

## Diversity of Bumblebees under Different Agro Climatic Condition of Jammu, India

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### ABSTRACT

The study was conducted under sub-tropical, intermediate and temperate areas of Jammu division for determining the diversity of different species of bumblebee. The studies were conducted at elevations ranging from 280 m (Chatha) to 422 m amsl (Kot Bhalwal) in sub-tropics, from 477m (Reasi) to 1022 m (Chenani) Intermediate zone. The temperate zone ranges from Chandrakot (above 1000 m) to Kishtwar Padder (2214 amsl) during the two consecutive year of 2016 and 2017. The results revealed that in sub-tropic zone, only two different types of bumblebee were recorded viz., *Bombus haemorrhoidalis* Smith 1852 and *Bombus trifasciatus* Smith 1852. Three species of bumblebee such as *B. haemorrhoidalis* Smith 1852, *Bombus simillimus* Smith 1852 and *Bombus tunicatus* Smith 1852 were recorded in intermediate zone during 2015- 2016. In temperate zone, five species of bumblebee like *B. haemorrhoidalis*, *B. simillimus*, *B. tunicatus*, *B. trifasciatus* and *Bombus pyrosoma*

Morawitz 1890 were observed foraging on different types of host plants. In-total, seven different types of bumblebee species such as *B. haemorrhoidalis*, *B. simillimus*, *B. tunicatus*, *B. trifasciatus*, *B. melanurus*, *B. asiaticus* and *Bombus pyrosoma* were recorded during 2016 and 2017, respectively with two species from sub-tropics, four species from intermediate zones, respectively.

**Keywords** Bumblebees, Species diversity, Agro climates, Pollination.

### INTRODUCTION

Union territory of Jammu and Kashmir presents great diversity of climates and altitudinal variation which provide a broad range of habitat for bumblebees. The bumblebees of this region are of particular interest as this area presents a narrow corridor of mountains between the large and divergent oriental and palaeartic bumblebee fauna's. Different climatic regions not only differ in their flora but in combination with altitudinal zonation and variation in local flora contribute toward a particularly broad range of habitats. Bumblebees are the most efficient pollinators of plant species of great economic importance. They can work well in confinement and especially in small enclosures and have been extensively utilized for pollination purposes in several countries of the world like France, Japan, Korea, Germany, Canada, Sweden, Brazil, UK, USA and many other countries. In these countries they have been reared /domesticated in artificial domiciles to increase their population for effective crop pollination and used for pollination in cages for several crops like *Brassica oleracea*, *B.*

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**Table 1.** Survey of bumblebee species in different agro-climatic zones of Jammu division during 2016 and 2017.

Sl. No.	Kathua	Rajouri	Locations Banihal	Batote	Bhaderwah
1.	Udheywalla	Akhnoor	Chandrakot	Udhampur	Doda
2.	Bag-e-Bahu	Chouki-Choura	Rajgarh	Ramnagar	Bhaderwah
3.	Channi	Bhamla	Ramban	Chenani	Sartangal
4.	KotBhalwal	Sunderbani	Banihal	Basht	Jai valley
5.	Samba	Reasi		Sudh Mahadeo	Gwari
6.	Kathua	Nowshera		Patnitop	Hanga
7.	Bazalta	Rajouri		Nathatop	Thathri
8.	Surinsar			Sanasar	Kishtwar Padder
9.	Mansar			Batote	

*napus*, *Cichorium endivia*, *Raphanus sativa*, *Solanum melongena*, *Lycopersicum esculentum*. They have been reported to increase seed yield from 110 kg/ha to 210 kg/ha in red clover at differing bumblebee densities. They can work at extremely low temperatures (-3.6°C) at which no other insect pollinator can fly, exploit flower resources with deep corollas and have higher foraging rates. The chief problem associated with their utilization is the erratic and unpredictable fluctuations in their numbers during different years/seasons. The variations in their numbers largely occur due to reduction in nesting sites due to deforestation, depletion in natural or floral vegetation, degradation of habitat due to urbanization and erratic weather

conditions, which determine food supply and attack of enemies/diseases. However, the distribution of bumblebee fauna from North West Himalaya is still poorly understood despite their potential to contribute to crop production and stability in the face of environmental change.

Among the insect pollinators, bumblebee has always been a matter of obsession for humanity because of their beautiful colors and potential to perform vital pollination services in several crops (Free and Butler 1959, Plowright 1996, Michener 2000, Abrol and Shankar 2013). There are nearly 20,000 species of bees worldwide of which just 250 belong to the

**Table 2.** Zone wise survey of bumblebee species in different agro-climatic zones of Jammu division during 2016 and 2017. \*Elevation/altitude.

Sl. No.	Sub-tropics	Zones/Regions Intermediate	Temperate
1.	Udheywalla (285 m*), Chatha (280m)	Udhampur (756 m*)	Patnitop (1764 m*)
2.	Channi-Himmat (400m)	Ramnagar (1121)	Nathatop (2151 m)
3.	KotBhalwal (422 m)	Bhamla (542)	Sanasar (1817 m)
	Reasi (477m)	Sanasar (1817 m)	
4.	Marh (261 m)	Sunderbani (608 m)	Batote (1405 m)
5.	Bag-e-Bahu (352 m)	Nowshera (846 m)	Ramban (1262 m),
	Rajgarh (1086m), Chandrakot (772 m)		
6.	Bazalta (418 m)	Rajouri (905 m)	Banihal (1825-2100 m)
7.	Samba (381 m)	Chenani (1022 m)	Bhaderwah (1862 m) Sartangal (1760 m), Gwari (1700 m), Hanga (1712 m), Jai valley (1754 m)
8.	Kathua (392 m)	Basht (1164 m) Sudh Mahadeo 1552 m 1200	Kishtwar Padder (2214 m), Thathri (1205 m)

