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Showket A Dar
Assistant Professor, Division of Entomology, KVK- Kargil-Ladakh, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Jammu and Kashmir, India

Umer Bin Farook
Research Scholar, Division of Entomology, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Wadura, Sopore,

Kounser Javeed
Assistant Professor, Division of Fruit Science, AAC, Pahnoo Shopian Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Jammu and Kashmir, India

Sajad H Mir
Assistant Professor, Division of Entomology, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Wadura, Sopore

Munazah Yaqoob
Associate Professor, Division of Entomology, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Wadura, Sopore

Abid Showkat
Junior Agriculture Assistant, Department of Agriculture Govt, Jammu and Kashmir, India

Ajaz A Kundoo
Research Scholar Division of Entomology, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Shalimar, Jammu and Kashmir, India

Rohie Hassan
Research Scholar, Department of Zoology, OPGS University of Rajasthan, Rajasthan, India

Tajamul Islam
Research Scholar College of Temperate Sericulture, Mirgund Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Shalimar, Jammu and Kashmir, India

Corresponding Author:
Showket A Dar
Assistant Professor, Division of Entomology, KVK- Kargil-Ladakh, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Jammu and Kashmir, India

Pesticide legislation, national and international policies to maintain sustainable crop production through insect pollinator intervention

Showket A Dar, Umer Bin Farook, Kounser Javeed, Sajad H Mir, Munazah Yaqoob, Abid Showkat, Ajaz A Kundoo, Rohie Hassan and Tajamul Islam

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Abstract
Chemical control of pests is a common practice in agriculture. There are enormous pesticides of both chemical and biological nature used around the globe to minimize crop losses. Agriculture in developing countries suffers most because of high incidence of various pests. In India, estimated annual production losses were in millions. Although chemical pesticides are well known for their effectiveness, their impact on soil and environment, and presence of residue in food products are matters of concern. In addition to this there exists poor appropriate and alternative framework to the use of pesticides besides having full-fledged pesticide legislation. It is important to understand the crucial issues like what are the agriculture crop production issues of using pesticides, and alternative frameworks that could help to solve the problem? Lastly, there are certain gaps in data on pesticide production and use, structure of pesticide industry, regulations for registration, quality assessment, efficient spraying applicators and adverse impacts on the insect pollinator communities. Regarding declining of insect pollinators, a case study will be discussed in this article; however the detailed literature on the ecosystem and health dimensions of pesticide use in Indian agriculture is found to be scarce.

Keywords: Pesticides, insects, pollinators, insecticide act, pest management bill, yield

Introduction
The use of Chemicals in agriculture to mitigate the stresses due to multitude of biotic factors like insects, fungi, bacteria, viruses, weeds, rodents etc are under way. The highest crop damage is caused by insects followed by pathogens and weeds. In India, estimated annual production losses due to pests are as high as US$ 42.66 million (Sushil, 2016) [29]. Although chemical pesticides are considered to be the first line of defense because of their effectiveness, but their impact on soil and environment, and presence of residue in food products are matters of concern. There are numerous reports and evidences on the negative impacts of pesticides as a threat to humans. Detailed literature on the environment and health dimensions of pesticide use in Indian agriculture is found to be scarce. India being a huge country has framed laws to tackle the problems arising from these chemicals besides their manufacturing, regulation and policies designed.

Globally, 2 million tonnes of pesticides are utilized annually worldwide, where China is the major contributing country, followed by the USA and Argentina. However, by the year 2020, the global pesticide usage has been estimated to increase up to 3.5 million tonnes (Sharma *et al*. 2019) [27]. Although pesticides are beneficial for crop production point of view, extensive use of pesticides can possess serious consequences because of their bio-magnification and persistent nature. Diverse pesticides directly or indirectly polluted air, water, soil and overall ecosystem which cause serious health hazard for living being. In the view of harmful impacts of pesticides on environment the famous writer Rachel Carson (1962) [4] through her contribution titled, Silent Spring diverted the attention of the national and international policy makers towards the impacts and consequences of the harmful toxicants on environment. Pollinators are indispensable for the crop production (Dar *et al*. 2016a, Dar *et al*. 2018a) [10, 6], So their conservation, habitat management (Dar *et al*. 2017a) [12] and overall their interaction (Dar *et al*. 2017b) [8] with angiosperms is of prime importance. However, the information about impact of pesticides on insect pollinators in India is very scanty. Currently, at international level huge decline in bees has sparked the formation of a global policy framework for pollinators, primarily through the International Pollinator Initiative within the Convention of Biological Diversity.

Concept of IPM and reduction of pesticide use

The implementation of the IPM is basically centered towards the reduction of pesticide use, resulting in savings of materials, application costs and environment as whole. Contamination of the environment and the worker health problems can also be reduced, and energy for the manufacture and application of pesticides is conserved. The reduction in development of the pesticide resistance and pest outbreaks can be reduced. Depending on the complexity of the management system, crop grown, region and seasons an IPM program may target a single pest (Dar *et al*. 2017d) [5], a pest category or the whole pest complex taking into account the interactions among pests, beneficial organisms, the environment, and the crop. The development of an IPM system requires a thorough understanding of the biology of the crop (or resource), pest complex. Further other abiotic factors those influence the pest complex of particular crops includes sunshine hours, growing degree days (Dar *et al*. 2018c) [14], moisture regimes (Dar *et al*. 2017e) [16] and nitrogen application (Dar *et al*. 2014) [15].

