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Reproductive biology of *Capparis decidua* (Kair): A potential underutilized multipurpose plant of arid and semi arid region

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Abstract: Foliation and flowering of *Capparis decidua* occurs three times a year i.e. from January to November months. Flowers are bracteate, pedicellate, complete, hermaphrodite, zygomorphic, hypogynous with slender pedicel, usually light red, scarlet red and yellow in colour. Anthesis was maximum between 4.00 p.m. to 8.00 PM and 6.00 to 10.00 AM. Pollen grains are prolate, tricolporate, trilobed, with costae, colpal membrane sparsely granulated. Anther dehiscence takes place after 20–30 minutes of anthesis at 6.00 to 8.00 PM by the time the flowers starts antehsizing, the anthers are almost mature. The viability of pollen grains ranges from 38–52%, and starts decreasing in the stored pollen. The percentage fruit set decreases with the collection time of the pollen grains and plant type. According to visual observation stigmatic surface change in the appearance i.e. green coloured stigma was considered receptive while dull and brown was accounted non-receptive. Pollen germination *in-vivo* showed 80 per cent stigma receptive and 90 percent of fruit set in the flowers pollinated on the time of anthesis. Pollen grains per anther were ranging from 331–369, fully developed and mature anthers differing significantly among the plant types. The mean number of pollen grains per ovule was 4309 thus the pollen-ovule ratio was 431:1. There is 17–23% fruit set observed under self pollination (autogamy and geitonogamy) and 52–72% as a result of cross pollination. The cross pollinated nature of *C. decidua* is due to entomophilic nature of flowers, insect visitors which play the main role of pollination are from Apidae and Papilionidae.

Keywords: *Capparis decidua*, Reproductive biology, Pollen, pollination, viability

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Introduction

Capparis decidua (Forsk.) Edgew. is a shrub of family Capparaceae and genus Capparis. The family comprises ~30 genera and 600 species (Vyas et al., 2009), the genus Capparis comprises approximately 250 species among these 26 species occurs in India (Hooker, 1960; Heywood, 1978). *C. decidua* ensues in arid and semi-arid regions of India (Bhandari, 1990). It is an important part of arid and semiarid regions because of its xerophytic and psammophytic nature i.e. it is tolerant to drought, salt and heat stress (Gupta et al., 1989). It affords food (pickle and vegetable), fodder, fuel wood and timber, thus plays an important role in the rural economy of arid regions (Kumar et al., 2005). Besides economic significance, the species has important ecological roles *viz*. provides vegetation cover, improves soil, prevents soil erosion and promotes biodiversity (Shankarnaryan et al., 1987). It is also used as hedge (Hammer, 2001). As per the literature and field observation the species is rich in diversity, we encountered different plant type (tree, shrub and bushy type) and variation in flower colour (Light red/pink, crimson red and yellow) (Mahala et al., 2013; Singh & Singh, 2011). Relatively little scientific attention has been given to this species, which hinders its development and sustainable utilization. It can become a perspective species for arid and semi-arid lands with appreciable development potential. So for developing it as perspective species it is necessary to study and understand the reproductive biology of the aspirant species. There is a need to develop large scale breeding programs for its genetic improvement, conservation and sustainable utilization. The detailed study on reproductive biology of the genus capparis was very meager. The information available for *C. decidua* is mainly on the pollen structure, (Perveen & Qaiser, 2001) however for studies on reproductive biology is lacking in this species. In order to practice effective genetic improvement of *C. decidua* the knowledge of reproductive biology is essential. Hybridization is one of the potential modes for improving planting materials. Reproductive success of plants depends on the quantity and quality of the gametes and off-springs produced. Therefore reproductive studies play a vital role in improvement of the species. This paper is an attempt to summarize information on reproductive studies of *C. decidua* to stimulate interest in this species. Basic information has been gathered from meagre published literature and majorly by field observation.

