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Essential ecological services provided by insects through pollination for achieving sustainable goals

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Abstract
Pollination is an ecological process that involves the transfer of pollen from the male to the female part of the flower with the help of various abiotic and biotic pollen dispersal dust like agents and is an essential pre-requisite for fertilization and fruit/seed dispersal. Insects possesses one among the primary groups of pollinating agents, as the association between insects and flowers is well established. As flowers blossoms so did the mouthparts of the insects exploiting them. Various insect groups, which are of prime significance in pollination of agricultural and horticultural crops mainly belong to the orders Hymenoptera (bees, ants and wasps), Diptera (flies, mosquitoes, fungus black flies midges etc.), Coleoptera (beetles and weevils), Lepidoptera (moths and butterflies), Thysanoptera (thrips), Hemiptera (bugs) and Neuropteran (lace wing flies). This work is mainly based on detailed and thorough observations/study made from various cash crops *viz. Brassica nigra*, *Coriandrum sativum*, *Tagetes erecta* and *Helianthus annuus* from North 24- Parganas of South Bengal region.

Keywords: Pollination, pollinators, fertilization, ecosystem

Introduction

Taxa Insects constitute one among the primary groups of pollinating agents, as the association between insects and flowers are well established since evolutionary times. Insect pollination is important to the reproduction and persistence of many wild plants (Ollerton *et al.* 2011) [13]. The major anthophilous (flower frequenting) taxa among insects are the beetles (Coleoptera), flies (Diptera), wasps, bees and ants (Hymenoptera), thrips (Thysanoptera), and butterflies and moths (Lepidoptera) (Free 1993 [5]; Kearns *et al.* 1998 [7]; Mitra & Parui 2002 [11]; Mitra *et al.* 2008) [10]. Approximately estimated pollinator taxa of Tropical countries are presented in a bar graph (Fig.1) (Roubeik). The first rule of Insect-plant association is based on a give and take policy, which is rather a part of co-evolution. Insects will always forage the flower primarily for getting some rewards, whether it is in the form of nectar or pollen, and that opportunity is exploited by the floral parts of the plant and thus pollination occurred.

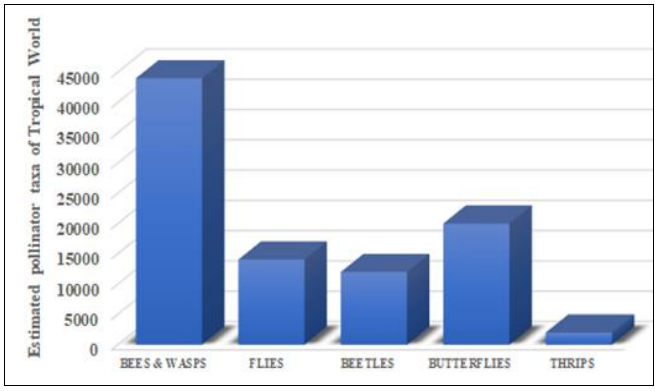

Fig 1: Approximately estimated pollinator taxa of tropical world

Pollination, an essential ecosystem service provided by insect pollinators, is many times taken for granted and little attention is paid to the need of conserving and enhancing the pollinator diversity in crop ecosystem. It has been observed that flowers of most angiosperm species are visited by more than a single species of pollinator (Fishbein and Venable, 1996 [4]; Pellmyr and Thompson, 1996 [14]; Waser *et al.*, 1996 [18]; Young 2002). Two major factors determine the effectiveness of each species of pollinator: their relative abundance among the pollinator ‘‘pool’’ and the efficiency with which they remove and deposit pollen. Pollination success can be measured by two factors: female reproductive success (number of pollen grains deposited on stigmas, ovule fertilization, seed production) and male reproductive success (pollen removal, pollen movement distances, success of pollen on the stigmas of conspecifics). These may be coupled such that pollinators deposit a high proportion of the pollen they remove (Conner *et al*. 1995) [1], or they may be uncoupled resulting in visitors that remove large quantities of pollen but deposit very little pollen on conspecific stigmas. Insect-pollinated crops include many fruits, nuts, seeds, beans, coffee and oilseed rape (canola) (Free, 1993 [5]; Klein *et al*. 2003 [9], 2007) [8]. These provide vital nutrients (e.g. vitamins and proteins) and variety to human diets worldwide, while in some developing countries insect-pollinated crops provide substantiate amount of calories and nutrients to people (Eilers *et al.* 2011) [3]. Pollination is therefore an important process in maintaining healthy and bio diverse ecosystems.