The Insecticides Act 1968 ignored important crop production factors

In India, the Insecticides Act, 1968 and Insecticides Rules, 1971 regulate the import, registration process, manufacture, sale, transport, distribution and use of insecticides (pesticides) with a view to prevent risk to human beings or animals and for all connected matters, throughout India. All insecticides (pesticides) have to necessarily undergo the registration process with the Central Insecticides Board & Registration Committee (CIB & RC) before they can be made available for use or sale According to Section 3 (e) of Insecticides Act, 1968. The CIB & RC scrutinizes and periodically reviews all pesticides and their usage - some are banned from registration itself. Sometimes a pesticide can be banned even after registration when it causes serious environmental and public health concerns. Some pesticides are meant for "Restricted Use" which means that they can be used only for prescribed purposes and by authorized personnel by obtaining the appropriate Government license. In whole of this process conservation of insect pollinators were never considered intensely, the reason behind this is that India is a dense populated country and shortage of food had always remained a problem. Therefore, policy makers always focused over the pest management but the greater loss caused at the expense of pollinator can't be recovered. Considering the adverse impacts of pesticides to human and residual impacts that polluted the environment, the following chemicals have been banned in India. However, none of the chemicals were banned with the sole reason that it showed toxic impacts to insect pollinators.

Table 1: List of pesticides which are banned, refused registration and restricted in use (As on 31.10.2019)

Pesticides Banned for manufacture, import and use				
Aldicarb	Chlordane	Endrin	Menazon	Sodium Cyanide
Aldrin	Chlorofenvinphos	Ethyl Mercury Chloride	Methoxy Ethyl Mercury Chloride	Sodium Methane Arsonate
Benzene Hexachloride	Copper Acetoarsenite	Ethyl Parathion	Methyl Parathion	Tetradifon
Benomyl	Diazino	Ethylene Dibromide (EDB)	Metoxuron	Thiometon
Calcium Cyanide	Dibromochloropropane (DBCP)	Fenarimol	Nitrofen	Toxaphene(Camphechlor)
Carbaryl	Dieldrin	Fenthion	Paraquat Dimethyl Sulphate	Tridemorph
Chlorbenzilate	Endosulfron	Heptachlor	Pentachloro Nitrobenzene (PCNB)	Trichloro acetic acid (TCA)

Table 2: Pesticide formulations banned for import, manufacture and use (As on 31.10.2019).

S. No.	**Name of Pesticide**	**Refused registration**	
1	Carbofuron 50%	2,4, 5-T	EPN
2	Methomyl 12.5% L	Ammonium Sulphamate	Fentin Acetate
3	Methomyl 24% formulation	Azinphos Ethyl	Fentin Hydroxide
4	Phosphamidon 85% SL	Azinphos Methyl	Lead Arsenate
Pesticides phase out by 30th December 2020		Binapacryl	Leptophos
1	Alachlor	Calcium Arsenate	Mephosfolan
2	Dichlorovos	Carbophenothion	Mevinphos
3	Phorate	Chinomethionate	Thiodemeton
4	Triazophos	Dicrotophos	Vamidothion
5	Trichlorfon	Disulfoton	

Pesticides Management Bill, 2008

At national level, pollinator conservation initiative is must for sufficient crop production to feed the growing population. In India 75% farmers are associated with agriculture directly or indirectly. The Pesticides Management Bill, 2008 was introduced in the Rajya Sabha on October 21, 2008. The Bill seeks to regulate the manufacture, quality, import, export and sale of pesticides to control pests, ensure availability of quality pesticides and minimize contamination of agricultural commodities with pesticide residue; however nothing was discussed about the conservation of important insect pollinators. The bill repeals the Insecticides Act, 1968, and under which "Pesticide" means any substance of chemical or biological origin intended for preventing or destroying any pest, which includes unwanted plants and animals during the production, storage and distribution of agricultural commodities or animal feed.

National policies

Concept of conservation of insect pollinators was again unlucky to get any importance at national level. Government of India has taken several measures for proper use of pesticides by the farmers in the country. The pesticide residue data generated under the "Monitoring of Pesticide Residues at

National Level" are shared with State Governments and concerned Ministries/Organizations to initiate the corrective action for judicious and proper use of pesticides on crops with an Integrated Pest Management approach and to generate awareness amongst farmers. It is confirmed fact that pesticides have cause a significant decline in pollinators but in developing countries, like India, no action were taken to frame a policy for their well being and were always at the risk through the hands of policy makers.

