Study of flowering phenology and pollination in *Cajanus cajan* L

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Abstract
The present investigations are being carried out during the period 2005-2007 at Amravati. The plant species were visited daily or on alternate day, for collection of blooming phonological. During the present investigation it is observed that in *Cajanus cajan* L. first flower opens on 12th September to 28th September. The pollen production was found to be 14455.35 ± 2475.93 to 18826.83 ± 6068.99. The pollen viability percentage was recorded 83.33 to 91.27%. Estimated pollen: ovule ratio was found to be 2891.07 to 3765.36. The important flower pollinators in *C. cajan* were *Xylocopa* spp., *Apis dorsata*, *A. florea*, *Trigona* spp., *A. cerana indica*, *Ceratina* spp. and moth. The effect of different treatments on the yield in terms of weight of mature fruit was measured 28.00 to 47.02 gm in self- pollination, 41.56 to 60.00 gm in open-pollination and 54.12 to 70.54.

Keywords: Amravati, *Cajanus cajan* L., pollinators, *Apis dorsata*, yield

1. Introduction
Pollination is an important and essential stage in the sexual reproduction of flowering plants. It involves the transfer of pollen from anther to the receptive stigma of the flower. As such pollination is an essential prerequisite to seed and fruit set. Plants in general are classified on the basis of their floral biology as adapted to self and cross-pollination, either by wind or by animals, a majority of these being insects [1].
Cross-pollination needs a biological vector for the transfer of pollen from anthers of one flower to the stigma of another flower, to accomplish the process of pollination. Only the potential biological vector can fulfill this job [2]. Bees are considered to be the most important pollinators because they are the only insects whose immature stages are reared exclusively on pollen and nectar [3]. The foraging mode of the insect visitors determines them as pollinators or non-pollinators. Insect visitors are characterized as pollinator, if it transfers pollen intentionally in a foraging attempt or unintentionally [4]. Several factors like abundance, foraging behavior, number of loose pollen grains carried on the body, foraging rate and activity duration of the insect pollinator determine its pollinating efficiency [5]. During the present investigation detail study of these parameters of insect pollinators was carried out. Indian economy is more depend on agricultural and horticultural practice and this serves as a most important livelihood source. Several agricultural and horticultural crops are being cultivated in various parts in India derived benefit or depended on pollinating insect for maximum fruit and seed yields.

2. Materials and methods
The present investigations are being carried out during the period 2005-2007 at Amravati ($20^0$54' to $20^0$57' North Latitude and $77^0$43' to $77^0$48' East Longitude) situated in Amravati district of Maharashtra State. The observations were taken from different cultivated fields around Amravati city. Three different study sites were selected for study.
Blooming Phenology **t**he plant species were visited daily or on alternate day, for collection of blooming phonological observations. The opening of flower and anthesis were observed with help of hand lens (10 x). Simple method of Nair and Rastogi [6] was adopted to know the pollen production per anther/ flower. Pollen viability rates were observed with tetrazolium (TTC) test method [7] to determine the pollen viability *in vitro*. Pollen: ovule ratio calculated by dividing the number of pollen grains produced per flower by the number of ovules in the flower the pollen: ovule ratio of plants under investigation was obtained [8].
Stigma was observed through hand lens of 10 X magnification. Pollen load carried out by insect was estimated as per method proposed by Dafni [9]. The flower visitors were observed for their visit timings at the different study sites during the flowering period of plant. Yield comparison of three different pollination treatments, viz., "SP" (self-pollinated), "BP" (insect pollination) and "OP" (open pollination) were done as per the method followed by Panda *et al*. [10] and Rao and Suryanarayana [11].

