Original Research Article

FARMERS' PERCEPTION ON INSECT POLLINATORS DECLINE AND CONSERVATION METHODS IN HIMACHAL HIMALAYA, INDIA

ABSTRACT

Insect pollinators are important for the sustainability of agriculture and other natural ecosystems. Many insects such as bees, flies, butterflies, beetles, wasps and moths are important pollinators of many fruit crops. The climate and soil of Himachal Pradesh is suitable for growing various kinds of fruit crops but in the recent years, yield and quality of fruit crops is decreasing due to insufficient pollination. This study was conducted to assess the pollinator declining factors and farmers' perception in respect of conservation and management of pollinators in Himachal Himalaya. The diversity and distribution of insect pollinators is decreasing due to various threatening factors observed in Himachal Himalaya. These factors include: loss of insect habitats; pests and diseases of honey bees; use of pesticides; cell phone radiations; environmental pollution; susceptibility to climate change; impact of introduced species; increase in mono-cropping; livestock grazing and mowing; forest fires; ruthless honey hunting and introduction of exotic honey bees.

The farmers here are practicing beekeeping as a part time or whole time job while there are different types of constraints such as non-availability of bee flora all over the year, heavy snowfall, shortage of laborers, honey bee absconding and poor knowledge among farmers about medicines. Most of the farmers expect to have financial support for various horticultural practices, management technology and training purposes. The farmers have knowledge about different aspects of honey production, processing and marketing. But only a few farmers are aware about different pests, predators and diseases of honey bees as well as their remedial measures. To minimize the effect of pesticides, majority of farmers sprayed them in the morning and during nonflowering session.

KEY WORDS: - Himachal Himalaya, Pollinators decline, Bee Pollination, Threatening factors, Farmer's Perception, Climate change, Bee Management

INTRODUCTION

Insect pollinators are very important for the sustainability of agricultural/ horticultural ecosystems. The diversities of insects are important for stabilizing crop pollination and its yield. It has been estimated that over 80% of all flowering plants depend on insect pollinators, especially bees. Among insects, honey bees, flies, beetles, butterflies, moths and wasps are important pollinators of many crops [1]. Most crops would produce no fruit or seed without the pollination of their flowers. Reduced crop yields and deformed fruits are often due to poor pollination. In the recent years, diversity and distribution of insect pollinators is declining. Many factors responsible for the decline of insect pollinators including the loss and degradation of habitat; exotic species; habitat disruption due to grazing, mowing and fire; the use of pesticides; diseases and parasites, climate change and mono-cropping [2]. The decline of pollinators caused the lowering of yield of pollinator-dependent crops and referred to as pollination crisis and subjected to different sciences like politics and economy [3]. Many types of fruit crops grown in Himachal Himalaya are apples, almonds, apricot, peaches, plums, pears, cherries, walnuts and pine nuts in the mountains and citrus fruit, mangoes, litchis, kiwi, guavas and loquat in the foothills as well as in the plains. But apple is the main cash crop accounting for 42% of the total area under fruit cultivation and about 88% of total fruit production [1].

Insect pollinators mainly belong to the orders of Hymenoptera (bees), Lepidoptera (butterflies) and Diptera (Syrphid flies). There are also vertebrate pollinators like birds, bats, monkeys, etc. but honey bee (*Apis* sp.) is dominant pollinator of fruit crops [4]. There are many abiotic and biotic factors that weaken the beekeeping and its values. Among the abiotic factors, climate change is a major factor. Global warming due to climate change may also have a substantial negative impact on the production of honey [5]. Birhan et al. (2015) reported that lack of honey bee forage, shortage of rainfalls, agrochemical poisons, pests and lack of honey storage facilities have negatively affected honey bee production and productivity [6]. In addition to climate change, higher pathogen prevalence and competition between native and invasive species has brought instabilities in pollinator population and plant diversity [7] [8].

Lack of honey bee professionals and trained laborers results poor management of colonies. The transport costs are also very high in migratory beekeeping [9]. Many commercial beekeepers face problems such as interference of police and octroi people during the migration of their bee colonies. Indiscriminate use of pesticides

on crops poses a major threat to honey bees [10]. Producer price for honey and other bee products is very low compared to retailer price and this always discourages the beekeepers [11]. Many beekeepers report that the cost of the equipment is too high and this will also disappoint the entrepreneurs in this field. Most of the commercial beekeepers are distressed by the international standards for exporting honey as the beekeepers have poor knowledge of these standards [9].