The present studies were undertaken to document insect pollinator diversity, abundance and pollination efficiency index in various cash crops *viz. Brassica nigra*, *Coriandrum sativum*, *Tagetes erecta* and *Helianthus annuus* from the South Bengal region, where so far, no data is available. Therefore, the present study will definitely help to identify the insect pollinators, their diversity and behaviour from this locality which in turn helps to broaden our knowledge about the pollination biology of the cash crop plants of this locality.

A complete list of all the pollinators and foragers of *Brassica nigra*, *Coriandrum sativum*, *Tagetes erecta* and *Helianthus annuus* from different insect orders/families are enlisted in Table 1.

Table 1: Mean number of pollen grains counted from the body hair of some flower visitors of Helianthus annuus and Brassica nigra at the Agricultural field form Samudrapur and Hizlia respectively of South Bengal.

Species	Pollen from ***Helianthus annuus***	Foreign pollen	Flower: insect ratio/hour	Pollination efficiency index	Pollen from ***Brassica nigra***	Foreign pollen	Flower: insect ratio/hour	Pollination efficiency index
Apis megapis dorsata	1207	38	146: 32	5507	NF	ND	-	-
Apis mellifera	1026	27	146: 21	7133	978	20	146: 22	6490
Apis cerana indica	ND	ND	-	-	1074	23	146: 23	6818
Non-Apis bees	10	7	146: 12	122	NF	ND	-	-
Eristalinus arvorum	NF	ND	-	-	576	17	146: 22	3823
Musca indica	621	19	146:19	4772	NF	ND	-	-
Pollination efficiency index was calculated using procedures developed by Vithanage (1990). ND: not determined; NF: not found.								

Materials and methods

The study was conducted at Agricultural land from Pabdara, Masunda, Beraberi, Rajibpur, Chandigacha, Samudrapur, Amragachi, Rajberia, Pumlia, Hizlia, Bamondanga, Daoulatpur of District North 24 Parganas from South Bengal region (Fig.2) from 10th of April 2021 to 15th of July, 2023. The study was conducted in four plots measuring each of approximately 14400 square feet. Sweep net of 20 cm radius was used to collect the pollinating insects at different time periods, *viz* 7-8 am, 9-10 am, 11-12 am, 1-2 pm, 3-4 pm, 5-6 pm and 7-8 pm. Record of daily mean temperature and relative humidity was also taken from the local meteorological laboratory. Insect behavior at flowers was recorded through field notes and photographs. The methods for collection, killing, preservation, setting and pinning of the insects were adopted from the manual of Zoological Survey of India (Jonathan & Kulkarni, 1986), (Fig. 4). The collected specimens were identified from Zoological Survey of India, Kolkata. Finally, pollination efficiency index for some visitor species was calculated using procedures developed by Vithanage (1990) [17].