3. Results and discussion
The present research work was started with the aim to know the role of insects in general and bees in particular in pollination of the crop plants cultivated in Vidarbha and thus to enhance the yield of crops. It was proposed to study the population of pollinators, their activity, behavior and their role in crop pollination.
To fulfill the above said objectives observations on different aspects of pollination and the flower visitors were undertaken for three consecutive years. Asia represents a wide variety of climatic zones and accordingly several kinds of crops are grown; many of these are cross-pollinated and required external agents for pollination for increased fruit/seed production [12].
Pollination is an essential prerequisite for seed and fruit development in temperate and tropical crops involving the transfer pollen from the male organs or anthers to the female organs of receptive stigmas [13]. Furthermore, in majority of crop plants seed production is very important in both natural and managed ecosystem [14]. It is important to study the process of pollination and pollinators in crop plant because more than 80% of all flowering plants species relay on different animals for pollination [15-16].

C. cajan is a shrub, widely cultivated in states of Madhya Pradesh, Bihar, Andhra Pradesh, Maharashtra, Uttar Pradesh and Karnataka. It is commonly known as "Pigeon Pea". Leaves are trifoliate, 8-10 cm long. Leaflate elliptic, lanceolate or oblong, 4-8 cm long and 1 – 2.5 cm broad. Cuneate, entire, acute or apiculate. Flower in terminal panicles and in axillary racemes. Calyx hairy, corolla yellow. Seeds used in form of "Dal". It is the second important pulse crop of India. Both immature and ripe seeds are used for human food as a good source of protein. The leaves and twigs are used as a fodder.

Flowering phenology is a critical life-history trait that strongly influences reproductive success [17]. Many species show gradual changes in flowering time over geographical and environmental gradients [18-19]. During the present study observations were carried out during the months of October to January. The flower initiation observed on 12th October to 20th October, the period of full blooming was observed to be from 17th October to 24th November. The various parameters influencing flowering are photoperiod, light intensity, temperature, moisture supply including ambient humidity and soil moisture, nutrient supply and various agricultural practices involved [20].

During present study the timing of anthesis was 10.20 to 10.40 hrs. and the flower opens during 10.40 hrs. to 11.20 hrs. The anther dehiscence was observed at 10.20 hrs. In the present investigation it was observed that anthesis starts during morning hours. The process of anthesis was delayed by an hour during rainy days. The present findings on anther dehiscence are in agreement with the Free [21] and Deodikar *et al.* [22]. However, Opler *et al.* [23] demonstrate that the rainfall is an important factor in the release, timing and synchronization of anthesis. [24]Patil and Zingre observed anther dehisces generally in the morning period in majority of the crop plants. The environmental factors such as temperature, relative humidity (RH) and rainfall influences the time of anthesis.

During present investigation the pollen production was found to be 14455.35 $\pm$ 2475.93 to 18826.83 $\pm$ 6068.99. Present finding indicates that the pollen production and flower size are positively correlates with each other. Cross-pollinated plants usually produce greater number of pollen grains than self-pollinated ones, thus increasing the probability of success of fertilization. The ample pollen grains were observed in flower of *C. cajan.* There may be little correlation between pollen production and removal of paternity. In addition, post pollination processes such as pollen tube competition, incompatibility and selective abortion can alter the paternity of resultant seeds [25-26].

The pollen viability percentage was recorded 83.33 to 91.27%. It was further noted that pollen viability also plays an important role in fruit and seed set. In present observation maximum fruit set was noted during open pollination which is an indication of pollen viability.

The pollen: ovule ratio was determined by counting the number of pollen grains produced per flower and divided by the number of ovules per flower. There is a strong correlation between pollen: ovule and breeding system [8]. During present investigation estimated pollen: ovule ratio was found to be 2891.07 to 3765.36. According to Cruden [8] the pollen: ovule ratio ranges between 2.7 to 6.7 in cleistogamous flowers, 18.1 to 39.0 in obligate autogamous flowers, 31.9 to 396.9 in facultative autogamous flowers, 244.7 to 2558.6 in facultative xenogamous flowers and 2108 to 19523 in xenogamous flowers. During the present investigation the data of pollen: ovule ratio corroborates with the result reported by Cruden [8].