International policies

In a comprehensive review compiled by Byrne and Fitzpatrick (2009) [3] Ireland documented the bee conservation policies at national and international levels in depth explained that global decline (decline through various factors, like pesticides and disease) in bees urgently needs the formation of a global policy framework for pollinators, primarily through the International Pollinator Initiative within the Convention of Biological Diversity. On emergency basis the regional Pollinator Initiatives, along with regional and national conservation legislation, that can impact on the conservation of bees have been initiated in many countries. The creation of bee Regional Red Lists, under guidance from the International Union for Conservation of Nature, along with conservation priority lists offer another mechanism for streamlining bees into regional, national or sub-national conservation policy and practice. These structures, is focused to form a coordinated and effective policy framework on which conservation actions can be based. With respect to pollinators, there is an overarching global framework in place that guides initiatives at lower policy levels. During the mid 1990's global concern emerged regarding the survival of pollinator diversity from research within academic and other wildlife institutional sources (Watanabe, 1994) [32], "The Forgotten Pollinators Campaign" was launched in 1995 in the United States, accompanying book, of the same name (Buchmann and Nabhan, 1994) published in North America. The devisors of the campaign called for policy changes to protect habitats for pollinators and suggested sub-sidising farmers to do so (Ingram *et al*., 1996) [21]. In 1996, the Third Conference to the Parties (COP3) of the Convention on Biological Diversity (CBD) gave pollinators priority for the publication of case studies in its agro-biodiversity programme. The Convention on Biological Diversity legitimized the global concerns through prioritizing pollinators in their Conservation and Sustainable use of Agricultural Biological Diversity programme. This led to an international pollinator workshop, with the emphasis on bees, hosted by the Brazilian Government at the University of São Paulo in October 1998 (Dias *et al*., 1999) [13]. A total of 61 scientists from 15 countries and 5 International organizations attended, and resulted into creation of "The São Paulo Declaration on Pollinators" and it was in this document that an International Pollinator Initiative (IPI) was proposed (Imperatriz-Fonseca and Dias, 2004; Freitas *et al*., 2009) [20, 19]. The executive secretary of the CBD Nairobi Kenya invited the Food and Agriculture Agency (FAO) of the United Nations (UN) to facilitate and coordinate the IPI in cooperation with other relevant organizations. The FAO, in collaboration with key experts, developed a Plan of Action (POA) for the IPI. This plan, which built on recommendations from the São Paulo Declaration on Pollinators, was accepted and adopted by member countries at COP6 (April 2002), with the objective to "promote coordinated and proposed action worldwide" a global policy platform for conservation of pollinators, including bees.

IPI Regional Policy

The Global IPI currently has five regional representative IPI's, put together by The São Paulo Declaration forum: the African Pollinator Initiative (Eardley *et al*., 2009) [17], Brazilian Pollinator Initiative (BPI), the European Pollinator Initiative (EPI), the North American Pollinator Protection Campaign (NAPPC) and the International Centre for Integrated Mountain Development (ICIMOD). The rationale behind the regional initiatives is the need for a collective approach towards implementing and developing the plans set out in the IPI-POA, to create regional networks. Expertise can be one of the limiting factors in conservation efforts, but can be minimized when countries take a collective approach to the conservation of bees (Eardley, 2001) [18]. The European Pollinator Initiative has used this idea to facilitate links between experts in different fields and provide a look-up service for those people seeking specific advice or skilled input (Potts, 2004) [25]. A similar internet based network has been developed in the University of Guelph, Canada, called International Network of Expertise for Sustainable Pollination (Tang *et al*., 2005) [30].

Building Capacity

Awareness of bee conservation issues among the farmers to important stakeholders at many levels should be promoted locally to globally. Widespread dissemination of high quality and easy to understand information to the general public and to special interest groups is of huge importance at present time. The IPI supports policies that promote the collection and dissemination of biodiversity data, and it is felt that unless awareness from very lower level is not imparted, the implementation of conservation would not be achieved fully. At Institutional level the capacity building includes developing conservation networks, infrastructure, for example data basing, websites and making relevant information and literature available to interested parties at an earliest. An important step in building capacity is development of targeted educational and outreach material which is disseminated appropriately among the educated youth of the farming society. The role of the internet as an important tool in aggregating and facilitating information sharing is stressed; for example the global databases that hold data on bees and make it freely available, like Global Bee Checklist (Ascher *et al.* 2008) [1], held online on Integrated Taxonomic Information System (ITIS) website. This checklist has been the result of collaborative work between IT IS and Global Biodiversity Information Facility (GBIF), The Inter-American Biodiversity Information Network (IABIN), The Food and Agricultural Organization (FAO)) (Remsen and Ruggiero, 2007) [26]. Another proposed awareness strategy is the development of 'pollinator friendly' products and branding.

Sustaibale crop production and pesticide regulations

Pesticide and pollinator interaction is an issue has been approached by scientific community in a compartmentalized and intra-disciplinary way, such that evaluations of organismal pesticide effects remain largely disjoint from their upstream drivers and downstream consequences. We will briefly discuss here the socio-ecological framework designed to synthesize the pesticide-pollinator system and inform future scholarship and action especially under the heading of toxic effects of pesticides on the pollinator habitat and behaviour and consists here only this domain (pesticide effects). We elaborate these domains and their linkages, reviewing relevant literature and providing our personal case studies of last ten years. Briefly the guidelines for future pesticide-pollinator scholarship and action agenda aimed at strengthening knowledge in neglected domains and integrating knowledge across domains to provide decision support for stakeholders and policymakers, specifically emphasizing a) stakeholder engagement, b) mechanistic study of pesticide exposure, c) understanding the propagation of pesticide effects across levels of organization, and d) full-cost accounting of the externalities of pesticide use and regulation. These items will require transdisciplinary collaborations within and beyond the scientific community, including the expertise of farmers, agrochemical developers, and policymakers in an ex-tended peer community.