Materials and Methods

Plant material and study site

The study was conducted for successive flowering seasons between 2022 to 2023 at Agricultural Research Station, Keshwana, Jalore, Rajasthan. The site is located at latitude of 25°25'58.86"N and longitude of 72°29'07.26"E, elevation 149.9 msl. Phonological stages were observed to determine the floral biology- flower morphology, anthesis, time of anthesis, anther dehiscence, stigma receptivity, pollen structure, production, viability and germination. Branches having maximum number of flowers were selected in the peak flowering season. Flowers were collected in paper bags and pollen biology studies were conducted in the laboratory. Petals and sepals from the collected flowers were separated and the anthers were placed in sterile petri-dishes and pollens were collected and observations were made. Floral Formula for *C. decidua* is % ☿ $K_{2+2}C_4A_{\alpha}G_{(2)}$ (https://eol.org/pages/2881665/articles, http://www.efloras.org/florataxon.aspx?flora_id=5&taxon_id=250063266).

Pollen studies

The flowering branches were tagged and anthers were collected to examine morphological changes under microscope in order to determine the pattern of pollen structure and shedding.

Pollen structure and pollen dehiscence

Pollen were collected to examine morphological changes under microscope and photographed in order to determine the pattern of pollen structure and shedding and followed classification of Erdtman (1952).

Pollen viability

In-vitro testing the pollen viability

The acetocarmine test is used to determine the viability of the *C. decidua* pollen. The pollen absorbing

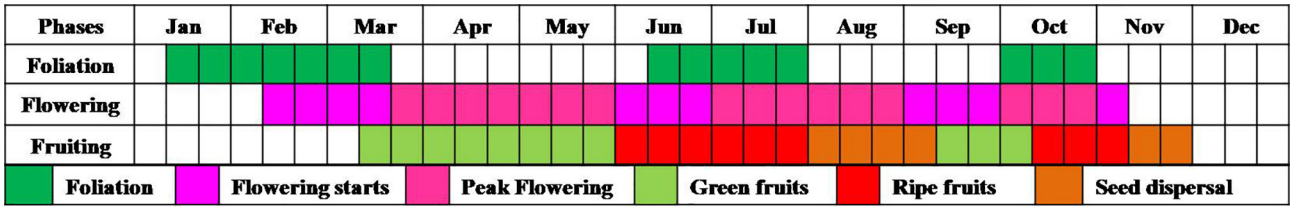


Fig. 1. Phenology bar of *C. decidua*

acetocarmine stain is considered as viable when it observed under microscope.

In-vivo pollen viability test

The *in-vivo* testing of pollen grains viability based on the fruit set was analyzed. The pollen collected at different duration were hand pollinated and percentage fruit set was observed based on this the viability was confermed.

Stigma receptivity and pollen germination

Visual observation of stigmatic surface were observed using hand lens and changes in the appearance of stigma was observed repeatedly after opening of bud and its development processes is considered as receptive stigma.

In vitro pollen germination

The fresh pollen from each flower was placed in a petri-dish containing varying concentration of sucrose (5, 10, 15 and 20%) and to periodic observations were recorded per microscopic field to detect the optimum level of sucrose required for the pollen germination.

In-vivo pollen germination by fruit set method.

Pollen germination by fruit set method was carried out by selecting buds of different age groups, emasculing and pollinated with fresh pollen grains based on fruit set pollen germination was confermed.

Pollen production and pollen ovule ration

Pollen production

To determine the number of pollen grains per flower one mature undehisced anther per flower was removed from ten flowers. Anthers were placed on a slide and dabbed with a needle until all the pollen grains were released on to the slide. A drop of acetocarmine stain (2 µl) was put on the dehisced pollen and covered with cover slip. Pollen grains in each anther were counted with the help of photograph captured under a compound microscope (40× objective and 10× eyepiece). From this value pollen production per anther and pollen grains per flower were calculated (Bernardello et al., 1994).

Pollen ovule ratio

The number of pollen grains divided by the number of ovules per flower yield the pollen- ovule ratio (Anderson & Symon, 1989; Cruden et al., 1985).

Breeding System

To study breeding system autogamy, geitonogamy, open pollination and hand pollination were done using the fresh pollen of *C. decidua*. Repeated visual observation on pollinator were made and recorder accordingly.

