Insect pollination and crop production in Jammu and Kashmir

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Owing to the wide variation in the altitude and latitude and consequent diversity in the agro-climatic conditions of Jammu and Kashmir, it is difficult to assess the role of, and the foraging strategies adopted by, the pollinators. This also makes their management and utilization a difficult task.

In this paper we review the foraging behaviour, energetics, the role of pollinator in fruit and seed production and conservation and management of native pollinators in the context of such wide ranging agroclimatic conditions of the state.

THE State of Jammu and Kashmir (32–36° N, 73–80° E) constitutes one of the most important bee-keeping areas in India. At least four distinct agro-climatic conditions ranging from low altitude sub-tropical, intermediate, temperate to cold arid alpine occur in this state. Such varied habitats and climatic conditions have encouraged the cultivation of a number of fruit, vegetable, fodder, oilseed and other commercial crops which differ greatly in their pollination requirements. A wide diversity of pollinating insects adapted to the various climatic/geographic zones and their host plants are available. Studies on pollination biology of the various crops in relation to their pollinators have been initiated with the view to augmenting crop yields. At our centre, we have addressed several issues such as i) ecology of bee–host plant interaction, ii) role of insect pollinators on fruit production, iii) genetic variability in different crops in relation to pollinator preference and seed/fruit set and iv) management of pollinators. We briefly summarize some of the findings on these issues below.

Distribution, abundance and diversity of pollinating insects

A number of insect pollinator visitors to various cultivated/wild plants in different agro-climatic zones of the state have been reported earlier[1–23]. Abrol[6] recorded two species of honeybees, several species of wild bees and flies visiting various field crops and fruit plants in Kashmir. In an extensive survey of greater Kashmir (including part of Kashmir occupied by Pakistan), Williams[23] recorded 28 species of bumblebees. In a more comprehensive survey of different agro-climatic zones of Jammu and Kashmir, a rich diversity of pollinating insects has been found (Tables 1 and 2). Hymenopterous followed by Lepidopterous and Dipterous insects were the most abundant and widely distributed pollinators. However, the species composition of the insects belonging to three orders differs significantly ($P < 0.01$).

Role of pollinating insects in fruit/seed production

Studies at our centre have shown that insect pollination is very essential for fruit production in almond, apple, cherry, peach, plum, pears, and strawberry[4,6,15,17,18,20,24]. Open pollinated flowers of almond exhibited mainly 43 per cent fruit set compared to none at ail in flowers deprived of visits by insects[20]. Similarly, in strawberry, per cent fruit set and well-formed fruits was much higher in insect-pollinated flowers compared to those from which insect visitors were excluded[24]. In pears, fruit set ranged between 24.6 and 53.6 per cent in open-pollinated plants compared to 3.3 to 17.8 per cent in caged plants[15].

Influence of environmental factors on pollination activity of bees

The influence of a few environmental factors on the bee activity has been examined using multivariate statistical techniques[1–4,14,16,18,20,24–32]. A dual threshold of temperature and light intensity was found to influence the flight activity of the honeybees *Apis dorsata* and *A. cerana indica*; cessation of flight activity was independent of atmospheric temperature and was controlled mainly by light intensity and solar radiations[31]. During winter, temperature acted as a stimulus for initiation of flight activity in honeybees whereas during summer, light intensity provided the minimum threshold. The large black bodied insects of the genus *Xylocopa*, exhibited a less pronounced bimodality in diurnal foraging patterns[29]. Foraging activity of the *Xylocopa* bees was negatively related to air temperature and intensity of direct solar radiation, and positively to nectar availability. Variation in nectar sugar concentration was mainly influenced by temperature and solar radiation inputs and had little direct bearing on bee activity[32].

Table 1. Insect pollinators of various cultivated/wild plants in different climatic zones of Jammu and Kashmir, India