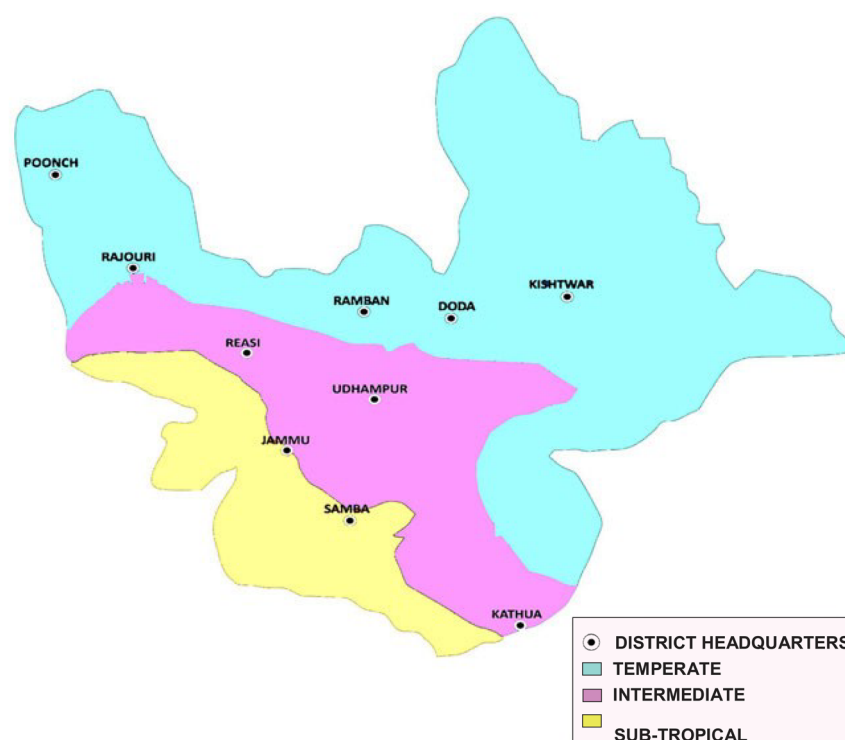


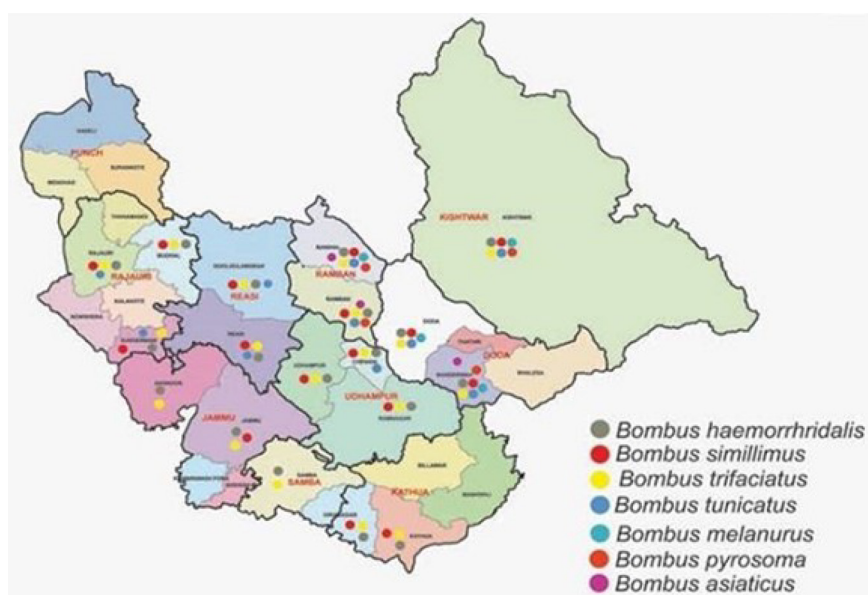
Plate 1. Agro-climatic zones of Jammu region.

genus *Bombus*, or bumblebees. The bumblebees are the best studied bee taxon and the only taxon that has been globally assessed for its endangerment status (Winfree 2010). The species composition, distribution pattern and factors affecting population dynamics and rearing under artificial conditions remains unexplored from Jammu region whose temperate areas abound rich bumblebee faunal diversity (Abrol 1998) which needs to be explored for their potential in planned crop pollination. Furthermore, the present studies

also assume utmost significance in sub-tropical areas of Jammu and Kashmir as the indigenous honeybee, *Apis cerana* has almost been wiped out due to spread of Thai sac brood virus disease and *A. mellifera* does not forage at low temperatures and inclement weather conditions resulting in low fruit set and reduced crop yields. With these backdrops the present study was designed to study of bumblebees diversity for crop pollination in different landscape of Jammu with emphasis on their host range, species composition,

Table 3. Zone wise list of bumblebees recorded during 2016.

Sl. No.	Sub-tropics	Zones/Regions Intermediate	Temperate
1.	<i>Bombus haemorrhoidalis</i> Smith 1852	<i>Bombus haemorrhoidalis</i> Smith 1852	<i>Bombus haemorrhoidalis</i> Smith 1852
2.	<i>Bombus trifasciatus</i> Smith 1852	<i>Bombus simillimus</i> Smith 1852	<i>Bombus simillimus</i> Smith 1852
3.		<i>Bombus tunicatus</i> Smith 1852	<i>Bombus tunicatus</i> Smith 1852
4.			<i>Bombus trifasciatus</i> Smith 1852
5.			<i>Bombus pyrosoma</i> Morawitz 1890



**Plate 2.** Showing distribution map of bumblebees in different areas of Jammu division.

food preference and ecological distribution pattern and foraging ecology of bumblebee in relation to different hosts plants in different agro climatic zones of Jammu division. Thus, the present work were undertaken to provide a basic document on the abundant species of bumblebee in Jammu division which could be better exploited through domestication for managed pollination in agri-horticultural crops of Jammu region. The present investigation was conducted with the objective to survey of bumblebee species in different agro climatic zones of Jammu division, determine their species composition in relation to host plants.