During present investigation in C. cajan stigma becomes receptive during 09.30 hrs. to 11.00 hrs. which appeared glossy and yellowish red in colour on the loss of receptivity it becomes blackish red during 17.00 hrs. to 18.00 hrs. next day of flower opening. The duration of stigma receptivity varies from a few hours to few days and the age of flower, the time in the day and the presence or absence of stigmatic exudates may influence stigma receptivity [9]. The period of receptivity is influenced by environmental factor such as temperature and humidity. During the cloudy and rainy days normally receptive period of stigma is extent up to the third day of flower opening. Stigma receptivity also shows relations with change in flower colour [27]. The present findings are in agreement with Dafni [9] and Gori [27].

The important flower visitors in *C. cajan* were *Xylocopa* spp., *Apis dorsata* (Fig. No.5), *A. florea* (Fig. No.3), *Trigona* spp. (Fig. No.2), *A. cerana indica* (Fig. No.6), *Ceratina* spp. (Fig. No.1 and Fig. No.8) and moth (Fig. No.7). Occasionally, wasp and house fly (Fig. No.4) also visited the flower. The activity of visitors was more from 09.30 hrs. to 13.30 hrs. The flower visitor activity was less during the afternoon time, however, from 15.30 hrs. onwards towards the evening hours activity was again more. *Xylocopa* spp. visited the flower regularly through out the day time. *Xylocopa* spp. visited one to ten flowers in a single bout. Duration of the visit was two to eighteen seconds per flower. Bees visited one to seven flowers in a single bout and the duration was four to sixty seconds per flower.

Bees visit the flower to collect pollen and nectar is found to be most valuable process in the pollination. Their frequent visit from one flower to other flower may perhaps help transfer of pollen [1]. During the present investigation several insect foragers were found to be visiting on *C. cajan.*

Flowers of *C. cajan* are yellow, having landing platform on petals. A number of insect species were visited the flowers. The activity of pollinators starts after the opening of the flowers. The insect activity diminished during cloudy days. The bright yellow flowers represent flag type blossom. Insect visits the flower to collect pollen and nectar. *A. dorsata*, *A. florea*, *Trigona* spp., *A. cerana indica* and *Ceratina* spp. lands on petals and enter inside to collect the pollen in their pollen basket. *Xylocopa* spp. was found to be hovering around the blossom. They alight on the petal and thrust the mouth between the anther filaments to collect the nectar. During this activity style emerges out and the stigma touches the underside of the abdomen of *Xylocopa*. When *Xylocopa* leaves the flower after tripping, the floral parts resume their original position and pollen transfer take place. Thrips were commonly found within glued petals. The wasp also found hovering around the flower. The foraging rate of this bee was more than others bees. It visited many flowers within short period than the other bees. The peak period of bee visits was

found to be between 09.30 hrs. to 13.30 hrs. and 15.30 to 17.30 hrs. On single flower *Xylocopa* spp. spent 2 to 18 seconds, *A. dorsata* spent 5 to 57 seconds, *A. florea* spent 4 to 60 seconds, *Trigona* spp. spent 6 to 60 seconds, *A. cerana indica* spent 4 to 45 seconds, *Ceratina* spp. spent 4 to 55 seconds and moth spent 2 to 6 seconds. The wasp and house fly spent 4 to 21 and 2 to 4 seconds respectively during their visit to the flower.

According to Deodikar and Suryanarayana [1] red gram (Tur) is a very important honey source in several states of India and frequently visited by bees as a food resources.

The majority of species of flowering plants rely on pollination by insects, so that their reproductive success and in part their population structure are determined by insect behaviour. The foraging behaviour of insect pollinators is flexible and complex, because efficient collection of nectar or pollen is no simple matter. Each flower provides a variable but generally small reward that is often hidden; flowers are patchily distributed in time and space and are erratically depleted of rewards by other foragers. Insects that specialize in visiting flowers have evolved an array of foraging strategies that act to improve their efficiency, which in turn determine the reproductive success of the plants that they visit [28].