Effects of pesticides on agriculture production

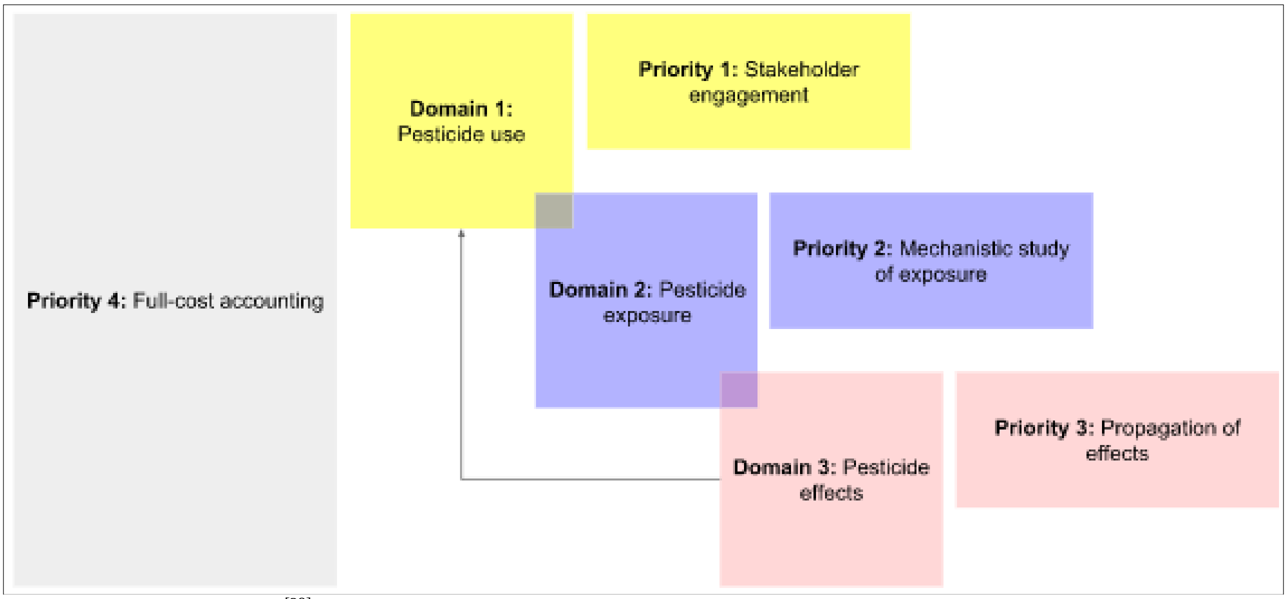
Pesticides and pollinators-A socioeconomic analysis

Sponsler *et al.* (2019) [28] reviewed the relationship between pesticides and pollinators, and focused the gaps of this serious concern of issue of toxicity of synthetic chemicals on pollinator communities. The issue has shortage of attention from scientists, regulators, and the public, and has proven resistant to scientific synthesis and fractious in matters of policy and public opinion.

The knowledge of pesticides and pollinators suffers from vast gaps, not just in data but in theory, communication, and practice. So far, the knowledge generated about the various adverse factors like diseases impacting bees (Ullah *et al.* 2020) [31] have be well generated; however the information about the adverse impacts by pesticides and necessary policies to curb these impacts have yet not achieved fully. A new generation of pesticide-pollinator scholarship could provide both a synthesis and set of applications, informed by the structured relationships. To look over pollinator conservations and management in current age of climate change, we have to shear responsibilities among different groups from farmers' level to govt. policies and implementations.

Stakeholder engagement

This often occurs through public extension services, comprehensively addressing the pesticide-pollinator relationships that need to focus on pollinator extension services to include pollinator health in addition to issues related to apiculture and crop pollination (Fig 1). Inter-institutional bodies that span the diverse domains needed to address pollinator health may help further facilitate an exchange of information and expertise at national or regional levels. These efforts will be to document a reduction of pollinator exposure to pesticides besides achieving the effective pest management. It will be beneficial as well as critical for the policy-makers looking to address existing conflicts around pollinators.



Source: Sponsler *et al.* 2019 [28]

Fig 1: Pesticide and pollinator interaction is an issue that has been poorly approached by scientific community, therefore for the future needs the following domains and their linkages need to be understood.

Pollinator behavior and life history

Pesticide use, fate dynamics, and environmental conditions determine the spatiotemporal patterns of pesticide contamination in the environment. Connecting patterns of contamination to patterns of pollinator exposure, requires an understanding of the behavioral and life history traits that govern the interactions between pollinators and their environment, and hence the spatio temporal intersection between pollinators and environmental contaminants.

General behavioral and life history traits

Pollinator behavioral traits can be parsed in many ways, but we highlight four trait classes that are especially relevant to pesticide exposure (Fig 2): foraging behavior, nesting behavior (Dar *et al.* 2016b) [9], phenology, and sociality. Foraging behavior in pollinators varies in terms of host plant (Dar *et al.* 2018b) [11], localization, range, and diet breadth (ranging from highly specialized to highly generalized). An important corollary of non-central place foraging is that juveniles, lacking a nest, are free-foraging rather than provisioned by adults, multiplying potential routes of juvenile pesticide exposure. Foraging range, strongly correlated with body size in bees, influences how much of the environment a pollinator interacts with and, therefore, its extent of intersection with environmental contaminants. Diet breadth similarly constrains environmental interactions. It is likely that long foraging range and broad diet breadth, contribute to simultaneous exposure to multiple pesticides, but these traits may also have the effect of diluting dietary pesticide exposure by the combination of contaminated and uncontaminated sources. Conversely, shorter foraging range and narrower diet breadth make pesticide exposure dependent, for better or worse, on a smaller subset of the environment. It must be noted, foraging range and diet breadth can vary facultative based on resource availability. In pollinators that form nests, nesting behavior includes wax comb construction, subterranean burrows, above-ground cavities (Dar *et al*. 2017c) [7], and various uses of leaves and flowers (e.g. nest cell lining in Megachilidae leafcutter bees), wood pulp, and plant resins (e.g. nest sealing honey bees and resin bees). Each of these nesting substrates presents a potential source of pesticide exposure. In terms of phenology, the majority of pollinators have discrete seasonal activity periods, but some remain active throughout year.