## MATERIALS AND METHODS

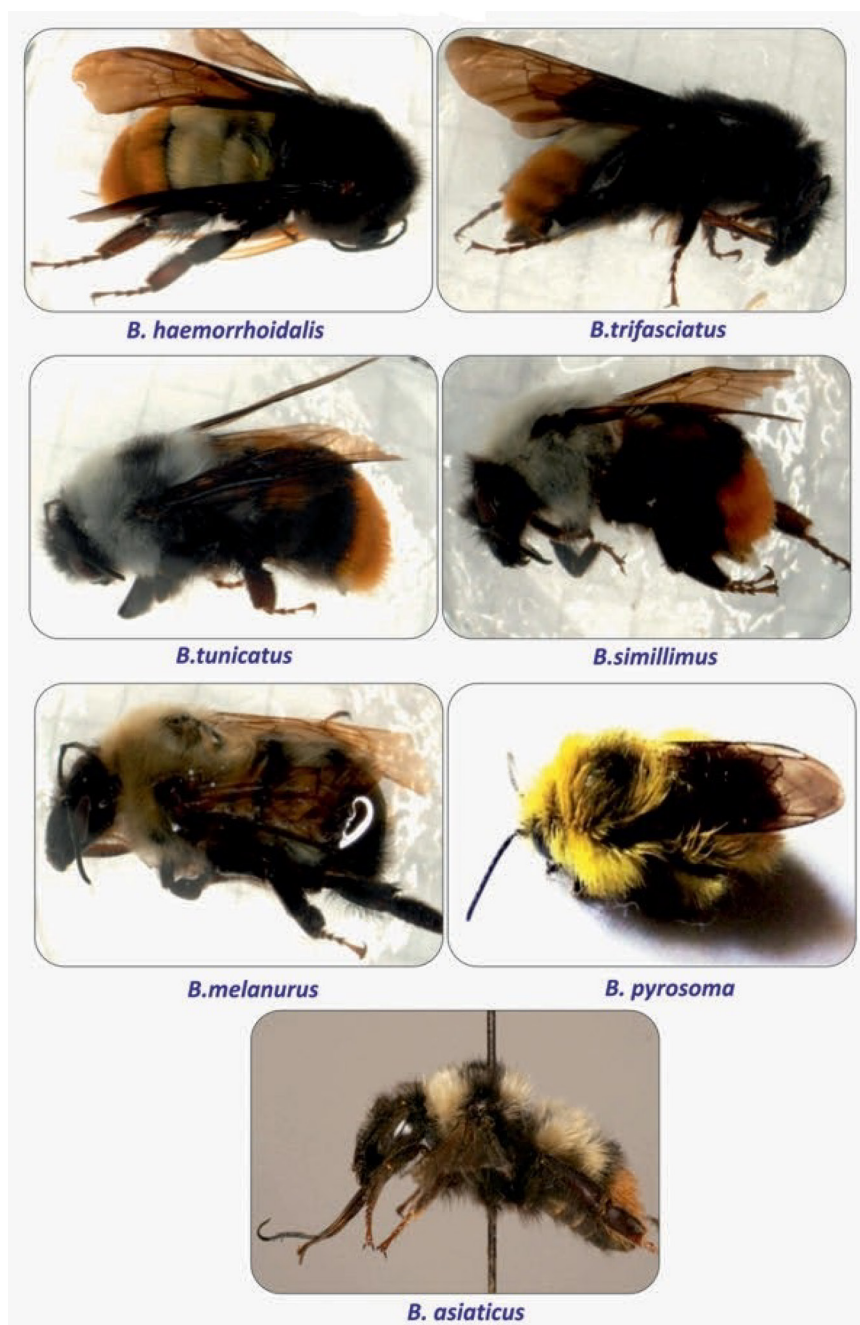
The studies were conducted to survey the bumblebee species in different agro climatic zones of Jammu division, determine their species composition and to study the foraging ecology of bumblebee in relation to different host plants. The details of methods used in recording the observations are as given below —

### Details of the experiments

The studies were undertaken in the Jammu divisions covering districts of Kathua, Rajouri, Banihal, Batote

**Table 4.** Zonewise list of different types of bumblebee recorded during 2017.

Sl. No.	Sub-tropics	Zones/Regions Intermediate	Temperate
1.	<i>Bombus haemorrhoidalis</i> Smith 1852	<i>Bombus haemorrhoidalis</i> Smith 1852	<i>Bombus haemorrhoidalis</i> Smith 1852
2.	<i>Bombus trifasciatus</i> Smith 1852	<i>Bombus simillimus</i> Smith 1852	<i>Bombus simillimus</i> Smith 1852
3.		<i>Bombus tunicatus</i> Smith 1852	<i>Bombus tunicatus</i> Smith 1852
4.		<i>Bombus trifasciatus</i> Smith 1852	<i>Bombus trifasciatus</i> Smith 1852
5.			<i>Bombus melanurus</i> Lepeleitier 1836
6.			<i>Bombus asiaticus</i> Morawitz 1890
7.			<i>Bombus pyrosoma</i> Morawitz 1890



**Plate 3.** Bumblebee species collected from different landscapes of Jammu.

and Bhaderwah and nearby areas. Based on landscape elevation the districts were classified into three zones such as sub-tropical zone including Udheywalla, Bag-e-Bahu, Channi-Himmat, Kot Bhalwal, Samba,

Kathua, Bazalta, Surinsar and Mansar areas, Intermediate zone includes Udampur, Ramnagar, Bhamla, Reasi, Sunderbani, Nowshera, Rajouri, Chenani, and temperate zone covering Basht, Sudh Mahadeo, Pat-