MATERIALS AND METHODS

A field survey was conducted at different localities in Himachal Pradesh**.** The data prepared for the present study is primary as well as of secondary nature. Primary data was collected from farmers with the help of a questionnaire prepared for the purpose. The questionnaire was pre-tested on 40 (10 % of sample size) respondents in four selected localities. As a result of the pre-testing necessary revision of the questionnaire was done and the revised questionnaire was administered to the orchardists. In total 400 respondents were randomly selected for this study. Farmers were asked about the various types of bee management practices. They were also asked about different hive products, honey bee diseases & pests and pollinator declining factors. The farmers were also questioned about different problems they faced in beekeeping and getting institutional support. The secondary data was collected from different agencies like Directorate of Horticulture and Directorate of Industries Government 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 Government of Himachal Pradesh.

RESULTS AND DISCUSSION

In recent years, pollination services are being hindered by a decline in their number, abundance, diversity and distribution of pollinator populations throughout the Himalayan region. The inadequate pollination in fruit orchards is largely due to decline of natural pollinators such as honey bees. This is forcing farmers to find out different ways for conservation and management of insect pollinators in their orchards.

1. POLLINATOR DECLINING FACTORS

Human activities are primary responsible for the loss of habitats of pollinators which lead to a decrease in their food supplies, nectar and pollen. Other major factors contributing to pollinator decline include an increase in monocrop dominated agriculture, forest fires, discriminate use of pesticides and climate change. Some of the possible factors for pollinator decline in the context of Himachal Himalaya are observed as under: -

Loss of insect habitats: Farmers living in the high mountain regions of Himachal Himalaya are planting apples in their pasture lands and an increase of 135% in apple orchards has been observed here. The continuing increase in agricultural and horticultural area at the cost of grasslands and forests is seemingly leading to the loss of nesting sites and food sources of insect pollinators. About the impacts of human disturbances on bees, Winfree et al. (2009) observed habitat loss and fragmentation as one of the most significant factor causing declines of abundance and species richness of honey bees [12]. Factors responsible for habitat loss and fragmentation include ever increasing urbanization, expansion in intensive agriculture, invasive plants and climate change. These factors can reduce, degrade or eliminate pollinator habitat.

Pests and diseases of honey bees: There are many types of pests (wax moths, mites, wasps, lizards, birds) and diseases (bacterial, viral, fungal and Protozoan) affecting the bee pollination in Himachal Himalaya. Only 42.10% farmers had knowledge about pests and diseases of honey bees and a few persons (34.50%) used medicines for the cure of bee diseases (Table 1). Mostly there occur attacks of pests on bees.

Table 1: Pests and disease of honey bees

		Responses (%)
a.	**Knowledge about honey bee diseases**	
	Yes	42.10
	No	55.20
	DNK	2.70
b.	**Knowledge of medicines for cure of bee diseases**	
	Yes	34.50
	No	29.10
	DNK	6.40
c.	**Types of pests**	
	Wasps	36
	Viral diseases	24

	Acarine diseases	11
	Mite attacks	26
	Wax moths	3

Use of pesticides: In Himachal Pradesh farmers spray different pesticides on apple trees as many as 10 times in a season and in almost 31% of farmers spray during the flowering period (Table-2). Agricultural pesticides kill not only the foraging insects, but also *Apis dorsata* and *Apis florea* colonies in adjoining areas.

Table 2: Number, period and time of pesticides spray on apple crop in Himachal Pradesh

		Responses (%)
a.	**Number of sprays per season**	
	3-4	10
	4-5	8
	6-7	15
	9-10	67
b.	**Period of pesticide spray**	
	Non-flowering	61.10
	Flowering	30.90
	Both	8.00
c.	**Time of spray**	
	Morning	52.20
	Afternoon	29.80
	Evening	18.00
d.	**Most commonly used pesticides**	Metacid, metasystox, diethane M-45, malathion, thiodan, monocrotophos, fenitrothion,

The practice of pesticides is detrimental to a healthy community of insect pollinators. Pollinator larvae are also damaged directly and by consuming food contaminated with pesticides [13]. Herbicides also kill plants that pollinators depend on when the crops are not in bloom, thus reducing the extent of foraging and egg-laying resources available [14]. In the eve of cash crop orchardists use pesticides indiscriminately, contributing to the decline in natural insect pollinators.