	Foraging							Nesting			Phenology		Sociality		
Guild	Localization		Range (m)			Diet breadth									
	CP†	non-CP	<500	500-3000	>3000	specialist	generalist	wax	soil	plant	seasonal	continuous‡	nonsocial	weakly social	highly social
honey bees	■				■		■	■				■			■
stingless bees	■		■	■			■	■				■			■
bumble bees	■			■		■	■	■	■			■		■	
other bees	■		■	■		■	■		■	■	■		■	■	
social wasps	■		■	■			■		■	■	■	■		■	■
solitary wasps	■		■	■		■	■		■	■	■		■		
other insect pollinators*		■	NA	NA	NA	■	■	NA	NA	NA	■	■	■		

Source: Sponsler *et al*. 2019 [28]

Fig 2: Species foraging range, diet breadth, localization, behaviour (nesting), phenology and sociality vary facultatively under continuous pesticides spraying Biorationals to lessen the dependence on synthetic chemicals

Biorational management of insect pests is an ecofriendly method. For many of the insect pests, e.g. fruit flies, the pheromones are used for their monitoring and management based on the mechanism of sending the chemical signals to help attract mates or disperse mating pairs to prevent mating. At vegetables farms using specific pheromones, traps can be installed to monitor target pests in fields or in residential areas. By constantly monitoring for fruit flies, it may be possible to detect an infestation before it occurs, and control measures would be taken to enhance the yield. Biofix of the insect pest using traps can also lessen damage to agriculture and other plants. Asian gypsy moth, Japanese beetles and fruit flies (Mir *et al*. 2014; Mir *et al*. 2017) [23, 24] can be damaging to fodder crops and other plants and may be controlled with a community effort.

Case study

During the period of ten years (Fig 3), it was observed that use of various pesticides in vegetables gardens and fruit crops, has increased many times. The magnitude of the pesticide has created many problems in arthropod living in a rural setting in Kashmir, India. The study describes pesticide usage in a sample of 100 randomly selected fruit crops in higher belts of three districts taken as experimental locations. The most widely used pesticides especially in apple orchards we observed were HMO, Mancozeb 75 WP (300 g), Propineb 70 WP (300 g), Zineb 75 WP (300 g), Captan 50 WP (300 g), Ziram 80 WP (200 g), Dodine 65 WP (60 g), Dodine 40 SC (90 ml), Zineb 68% + Hexaconazole 4% 72 WP (100 g), Difenaconazole 25EC (30 ml), Flusilazole 40 EC (20 ml), Trifloxystrobin 25% + Tebuconazole 50% 75 WG (40g), Chlorpyriphos 20 EC (100 ml), Hexythiazox 5.45 EC (40 ml) or Spiromesifen 22.9 SC (40 ml), Hexythiazox 5.45 EC (40 ml), Spiromesifen 22.9 SC (40 ml), Flusilazole 40 EC (20 ml), Metiram 55% + Pyraclostrobin 5% 60 WG (100 g), Myclobutanil 10WP (50 g), Fenazaquin 10 EC (40 ml); that are known to have less toxicity. Further, the most widely used applicators are those in the form of spray devices, and during pesticides application people do not use full protective equipment, neither care of adjacent crops were taken. Results showed that the investigated wild bee species got exposed to pesticides as after 8:30 am, their foraging activity increases over the apple flowers, further the exposure to other organism were due to non-mechanized agricultural activity and limited education on pesticides handling, spray and dosage used. For our studies, we took natural landscapes near the apple orchards to estimate the population of wild bee complex especially family Halictidae genus *Lasioglossum*. Based on nest density (Fig-3) per square meter on the natural landscape 5º steep slope, we observed high significant difference in nest density, and population catch from the *Brassicae rapa*, grown near by the nesting habitat.