**Table 5.** Zone wise list of bumblebee flora recorded during 2016.

Sl. No.	Sub-tropics	Zones/Regions Intermediate	Temperate
1.	Floss flower, <i>Ageratum houstonianum</i>	Floss flower, <i>Ageratum houstonianum</i>	Wild Balsum, <i>Impatiens bicolor</i> and <i>I. glanduliflora</i>
2.	Brinjal, <i>Solanum melongena</i>	<i>Caryopteris odorata</i>	Sulai, <i>Plectranthus rugosus</i>
3.	Cucumber, <i>Cucumis sativus</i>	Cream/white thistle, <i>Cirsium falconeri</i>	Purple betony, <i>Stachys alpina</i>
4.	Kaner, <i>Nerium indicum</i>	Milk thistle, <i>Salybum marianum</i>	Catmint, <i>Nepeta cataria</i>
5.	Citrus, <i>Citrus sinensis</i>	Chaste Tree, <i>Vitex negundo</i>	Red clover, <i>Trifolium pratense</i>
6.	Taroi, <i>Luffa cylindrica</i>	Okra, <i>Abelmoschus esculentus</i>	White clover, <i>Trifolium alexandrinum</i>
7.	Safflower, <i>Carthamus tinctorius</i>	Tomato, <i>Solanum lycopersicum</i>	Foxglove, <i>Digitalis purpurea</i>
8.	Tomato, <i>Solanum lycopersicum</i>	Kaner, <i>Nerium indicum</i>	Potato, <i>Solanum tuberosum</i>
9.	Okra, <i>Abelmoschus esculentus</i>	Aster, <i>Aster amellus</i>	Wild tobacco, <i>Nicotiana tabacum</i>
10.	Arhar or Tur, <i>Cajanus cajan</i>	Potato, <i>Solanum tuberosum</i>	Elegant tick clover, <i>Desmodium elegans</i>
11.	Gandhraj, <i>Lantana camara</i>	Gandhraj, <i>Lantana camara</i>	Aster, <i>Aster amellus</i>
12.	Wild rose, <i>Rosa floribunda</i>	Sesame, <i>Sesamum indicum</i>	Marigold, <i>Tagetes erecta</i> and <i>Tagetes patula</i>
13.	Larkspur, <i>Delphinium ajacis</i>	Wild tobacco, <i>Nicotiana tabacum</i>	Wild Lily, <i>Iris hookeriana</i>
14.	White rose, <i>Rosa rugosa</i>	Tiger claws, <i>Erythrina variegata</i>	Kaddu, <i>Cucurbita moschata</i>
15.	Chaste Tree, <i>Vitex negundo</i>	Dahlia, <i>Dahlia pinnata</i>	Chilli, <i>Capsicum annum</i>
16.		Brainkad, <i>Adhatodavasica</i>	Globe thistle, <i>Echinops echinatus</i>
17.		Bottle gourd, <i>Lagenaria sinerraria</i>	Cream/white thistle, <i>Cirsium falconeri</i>
18.		Ram tulsi, <i>Anesomeles indica</i>	Canada thistle, <i>Cirsium arvense</i>
19.		Legume grasses weeds	

nitop, Nathatop, Sanasar, Batote, Ramban, Rajgarh, Chandrakot, Banihal, Bhaderwah, Sartangal, Gwari, Hanga, Jai valley, Kishtwar Padder and Thathri. Agri- horticulture crops fields were visited at peak flowering time during respective cropping seasons mostly in the months of April to October during the two consecutive years i.e., 2016 and 2017. Collection of bees was mainly based on 'Direct search method' using Hand picking and Net sweeping methods. Bees captured from flowers were killed using killing bottle containing cotton soaked with 98% solution of ethyl acetate. All the bees were then transferred to separate individual containers. Individual specimens were preserved in 70% ethyl alcohol and card mounted (wherever necessary) assigning unique code. Based on morphological differences, recognizable taxonomic units (RTU) (Gadagkar *et al.* 1990) were separated. Identification of bees up to genus/ species (wherever possible) was done in laboratory and the same was authenticated by various international institutes. Host range and other parameters viz., climatic condition were recorded in field at the time

of collection of specimens and the same was used to derive the host spectrum of individual/ group of bees.

#### Survey of bumblebee species in different agro-climatic zones of Jammu division

For this purpose survey was conducted in sub-tropical, intermediate and temperate areas of Jammu division for recording the different species of bumblebee and their host range for foraging. In each zone, two locations were selected for sampling and collection of bumblebees to determine their diversity. During 2016 and 2017 twenty five major and eleven minor collection cum survey tours were conducted in various localities situated in the state of Jammu and Kashmir (Plates 1–2).

#### Identification and determination of species composition

The bumblebees were collected using hand net/sweep



**Table 6.** Zone wise list of bumblebee flora recorded during 2017.

Sl. No.	Zones/Regions Sub-tropics	Intermediate	Temperate
1.	Floss flower, <i>Ageratum houstonianum</i>	<i>Ageratum houstonianum</i>	Wild Balsum, <i>Impatiens bicolor</i> and <i>I. glanduliflora</i>
2.	Brinjal, <i>Solanum melongena</i>	Bluebeard, <i>Caryopteris odorata</i>	Sulai, <i>Plectranthus rugosus</i>
3.	Cucumber, <i>Cucumis sativus</i>	Cream/white thistle, <i>Cirsium falconeri</i>	Purple betony, <i>Staychus sericea</i>
4.	Kaner, <i>Nerium indicum</i>	Milk thistle, <i>Salybum marianum</i>	Catmint, <i>Nepeta alba</i>
5.	Citrus, <i>Citrus sinensis</i>	Chaste tree, <i>Vitex negundo</i>	Red clover, <i>Trifolium pratense</i>
6.	Taroi, <i>Luffa cylindrica</i>	<i>Abelmoschus esculentus</i>	White clover, <i>Trifolium alexandrinum</i>
7.	Safflower, <i>Carthamus tintorius</i>	Tomato, <i>Solanum lycopersicum</i>	Foxgove, <i>Digitalis purpurea</i>
8.	Tomato, <i>Solanum lycopersicum</i>	Shimla mirch, <i>Capsicum annuum</i>	<i>Desmodium elegans</i>
9.	Okra, <i>Abelmoschus esculentus</i>	Kaner, <i>Nerium indicum</i>	Aster, <i>Aster amellus</i>
10.	Radish, <i>Raphanus sativus</i>	<i>Calendula officinalis</i>	Marigold, <i>Tagetes erecta</i> and <i>T. patula</i>
11.	Arhar or Tur, <i>Cajanus cajan</i>	<i>Aster amellus</i>	<i>Iris hookeriana</i>
12.	<i>Calendula</i> , <i>Calendula officinalis</i>	<i>Solanum tuberosum</i>	Kaddu, <i>Cucurbita moschata</i>
13.	Gandhraj, <i>Lantana camara</i>	Gandhraj, <i>Lantana camara</i>	Chilli, <i>Capsicum annuum</i>
14.	Wild rose, <i>Rosa floribunda</i>	Sesame, <i>Sesamum indicum</i>	Globe thistle, <i>Echinopschinatus</i>
15.	Larkspur, <i>Delphinium ajacis</i>	Wild tobacco, <i>Nicotiana tabacum</i>	Cream/white thistle, <i>Cirsium falconeri</i>
16.	Yellow trumpet tree, <i>Tabebuia argentea</i>	Tiger claws, <i>Erythrina variegata</i>	Canada thistle, <i>Cirsium arvense</i>
17.	White rose, <i>Rosa rugosa</i>	Brainkad, <i>Adhatodavasic</i>	Floss flower, <i>Ageratum houstonianum</i>
18.	<i>Portulaca quadrifida</i>	Maxican prick poppy, <i>Argemone maxicana</i>	
19.	Chaste Tree, <i>Vitex negundo</i>	Mustard, <i>Brassica campestris</i>	
20.		Bottle gourd, <i>Lagenaria sicerraria</i>	
21.		Dahlia, <i>Dahlia pinnata</i>	
22.		Ram tulsi, <i>Anesomeles indica</i>	
23.		Cactus, <i>Opuntia dillenni</i>	
24.		Globe thistle, <i>Echinopschinatus</i>	
25.		Rat ki Rani, <i>Cestrum nocturnum</i>	
26.		Legume grasses weeds	
27.		Coral vine bee bush, <i>Antigonanleptopus</i>	