Result and discussion

Phenology

As per the observation the foliation in *kair* population takes place for short duration and remains leaf less for the major part of the year. Foliation occurs three times a year i.e. during January to March, June to July and October months, where as Singh and Singh (2011) have also got similar foliation pattern in their study conducted for Rajasthan and Gujarat region. Leaves are alternate, stipulate, simple, sessile, highly caducous, acute apex with reticulate venation. Flower appears on 4–5 year plant and occurs on new as well as old shoots, but older shoots produces more flowers. Flowering starts during mid February and continues up to November in a scattered and discontinuous manner. Flowering was observed in three seasons: mid February–March, July–August and October– first week of November. Same flowering pattern was also observed by Mahla et al. (2013) and classified that into Ambe Bahar, Mrig Bahar and Hast Bahar. Fruit globose, 10–15 mm in diameter, slightly beaked, glabrous smooth, deep red when ripe and with thin pericarp; seeds reniform, many 2–5 mm in diameter.

Flower morphology

Inflorescence few to many flowered, ebracteate corymbs on short lateral shoots. Flowers (1–2 cm across and 0.8–1.5 cm long) bracteate, pedicellate, complete, hermaphrodite, zygomorphic, hypogynous with slender pedicel, usually light red, scarlet red, and yellow flowers. Calyx: Sepals 4 usually 4–8 mm long, 2.5–5.5 mm broad, polysepalous, arranged in two whorls, unequal, inner one saccate, imbricate aestivation, ovate-oblong, often with floccose ciliate margins. Corolla: Petals 4, polypetalous, imbricate aestivation, inferior petals about as long as the sepals, puberulous, upper pair slightly larger and hidden in the saccate sepal. Androecium: Stamens indefinite generally 9–15, about 10–20 mm long, often red in colour. Gynophores, 10–18 mm long; ovary about 2–3 mm in diameter, with a beak about 1 mm long. Gynoecium: Bicarpellary, syncarpous, ovary superior, unilocular, parietal placentation, ovules many at each placentum, gynophore long and slender (Fig. 2).

Fig. 2. Dissected flower and floral diagram of *C. decidua*

Bud development stages

Bud development is the morphological changes in the shape and size of flower buds from the time of their emergence to the opening stage. Bases on distinct characteristic features these are grouped into six stages. Bud development took about 14–19 days, brief description of the different stages of bud development is given in Table 1. Bud development noticed by Singh and Singh (2011) showed six stage and took 14–15 days. Similarly eight stages of bud development was carefully studied by Pant et al. (1997) and Verma et al. (2011) and the chronology of stages from bud to anthesis was observed among different location which indicated that the floral buds took a period of 25–31 days to mature. The period of bud maturity varies with the sequence of their emergence (Pant, 1991).

Anthesis

Mode and time of anthesis

The mode of flower opening can be observed from the appearance of slits in the calyx till the flowers were fully open. The slitting of the calyx in the fully developed flower buds occurs in a longitudinal fashion. This slit appeared from the stage II of bud development and starts expanding longitudinal and split opens to initiate anthesis. In this way, the whole calyx splits into four parts and separated from each other exposing the 4 petals where upper pair slightly larger and hidden in the saccate sepal. The whole process of anthesis will take half hour duration (Fig. 3). After anthesis the petals usually withered off after 7–10 days whereas, the filaments withered within 6–8 days after stigma receptivity.

The flowering branches were tagged and about 50 flowers buds were observed during its peak flowering months (March & April) for time of anthesis. Anthesis was maximum between 4.00 p.m. to 8.00 p.m during March month and 6.00 to 10.00 AM. The anthesis was influenced by maximum and minimum temperature (Table 2). The study conducted by Sharma (2020) on *C. decidua* in Agra (U P) and the observations regarding the time of anthesis were recorded that flowers open in the evening at 6.00–9.30 PM and also during the morning hours (5.00–10.00 AM). Among the plant type tree showed maximum anthesis followed by shrub and bushy type both in the March and April month.