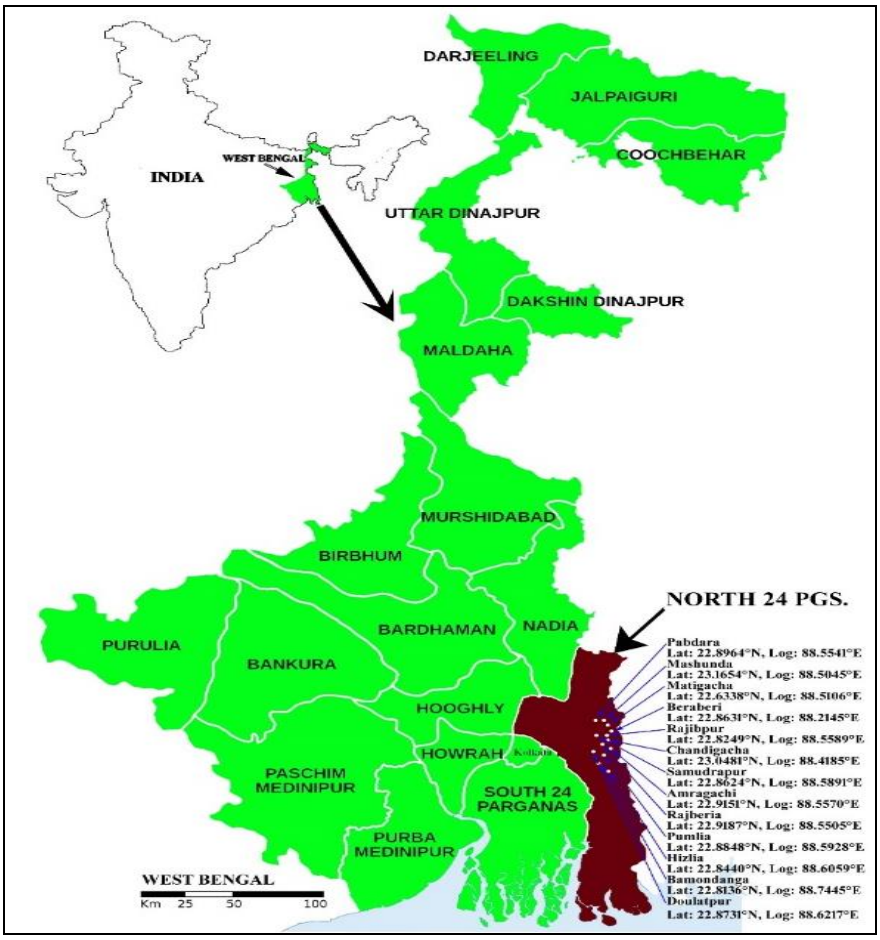

Fig 2: Map showing the various locations of southern part of West Bengal

Results and Discussion

In the present study, total 34 species under five orders *viz.* Coleoptera (5 species under 3families), Hymenoptera (4 species under 1 family), Diptera (13 species under 6 families), Hemiptera (4 species under 4 families) and Lepidoptera (8 species under 7 families) were observed to be associated with the flowers of *Brassica nigra*, (Fig. 5). *Coriandrum sativum* (Fig. 6), *Tagetes erecta* and *Helianthus annuus* (Table1). The floral rewards offered to the pollinators by the four crop plants in the present study were mostly nectar and also pollen to some extent. Most of the insect visitors associated with the crops were found to be active during the day from 8 am -12 pm. The composition, diversity and abundance / quadrate of different insect orders associated with the plants during various time schedules have been presented by a bar graph and pie chart (Fig. 3 A-D). Pollination efficiency index was calculated using procedures developed by Vithanage (1990) [17] and presented in Table 2.