Cell phone radiations: Electro-magnetic radiations of cell phones affect the behavior of honey bees. They are dyeing due to losing the site of their colonies and behavioral disorders. Sharma and Kumar (2010) compared the behavior of exposed and unexposed honey bee colonies in cell phone radiation [15]. A significant decline in colony strength and fecundity rate of the queen was detected. The behavior of radiation exposed foragers was negatively influenced. There was neither honey nor pollen in the colony at the end of the experiment. Radiations of the cell phone influenced the behavior and physiology of adult workers of *Apis mellifera* [16]. Initially, there was reduced motor activity of the worker bees in the hive toward "talk mode" cell phone but later they showed mass migration and movement.

Environmental pollution: Pollutants present in air, water and land always affect the physiology and behavior of the insects. The change in the carbon-nutrient balance in plant tissues due to increase in carbon dioxide will reduce the nutritional quality of plant tissues and alter production of secondary compounds. Predicted effects for herbivorous insects with chewing mouth parts include increased mortality of first-instar, longer development time and decreased digestive efficiency. Lower development rates may also increase herbivore mortality due to natural enemies and result in asynchronous plant–insect life cycles [17]. Fuentes (2008) observed that the ability of pollinators to find the fragrances of flowers has been diminished by air pollution from automobiles and power plants [18].

Susceptibility to climate change: Environmental change has great impact on biodiversity of insects. The effect of climate change on insect pollinators will differ from species to species depending on their biology, current environment and geographical distribution. As a result, some species are likely to be more susceptible to climate change than others. Water availability is one of the most important determinants for the diversity, distribution and abundance of insects. Insects are particularly vulnerable to water loss because of their small body size and water loss rates are positively related to precipitation levels [19]. Increased frequency of life-threatening events such as floods, droughts and fires will increase mortality and may result in extinction of restricted-range species**.**

Impact of introduced species: In addition to habitat loss and climate change, the biological invasion is predicted throughout the world as one of the major threatening factors to biodiversity. The accidental and/or deliberate introduction of alien species of plants, microbes, vertebrates and other invertebrates is also of major concern to insect conservation. Alien invasive plants impact negatively on insect diversity by changing of habitat quality, outcompeting the native host plants and interrupting vital ecological interactions [20]. Introduced nonnative plants

compete with native plants for resources as well as alter habitat composition. Some of them cause significant reductions in the abundance and diversity of pollinators and other herbivorous insects. There is also evidence that native pollinator insects prefer native plants [21].

Increase in mono-cropping: Although, mono-cropping provides abundant forage for insect pollinators over a limited flowering period, yet practically available forage before and after the main flowering period of that crop may not commensurate with the requirements of pollinating agents. The replacement of natural plant communities by monoculture is also a pollinator declining factor since most monocultures are not capable of sustaining their populations [2]. In the past, mountain farmers grew a variety of crops which bloomed at different sessions of the year and provided food for a number of natural insect pollinators. The transformation of agriculture from traditional mixed crop farming to high value cash crop farming in recent years has led to an increase in monocrop agriculture, reducing the food sources for natural insect pollinators. Now the farmers Himachal Pradesh are switching on a large scale to the cultivation of cash fruit crops and off-seasonal vegetables.

Livestock grazing and mowing: It is mostly practiced in Himachal Pradesh. It has damaging impacts on insect pollinators but can be beneficial if managed carefully. Livestock grazing may greatly alter the structure, growth and diversity of the floral community which in turn can affect the accompanying insect community [22]. Different ways that grazing can harm pollinator habitat include: destruction of potential nesting sites, destruction of existing nests and contents, direct trampling of adult insects and removal of food resources [23]. Like grazing, mowing can alter grassland succession and species composition by suppressing growth of woody vegetation [24]. Mowing can have a significant negative impact on insects through direct mortality particularly of eggs and larval stages that cannot avoid the mower [25].