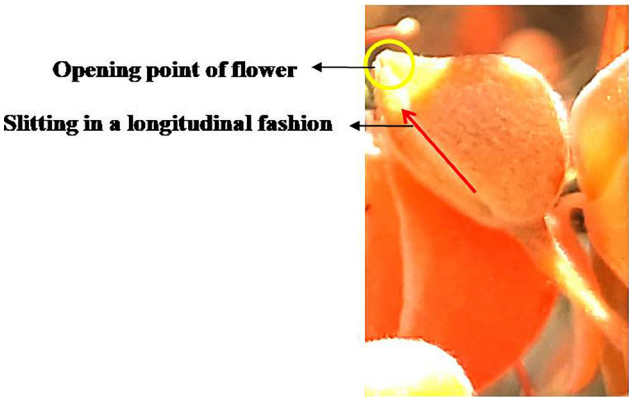


Fig. 3. Mode of anthesis in *C. decidua*

Table 1. Bud development stages of *C. decidua*

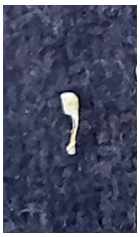
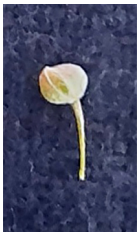
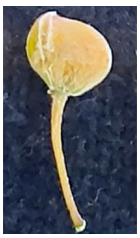
Stages	Description	
I	This is the first stage of bud development. The buds, receptacle and pedicel appears with whitish hairy and powdery . About 1.48 to 1.84 mm dia.	
II	In this stage the distal end of the bud starts bulging still with whitish and hairy bud and receptacles, disappearance of hair and elongation of pedicel turning to light brown colour, appearance of slit with green line and light red colour. The bud attains the size of about 4.45 to 5.31 mm. The bud requires 3–4 days to reach this stage from the previous one	
III	Whitish and hairy in small area in the lower part of bulged bud and receptacles disappears and elongation of pedicel turning to light brown colour, and slit remains same as in the stage II, the bud attains the size of about 4.86 to 6.81 mm. The bud requires 4–5 days to reach this stage from the previous one	
IV	Disappearance of whitish and hairs, increase in bud size, appearance of red colour on bud and pedicel, expansion of slit, the bud attains the size of about 7.56 to 8.62 mm. The bud requires 3–4 days to reach this stage from the previous one.	
V	Increase in bud size, appearance of complete red colour on bud and pedicel, expansion of slit, the bud attains the size of about 7.63 to 8.50 mm. The bud requires 3–4 days to reach this stage from the previous one.	
VI	The red flower buds just before the commencement of anthesis are classified under this stage. Bud swells and slit opens from tip to bottom in 2 days.	

Table 2. Time of anthesis in different plant type of *C. decidua*

Plant type	Anther dehiscence in the month of March 2022 (Mean Max – 38 °C and Min – 20 °C)							Anther dehiscence in the month of April 2022 (Mean Max – 45 °C and Min – 25 °C)						
	6–8 AM	08–10 AM	10–12 AM	12–2 PM	2–4 PM	4–6 PM	6–8 PM	6–8 AM	8–10 AM	10–12 AM	12–2 PM	2–4 PM	4–6 PM	6–8 PM
Tree	6	5	0	0	0	25	16	12	4	4	0	0	22	16
Shrub	7	3	0	0	0	23	12	6	3	0	0	0	19	9
Bushy	6	4	0	0	0	19	14	2	4	0	0	0	17	6

Pollen studies

Pollen structure and pollen dehiscence

According to the classification of Erdtman (1952) pollen grains of *C. decidua* are prolate, tricolporate, trilobed, with costae, colpal membrane sparsely granulated (Fig. 4). As per the study conducted by Perveen and Qaiser (2001), the pollen grains are prolate, tricolporate, trilobed, size: Polar axis P (18.2–) 20.16 ± 0.28 (–22.4) µm, and equatorial diameter E (11.2–) 13.9 ± 0.45 (–16.11) µm. P/E ratio: 1.44, colpi (16.8–) 17.78 ± 0.55 (–21.01) µm long, with costae, colpal membrane sparsely granulated. Mesocolpium (8.4–) 9.66 ± 0.25 (–11.2) µm. Apocolpium C. 1.48 µm. Exine (1.4–) 1.47 ± 0.07 (–2.1) µm thick, sexine slightly thicker at the polar region than at the equator. Tectum finely reticulate lumina 0.05–0.15 µm in diameter, ± circular in shape.