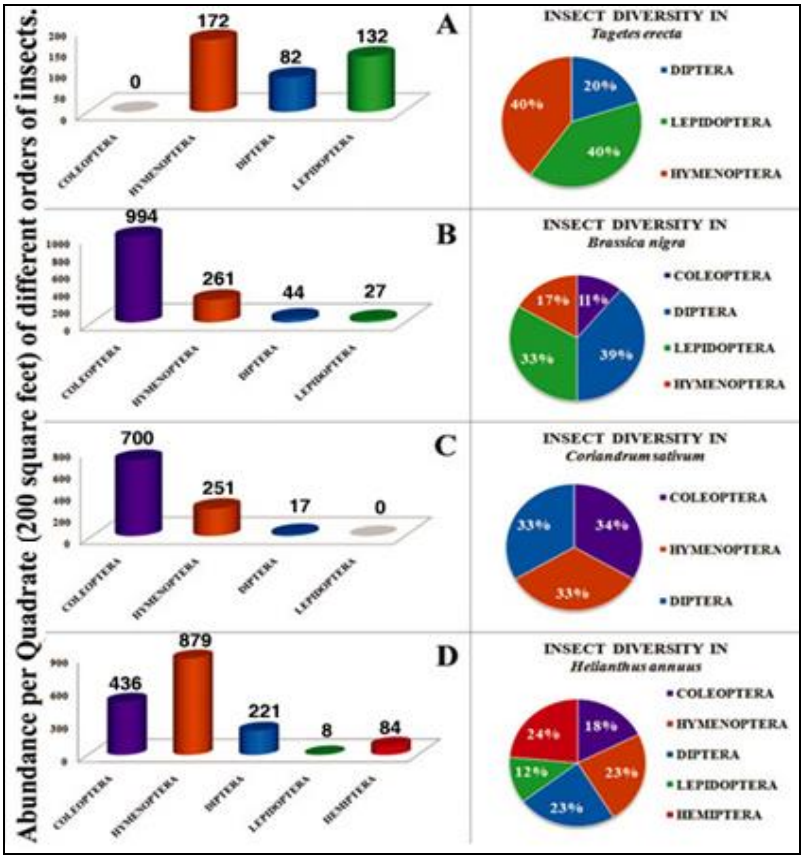

Fig 3: Bar graphs and pie charts showing abundance per quadrateand diversity, respectively of different orders of insect found in cash crops.