Climatic zone	Bee insect species	Order	Family	Activity period	Crop/plant species	Ref.
Lowland subtropical areas (300-1350 m MSL)	*Xylocopa fenesterata*	F. Hymenoptera	Xylocopinae	Feb–Nov	Cucurbits, sunflower, *Crotalaria*, *Cajanus cajan*	Present study
	X. pubescens Spinola	"	"	"	"	"
	Andrena ilerda Cameron	"	Andernidae	Jan–Dec	*Brassica* sp.	"
	A. leaena	"	"	"	"	"
	Megachile lanata Lepel	"	Megachilidae	April–Oct	Alfalfa, *Cajanus cajan* Berseem, sunflower	"
	M. nana Bingh	"	"	"	"	"
	M. bicolor Smith	"	"	"	"	"
	M. cephalotes Smith	"	"	"	"	"
	Megachile sp. (i)	"	"	"	"	"
	Megachile sp. (ii)	"	"	"	"	"
	Threus sp.	Hymenoptera	Megachilidae	April–Oct	Alfalfa, *Cajanus cajan* Berseem, sunflower	Present study
	Pithitis smaragdula F.	"	Anthophoridae	May–Sep.	Alfalfa, cucurbits,	"
	Amegilla sp.	"	"	"	"	"
	Melissodes sp.	"	"	"	"	"
	Anthophora sp.	"	"	Jan–Dec.	*Brassica* sp.	"
	Centris inermis	"	"	"	"	"
	Colletes sp.	"	Colletidae	Feb.–Oct.	Peach, Plum, Pears	"
	Episyrphus balteatus	Diptera	Syrphidae	Jan–Dec.	Carrot, Onion, etc.	21
	Episyrphus balteatus	"	"	"	Brassica, Dacus, Allium, etc.	21
	Macrosyrphus confacter (Weid)	"	"	"	"	21
	Metasyrphus corollae (Fab.)	"	"	"	"	21
	Sphaerophoria bengalensis Macquart	"	"	"	"	21
	Scaeva pyrastri (L.)	"	"	"	"	21
	Syrphus sp.	"	"	"	"	21
	Camponotus compressus	Hymenoptera	Formicidae	"	"	Present study
	Formica sp.	Hymenoptera	Formicidae	Jan–Dec.	Brassica, Dacus, Allium etc.	"
	Musca domestica	Diptera	Muscidae	"	"	"
	Calliphora sp.	"	Calliphoridae	"	"	"
	Lasioglossum sp.	Hymenoptera	Flalictidae	Feb–Oct.	Fruit crops peach, plum, pears	"
	Apis dorsata	"	Apidae	Jan–Dec	All cultivated wild	"
	A. mellifera	"	"	"	"	"
	A. cerana indica	"	"	"	"	"
	Halictus sp.	"	Halictidae	Feb–Nov.	"	"
	Nomia sp.	"	"	"	*Brassica*	"
Subtropical temperate transition areas (1350 to 3000 m MSL)	*Bombus haemorrdalis* Smith	" "	Apidae: Bombini "	March–Oct Bombini sunflower	Cucurbits, *Brassica*, sunflower, clovers	23
	Bombus sp.	"	"	March–Oct.	Breccia	Present study
	Colletes cous Morice	"	Colletidae	April–Oct	"	"
	Megachile lanata	"	Megachilidae	"	Alfalfa, Berseem	"
	M. flavipes	"	"	"	"	"
	M. cephalotes	"	"	"	"	"
	M. nana	"	"	"	"	"
	M. femorta	Hymenoptera	Megachilidae	April–Oct.	Alfalfa, berseem, Sunflower, Sunhemp,	Present study
	Megachile sp.	"	"	"	"	"
	Megachile sp.	"	"	"	"	"
	Andrena flavipes	"	Andrenidae	Jan–Dec.	*Brassica*	"
	A. leaena	"	"	"	"	"
	A. ilerda	"	"	"	"	"
	Amegilla quadrifasciata	"	Anthophoridae	"	"	"
	Amegilla sp.	"	"	"	"	"
	Pithitis smaragdula	"	"	May-Sept.	Alfalfa, cucurbits	"
	Xylocopa pubescens	"	Xylocopinae	Feb–Nov.	"	"

Table 1. (*contd.*)