In *C. decidua* anther dehiscence takes place after 20–30 minutes of anthesis at 6.00 to 8.00 PM when the temperature slightly dropped. By the time the flowers starts antehsizing, the anthers are almost mature. The dehiscence of anthers started from the point which is attached with the filament and goes along the periphery in a longitudinal manner and split opens to spread pollen grains. The anther dehiscence was more in matured tree as compared to shrub and bushy type. In the study conducted by Sharma (2020), showed that the dehiscence of anther at about 6.30–7.00 PM in the evening. It is interesting to note that pollen grains dehisced by longitudinal slits, while in the morning, open flowers anthers are dehisced at 5.30–6.30 AM. The dehiscence was more in the march month the mean maximum and minimum temperatures were 38 and 20 °C compared to April (45 and 25 °C). The difference of 7 °C in mean maximum and 5 °C in mean minimum has lowered the anthesis and dehiscence rate during the study period (Table 2 & 3). The observations by Pant (1991) and Verma et al. (2011) regarding anther dehiscence in *Grewia optiva* which indicates that the increase in the minimum temperature hastened the opening of flowers. Similarly, a comparative study of the weather conditions and time of anthesis and dehiscence reveals that the minimum temperature influences the rate of anthesis.

Table 3. Anthesis dehiscence in different plant type of *C. decidua*

Plant type	Anther dehiscence in the month of March 2022 (Mean Max – 38 °C and Min – 20 °C)							Anther dehiscence in the month of April 2022 (Mean Max – 45 °C and Min – 25 °C)						
	6–8 AM	8–10 AM	10–12 AM	12–2 PM	2–4 PM	4–6 PM	6–8 PM	6–8 AM	8–10 AM	10–12 AM	12–2 PM	2–4 PM	4–6 PM	6–8 PM
Tree	0	0	0	0	0	0	20	0	0	0	0	0	0	16
Shrub	0	0	0	0	0	0	14	0	0	0	0	0	0	12
Bushy	0	0	0	0	0	0	16	0	0	0	0	0	0	14

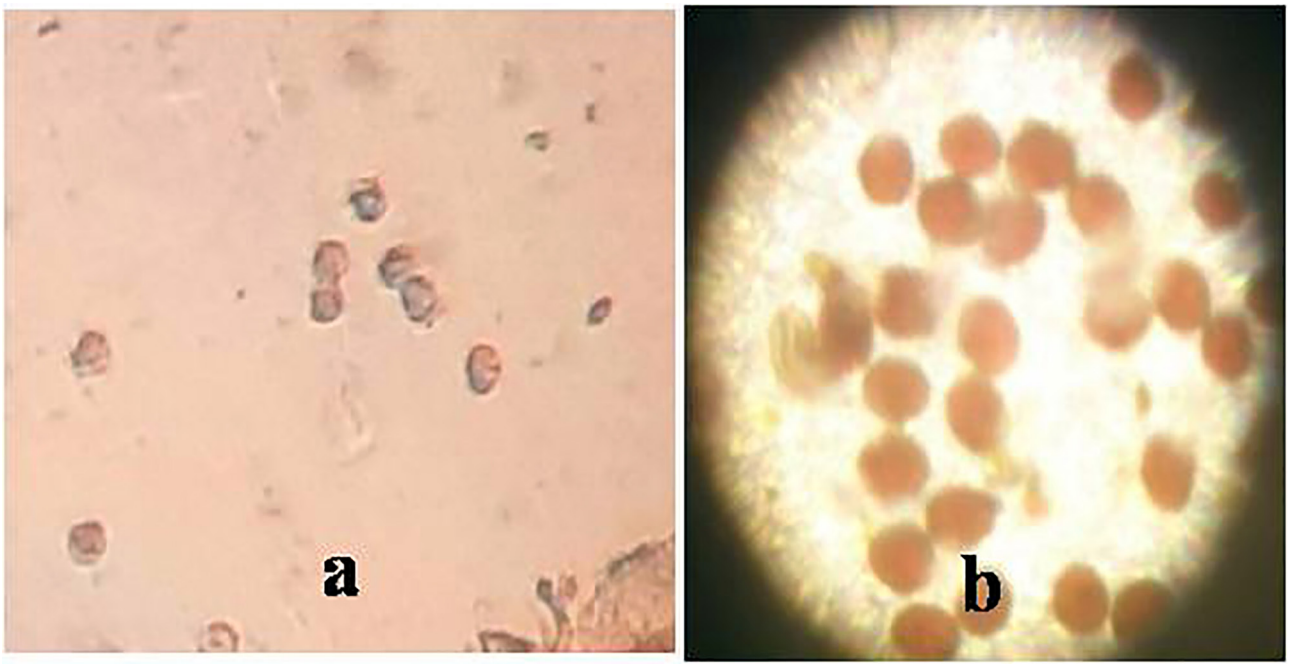


Fig. 4. Pollen grains at a) 10× and b) 40× view

Pollen viability

In-vitro testing the pollen viability:

