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Floral Biology and Pollination of *Abelmoschus esculentus* (L.) Moench.

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ABSTRACT

Present investigation deals with the flowering phenology, pollen production, flower visitor interaction, pollen dispersal and pollination of a highly economic important crop plant *Abelmoschus esculentus* (L.) Moench. belonging to the family Malvaceae. Flowering occurred in between April - October, which are yellowish, actinomorphic flowers open in morning (05:00am to 06:30am) and anther dehiscence takes place transversely after flower opening. In average a single anther produces 1250 pollen grains. After flower opening large number of insects come in contact with flower like member of Hymenoptera (Ant, *Apis cerana indica*, *Pithitis* sp.), Lepidoptera (*Borbo* sp.) and member of Diptera. The style is surrounded by a staminal column which bears large number of anthers. The pollen grains come in contact with the stigmas around the throat of the staminal column. It has been found experimentally that there is significant difference in fruit set under open-pollinated (75%) and bagging (45%). Bagging result indicates the self-pollination and open-pollinated fruit set shows insects are helpful for cross-pollination and fertilization because the flowers are very attractive to the flower visitors.

***Key words*:** Flower- visitors, Foraging materials, Pollination, Fruit set, Style, Staminal column, Stigma

A flower consists of four parts (i) calyx-the outer whorl protects the flower bud; (ii) corolla- the second whorl which protects the bud as well as attract different flower visitors by their attractive colour; (iii) androecium- the third whorl which consists of stamens, showing the grow male reproductive unit i.e., pollen grain within the anther and (iv) gynoecium- the innermost whorl and consists of pistil, the female reproductive organ of plants. The third and fourth whorl i.e., androecium and gynoecium directly take part in the reproduction. Structural features of flowers are of great importance for knowledge of pollination and reproduction systems. In some plants, the flower structure favors self-pollination, while in others it favors cross-pollination. Darwin's first book on flower biology states that the various devices insects use to pollinate orchids result in cross-pollination.

Wide variety of orchid flower morphologies arose as a result of natural selection by various mechanisms that facilitated pollination and fertilization from one flower to another [1]. In a natural environment, flowering plants reproduce due to both biotic and abiotic influences [2]. Pollinators influence the production of various crops such as fruits and vegetables. Increasing crop yields is important for health, nutrition, food security and increasing farmer incomes. Classifying attractants into primary attractants such as pollen, nectar and hatchery and secondary attractants such as odor, color and temperature, knowledge of flower morphology is essential for assessing pollination and flower-visitor interactions [3].

The facts of plant-pollinator interactions and their role in pollination and maintenance of plant diversity are the subject of co-evolutionary relationships between flowers and pollinators under different conditions during reproductive periods when floral traits are different. emphasized by complexity. Most plants are pollinated by insects, with bees being the predominant pollinator [4]. Butterflies are also important pollinators [5-6]. Pollination of crops by various insects such as bees, butterflies, flies and other animals is a potentially valuable ecosystem service, often in mixed farming and fruit production. Most of our crops are poorly adapted to biotic and abiotic stresses such as disease, pests, drought, salinity and the constant introduction of new adaptive genes, so maintaining crop diversity and to improve further, you need cultivated crops.

Some crop plants exhibit the entomophilous pollen dispersal mechanism in atmosphere [7]. Plant-pollinator interactions in relation to floral symmetry and nectar guides functionally significant [8]. Increased pollinators population in presence of nectar and pollen abundance [9]. Insect mediated airborne pollen dispersal of *Alangium salviifolium* (L.F.) [10]. In this study, an attempt was made to investigate flower phenology, flower visitor interactions, pollen dispersal, and flower visitor contribution to successful pollination of *Abelmoschus esculentus* (L.) Moench. Known as lady's finger

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or ocher in many English-speaking countries, is a flowering plant. It has edible green seed pods. The geographical origin of okra is debated with proponents of West African, Ethiopian, Southeast Asian, and South Asian origins. Cultivated in tropical, subtropical, and temperate regions around the world, okra is used in many countries' cuisines [11]. Okra provides an important supply of nutrients and minerals [12]. In addition, carbohydrates, potassium and magnesium were found to be widely used. Okra seeds are reported to contain 15-26% protein and over 14% oil [12-13].