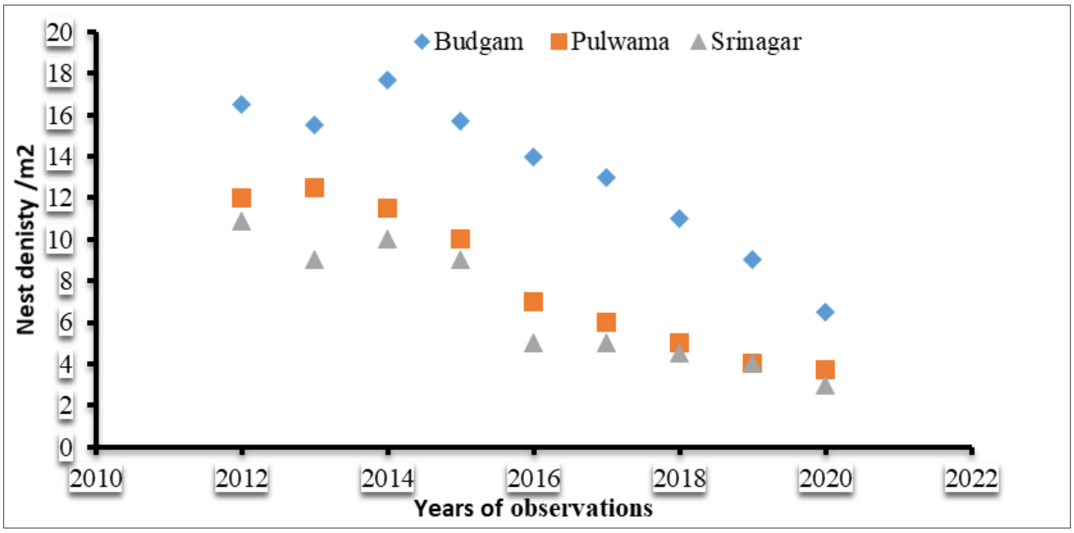


Fig 3: Variation of live nesting density across the years of study, showing the toxic effects of various pesticides on bees residing in the nearby habitat

Pesticide Risk factors to wild bees

A basic list of major factors considered to potentially influence pesticide risk to bees was established. The list was summarized after considerable review, but it is not necessarily exhaustive (Table 3). It could be that factors mentioned may have different possible effects on pesticide risk to bees, however, in many cases, a clear correlation between a given factor and an increase or reduction of risk can be assumed. In few cases the correlationship is less clear and requires more research information on bee biology or the cropping situation. Life history and population dynamics factors were originally not included in the survey.

Table 3: Risk factor possible effect on the risk of pesticide on wild bee

Exposure – crop factors	**Possible inference**
Surface area under crop: - overall size - patchiness	Larger surface area under the specific crop è higher exposure risk Lower fraction of the crop in the overall area è lower exposure risk
Period(s) in the growing season when pesticides are applied to the crop	(Determinant for factors below)
Period(s) in the year when the crop flowers	If overlap between flowering of crop and pesticide applications è higher exposure risk
Period(s) in the year when bees are foraging or collecting nesting materials	If overlap between bee activity in crop and pesticide applications è higher exposure risk
Period(s) when weeds are flowering in the crop which may be attractive to wild bees	If overlap between flowering of weeds and pesticide applications è higher exposure risk
Crop has extrafloral nectaries	If extrafloral nectaries present in crop è higher exposure risk
Crop is regularly infested with honeydew producing insects	If honeydew producing insects present in crop è higher exposure risk
Drinking water is available in the crop	If drinking water in the crop è higher exposure risk
Exposure – bee biology factors	
Location of nest in relation to crop field	In-field and field-border nests è higher exposure risk Off-field nests è lower exposure risk (depending on distance)
Bee foraging range	If in-field and field border nests: shorter foraging range è higher exposure risk If off-field nests è risk depends on distance between nest and sprayed field
Time spent foraging, or collecting nesting materials, per day (“time-out-of-nest/hive”)	More hours out-of-nest/hive è higher exposure risk
Period of the day when foraging or collecting nesting materials	Early/middle in the day è possibly lower exposure risk (if pesticide is applied afterwards and has very low persistence) All-day/late in the day è higher exposure risk
Number of days spent foraging on the crop (for an individual bee)	More days spent foraging è higher exposure risk
Number of days spent foraging on the crop (for the colony)	More days spent foraging è higher exposure risk
Number of different nectar and pollen plant species used during crop flowering	Fewer species è higher exposure risk
Quantity of pollen collected per day	Higher quantity è higher exposure risk
Quantity of nectar collected per day	Higher quantity è higher exposure risk
Quantity of nectar consumed per day	Higher quantity è higher exposure risk
Body weight	Higher body weight è possibly lower exposure or impact risk (also determinant for other factors)
% of pollen self-consumed	More self-consumed è higher exposure risk to adult
% of pollen fed to brood	More self-consumed è higher exposure risk to adult
% of nectar self-consumed	More self-consumed è higher exposure risk to adult
% of nectar fed to brood	More fed to brood è higher exposure risk to brood
Collective pollen and/or honey storage in the	If collective pollen and honey storage è lower exposure risk due to mixing, maturation and