The acetocarmine test is used to determine the viability of the *C. decidua* pollen. The pollen collected just after anthesis and observed them under microscope after staining with acetocarmine. The viability of pollen grains ranges from 38–52% which is quite good, the viability starts decreasing in the stored pollen i.e. 22–35% (stored at 4 °C for 6 hr) and 17–22% (stored at 4 °C for 24 hr) although it varies from plant type also (Fig 4). This variation is due to the heterozygous nature of the plants. The percentage of the pollen grains taking acetocarmine stain was good indicative of fertility. In an observation on *C. decidua* it is clear that during flowering period the pollen fertility was 86±5.8 percent as tested by Alexander stain and was 76.2±2 percent as tested by 1%TTC (Sharma, 2020).The study done by Verma et al. (2011) showed that the viability of twelve genotypes of *Grewia optiva* pollen can be retained up to 60–73% even after one year when it is stored in the sealed eppendorf under −20 °C condition.

In-vivo pollen viability test

The *in-vivo* testing of pollen grains viability based on the fruit set was analyzed. The percentage fruit set was found to decrease with the collection time of the pollen grains and plant type. The pollen grains collected at the beginning of anthesis showed maximum fruit set (40–60%). The pollen grains collected after 6 h (32–52%) and 24 h (25–42%) of anthesis showed decreased fruit set (Fig. 5). The viability per cent in pollens collected at 0 h after anthesis, highest in tree type (60%) followed by shrub (48%) and least bushy (40%) type whereas; the trend was same for stored pollen at 4 °C for 6 and 24 hr. similar findings was encountered by Sharma (2020) in *C. decidua*, Verma et al. (2011) and Saresh et al. (2021), in *Grewia optiva* and Thangaraja and Ganesan (2008) in *Terminalia paniculata*

Stigma receptivity and pollen germination.

Visual observation of stigmatic surface: The change in the appearance of stigma was observed after opening of bud. The green coloured stigma was considered receptive while dull and brown was accounted non-receptive. Change in colour of the stigma after pollination is the indicative of fertilization success process, light green receptive stigma (a) after fertilization changes to reddish colour (b) was indicative of fertilization completion process and there is a eventual development of fruit to light green (c) to dark green colour (d) (Fig. 6.). The time that stigma received the pollen grains during 6.00- 8.00 p.m. which also coincided with the anther dehesance . However, in the morning stigma becomes receptive at 6.00–10.00 AM. (Nagarajan et al., 1998; Verma, 2012)

In vitro pollen germination

The fresh pollen from each flower was placed in a petri-dish containing varying concentration of sucrose (5, 10, 15 and 20%) to detect the optimum level required for the species. Periodic observations were recorded per microscopic field but none of these sucrose concentration stimulated pollen germination in *C. decidua.* In contrary the experiment