MATERIALS AND METHODS

The whole study was conducted to observe different phenological events with plants of same species growing in and around of Birbhum district (87° 31' 57" east and 23° 53' 24" N latitude) following the methods [14-18]. Pollen contribution by the flower visitors to fruit set was quantified by comparing fruit set between netted and opened flowers. Pollen grains per anther and per flower were quantified following the procedure [19]. Pollen grains counted of each anther flower were done using the method [19]. The pollen viability was tested using 1% TTC [20]. The pollen-ovule ratio was determined [21]. The atmospheric pollen incidence was determined by operating 'Rotorod' sampler [22]. and frequency of the pollen grains were calculated using the following formula [23].

$$\text{Percentage of particular pollen grains} = \frac{\text{Number of particular pollen grains trapped}}{\text{Total number of pollen grains trapped}} \times 100$$

RESULTS AND DISCUSSION

Between April and October, the plant flowers. Flowers are Actinomorphic, yellowish in colour and opens in morning from 5:30 am to 6:30 am. Anther dehiscence (transversely) after flower opening. Flowers are large (55-57mm ×19-21mm), bracteate, pedicillate, complete, bisexual, actinomorphic, hypogynous, bright yellow in colour, bracteoles 8-10. Calyx consists of five Sepals, hairy, gamosepolous, acute, green, valvate, segments are completely fused as the flowers develop forming a complete protective covering for the bud, this splits when the flowers opens, being ruptured by a longitudinal slits.

Corolla with five petals, polypetalous, large (40-41mm ×15-16mm), showy, bright yellow in colour and with a deep reddish-purple spot on the claw, connate at the very base and there adnate to staminal column, twisted. Androecium consist of numerous stamens (more than –85) united in to a central staminal column (25-27 mm × 2-3 mm) which is also united to the petals at the base, anther small reniform, dehisced transversely after flower opening, basifixed.

Gynoecium with five Carpels, ovary elongated, superior, syncarpus, five locules with many ovules, style long, and through the staminal column the style is pushed with five lobed, deep red capitate stigmas appear at the top of the tube, axile placentation.

Fruits - elongated conical capsules with five valves.

Large bisexual actinomorphic flowers of *Abelmoschus esculentus* (L.) Moench. open in morning (05:00am to 06:30am) during April-October. After flower opening anther dehisced longitudinally. Five showy bright yellow petals attract different flower visitors like members of Hymenoptera (Ant, *Apis cerana indica, Pithitis* sp.), Lepidoptera (*Borbo* sp.) and Diptera which were found to visits the flower for collecting foraging materials. Each flower produces 27000 pollen grains which along with copious amount of nectar act as main flower rewards for flower visitors. It is reported approximately 80% of all flowering plant species are pollinated by animals, including vertebrates and mammals - but the main pollinators are insects [24].

Table 1 Floral characters of *Abelmoschus esculentus* (L.) Moench.

Floral characters	Observations
Flowering period	April - October
Flower type	Actinomorphic
Flower colour	Yellow
Flower opening time	5:00 am - 6:30 am
Nectar	Present
No. of anthers/ flower	90 (Average)
Anther dehiscence mode	Transverse
Average no. of pollens/anther	300
Average no. of pollen grains/flower	27000
Average no. of ovules/flower	86
Pollen/ ovule ratio	314:1
Pollen shape	Spheroidal
Pollen type	Pantoporate
Pollen size	151.85 × 151.85µm
Stigma type	Dry, papillate
Pollen viability (TTC)	80%

Due to sticky pollen, allo-fertilization in okra is necessarily entomophilous [25] observed very low (2%) allogamy in natural flowering conditions. Finally, everything depends on the entomological environment, the dynamics of insect movements and their attraction by okra pollen [26].

Table 2 Flower visitors of *Abelmoschus esculentus* (L.) Moench.