Many agricultural and horticultural crops grown in India are either dependent or are benefited by insect pollination of crop. Many pollen collecting insects harvest pollen from several flowering species. The estimation of pollen load carried by the pollinators is one of the traditional methods of measuring constancy [9]. Priti and Sihag [5] reported the number of loose pollen grains that adhered to the body of the insect visitors. *A. florea* carried out the pollen load 6578.90 ± 755.31, *A. dorsata* carried the pollen load 9891.10 ± 901.13, *A. mellifera* carried the pollen load 9002.15 ± 849.09 and also reported that maximum number of pollen grains were carried by *A. dorsata* among all the insect visitors.

During the present investigation maximum pollen load carried out by *Xylocopa* spp. was found to be 28487.8 to 101722.5. The pollen load carried out by bees *A. dorsata* 12604.5 to 29769.3; *A. florea* 3583.8 to 19675.2 and *Trigona* spp. 3666.0 to 11923.0 number of pollen grains respectively. During the present investigation bees are found to be dominant amongst all foragers. Bees forage on the flower to collect the pollen and nectar. The maximum pollen load was found to be carried out by *Xylocopa* spp. and *A. dorsata* as compared to other foragers.

The amount of loose pollen on the body of insect varies on different body parts. Usually there is about twice as much on a bee thorax as on its abdomen and pollen gathers tend to have more pollen than nectar gathers [29-30]. Positive correlations between pollen load and reproductive success have been attributed to several related phenomena.

During the present investigations breeding experiments showed that fruit set in open or natural and insect pollination is always higher, which is an indication of successful pollination. Pollen: ovule ratio is also served as an index of breeding system. The proportion in which pollen gains and ovules differentiate in an individual reflects the efficiency of pollen transfer among its flowers [8]. It is reported that pollen: ovule ratio more or less reflects the breeding system in all crop plant species. The present observations corroborate with the observations made by Cruden [8]. Crop plants which are predominantly self-pollinated have low pollen: ovule ratios, however, the plants which are cross pollinated have high pollen: ovule ratio.

Deodikar and Suryanarayana [1] roughly estimated the data on yield parameters. The effect of different bee species on yield shows that there is a gradual increase in number of seeds and seed weight per pod in order of *A. florea, A. cerana and A. dorsata* visited flowers. Sinha and Chakrabarti [31] reported the effect of two pollination modes on seed yield and weight. In the present investigation the effect of different treatments on the yield in terms of weight of mature fruit was measured 28.00 to 47.02 gm in self- pollination, 41.56 to 60.00 gm in open-pollination and 54.12 to 70.54 (Table no.1). It was found higher seed yield in insect-pollination and open-pollination over self-pollination.

Table 1: Effect of different pollination treatment on the yield (in grams).

Year	Site	Self-pollination	Open pollination	Insect pollination
2005-06	1	47.02	60.00	59.01
	2	42.15	51.30	62.88
	3	37.40	47.60	70.54
2006-07	1	28.20	42.56	57.23
	2	32.63	43.50	54.72
	3	36.45	47.18	61.49
2007-08	1	33.11	48.87	65.42
	2	32.75	41.56	57.31
	3	38.67	53.37	54.12

Fig. No.1. *Ceratina* spp. foraging on the flower

Fig. No.2. *Trigona* spp. foraging on the flower

Fig. No.3. *A. florea* foraging the flower

Fig. No.4. House fly visiting the flower

Fig. No.5. *A. dorsata* foraging on the flower

Fig. No.6. *A. cerana indica* foraging on the flower

Fig. No.7. Moth collecting nectar from flower

Fig. No.8. *Ceratina* spp. foraging on the flower

4. References

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