method from Udheywalla, Bag-e-Bahu, Channi-Himmat, KotBhalwal, Samba, Kathua, Bazalta, Surinsar, Mansar areas, Udampur, Ramnagar, Bhamla, Reasi, Sunderbani, Nowshera, Rajouri, Chenani, Basht, Sudh Mahadeo, Patnitop, Nathatop, Sanasar, Batote, Ramban, Rajgarh, Chandrakot, Banihal, Bhaderwah, Sartangal, Gwari, Hanga, Jai valley, Kishtwar Padder and Thathri locations from different zones of Jammu division and further preserved as dry and wet collection for identification of species and determine of bumblebees species composition. The identification were got confirmed from bumblebee taxonomists.

Bumblebees were collected with sweeping hand net made up of nylon cloth and latter killed with ethyl acetate. Some collection was also made by setting up the malaise trap. Most of the collections were

available from open areas rather than closed ones. The collection was based mainly on random sampling methods, covering different agro-ecosystem(s). In addition to collection their live macro photography was done with Nikkon camera. During the study it was found that bumblebee collection with sweeping hand net was found more effective than malaise trap, the latter does not work at high altitude because of very high wind velocity accompanied with intermittent rains.

#### Killing and setting techniques

The collected insect material was first sorted out in the field and latter brought to the laboratory for further identification and analysis. For the collection of these insects, special transparent killing jars were designed,

**Table 7.** Seasonal survey and species composition of bumblebee in Jammu region.

Sl. No.	Date of survey	Area	GPS position	Plants recorded	Bumblebee species
1	February 2016 and 2017	Udheywalla	32.74 N 74.80 W	Brinjal, citrus, mustard, cauliflower	<i>Bombus haemorrhoidalis</i>
		Chatha	32.39N 74.48 W	Radish, <i>Vicia faba</i>	<i>B. haemorrhoidalis</i>
		Bhamla	33.2 N 74.34 W	<i>Vitex negundo</i>	<i>B. trifasciatus, B. tunicatus, B. simillimus, B. haemorrhoidalis</i>
		Sunderbani	33.2 N 74.27W	<i>Caryopteris</i>	<i>B. trifasciatus, B. tunicatus, B. simillimus, B. haemorrhoidalis</i>
		Nowshera	33.2 N 74.14W	<i>Ageratum</i>	<i>B. trifasciatus, B. tunicatus, B. simillimus, B. haemorrhoidalis</i>
		Bag-e-Bahu	32.43N 74.52E	Yellow trumpet tree, <i>Rose floribunda</i> and <i>Rosa regusa</i> , <i>Delphinium</i>	<i>B. haemorrhoidalis, B. trifasciatus</i>
2	March 2016 and 2017	Vijaypur	32.33N 75.1E	Milk thistle	<i>B. haemorrhoidalis, B. trifasciatus</i>
		Samba	32.55N 75.11E	Arhar, lantana, Salybum	<i>B. haemorrhoidalis, B. trifasciatus</i>
		Kathua	32.37 N 75.52 W	Arhar, lantana, Salybum	<i>B. haemorrhoidalis, B. trifasciatus</i>
3	April 2016 and 2017	Sunderbani	33.2 N 74.27W	Cream thistle, <i>Vitex</i> , Citrus, Brinjal, Okra, <i>Lantana</i>	<i>B. haemorrhoidalis, B. trifasciatus, B. simillimus, B. tunicatus</i>
		Bhamla	33.2 N 74.34W	Pumpkin, Vitex, Ram tulsi, Cream thistle, cucurbits, <i>Lantana</i>	<i>B. haemorrhoidalis, B. trifasciatus, B. simillimus, B. tunicatus</i>
		Reasi	33.2 N 74.33W	Argemon, Vitex, <i>Lantana</i>	<i>B. haemorrhoidalis, B. trifasciatus</i>
		Nowshera	33.2 N 74.14W	Cucumber	<i>B. haemorrhoidalis, B. trifasciatus, B. simillimus, B. tunicatus</i>
		Rajouri	33.22 N 74.18 W	Cucumber, Tomato, Impatiens	<i>B. haemorrhoidalis, B. trifasciatus, B. simillimus, B. tunicatus</i>
4	May 2016 and 2017	Bazalta	32.46 N 75.0 W	Safflower, Vitex, Ram tulsi	<i>B. haemorrhoidalis, B. trifasciatus</i>
		Surinsar	32.46N 75.2E	Cream thistle, Kaner, Vitex	<i>B. haemorrhoidalis, B. trifasciatus</i>
		Mansar	34.24N 74.66E	Cream thistle, Kaner, Vitex	<i>B. haemorrhoidalis, B. trifasciatus</i>
		Samba	32.55N 75.11E	Arhar, Milk thistle	<i>B. haemorrhoidalis, B. trifasciatus</i>
		Kathua	32.37N 75.52E	Arhar, Milk thistle	<i>B. trifasciatus</i>
		Bani	32.70 N 75.81W	Beans and Rajmash	<i>B. haemorrhoidalis, B. trifasciatus</i>
		Ramkot	32.39N 75.21W	Vitex, Kaner	<i>B. haemorrhoidalis, B. trifasciatus</i>
5	August 2016 and September 2017	Patnitop	33.42 N 75.20 W	Cream thistle, Sulai, Catmint, Purple betony	<i>B. haemorrhoidalis, B. trifasciatus, B. simillimus, B. tunicatus</i>
		Nathatop	33.5 N 75.15W	Purple betony, Catmint, Cream thistle, Ballthistle, Wild tobacco, Wild balsum, Foxglove	<i>B. haemorrhoidalis, B. simillimus, B. trifasciatus, B. tunicatus, B. asiaticus</i>
		Chenani	33.03 N 75.28 W	Brinjal, Tomato	<i>B. haemorrhoidalis, B. simillimus, B. trifasciatus, B. tunicatus</i>
6		Bhaderwah	32.98 N 75.72 W	Wild balsum, Foxglove, wild tobacco, Sulai, Catmint, Purple betony, Wild legume, Grasses, Redclover	



Table 7. Continued.