Flower visitors with order	Visiting time	Foraging materials	Pollen adhering region
Hymenoptera:			
Apis cerana indica	Day	Pollen and Nectar	Ventral region, Legs and mouth parts.
Ants (*Formicidae*)	Day	Nectar	Ventral region, Legs and mouth parts.
Pithitis sp.	Day	Pollen and Nectar	Proboscis, Legs
Lepidoptera:			
Borbo sp.	Day	Nectar	Proboscis
Catopsilia sp.	Day	Nectar	Proboscis
Diptera:			
Member of Diptera	Day	Nectar	Ventral region

Flowering plants and their pollinators started co-evolution about 225 million years ago [27]. As early as 800 B.C, stone carvings and bricks from the palace of Assyrian kings depict the significance of pollen and pollination of fruits that pollination enhances quality and yield of seeds and fruits [28]. Lack of sufficient number of suitable pollinators causes decline in fruit and seed production [29]. Of the total pollination activities, over 80% is performed by insects, and bees contribute nearly 80% of the total insect pollination, and therefore, they are considered the best pollinators [30].

Another value of pollination lies in its effect on quality and efficiency of crop production. Inadequate pollination can result not only in reduced yields but also in delayed yield and a high percentage of culls or inferior fruits. stressed that flowers of plants making preferential autogamy tend to self-pollinate before or during opening [31]. Exposure of still receptive stigmas to potential pollinators occurs only after self-pollination. The style is surrounded by a column of stamens with an average of 85 anthers. The anthers are arranged so that the pollen grains of the anther (located just below the stigma and connected to the lower part of the stigma) readily contact the lower receptive part of the stigma, facilitating self-pollination. It is also responsible for the packaging state of a significant amount of fruit set (45%). Scarring to potential pollinators only occurs after self-pollination.

Flower visitors actively contribute to pollen deposition, which aids in both self- and cross-pollination. *Apis cerana indica* and *Borbo* sp. are the most common flower visitors, and they play an important role in pollination. Insects used the large spreading corolla as landing gear. Insects enter directly or after landing through the petals and stamina columns to collect nectar and circle the base of the corolla tube. During foraging, pollen grains were deposited on the stigma after being pollinated at the sterno and nototribically. It was concluded that insect pollination increased okra fertility [32]. As a result, even self-pollinated plants require some insect pollination to increase yield. Fruit setting (75% during flowering) indicated that insects were involved in better fruit development and outcrossing. Pollen dispersal was also slightly enhanced by air, as evidenced by 55% formation in net experiments. At 12:00, pollen grains accounted for up to 0.58% of the total. As a result, the plants had both self- and cross-pollination systems.