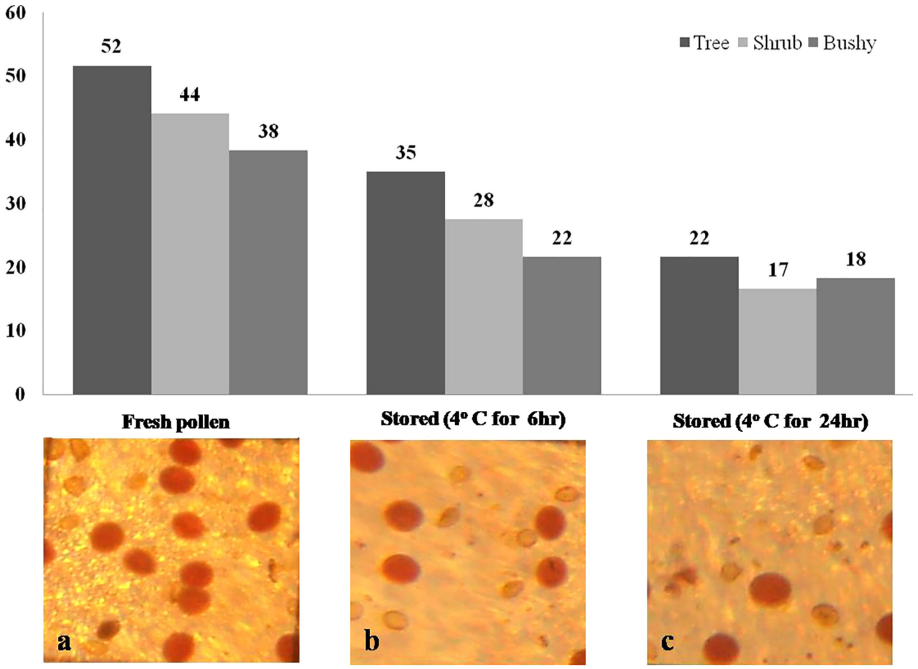


Fig. 5. In-vitro pollen viability using acetocarmine test for fresh (a) and stored pollens (b & c) of *C. decidua*

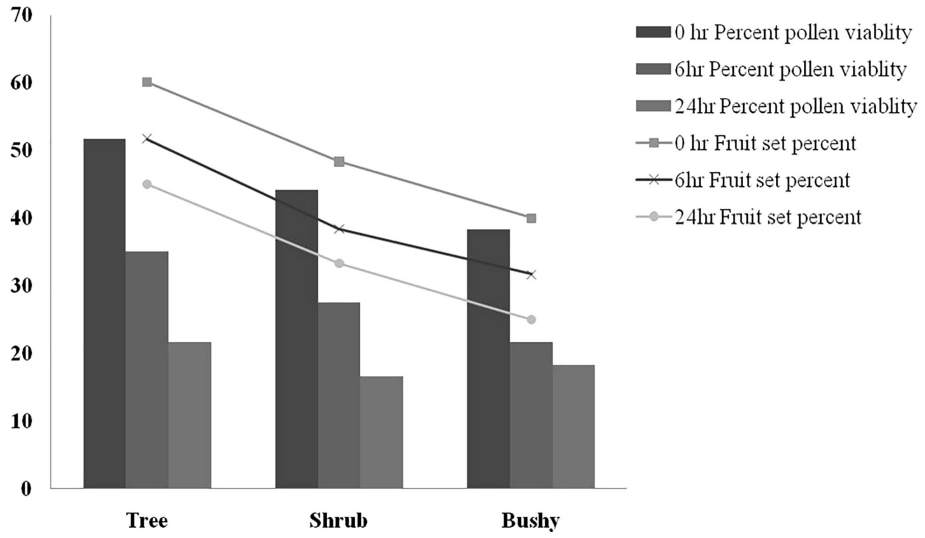


Fig. 6. In-vivo pollen viability and fruit set percent of fresh and stored pollens of *C. decidua*

conducted by Sharma (2020) the highest pollen germination (29.49±2.72%) with longest pollen tube length (293.16±24.49 µm) was recorded in 10% sucrose solution as compared to 15% and 20% sucrose solutions.

In-vivo pollen germination by fruit set method.

To ascertain pollen germination by fruit set method buds of different age groups were emasculated and pollinated with fresh pollen grains. The observations recorded on the pollen germination in-vivo are presented in Table 4 the study revealed that stigma was non-receptive before 24 hours of anthesis resulted in no fruit set. Stigma became receptive before 12 hours of anthesis, maximum receptivity on the day of anthesis and receptivity last for 24 hours after anthesis. Those flowers which had been pollinated 12 hours after anthesis resulted in 32 percent of stigma reciptive and 38 per cent fruit set and 80 per cent stigma recptive and 90 percent of fruit set in the flowers pollinated during the time of anthesis. The flowers pollinated 6 hours after anthesis gave the 72 percent stigma reciptive and 65 percent fruit set whereas lowest percentage of stigma reciptivity and fruit set was observed in 24 hours age of stigma (48% stigma reciptive and 34% fruit set) and after that there was no fruit set. It is thus clear from the table that the maximum receptivity of stigma was on the day of anthesis. It is thus clear from the study of Verma et al. (2011) that the stigma of beul became receptive 24 hours before anthesis and remained receptive till 12 hours after anthesis. The fruit set and development takes place in seven phases, which end up with the final product of any reproductive cycle i.e., matured fruit.