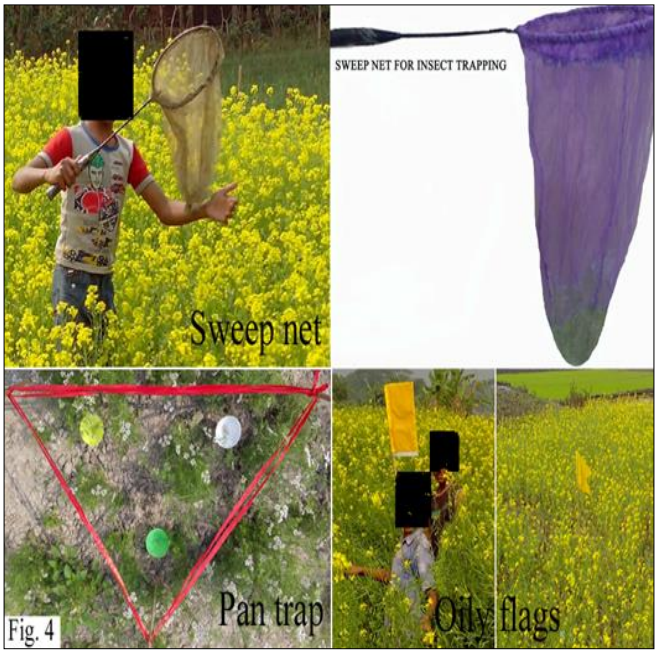

Fig 4: Sweep net for insect trapping

Fig 5: Different pollinators of *Brassica nigra*

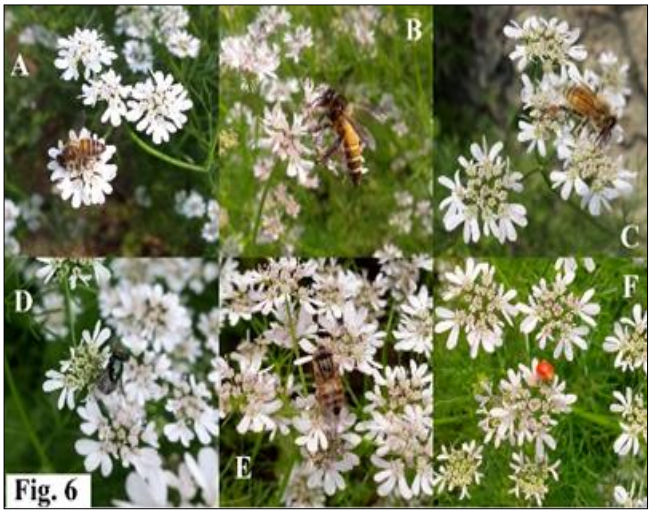

Fig 6: Different pollinators of *Coriandrum sativum*

At a time 200 square feet area was selected for the observation and collection of the species, so out of total 14400 square feet area, approximately 7 quadrates were chosen for the data analysis.

Role of insect pollinators / visitors in *Brassica nigra*

During morning from 9-11 am, maximum number of *Apis cerena indica* and a few *Apis megapis dorsata* under family Apidae from order Hymenoptera were reported. They were observed to visit almost 10-15 plants per minute and were reported to spend about 12-15 seconds on single flower. Furthermore, several types of species from order Diptera (7 different types of species) were also reported to play important role as pollinator in case of *Brassica sp*. (Table 1). During morning from 7 am till 10 am, number of species *viz. Stomorhina discolor* and *Episyrphus basteatus*, from family Syrphidae were observed to visit almost 15-20 plants per minute and were reported to spend about fraction of a second on each flower. After 11 am, diversity of Dipteran species increases and several species of *Eristalinus arvorum*, from family Syphidae, *Chrysomya megacephala* from family Calliphoridae, *Orthellia coerulifrons* from family Muscidae, *Sarcopaga sp.* from family Sarcophagidae and only a few numbers of *Slakkendoders sp.* from family Sciomyzidae were reported. Though, few in number, but 6 different types of species from order Lepidoptera were also reported to play important role in pollination (Table1). Among order Coleoptera, two types of species, *viz. Oenopia sp*. and *Coccinella transversalis*, both from family Coccinellidae were reported to be present in maximum number (~1200 per 200 square feet area studied). Though, they were observed to forage mainly as predators attacking the resting aphids and no noticeable effect on pollination was observed in this case.

Role of insect pollinators / visitors in *Coriandrum sativum*

Like Brassica, Coriander was also found to be dominated by insect pollinators of Order Hymenoptera followed by order Diptera. But unlike Brassica, *Apis cerana indica* was the only Hymenopteran species found to be the most active, abundant and efficient pollinator. Diversity of Dipteran species was also not that reach like in Brassica, only species found was, *Eristalinus arvorum*, from family Syphidae. A few numbers of *Oenopia sp.* from family Coccinellidae under order Coleoptera was also reported to forage the crop plants.

Role of insect pollinators / visitors in *Tagetes erecta*

Three species *viz*. *Apis megapis dorsata, Apis cerana indica* and *Apis mellifera* from Apidae under Hymenoptera were recorded as active and efficient pollinator. Only one species, *Chrysomya megacephala,* from family Calliphoridae under Diptera was observed. Lepidopteran foragers playing important role as pollinators, belonged to two families, among which Hesperiidae constituted *Potanthus omaha,* and the other family, Arctiidae constituted *Amata cyssea*.