	X. fenesterata	"	"	"	"	"
	Polistes habreus	"	"	"	"	"
	Nephele didyma (Fab.)	Lepidoptera	"	"	"	"
	Anthophora sp.	Hymenoptera	Anthophoridae	Jan–Dec.	*Brassica* sp.	"
	Eristalis tenax	Diptera	Syrphidae	"	Brassia, peach, plum, pears	"
	Musca domestica	"	Muscidae	"	"	"
	Osmia sp.	Hymenoptera	Megachilidae	April–Oct.	"	"
	Camonotus compressus	"	Formicidae	Jan–Dec.	"	"
	Calliphora sp.	Diptera	Calliphoridae	"	"	"
	A. dorsata	Hymenoptera	Apidae	Jan–Dec.	All cultivated/ wild crops	"
	A. C. indica	Hymenoptera	Apidae	Jan–Dec.	All cultivated/ wild crops	Present study
	A. mellifera	"	"	"	"	"
	A. mellifera	"	"	"	"	"
	A. florea	"	"	"	"	"
	Episyrphus balteatus	Diptera	Syrphidae	"	Brassica, dacus, sunflower	21
	Macrosyrphus confacter	"	"	"	"	21
	Metasyphus corolla	"	"	"	"	21
	Sphaerophamia bengalensis	"	"	"	"	21
	Scaeva pyrastri (L.)	"	"	"	"	21
Temperate zone (Kashmi valley) 1560–420 m MSL)	*Xylocopa valga*	Hymenoptera	Xylocopinae	Feb–Nov.	Peach, plum, pears cherry, apple, persiman strawberry, sunflower,	17
	Xylocopa sp. (i)	"	"	"	"	"
	Xylocopa sp. (ii) study	"	"	"	"	Present study
	Xylocopa sp. (iii)	"	"	"	"	"
	Xylocopa sp. (iv)	"	"	"	"	"
	Xylocopa sp. (v)	"	"	"	"	"
	Amegilla Quadrifasciata fasciata	"	Anthophoridae	May–Oct.	Lavender	19
	Ameilla sp.	"	"	"	"	19
	Anthophora sp.	"	"	"	Apple, *Brassica*	19
	Colletes eous	Hymenoptera	Colletidae	Feb–Nov.	Apple, peach, plum, cherry etc.	19
	Megascolia flavifrons	"	Scolidae	May–Oct.	"	19
	Andrena flavipes	"	Andrenidae	March–Oct.	Brassica, strawberry apple, plum, peach, Brassica crops.	19
	Megachile sp. (i)	"	Megachilidae	April–Oct.	Apple, cherry, plums	Present study
	" (ii)	"	"	"	"	"
	" (iii)	"	"	"	"	"
	" (iv)	"	"	"	"	"
	Osmia sp.	"	"	"	Apples	"
	Eristalis tenax	Diptera	Syrphidae	March–Nov.	*Brassica*, carrot, onion	"
	Episyruphus balteatus DeGeer.	"	"	"	"	21
	Metasysphus confacter (Weid)	"	"	"	"	21
	Ischodon scutellaris	"	"	"	"	21
	Eumerus albifronss	"	"	"	"	21
	Sphaerophoria indiana Bigot	"	"	"	"	21*
	Syrphs sp.	"	"	"	"	"
	Emerus nepalnensis Brunetti	Diptera	Muscidae	Feb–Nov.	Apple, peach, plum, strawberry, carrot, Brassica onion, etc.	Present study
	Musca domestica	"	"	"	"	"
	Musca sp.	Hymenoptera	Apidae	"	All cultivated/wild crops	"
	Apis mellifra	"	"	"	"	"
	Apis cerana indica	"	Formicidae	"	"	"
	Camponotus compressus	"	"	"	"	"
	Monomorium Indicum	"	Apidae: Bombini	April Oct.	"	"
	Bombus asiaticus	"				

Table 1. (*contd*)

	B. simillimus	"	"	"	"	"
	B. trifasciatus	"	"	"	"	23
Temperate areas (Kashmir valley high altitude areas of inner Himalaya)	*Bombus avinoviellus*	"	"	"	"	23
	B. himalayans	"	"	"	"	23
	B. marussinus	"	"	"	"	23
	B. bohemicus	"	"	"	"	23
	B. novus	"	"	"	"	23
	B. branickii	"	"	"	"	23
	B. ferganicus	"	"	"	"	23
	B. morawitzians	"	"	"	"	23
	B. ferganicus	"	"	"	"	23
	B. morawitzians	"	"	"	"	23
	B. trifasciatus	"	"	"	"	23
	B. haemorrhoidalis	"	"	"	"	23
	B. melanurus	Hymenoptera	Apidae: Hombini	April–Oct.	Clovers alfalfa sunflower, cucurbits cultivated/wild plants	23
	B. personatus	"	"	"	"	23
	B. kashmirensis	"	"	"	"	23
	B. hyponourum	"	"	"	"	23
	B. subtypicus	"	"	"	"	23
	B. lemniscatus	"	"	"	"	23
	B. lepidus	"	"	"	"	23
	B. biroi	"	"	"	"	23
	B. tunicatus	"	"	"	"	23
	B. lucorum	"	"	"	"	23
	B. asiaticus	"	"	"	"	"
	B. oberti	"	"	"	"	23
	B. ladakhensis	"	"	"	"	23
	B. semenovianus	"	"	"	"	"
	B. kerriensis	"	"	"	"	23
	B. simillimus	"	"	"	"	23
	B. pyrosoma	"	"	"	"	23
	B. Infofasciatus	"	"	"	"	23
	Osmia sp.	"	"	"	"	23
	Colletes sp.	"	Megachilidae Colletidae	" "	" "	Present study