Sl. No.	Date of survey	Area	GPS position	Plants recorded	Bumblebee species
				grasses, Redclover	<i>Bombus haemorrhoidalis</i> , <i>B. simillimus</i> , <i>B. tunicatus</i> , <i>B. asiaticus</i> , <i>B. trifasciatus</i> , <i>B. pyrosoma</i> , <i>B. melanurus</i>
		Jai valley	33.2 N 75.77W	Wild Balsum, Foxglove, wild tobacco, Sulai, Catmint, Purple betony, wild legume, grasses, Red clover	<i>B. melanurus</i> , <i>B. asiaticus</i> , <i>B. trifasciatus</i> , <i>B. pyrosoma</i>
		Sartangal	32.59 N 75.41W	Sulai, Catmint, Purple betony, wild legume, grasses, Red clover	<i>B. tunicatus</i> , <i>B. haemorrhoidalis</i> , <i>B. simillimus</i> , <i>B. tunicatus</i> ,
		Gwari	32.86N 76.14W	Sulai, Catmint, Purple betony, Wild legume, Grasses, Red clover	<i>B. haemorrhoidalis</i> , <i>B. simillimus</i> , <i>B. tunicatus</i> ,
		Paddar	-	Sulai, Catmint, Purple betony, Wild legume, Grasses, Red clover, Foxglobe	<i>B. asiaticus</i> , <i>B. trifasciatus</i> <i>B. trifasciatus</i> , <i>B. simillimus</i> , <i>B. tunicatus</i> , <i>B. melanurus</i>
		Udhampur	32.93 N 75.13 W	Milk thistle	<i>B. haemorrhoidalis</i> , <i>B. trifasciatus</i>
		Doda	33.14 N 75.54 W	Cream thistle	<i>B. tunicatus</i> , <i>B. simillimus</i>
7	September-October 2016 and 2017	Batote	33.11 N 75.30W	Cream thistle, Wild balsum	<i>B. haemorrhoidalis</i> , <i>B. trifasciatus</i>
		Ramban	33.14 N 75.14 W	Cream thistle, Sulai, Catmint, Purple betony, Wild legume, Grasses, Red clover, <i>Desmodium</i>	<i>B. haemorrhoidalis</i> , <i>B. trifasciatus</i> , <i>B. simillimus</i> , <i>B. tunicatus</i>
		Banihal	33.43 N 75.19W	Sulai, Catmint, Purple betony, Sulai, Catmint, Wild legume, Grasses, Red clover, Cream thistle, <i>Desmodium</i>	<i>Bombus haemorrhoidalis</i> , <i>B. simillimus</i> , <i>B. tunicatus</i> , <i>B. asiaticus</i> , <i>B. trifasciatus</i> , <i>B. pyrosoma</i> , <i>B. melanurus</i>

so as to preserve the color of the pubescence. As the color of the pubescence in bumblebees holds great importance in identification of species, so proper care was taken during the collection period. Keeping in view the delicacy and grace of pubescence, insects killed in the killing jar were continuously shifted to other jar of same size so as to protect the pubescence. After coming to the laboratory, the specimens were pinned with the help of entomological pins of different sizes, keeping in view the size of specimen. After stretching the specimens were appended with data label containing the important information regarding its locality, altitude, date of collection and name of the collector. Later on, stretched specimens were transferred to the storage boxes, poisoned with ethyl acetate soaked cotton and naphthalene powder filled in

the side grooves of boxes. All the identified specimens have been deposited in the Division of Entomology, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, Chatha, Jammu for future references.

## RESULTS

In the present investigation an effort was made to understand the survey on bumblebee diversity on cultivated as well as wild flora of Jammu region throughout the different landscapes divided into three important zones i.e., plain, intermediate and temperate. The results obtained are presented under following sub-heads :

### Survey on diversity of bumblebee in Jammu region

A survey was conducted under the present investigation for the consecutive two years i.e., 2016 and 2017 for assessing the faunastic diversity of bumblebees on cultivated and wild host plants and their role in crop pollination as plant-pollinator interaction in different landscapes of Jammu. For the true representation of Jammu region, the entire Jammu region was divided into six locations i.e., Kathua, Rajouri, Banihal, Batote and Bhaderwah. Each location was further divided into sub-locations for recording the foraging and diversity of bumblebee on different host plants. Kathua comprises Udheywalla, Bage-Bahu, Channi- Himmat, KotBhalwal, Samba, Kathua, Bazalta, Surinsar and Mansar areas. Rajouri include Akhnoor, Chouki-Choura, Bhamla, Sunderbani, Reasi, Nowshera and Rajouri. Banihal include Chandrakot Rajgarh, Ramban, Banihal whereas, in the way to Batote, Udampur, Ramnagar, Chenani, Basht Sudh, Mahadeo, Patnitop, Nathatop area were covered. Bhaderwah com location comprises Doda, Bhaderwah, Sartangal, Gwari, Hanga, Jai valley, Thathri and Kishtwar Padder (Table 1, Plate 3).

To improve the collection and record of bumblebee host plants and their diversity, the selected locations of the study were categorized into three main zones i.e., Sub-tropics, intermediate and temperate. At each location, the altitude or elevations were also recorded for the bumblebee foraging for vivid inferences. Subtropics include the elevation ranging from Chatha (280 m) to Kot Bhalwal (422 m) amsl whereas, Intermediate zone include Reasi (477 m) to Chenani (1022 m) Sudh Mahadeo. The temperate zone ranges from Chandrakot (above 1000m) to Kishtwar Padder (2214 amsl) (Table 2).