Role of insect pollinators / visitors in *Helianthus annuus*

During morning from 7-11 am, maximum number of *Apis megapis dorsata* and a few *Apis mellifera* under family Apidae from order Hymenoptera were reported. *Apis cerana indica* was the least reported species observer in this case. They were observed to visit almost 6-7 plants per minute and were reported to spend about 10-12 seconds on single flower head. Their activity and number decreased after 12 pm noon and again they came to the field after 2.30 pm and remained there till 5 pm. Furthermore, few (1-2 / plant) non-Apis bees (*Certaina unimaculata*) were also reported along with the Apis bees to forage the flower head. Presence of non-Apis bees associated with Apis bees was reported by many entomologists (De Grandi Hoffman & Watkins, 2006 [2]; Greenleaf & Kremen, 2006 [6]; Nderitu *et al*. 2008) [12]. The members of the family Apidae were found to forage on both pollen and nectar. Diversity of 4 different types of species under order Diptera was reported, playing important role as pollinator. During morning from 8 am till 11 am, number of species *viz. Musca indica* from family Muscidae, a few species of *Brachioma devia* under family Sarcophagidae and two unknown species from family Sciomizidae and Pipunculidae respectively were observed and found to forage mainly on nectar. Among all, *Musca indica* were reported to be the most abundant to visit almost 4-5 plants per minute and their number varied from 2-3 /plant. They were reported to spend about fraction of a second on each flower. Though, very few in number, but 4 different types of species *viz*. *Crysocoris stolli* (Scutellidae), *Leptocentrus Taurus* (Membracidae), *Nezara viridula* (Pentatomidae) and one unknown species (Miridae) under order Hemiptera were also reported to pay visit to the flower head. They were reported to show slow movement from one flower head to another and observed to forage mainly on the nectar of the flower head. They do not play any noticeable role in pollination. Among order Coleoptera, three species, *viz. Haltica sp.*, family Halticidae; *Menochilus sexmaculatus*, family Coccinellidae and *Smicronyx fulvus*, family Curculionidae were reported to be present (~3-4/plant). *Menochilus sexmaculatus* followed by *Haltica sp.* were found to be the most abundant Coleoptera visiting the crop plant during 11-1 pm and again after 2 pm that remained there till 5 pm. They were observed to forage mainly as predators.

Furthermore, two species *viz*. *Spodoptera Litura* and *Helicoverpa armigera* from family Noctuidae under order Lepidoptera were observed to forage the flower head during night from 16.00 hrs. till 19.00 hrs. as nocturnal pollinators,

which is in conformity with Radford *et al* 1979 [15]. They forage on the nectar of the crop plant.

Conclusions

The following observations led us to the inference that the floral visitors reported and observed were the pollinators of the aforesaid crop plants: 1) The time of visit by these visitors corresponds with the duration of pollen transfer onto the hairy stigma; 2) The visitors in a flower were seen to be profusely smeared with yellow pollen grains on the dorsal surface of their head, thorax, legs and antennae; 3) While moving within a flower, they come in contact with the dehisced anthers and the stigma. On the basis of the above observations, *Apis sp.* was found to be the active and efficient pollinators in all the four crop plants. Out of the three species of honey bees, *Apis mellifera* was found to have the highest pollination efficiency index whereas the non-Apis bees were found to have a very low pollination efficiency index though it was presumed that probably these non-*Apis* bees enhanced the foraging capability of *Apis* bees.

Next to order Hymenoptera, it was the insect species under family Syrphidae and Muscidae, from order Diptera, that was found to be active pollinators with moderate pollination efficiency index. Their abundance per quadrate was reported to be maximum in *Helianthus annuus* whereas diversity was high in *Brassica nigra.*

Order Coleoptera, comprising of five species from three families, were reported to be active predators attacking the resting aphids rather than efficient pollinators, found in flower *Brassica nigra*, *Coriandrum sativum* and *Helianthus annuus*.

Abundance per quadrate was reported to be maximum with order Coleoptera in case of *Brassica nigra*, whereas the diversity of insect order was found to be maximum with order Lepidoptera found in *Tagetes erecta.*

Thus, this is a preliminary attempt to make a report of insect pollinators for the cash crops from South Bengal, which will certainly help the future workers as a baseline data of pollinators and pollination of the crops from this area. Hence, conservation of these species diversity is an absolute necessary for the crop plant pollination and seed production in future.

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