Forest fires: Forest fires are often observed in hills and grass lands during summer. These are largely engineered by farmers for fresh growth of grass on forest floors. It is a key factor affecting pollinator populations in some areas of Himachal Himalaya. Forest fires not only destroy the nesting places and food sources of pollinators but also destroy the pollinators hibernating or nesting in that area. The large-scale pine forests in the mid hills of the Himachal Pradesh pose a fire hazard in summer because of the falling of dried pine needles. Forests provide food sources and habitats for nesting and hibernation for a variety of insect pollinator species. Studies have revealed that there are more insect pollinators in apple orchards situated near forests than those that are far from forests [26]. Therefore, a decline in forest area due to forest fires has a negative impact on pollinator diversity. The farmers in the Himalayan region use fire in the fields and grasslands to control weeds and improve the quality of grass for the following year. The practice of weed removal reduces the diversity of food sources available for pollinating insects. Afraid of being stung, farmers also burn and poison *Apis dorsata* colonies and other pollinators in India [27].

Ruthless honey hunting: An increase in honey hunting of wild honey bees (*Apis dorsata*) by burning, smoking and cutting hives full of larvae is resulting in the decline of indigenous honey bee populations. In the past, honey hunting was a part of the culture and tradition of honey-hunter communities and provided them with a source of livelihood. Now, it is being commercialized and exploited by big contractors and companies. An increase in honey hunting and the ruthless hunting of the hives of wild bees is posing a serious threat to the population of these indigenous honey bees [28].

Introduction of exotic honey bees: The introduction of exotic honey bee species can adversely affect populations of native bees. This may be due to competition for food, transfer of diseases from one species to another or economic preference for exotic species. The introduction of *Apis mellifera* to increase honey production has led to a decline of indigenous *Apis cerana* in mountain region [29].

Thus, honey bees being a most important pollinator, the habitat deterioration by deforestation, forest fire, agrochemicals, diseases and other pests are reducing their colonies across the globe at an alarming rate. The decline of honey bee populations threatens not only honey bee products but also global agriculture and the world biodiversity [30].

II. FARMERS PERCEPTION REGARDING CONSERVATION OF INSECT POLLINATORS

Despite of overall success in promoting honey bees as pollinators, it was observed in this study that about a quarter of farmers in Himachal Himalaya had still not understood the potential role of honey bee pollination in enhancing their fruit yield. Most of the fruit growers here were aware that introduction of both native *Apis cerana* and exotic *Apis mellifera* colonies in orchards at the time of blooming can help in fruit set and yield. Many farmers were aware about the local bee flora and they agreed that they had sufficient availability of honey plant resources like mustard, pear, apple, plum, peach, almond, plectranthus, eucalyptus, rose, bottle brush etc. in their regions. The data collected from farmers/orchardists through questionnaire on various parameters is tabulated and described as below:

Farmers' Perception about Pesticide Use

More than two third (68 %) of the farmers used some type of pesticides in their orchards. They usually used fungicides, insecticides and other pesticides obtained from government and private stores. Less than half of the farmers knew that pesticides can kill insects. Most of them practice wettable powder (Table 3).

Table 3: Farmers' perception regarding the use of pesticides on fruit crops

		Responses (%)
a.	**Pesticides used on crop**	
	Yes	68
	No	25
	DNK	7
b.	**Do pesticides kill insect pollinators**	
	Yes	49
	No	32
	DNK	19
c.	**Kinds of pesticide formulation used**	
	Wettable powder	56.10
	Spray	27.20
	Dust	8.60
	DNK	8.10
d.	**Kinds of pesticide used**	
	Fungicides	46
	Insecticides	24
	Others	30

Farmers' Perception Regarding Honey Bee Management Practices

Only 56.40% of the farmers know about the bee management practices to be taken (Table 4). Most of the farmers (65.10%) handled the bees by themselves whereas some (34.90%) of them employed other employees. Most (49.50%) of the orchardists got the nucleus stock from the Department of Horticulture. Most of the farmers (84.30%) multiply the bees only once and (75%) used smokers for handling bees.

Table 4: Farmers' knowledge regarding Bee Management Practices

		Responses (%)
a.	**Farmers knowledge about bee management**	
	Yes	56.40
	No	40.60
	DNK	3.00
b.	**Honey bee Handling**	
	Themselves	65.10
	Extra hand	34.90
c.	**Source of obtaining the nucleus stock**	
	Forest Department	36.10
	Horticulture Department	49.50
	Grew Themselves	14.40
d.	**Multiplication of colonies**	
	Once	84.30
	Twice	14.20
	DNK	1.50
e.	**Equipment used in bee handling**	
	Smoker	75.00
	Bee veil	16.00
	Gloves	6.00
	Bee bush	3.00

Migration of Honey Bee Colonies

Most of the farmers (64.10) migrated the bee colonies and were satisfied with colonies migration. Farmers used various modes of transportation and faced many types of problems during migration (Table 5).