Zonewise list of bumblebees recorded during the year 2016 were depicted in Table 3. In sub-tropic zone, only two different types of bumblebee were recorded viz., *Bombus haemorrhoidalis* Smith 1852 and *Bombus trifasciatus* Smith 1852. Three species of bumblebee such as *B. haemorrhoidalis* Smith 1852, *Bombus simillimus* Smith 1852 and *Bombus tunicatus* Smith 1852 were recorded in intermediate zone during 2016. Intemperate zone, five species

of bumblebee like *B. haemorrhoidalis*, *B. simillimus*, *B. tunicatus*, *B. trifasciatus* and *Bombus pyrosoma* Morawitz 1890 were observed foraging on different types of host plants. In-toto, there were five (5) different types of bumblebee were recorded during 2016 (Table 3).

Similarly, during 2017, two species from sub-tropics, four species from intermediate zone and seven species of bumblebees were recorded visiting the different plants in different landscapes of Jammu region. In-toto, seven (7) different types of bumblebee species such as *B. haemorrhoidalis*, *B. simillimus*, *B. tunicatus*, *B. trifasciatus*, *B. melanurus*, *B. asiaticus* and *B. pyrosoma* were recorded during 2016 and 2017, respectively (Table 4). So far 7 different species have been put on record from Jammu region, out of which 5 species have already been reported by Abrol and Shankar (2013). Out of 7 different species of bumblebee, two viz., *B. pyrosoma* and *B. asiaticus* are recorded for the first time from Jammu region (Plate 3).

The survey of bumblebees diversity revealed the existence of seven species of bumblebee which foraged or visited on more than hundreds of different cultivated and wild species of plants ranging from herbaceous meadows of legumes grasses, clovers, weeds to bushy weeds, invasive species and forest plants and trees. The present experimentation depicts the zone-wise list of bumblebee flora recorded during 2016 (Table 5). There were 15 different plants recorded as the potential sources of bumblebee visitation for nectar and pollen as a reward or food sources from sub-tropics. While in case of intermediate zone and temperate zone 20 and 19 plants recorded as the good sources of pollen and nectar, respectively. There were many plants assumed to the good sources as the bees visitation were frequently observed.

Similarly during 2017, the host range were found to be expanded wherein, 19 plants from sub-tropics, 27 plants from intermediate zone and 17 plants from temperate zone were recorded (Table 6). Among the different flora observed as the good sources for bumblebee species, some of the species were found overlapping in sub-tropics and intermediate zone and some were common in intermediate and temperate

zone. The lists of floral resources were found to be as follows :-

Sub-tropics include Floss flower, *Ageratum houstonianum*, Brinjal, *Solanum melongena*, Cucumber, *Cucumis sativus*, Kaner, *Nerium indicum*, Citrus, *Citrus sinensis*, Taroi, *Luffa cylindrical*, Safflower, *Carthamus tintorius*, Tomato, *Solanum lycopersicum*, Okra, *Abelmoschus esculentus*, Radish, *Raphanus sativus*, Arhar or Tur, *Cajanus cajan*, Calendula, *Calendula officinalis*, Gandhraj, *Lantana camara*, Wild rose, *Rosa floribunda*, Larkspur, *Delphinium ajacis*, Yellow trumpet tree, *Tabebuia argentea*, White rose, *Rosa rugosa*, *Portulaca quadrifida* and Chaste Tree, *Vitexnegundo*.

Intermediate zone comprises *Ageratum houstonianum*, Bluebeard, *Caryopteris odorata*, Cream/white thistle, *Cirsium falconeri*, Milk thistle, *Salybum marianum*, Chaste Tree, *Vitexnegundo*, *Abelmoschus esculentus*, Tomato, *Solanum lycopersicum*, Shimla mirch, *Capsicum annum*, Kaner, *Nerium indicum*, *Calendula officinalis*, *Aster amellus*, *Solanum tuberosum*, Gandhraj, *Lantana camara*, Sesame, *Sesamum indicum*, Wild tobacco, *Nicotiana tabacum*, Tiger claws, *Erythrina variegata*, Brainkad, *Adhatodavastica*, Maxican prick poppy, *Argemone maxicana*, Mustard, *Brassica compestris*, Bottle gourd, *Lagenaria sicerraria*, Dahlia, *Dahlia pinnata*, Ram tulsi, *Anesomeles indica*, Cactus, *Opuntia dillenni*, Globe thistle, *Echinopsechinatus*, Rat ki Rani, *Cestrum nocturnum*, Legume grasses weeds and Coral vine bee bush, *Antigonon leptopus*.

While temperate zone includes Wild Balsum, *Impatiens bicolor* and *I. glanduliflora*, Sulai, *Plectranthus rugosus*, Purple betony, *Staychus sericea*, Catmint, *Nepeta cataria*, Red clover, *Trifolium pratense*, White clover, *Trifolium alexandrinum*, Foxgove, *Digitalis purpurea*, *Desmodium elegans*, Aster, *Aster amellus*, Marigold, *Tagetes erecta* and *T. patula*, Wild lily, *Iris hookeriana*, Kaddu, *Cucurbita moschata*, Chilli, *Capsicum annum*, Globe thistle, *Echino psechinatus*, Cream/white thistle, *Cirsium falconeri*, Canada thistle, *Cirsium arvense* and Floss flower, *Ageratum houstonianum*.

The seasonal survey and species composition of bumblebee in Jammu region have been portrayed in Table 7 along with the GPS position. Various areas of Jammu region of J and K state with dense vegetation and rich floral diversity were selected for the collection of bumblebees; these include : Udheywala, Chatha, Bag-e-Bahu, Bazalta, Surinsar, Mansar, Vijaypur, Samba, Kathua, Bani, Ramkot, Bhamla, Reasi, Sunderbani, Nowshera, Rajouri, Udhampur, Patnitop Nathatop, Chenani, Batote, Ramban, Banihal, Doda, Bhaderwah, Jai valley, Sartangal, Gwari, Paddar, which are located at an elevation ranging from 280 m amsl to 2214 m amsl. The different areas had different plants composition and different species of bumblebee foraging on the plants.