Table 2. Orderwise distribution of pollinating insects in different climatic zones of Jammu & Kashmir state

	Climatic zones			
Insect	I	II	III	IV
Hymenoptera	29 (5.43)	26 (5.14)	26 (5.14)	30 (5.52)
Diptera	9 (3.08)	9 (3 08)	10 (3.24)	0 (0.70)
Lepidoptera	0 (0 70)	1 (1.22)	0 (0.70)	0 (0.70)

Figures in parentheses are transformed values: $y+0.5$
CD at 5% between treatments = 9.64
CD at 5% between replications = Non-significant
*Climatic zone:
I = Low altitude auto-tropical region of Jammu foothills (300 to 135 m MSL)
II = Intermediate zone (1350 to 3000 m MSL)
III = Temperate zone (1560 m to 4200 m MSL)
IV = Cold arid alpine zone (2400 m to 8400 m MSL).

Energy intake expenditure relationship in bee–host plant interaction

Pollinators are selective in their floral visits and are shown to choose flowers which best meet their energetic requirements[5,15,29,33]. Abrol[33] found that foraging preferences of *Megachile nana* Bingh and *M. flavipes* Spinola was in the order: *Parkinsonia aculeata, Medicago sativa, Trifolium alexandrium. Andrena ilerda* and *A. leaena* preferred flowers of Brassica in the decreasing order of *Brassica napus, B. carinata, B. juncea,* and *B. campestris* var *toria.* Abrol[33] examined the foraging preferences of six bee species in relation to 25 crop plants. He found that energy intake and balance and foraging efficiencies varied with bee species, crops and seasons. It is suggested that energy budgeting of

pollinators on specific plant species may help provide an index for their utilization as prospective pollinators.

Inter-varietal differences in pollinator attractiveness and fruit set

Pollinators are very sensitive to variations in nectar rewards. They alter their behaviour patterns in relation to variability in natural plant populations thereby affecting pollination and fruit set[7,34]. Inter-varietal differences in pollinator attractiveness and fruit set has been evaluated in almonds, apples, pears, cherry and strawberry. Attractiveness of cultivars to insect pollinators was correlated with the quality and quantity of fruit produced.

Adaptation of bees to different climatic conditions

Studies on metabolic adaptation of bees have shown that *Megachile* spp. had the capability to metabolize nectar with very high sugar concentration (above 78%) compared to honeybees (30 to 50%). Further the former, are found to forage in extremely arid environments with high temperatures (above 43° C) and where concentrated nectar (above 78%) is anticipated[26]. These results have important implication for the management of bee pollinators of crops grown in semi-arid areas of the world. Efficient pollinators of various temperate fruit crops such as almond, apple, peach, plum, pears and cherry that forage at extremely low temperature have been identified. *Xylocopa valga* Gerstacker was found to forage at 6–7° C, on cloudy overcast days, at which no other bees were found visiting flowers. Similarly, bumble bees visited flowers at 3–5° C at which no other bee can fly[17].

Pollination efficiency of bees

Xylocopa valga visited greater number of flowers min^{-1} compared to honeybees and other wild solitary bees. Pollen loads carried by bee species was significantly positively correlated with body size. The pollen loads carried by bees ranged from 2.15 mg in *Halictus* sp. to 31.75 mg in *X. valga*. Relative to their body size, smaller bees carried heavier pollen loads than the large bees. In general, pollinating efficiency of bees was in the order *X. valga, B. simillimus, B. asiaticus, B. albopleuralis, A. melleria, A. C. indica, Amegilla quandrifasciata, Lasioglossum* sp., *Halictus* sp., *Colletes eous*[10].

Wing stroke frequency and pollinating efficiency of bees

Oscilloscopic studies on wing beat frequency of bees help in assessing their pollinating efficiency. On the basis of wing beat frequency Abrol[11] reported that *Bombus asiaticus* is a fast flier and efficient pollinator than *B. albopleuralis*. The study revealed that wing beat frequency along with a few other body parameters may be used in characterization of ecotypes of bees.

Management of pollinators for crop production

Because of their importance as crop pollinators, efforts are being made to conserve and manage pollinators. Our studies show that species of *Osmia, Xylocopa* and *Megachile* can be maintained in orchards by providing them with suitable nesting materials such as castor stems, bamboo stems, pith etc. In case of soil nesting bees, care should be taken not to dislocate nesting sites during farm operations. Further, for all category of pollinators, spraying pesticides just before and during the flowering of the crop should be avoided.

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