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Farmers' Perception on Insect Pollinators Decline and Conservation Methods in Himachal Himalaya, India

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Author's contribution

The sole author designed, analyzed, interpreted and prepared the manuscript.

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ABSTRACT

Insect pollinators are important for the sustainability of agriculture and other natural ecosystems. Many insects such as bees, wasps, flies, butterflies, moths and beetles are main pollinators of many fruit crops. The climate well as soil of Himachal Pradesh is apt for growing many kinds of fruit crops but in the last few years, produce and quality of fruit crops is decreasing due to lack of sufficient pollination. This study was conducted to assess the pollinator declining factors and farmers' perception in respect of pollinator conservation and management methods in Himachal Himalaya. The diversity and distribution of insect pollinators is declining due to many 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; escalation in mono-cropping; livestock grazing and mowing; forest fires; ruthless honey hunting and introduction of exotic honey bees.

The farmers are practicing here apiculture as a part time as well as whole time profession although there are different types of constraints such as lack of all-season bee forage, heavy snowfall, paucity of labour, honey bee absconding and meager knowledge of medicines. Majority of the farmers expect to have financial help for various horticultural works, management technology and training activities. The farmers have knowledge about different aspects of honey production, processing, storage 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.

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1. INTRODUCTION

Insect pollinators are vital for the perseverance of crop ecosystems. The pollinator diversity is important for stabilizing crop pollination and its yield. It has been estimated that over 80% of angiosperms rely on insect pollinators. Many insects like honey bees, wasps, flies, butterflies, moths and beetles are important pollinators of different fruit crops [1]. Self-incompatible crops would produce no fruit or seed without cross-pollination of their flowers. Reduced crop yields and deformed fruits are often due to poor pollination. In the recent few years, diversity and distribution of insect pollinators is declining. Main factors responsible for the reduction of insect pollinators include the loss and degradation of habitat, exotic species, habitat disruption, pesticides, diseases, climate change and mono-cropping [2]. The reduction in insect pollination resulted low yield in 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 include apple, almond, apricot, peach, plum, pear, cherry, walnut and pine nuts in mountain regions and citrus fruits, mango, litchi, kiwi, guava and loquat in the valleys as well as in the plains. Among so many crops grown here apple is the main cash crop occupying about 42% of the total area under fruit cultivation and nearly 88% of total fruit production [1].

Insect pollinators mostly belong to order Hymenoptera (bees), Lepidoptera (butterflies) and Diptera (Syrphid flies). There are also vertebrate pollinators like birds, bats, monkeys, etc. but honey bees (*Apis* sp.) are dominant pollinators of fruit crops [4]. Many abiotic and biotic factors weaken the beekeeping and its values. Among the abiotic factors, climate change is the major factor. Global warming due to greenhouse gases may also have a substantial negative impact on bee pollination and honey production [5]. Birhan et al. (2015) reported "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 introduced species has brought uncertainties in pollinator population and plant diversity [7] [8].

Lack of honey bee professionals and trained laborers results poor management of colonies. The transportation costs are also very high in migratory beekeeping [9]. During the migration of bee colonies, many apiculturists face the problems like interference of police and octroi. Haphazard usage of pesticides on crops is a major threat to insect pollinators mostly honey bees [10]. Beekeepers are always discouraged by the low producer price for honey and other bee products but high retailer price [11]. Many beekeepers reported that in beekeeping industry entrepreneurs are always disappointed by the high cost of the equipment. Most of the commercial beekeepers are distressed by the international standards for exporting honey because the beekeepers have little knowledge about these standards [9].

2. MATERIALS AND METHODS

A field survey was conducted at different localities of Himachal Pradesh**.** The data collected for this study is primary as well as secondary. Primary data was collected from farmers with the help of a questionnaire specially developed for this study. The questionnaire was pre-tested on 40 (10 % of sample size) respondents in four selected localities. Based on pre-testing necessary changes in the questionnaire was done and the revised questionnaire was introduced among the orchardists. In total 400 respondents were randomly selected for this study. The farmers were questioned about different 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 various 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 Horticulture Department, Government of Himachal Pradesh.

3. 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.

3.1 Pollinator Declining Factors

Human activities are primary responsible for the habitat loss of pollinators which lead to deprivation in food supply of nectar and pollen. Other factors resulting pollinator decline include an increase in monocrop dominated agriculture, forest fires, discriminate use of pesticides and climate change. Some pollinator declining factors observed in Himachal Himalaya are mentioned as under: -

Loss of insect habitats: Farmers living in the hill regions of Himachal Himalaya are planting apples in their pasture lands and an increase of 135% in apple orchards has been observed here. The continuous increase in agricultural and horticultural plantation at the cost of grasslands and forests is diminishing 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 climate change, ever increasing urbanization, expansion in intensive agriculture and invasive species. These factors can destroy or eliminate pollinator habitats.