## DISCUSSION

Bumblebees enjoy the status of curiosity for the people working in the field of pollination ecology due to their unique, color pattern, robust build and potential to perform vital pollination services in several crops. The present study was conducted in different agro climatic zones of Jammu and the results obtained are discussed under the heads :

### Survey on diversity of bumblebee in Jammuregion

The present findings are in conformity with the results obtained by Bingham (1897) who listed 24 species of bumblebees from higher elevations of the country including Kashmir, Himachal through Sikkim and Assam. Further, Mani (1962) reported four species of bumblebees at elevations of over 4000 m at Himalayas. The Indian species of *Bombus* has generally been restricted to higher elevations especially the Himalayan ranges. Further, Monfared *et al.* (2009) collected and identified 26 species of bumblebees wherein, most of the species of bumblebee were collected in altitudinal ranges of 1500–2500.

### Bumblebee species in different agro climatic zones of Jammu

In-toto, seven (7) different types of bumblebee species (Plate 3) such as *B. haemorrhoidalis*, *B. simillimus*, *B. tunicatus*, *B. trifasciatus*, *B. melanurus*, *B. asiaticus* and *B. pyrosomawere* recorded during both the

years of study. Zone wise list of bumblebees species include two species from sub-tropics, four species from intermediate zone and seven species of bumblebees were recorded visiting the different plants in different landscapes of Jammu region. The survey of bumblebees diversity revealed the existence of seven species of bumblebee which foraged or visited on more than hundreds of different cultivated and wild species of plants ranging from herbaceous meadows of legumes grasses, clovers, weeds to bushy weeds, invasive species and forest plants and trees.

The present investigation are in conformity with the study conducted by Abrol (1998) who has recorded *B. haemorrhoidalis* from intermediate areas of Jammu region. Further, the results obtained by Diaz-Forero *et al.* (2011) also confirmed the present findings who assessed the habitat quality by its suitability for insects using important ecological differences between generalist and specialist species. Specialist species are more severely affected by the degradation and decrease of suitable habitats than generalists, as they are dependent on specific types of flowering plants or local environment.

#### **Identification and determination of species composition and host range**

The seasonal survey and species composition of bumblebee in Jammu region have been portrayed along with the GPS position. Various areas of Jammu region of J and K state with dense vegetation and rich floral diversity were selected for the collection of bumblebees; these include: Udheywalla, Chatha, Bage-Bahu, Bazalta, Surinsar, Mansar, Vijaypur, Samba, Kathua, Bani, Ramkot, Bhamla, Reasi, Sunderbani, Nowshera, Rajouri, Udampur, Patnitop Nathatop, Chenani, Batote, Ramban, Banihal, Doda, Bhadrawah, Jai valley, Sartangal, Gwari, Paddar, which are located at an elevation ranging from 280m amsl to 2214 m amsl. The different areas had different plants composition and different species of bumblebee foraging on the plants.

The host range were found to be expanded during second year i.e., 2017 wherein, 19 plants from sub-tropics, 27 plants from intermediate zone and 17 plants from temperate zone were recorded. Among

the different flora observed as the good sources for bumblebee species, some of the species were found overlapping in sub-tropics and intermediate zone and some were common in intermediate and temperate zone. The total 15 major survey visits along with several small visits were planned to cover the entire areas of Jammu region for the collection and sampling of bumblebee. Seasonal survey was conducted throughout the year for both the years to collect maximum number of bumblebee foraging on different areas and on different flora except three months viz., November, December and January when bumblebee queen overwinters in the nest for rearing broods. Among the different floral crops surveyed during two years of study, the maximum number of bumblebee species were recorded on Asteraceae family plants (11) followed by Lamiaceae family plants (7) and Leguminaceae family plants (6). Among the cultivated plants, Solanaceae family contains maximum number of plants (4) followed by Cucurbitaceae and brassicaceae family plants (3 each). The reason for the preference of host plants by Bumblebees were attributed to group of factors such as shape, size and color of flowers, pollen contents and pollen amount, season and situation. They were found to forage and prefer flowers growing on open slopes of mountains rather than closed deep and dense forests. The host plant spectrum of *B. haemorrhoidalis* was recorded as 16 from sub-tropics, 21 from intermediate and 07 from temperate areas. The total number of families was observed to be 14 visited by *B. haemorrhoidalis* whereas, *B. Simillimus* were recorded from 11 and 03 families from intermediate and temperate areas, respectively. Among the 7 different species of bumblebee, the newly recorded two species viz., *B. pyrosoma* and *B. asiaticus* were recorded foraging on 04 and 03 families, respectively.

Species diversity index and richness of bumblebees is found to be highest at altitudinal range of 1200–1800 m (0.097321 and 1.079004 respectively) followed by 0-600 m (0.09004 and 0.414914) and lowest diversity index and richness is found at 600- 1200 m (0.088376 and 0.746744). Evenness of bumblebee species is found to be highest at 0-600 m followed by 600- 1200 m. Altitude levels 0-600 m and 1200–1800 m show more richer in species diversity of bumble bees whereas, altitude level 1200–1800 m

is most species rich. Bhaderwah pockets (1200–1800 m) (including Gwari, Sartangal, Hanga and Jai valley) contributes maximum number of bumblebee diversity followed by Nathatop and Banihal region of Jammu which is attributed to the variation in altitude, topography, climate and flora.

Different bumblebee species have differing flower preferences which require their resources need to be located in the vicinity of the nest to meet energy demands (Plowright and Lavery 1984). Bumblebees are believed to be quite site-specific in their foraging (Free and Butler 1970, Kevan and Baker 1983, Bowers 1985) and very meager information is available on how far bumblebees are willing to travel to collect nectar or pollen. The shape of flower is found to be important factor for their preference. Bilaterally symmetrical flowers were preferred over asymmetrical and radially symmetrical flowers which are in accordance with the earlier studies (Moller and Sorci 1998, West and Lavery 1998). Bright colored pink flowers of *Impatiens sulcata* Wall. (Balsaminaceae) are more preferred over yellow flowers of *Impatiens scabrada* Linn. (Balsaminaceae), even when both these plant species are growing side by side.

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