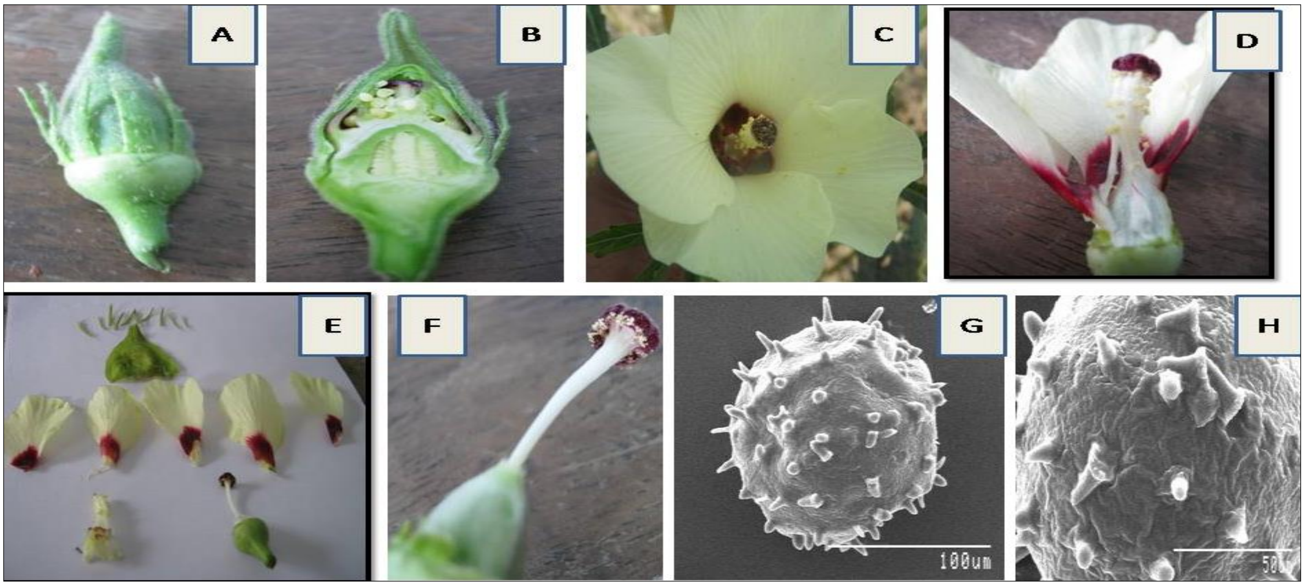

Fig 1 (Fig 1 A to 1F. 1G, H- Pollen in SEM)

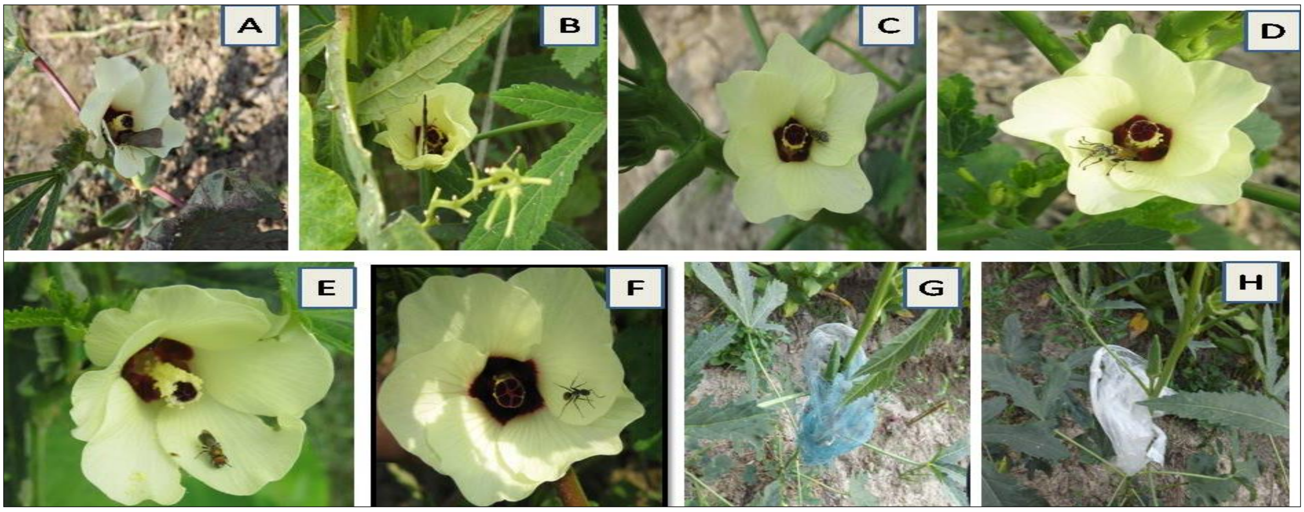

Fig 2 (Fig 2A to 2F Flower visitors, 2G, 2H Bagging and Netting)

CONCLUSION

Understanding such flower-visitor interactions is useful for both biodiversity conservation and aerial pollen logicalstudies. However, farmers' knowledge of pollination is limited. Many farmers confuse pollinators with pests and especially fail to save them, but pollinators can make a significant contribution to yields at no cost to farmers. Thus, understanding floral organization is a central theme for angiosperm phylogenetic reconstruction at all levels. Improved understanding of phylogenetic history and interactions between animals and plants is critical for the evolution of conservation actions for future research. As a result, detailed knowledge of floral biology, pollination, and flower-visitor interactions is required for the formation of fruits and seeds, as well as the development of various conservation protocols.

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