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 of honey bees and a few persons (34.50%) only used medicines to cure the bee diseases (Table 1). There were often attacks of pests on honey bees.

Use of pesticides: In Himachal Pradesh, farmers spray many types of pesticides on apple trees as many as 10 times per season and almost 31% of farmers spray them during apple bloom (Table-2). Pesticides kill not only the nearby foraging insects, but also *Apis dorsata, Apis mellifera, Apis cerana* and *Apis florea* colonies in adjoining areas.

Table 1. Pests and disease of honey bees

		Responses (%)
a.	**Knowledge of 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

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

		Responses (%)
a.	**Number of sprays per season**	
	3 to 4	10
	4 to 5	8
	6 to 7	15
	9 to 10	67
b.	**Period of pesticidal sprays**	
	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 hazardous to a healthy community of insect pollinators. Pollinator larvae are also destroyed directly and by consuming pesticide contaminated food [13]. Herbicides also kill plants on which the pollinators rely when the crops are not in bloom, so reducing the extent of foraging and egg-laying resources available [14]. In the eve of cash crop orchardists use pesticides indiscriminately which result in the decline of 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) studied the effect of cell phone radiations and compared the behavior of exposed and unexposed honey bee colonies [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 pollen nor honey in the colony at the end of the experiment. Radiations of the cell phone influenced the physiology and behavior of adult workers of *Apis mellifera* [16]. Initially, hive worker bees showed reduced motor activity toward “talk mode” cell phone but later they showed mass migration and movements.

Environmental pollution: Pollutant contaminated air, water and land always affect the physiology and behavior of insects negatively. With the increase in CO2, the carbon-nutrient balance of plant tissues is changed which will reduce the nutritional quality of plant tissues and also 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. Reduced 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 diversity of insects. The effect of climate change on insect pollinators will differ from species to species depending on their physiology, behavior, current environment and geographical distribution. That’s why some species are likely to be more vulnerable to climate change than others. Water availability is one of the most important determinants for the diversity, distribution and abundance of insects. Because of their small body size, insects are particularly vulnerable to water loss [19]. Increased frequency of life-threatening events such as floods, droughts and fires will increase insect 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 organisms, for example, microbes, vertebrates and invertebrates and

plants, is also of major concern to insect conservation. “Alien invasive plant species impact negatively on insect diversity by changing of habitat quality, outcompeting with native host plants and interrupting vital ecological interactions” [20]. Introduced plants compete with native plants for light, water and minerals as well as change the habitat composition. Some introduced plants cause significant reductions in the abundance and diversity of pollinators and other herbivorous insects. It is also evident that native pollinator insects prefer native plants [21].

Escalation in mono-cropping: Although, mono-cropping provides abundant forage to insects for a short flowering period, but the practically available forage before and after the main flowering period of that crop, may not proportionate with the requirements of pollinating insects. The replacement of natural ecosystems by monoculture is also a pollinator declining factor because most monocultures are not able sustain their populations [2]. Decades before, the farmers of higher altitudes grew a variety of crops which bloomed at different months of the year and provided forage for a number of insects. The agro transformation from traditional mixed crop farming to high gain cash crop farming in recent years is leading an increase in monocrop agriculture which is reducing the food sources for natural 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 of an area which in turn can affect the accompanying insect community [22]. Grazing can harm pollinator habitats by destroying the potential nesting sites, existing nests and their contents, direct trampling of adult insects and removal of food resources [23]. Like grazing, mowing can modify grassland species composition and succession by suppressing growth of woody vegetation [24]. Mowing has a significant negative impact on insects through direct mortality of eggs and larval stages which cannot avoid the mower [25].

Forest fires: Forest fires are often observed in dense forest hills and grasslands during summer. These are mostly ignited by farmers to grow fresh grass on forest floors. It is a most important factor affecting pollinator populations in many areas of Himachal Himalaya. Forest fires not only destroy the nesting places and food sources of insects but also destroy the pollinators hibernating or nesting in that area. The pine forests present in the mid hills of Himachal Pradesh pose a fire hazard in summer because of the falling of dried pine needles. Forests afford food and shelter for a variety of nesting and hibernating 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 also use fire in their fields and grasslands to control weeds and to improve the quality of grass for the succeeding years. The practice of weed removal reduces the diversity of food sources available for pollinators. In India, being afraid of stung, farmers also burn and poison *Apis dorsata* colonies and other pollinators [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 the culture and traditional heritage of honey-hunter communities and that was a source of their livelihood. Now, honey hunting is over exploited by big contractors and companies to earn money. 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 has adversely affected populations of native bees. This is because of competition for food, transfer of diseases from one species to another and 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 at an alarming rate across the globe. The decline of honey bee populations threatens

not only bee products but global agriculture and biodiversity [30].