Table 5: Migration of Honey Bee Colonies

		Responses (%)
a.	**Migrating the honey bee colonies**	
	Yes	64.10
	No	30.20
	DNK	5.70
b.	**Mode of transportation used**	
	Mini Trucks	51.40
	Maxi Cabs	22.50
	Trucks	11.20
	Medium Vehicles	14.90
c.	**Problems faced during migration**	
	Honey bees fly during migration	14.30
	Death of honey bees during migration	31.50
	Money and laborers needed	9.10
	Transportation problems	22.50
	Difficult terrains	22.60

Marketing of Honey and other Hive Products

Honey was collected from hives at different intervals. Most of the farmers (61.40%) were satisfied with the collection interval of honey. 66.30% farmers were not satisfied with the transportation arrangements in their areas. Nearly 80% orchardists faced different kinds of marketing problems.

Institutional Support

Only 38.30% of the farmers got financial assistance from the Department of Horticulture. Most of them that is about 83% wanted training in orchards management and improved methods of beekeeping. About 61% farmers wanted to have support from the government and technical knowledge about pollination. Nearly half of farmers (49%) wanted financial support to buy equipment of orchard and rearing honey bees (Table 6).

Table 6: Farmers Obtaining Institutional Support

a.	**Obtaining financial assistance from the Government**	**Response (%)**	**Remarks**
	Yes	38.30	
	No	58.50	
	DNK	3.20	
b.	**Sources for obtaining financial assistance**		
	Khadi and Village Industry Commission	15.20	
	Department of Horticulture	23.40	
	Beekeeping farm	17.70	
	DNK	43.70	
c.	**Desired institutional support**		
	Farmers training in orchards management and beekeeping	83	Farmers training in orchards management, improved methods of beekeeping and honey bee pollination management
	Financial support	49	Buying farm equipment for plantation and rearing honey bees

	Increasing awareness	61	Support towards increases awareness of technical aspects of pollination including honey bee pollination

Constraints in Mountain Beekeeping

The different kinds of constraints encountered by farmers of Himachal Pradesh in practicing apiculture are shown in Table 7.

Table 7: Major constraints in mountain beekeeping

	% of responses
Lack of bee flora throughout the year	29.30
Heavy snow fall	22.60
Lack of latest knowledge	16.50
Paucity of laborers	14.90
Absconding of honey bees	11.00
No knowledge about medicine	4.70

Most of the farmers questioned knew that insecticides could kill useful insect pollinators specially honey bees but even than they were making indiscriminate use of pesticides on their fruit crops. Insecticides have affected diversity, distribution and abundance of pollinating insects which was clearly reflected in farmers' perception. They have observed that there were large number of insects like honey bees, butterflies and wild bees during the flowering season of temperate fruit crops in the past but now there is decrease in their population which is affecting the crop productivity.

CONCLUSIONS

Although, the soil and the climate of Himachal Himalaya is suitable for growing different types fruit crops and orchardists are also putting their intensive efforts, yet the yield and quality of fruits is decreasing due to insufficient pollination. In recent years many threatening factors such as loss of insect habitats; pests and diseases of honey bees; use of pesticides; cell phone radiations; environmental pollution; susceptibility to climate change; impact of introduced species; increase in mono-cropping; livestock grazing and mowing; forest fires; ruthless honey hunting and introduction of exotic honey bees are imposing a serious threat to insect pollinators and maintenance of biodiversity. Some farmers of Himachal Pradesh are practicing beekeeping as a part time or some as whole time job and earning extra income besides using them for pollination. Different types of constraints such as lack of bee flora throughout the year, heavy snowfall, shortage of laborers, bee absconding and bee diseases are challenging the beekeeping here. A few farmers are getting financial assistance from Government agencies like Department of Horticulture but most of them preferred to be trained in orchard management technology and beekeeping practices. So we need more research to find out new methods, plans and policies for conservation and management of insect pollinators not only in Himachal Himalaya but across the globe.

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