nest (social bees)	microbial action
Exposure and impact – pesticide use/application practices	
Formulation type	Some formulations types (e.g. micro-encapsulation, sugary baits, DP, WP) è higher exposure risk
Pesticide is systemic	Specific exposure/impact assessment
Pesticide is an insect growth regulator (IGR)	If IGR è specific impact on brood
Mode of application	Some modes of application (e.g. dusting, aerial application) è higher exposure risk Some modes of application (e.g. seed/soil treatment with nonsystemic pesticide; brushing) è lower exposure risk
Application rate	For the same pesticide product: higher application rate è higher exposure/impact risk
Application frequency	Higher application frequency è higher exposure risk
Systemic pesticides are applied as soil treatment or seed treatment to a previous rotational crop	If systemic pesticides applied to a previous rotational crop è possibly higher exposure risk
Impact and recovery – pesticide properties	
Contact LD50 (adult)	Lower LD50 è higher impact (for similar exposure levels)
Oral LD50 (adult)	Lower LD50 è higher impact (for similar exposure levels)
Oral LD50 (brood)	Lower LD50 è higher impact (for similar exposure levels)
Foliar residual toxicity	Higher residual toxicity è higher impact (for similar exposure levels) & lower likelihood of recovery after pesticide impact
Impact and recovery – life history and population dynamics factors	
Individual metabolic rate	Higher metabolic rate è lower impact (increased detoxification)
Degree of sociality	High degree of sociality with one or more reproductive queens and separate foragers è lower risk of impact to the population/colony because pesticide affects primarily foragers (except for Insect Growth Regulators (IGRs)
Fraction of population/colony active out of the nest/hive (social bees)	Higher fraction of population of colony active out of the nest/ hive è higher risk of impact for the whole population/colony
Time to reproductive age of queen/reproductive female (egg-adult)	Shorter development time è lower exposure risk (if development partly overlaps with flowering)
Number of offspring per queen/reproductive female	Greater number of offspring è greater likelihood of population recovery after pesticide impact
Number of generations per year	Greater number of generations per year è greater likelihood of population recovery after pesticide impact
Population growth rate [note: as product of previous 3 factors]	Higher population growth rate è greater likelihood of population recovery after pesticide impact
Number of swarms per colony or reproductive events per year	More swarms or more frequent reproduction è greater likelihood of population maintenance, if swarming or reproduction occurs before pesticide impact or è greater likelihood of population recovery after pesticide impact
Migration and dispersal distance	Greater dispersal distance è greater likelihood of population recovery after pesticide impact (if cropping is patchy); however if migratory routes are used, possible multiple exposure to pesticide
Note : è stands for arrow pointing towards	

[**Source:** Harold van der Valk and Irene Koomen, 2013]

Conclusions

There are some issues which need immediate attention to strengthen domestic pesticide industry and safe application of pesticides. Firstly, it is important to regulate and encourage the use of cost-effective and environmentally safe pesticides. The uniformity in testing procedures (parameters, labs, actors, etc.) and deregistration of outdated, hazardous pesticides are necessary for avoiding the adverse impacts. The point-of-sale quality assurance and farmers protection mechanisms in case of spurious products must be strengthened. The industry association can also be involved in this task. The second important consideration is the promotion of safe application practices and awareness among farmers. The third issue relates to assessment of potential effects of strengthened patent regime on pesticide industry, particularly its likely effect on product prices. In such a situation, competition promoting policies should be adopted.

As far as the importance of pollinators is considered globally for about 38.23% of the food production we consuming, we recommend the further development of mechanisms that allow for the efficient dissemination of relevant bee conservation information through the different policy levels to stakeholders at national and sub-national levels to make them fully aware of existing global and regional policy initiatives as a priority. We support and encourage the development of taxonomic expertise and research networks, and the sharing of ideas, with the effective utilization of the internet is also must. Within regional initiatives, greater emphasis is placed on providing stakeholders at national and sub-national levels with advice on how national legislation can integrate effectively into existing global and regional policy frameworks for the conservation of bees. In the country where bee protection policies exist, policies should be expanded to protect wild bees due to the pollination services they provide and not just to support managed species or diversity. Organic farming should be encouraged to remove the dependence on synthetic pesticides. Further research and evaluation of bee species that may be afforded protection through the Global Red List, and the development of Regional Red Lists and Priority lists to establish actions for nationally or regionally threatened species is needed. Therefore, the implementation of some or all of these recommendations could improve significantly the chance of halting the decline of bees and the essential ecosystem service they provide.

References

1. Ascher J, Eardley C, Griswold T, Melo G, Polaszek A, Ruggiero M, *et al*. World Bee Checklist Project – update 2008-09, manuscript (version 10/09/2008), [online] Integrated Taxonomic Information System 2008.

