal Himalaya the farmers use a lot of pesticides, mostly fungicides are used and in addition to this one or two types of insecticides, to control various pests on their crop. The most commonly used insecticides are Metacid, Metasystox, Diathane M-45, Durmet, Thiodan, Monocrotophos, Fenitrothion and Malathion. Of these Fenitrothion, Monocrotophos, Malathion and thiodan are highly toxic to honeybees and other pollinating insects. Apples are sprayed for as much as ten times per season. Farmers spray pesticides both to control existing pests and diseases and to prevent the outbreak of diseases such as apple scab and red apple mite. In addition, it has been recorded that some farmers spray these chemicals, particularly fungicides to improve the size, colour and overall quality of the fruit. Now many farmers have reduced the pesticide applications from 9-10 to only 4-5 sprays in a season and have started using the less toxic chemicals. They also spray these pesticides when there are few insect pollinators present in the orchards and some farmers have started to control the pests using the bio-control methods. Many farmers have knowledge regarding the local bee flora and they feel that they have sufficient availability of honey plant resources like mustard, pear, apple, plum, peach, almond, kiwi, rose and bottle brush. Some of the farmers practice, some techniques, like use of windbreakers, artificial attractants etc. for pollination purposes. The farmers are acquainted with different beekeeping practices like handling of bees, multiplication of bee colonies, migratory practices, bee equipments etc.

The modern techniques for conservation of insect diversity are: Biotechnology, biological control, sustainable harvesting, re-greening, rehabilitation, ecological landscaping and restoration.

1. Biotechnology

Although, modern biotechnological pest management tools are designed to reduce environmental contamination and the non-target impacts, there remain concerns about the impacts of these strategies on insect biodiversity (Hill and Sendashonga, 2006). The use genetically modified insect resistant crops should reduce the quantity of pesticide usage. But, these genetically modified (GM) crops may still affect non-target and susceptible (to the strain of *Bacillus thuringiensis)* species feeding on these crops *e.g*. Lepidoptera and Coleoptera. The use of herbicide-tolerant GM crops may also reduce the plant and weed diversity and also insect biodiversity associated with the agro-ecosystem.

2. Biological control

Bio-control, in which non-native organisms are deliberately introduced into an area to control pests, was formerly considered to be an eco-friendly form of pest management. It has certainly reduced dependence on certain chemical control measures, but concerns have been raised about the higher trophic level and food web consequences of bio-agents (Howarth 1991; Memmott *et al.*, 2007).

3. Sustainable harvesting

Insects themselves are sometimes considered agricultural produce. For example, in Africa some species of edible caterpillars and wild silk-producing moth species are harvested as an important part of local diets and economies. These species are commonly harvested from natural populations rather than actively cultivated. In this case, studies of the maximum level of harvesting possible to ensure sustainability of the resource may be necessary. Such species may become of conservation concern as a consequence of either over-harvesting or habitat loss combined with sustained levels of harvesting.

4. Re-greening is simply putting back a vegetation cover for aesthetics and engineering purpose than for ecological integrity (e.g. grass cover of road cuttings). The maximal ecological integrity value for regreening is roughly at the level of recreational areas, with disturbance ranging from intense and frequent (mowing) to infrequent and mild.

5. Rehabilitation aims to recover some ecological integrity for aesthetic and/or human cultural components combined with ecological considerations *e.g*. mine dump rehabilitation or removal of pollutants from a stream. Like re-greening, the maximal ecological integrity value achievable through rehabilitation is low.

6. Ecological landscaping, deliberately aims to restore the historic 'natural' ecosystem, which may be aesthetic (deliberately or inadvertently anthropocentric) or not (purely biocentric). Carefully planned planting of indigenous trees along roadsides is an example of ecological landscaping. Researched well, ecological landscaping can have great ecological integrity value, at least over time after indigenous biodiversity returns. Ecological landscaping is also of value to greenways, ecological networks and reserves with management. We are then finally left with restoration, which can normally only be done on minimally degraded ecosystems.

7. Restoration aims for the historic 'original' state, but this is rarely actually achievable because of invasive alien species (Samways, 2000).

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