3.2 Farmers Perception Regarding Conservation of Insect Pollinators

Despite of enthusiastic efforts in promoting honey bees as best pollinators, it was observed in this study that about a quarter of farmers in Himachal Himalaya had still not implicit the potential role of bee pollination to enhance their fruit yield. Most of the orchardists here were aware that introduction of both native *Apis cerana* and exotic *Apis mellifera* colonies at the time of blooming in orchards could help in fruit set and yield. Many farmers had the knowledge of local bee flora and they agreed that they had sufficient availability of bee forage like brassica, pear, apple, cherry, 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:

3.2.1Farmers' Perception about Pesticide Use

More than two third (68%) of the farmers used some type of pesticides in their orchards. They usually used fungicides, herbicides, insecticides and other pesticides purchased from government and private stores. Only 49% of the farmers knew that pesticides could kill insects. Most of them (56%) practiced wettable powder (Table 3).

3.2.2 Farmers' Perception Regarding Honey Bee Management Practices

Only 56.40% farmers knew about the bee management practices (Table 4). Most of the farmers (65.10%) handled the bees themselves whereas some (34.90%) of them deployed other persons. Most (49.50%) of the orchardists got the nucleus stock colonies from the Department of Horticulture. 84.30% of beekeepers multiplied the bee colonies only once and (75%) used smokers to handle them.

3.2.3 Migration of Honey Bee Colonies

Majority of the farmers (64.10) used to migrate bee colonies and were satisfied with colonies migration. Farmers used various modes of transportation and confronted many difficulties during bee migration (Table 5).

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

		Responses (%)
a.	**Do pesticides kill insect pollinators**	
	Yes	49
	No	32
	DNK	19
b.	**Pesticides used on crop**	
	Yes	68
	No	25
	DNK	7
c.	**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

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

Table 5. Migration of Honey Bee Colonies

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

Table 6. Farmers Obtaining Institutional Support

a.	Obtaining financial assistance from Government	Response (%)	Remarks
	Yes	38.30	
	No	58.50	
	DNK	3.20	
b.	**Organization to obtain financial assistance**		
	Department of Horticulture	23.40	
	Khadi and Village Industry Commission	15.20	
	Beekeeping farm	17.70	
	DNK	43.70	
c.	**Desired institutional support**		
	Farmers training in horticulture management and apiculture	83	Farmers training in horticulture management, improved techniques of beekeeping and management of honey bee pollination
	Financial support	49	Buying farm equipment for plantation and rearing honey bees
	Increasing awareness	61	Increasing awareness in technical aspects of bee pollination

Table 7. Major constraints in mountain beekeeping

	Responses (%)
Lack of bee flora throughout the year	29.30
Heavy snow fall in winter	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

3.2.4 Marketing of Honey and other Hive Products

Honey was collected from hives at regular intervals. About 61.40% of farmers were contented with the collection time of honey. 66.30% farmers were disappointed with the transportation arrangements in their areas. Nearly 80% orchardists faced different kinds of marketing problems.

3.2.5 Institutional Support

Only 38.30% of the orchardists got financial assistance from the Department of Horticulture. Most of them (83%) wanted to have training in orchards management technology and improved methods of bee rearing. 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).

3.2.6 Constraints in Beekeeping

The different kinds of constraints faced by beekeepers of Himachal Pradesh in practicing beekeeping are listed in the Table 7.

Among the farmers questioned most of them had the knowledge that insecticides could eradicate vital insect pollinators specially honey bees but still they were making indiscriminate use of pesticides on their fruit crops. Insecticides had diminished diversity, distribution and abundance of insect pollinators which was clearly indicated in farmers' perception. They have observed that in a few years back, there were large number of insects such as honey bees, wild bees and butterflies during the blooming season of temperate fruit crops but now pollinator

population has decreased which is affecting the crop productivity.

4. CONCLUSIONS

Although, the soil and the climate of Himachal Himalaya is apt for planting different types fruit crops and orchardists are also putting their intensive efforts, yet the yield and quality of fruits is reducing due to inadequate pollination. In last few years, many pollinator threatening factors such as loss of insect habitats, diseases of honey bees, pesticides, cell phone radiations, environmental pollution, climate change, introduced species, mono-cropping, livestock grazing, fires, ruthless honey hunting and introduction of exotic honey bees are creating a severe threat to insect pollinators and conservation of biodiversity. Some farmers of Himachal Pradesh are practicing beekeeping to earn extra income besides using them for pollination. Different types of constraints such as lack of all-season bee forage, massive snowfall, shortage of laborers, bee absconding and bee diseases are challenging the beekeeping here. A few farmers are getting financial help from Government agencies but most of them wanted training in orchard management and beekeeping techniques. Thus, we require more research to discover new methods, plans, policies and technology for conservation and management of crop pollinators not only in Himachal Himalaya but across the globe.

CONSENT

As per international standard or university standard, Participants' written consent has been collected and preserved by the author(s).

COMPETING INTERESTS

Author has declared that no competing interests exist.

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