2. Buchmann SL, Nabhan GP. The Forgotten Pollinators, Island Press, Washington, DC 1996.
3. Byrne A, Fitzpatrick U. Bee conservation policy at the global, regional and national levels. La politique de conservation des abeilles aux niveaux mondial, régional et national. Richtlinien zum Schutz der Bienen auf globaler, regionaler und nationaler Ebene. National Biodiversity Data Centre, Beechfield House, WIT West Campus, Carriganore, Waterford, Ireland. Apidologie 2009;40(3):194-210. Bee conservation DOI: https://doi.org/10.1051/apido/2009017
4. Carson Rachel. [1st. Pub. Houghton Mifflin, 1962]. Silent Spring. Mariner Books. ISBN 978-0-618-24906-0. Silent Spring initially appeared serialized in three parts in the June 16, June 23, and June 30, 1962 issues of The New Yorker magazine 1962.
5. Dar SA, Wani AR, Sofi A, Pathana SS. IPM for brinjal shoot and fruit borer (Leucinodes Orbonalis)-A review. Indian Journal of Entomology 2017d;79(2):130-137.
6. Dar SA, Wani AR, Sofi MA. Diversity and abundance of insect pollinators of sweet cherry *Prunus avium* in Kashmir valley. Indian Journal of Entomology 2018a;80(3):725-736.
7. Dar SA, Mir GM, Parry MA, Parry SH, Yaqob M, Khrusheed R. Potential habitat value for wild bees in Kashmir valley. Journal of Crop and Weed 2017c;13(1):125-131.
8. Dar SA, Hassan GI, Padder BA, Wani AR, Parey SH. Pollination and evolution of plant and insect interaction. Journal of Pharmacognosy and Phytochemistry 2017b;6(3):304-311.
9. Dar SA, Mir GM, Parry MA, Sofi MA, Padder SA. Nest Distribution and Nesting Habits of Xylocopa Violacea (Donovan), Fabricius (Hymenoptera: Apidae) In Kashmir Valley. Journal of Experimental Zoology, India 2016b;19(1):155-162.
10. Dar SA, Mir GM, Parry MA, Ahmad SB, Ganie MA, Raja TA, Yaqob M. Diversity and Richness Indices and the Whittaker Plot Value of Insect Pollinators of Peach *Prunus persica* in Landscapes of Temperate India. Academic Journal of Entomology 2016a;9(4):62-73.
11. Dar SAM, Tanweer-Ul-H, Dar SH, Nissar M, Wani RA, Kandoo AA. Foraging pattern of Lasioglossum (Hymenoptera: Halictidae) species on Himalayan indigo (Fabaceae) in Kashmir. The Pharma Innovation 2018b;7(5-H):530.
12. Dar SA, Mir SH, Rather BA. Importance of hedgerows for wild bee abundance and richness in Kashmir Valley. Entomon 2017a;42(1):59-68.
13. Dias BSF, Raw A, Imperatriz-Fonseca VL. International Pollinators Initiative: The Sao Paulo declaration on pollinators, Report on the Recommendations of the Workshop on the Conservation and Sustainable Use of Pollinators in Agriculture with Emphasis on Bees 1999. www.biodiv.org/doc/case-studies/agr/cs-agr-pollinator-rpt.
14. Dar EA, Brar AS, Yousuf A. Growing degree days and heat use efficiency of wheat as influenced by thermal and moisture regimes. Journal of Agrometerology 2018c;20:168-170.
15. Dar EA, Harika AS, Tomar SK, Tyagi AK, Datta A. Effect of cropping geometry and nitrogen levels on quality of baby corn (*Zea mays* L) as fodder. Indian Journal of Animal Nutrition 2014;31:60-64.
16. Dar EA, Yousuf A, Brar AS. Comparison and evaluation of selected evapotranspiration models for the Ludhiana district Punjab. Journal of Agrometerology 2017e;19:274-276.
17. Eardley C, Gikungu M, Schwarz MP. Bee conservation in sub-Saharan Africa and Madagascar: diversity, status and threats, Apidologie 2009;40:355-366.
18. Eardley CD. Pollinators: a conservation priority. Science in Africa 2001, 2. http://scienceinafrica.co.za/pollinator.htm
19. Freitas BM, Imperatriz-Fonseca VL, Medina LM, Kleinert AMP, Galetto L, Nates-Parra G, *et al*. Diversity, threats and conservation of bees in the Neotropics, Apidologie 2009;40:332-346.
20. Imperatriz-Fonseca VL, Dias BFS. Brazilian Pollinators Initiative. In: Freitas B.M., Pereira O.P. (Eds.), Solitary bees- conservation, rearing and management for pollination, UFC 2004, 27-34. http://www.webbee.org.br/bpi/english/solitary_bees.htm
21. Ingram M, Nabhan G, Buchmann S. Our Forgotten Pollinators: Protecting the Birds and Bees, Global Pesticide Campaigner PANNA, San Francisco, CA 1996;6:4. http://www.pmac.net/birdbee.htm
22. International Pollinator Initiative (IPI) – Plan of Action. Pollinators – Plan of Action, 2002. http://www.cbd.int/agro/planaction.shtml
23. Mir SH, Dar SA, Mir GM, Ahmad SB. Biology of Bactrocera cucurbitae (Diptera: Tephritidae) on cucumber. Florida Entomologist 2014;97(2):753-758.
24. Mir SH, Ahmad SB, Showket Dar A, Bano P. *Hemilea malaisei* Hering (Diptera: Tephritidae): The First Record from India. Entomological News 2017;127(2):151-153.
25. Potts SG. European Pollinator Initiative, Crop and Crop Associated Biodiversity Pollinator Case Studies 2004. http://www.fao.org/ag/AGP/agps/C-CAB/Castudies/pdf/9-002.pdf
26. Remsen D, Ruggiero M. Towards a Global Bee Checklist: Summary and Status Report 2007. http://globalbees.editwebrevisions.info/en/node/913
27. Sharma A, Vinod Kumar, Babar Shahzad, Mohsin Tanveer, Gagan Preet Singh Sidhu, Neha Handa, *et al*. SN Applied Sciences 2019;1(11):1446. doi:10.1007/s42452-019-1485-1
28. Sponsler DB, Grozinger CM, Hitaj C, Rundlof M, Botias C, Code A, *et al*. Review: Pesticides and pollinators: A socioecological synthesis. Science of the Total Environment, Elsevier 2019;662:1012-1027. https://doi.org/10.1016/j.scitotenv 2019.
29. Sushil SN. Emerging Issues of Plant Protection in India. Natural Resource Management: Ecological Perspectives. International Conference, SKUAST, Jammu 2016.
30. Tang J, Wice J, Thomas VG, Kevan PG. Assessment of the capacity of Canadian Federal and Provincial legislation to conserve native and managed pollinators, A Report Compiled by The International Network of Expertise for Sustainable Pollination at the request of The North American Pollinator Protection Campaign 2005.
31. Ullah A, Gajger Tlak I, Majoros A, Dar SA, Khan S, Kalimullah, *et al*. Viral impacts on honey bee populations: a review. Saudi Journal of Biological Sciences 2020. Doi: https://doi.org/10.1016/j.sjbs.2020.10.037.
32. Watanabe ME. Pollination worries rise as honey bees decline, Science 1994;265:1170.