Pollen production and pollen ovule ration

grains per anther were ranging from 331–369, fully developed and mature anthers differing significantly among the plant types. The mean number of pollen grains per flower was ranging from 3896–4743. Pollen number per flower was highest in tree type (4743±312) followed by shrub (4289±310) and the lowest in bushy type (3896±167). Similarly, the pollen number/anther was higher in tree type (369±22) fallowed by shrub and bushy type (398±17 and 331±10). *C. decidua* contains nine to ten ovules per flower. The mean number of pollen grains per ovule was 4309 thus the pollen-ovule ratio was 431:1. The sequence of pollen ovule ration was higher in tree type, shrub and bushy type (474±31.2>429±31.0>390±16.7) (Table 5). According to Sharma (2020) average number of pollen grains produced per anther was 430±7 however pollen grains per flower was 8680±397 during

Table 4. Pollen germination by fruit set method

Age of stigma in relation to anthesis	No. of stigma found receptive out of 25 examined			Fruit setting method	
	Visual examination	Receptivity of stigma indicating pollen germination In vivo	Stigma receptive %	No. of fruit set	%
12 hr before anthesis	60	19	32	7	38
On the day of anthesis	60	48	80	43	90
6 hr after anthesis	60	43	72	28	65
24hr after anthesis	60	29	48	10	34

Table 5. Pollen production and pollen ovule ratio in *C. decidua*

Plant type	Stamen no.	Pollen/anther	Pollen/flower	Ovule	Pollen ovule ratio
Tree	13	369±22	4743±312	10	474±31.2
Shrub	11	398±17	4289±310	10	429±31.0
Bushy	12	331±10	3896±167	10	390±16.7

Table 6. Correlation coefficients (r) between Stamen number, pollen number per anther and pollen number per flower

Stamen no. and pollen per anther	−0.105
Stamen no. and pollen per flower	0.429*
Pollen per anther and pollen per flower	0.687**

*P ≤ 0.05; **P ≤ 0.01.

maximum flowering period. It is also evident that the pollen ovule ratio was 868± 39:1. Genotypic differences for pollen production have been reported for *Prunus armeniaca* by Alburquerque et al. (2004), Davarynejad et al. (1995) and Mahanoglu et al. (1995). Correlations between various parameters revealed a significant positive correlation between stamen number and pollen per anther and pollen per anther and pollen per flower (0.429 and 0.687), whereas, there is a negative correlation between stamen number and pollen production per anther (−0.105) (Table 6). Correlation studies with respect to this species is very merger but many researcher showed there is negative correlation between number of pollen per flower at both inter- and intraspecific levels in many plant groups, genotypes and plant type (Mione & Anderson, 1992; Knudsen & Olesen, 1993; Stanton et al., 1994; Vonhof & Harder, 1995; Worley & Barrett, 2000; Sarkissian & Harder, 2001; Yang & Guo, 2004; Hulwale et al., 1995; Saresh et al., 2021).

Breeding System

In order to ascertain breeding system autogamy, geitonogamy, open pollination and hand pollination were done on *C. decidua* (Fig. 7.). There is 17–23% fruit set observed under self pollination (autogamy and geitonogamy). On the other hand, results on cross pollination fruit set percentage varied from 52–72 percent. However, it is clear that the fruit set percentage enhanced by cross pollination (Open and hand pollination). The percentage of fruit in open pollinated flower is 72 percent and 52 percent in hand pollination. The total cross pollination made was 120 out of which 74 crosses set fruit and among 120 self pollinated flower 24 were developed into fruits, there is 62% success as compared to 20% success in self pollinated flower, which is clearly indicating the species is highly cross pollinated in nature. Comparing with the flower number, the rate of fruit setting was very low. Plants and fruits seem to be attracted by various insects. The results of Sharma (2020) that there is 20–40% fruit set was observed under cross pollination, whereas, self-pollination fruit set percentage was only 15–20 percent. The fruit set percentage found enhanced in cross of *C. decidua*.

Agents of pollination

The flowers of *C. decidua* were found adopted for cross pollination because they have attractive colour and It is also evident that the flowering occurs during the hot summer season and during these period there are very less plants which are in flowering stage that offers reward in the form of nectar and pollen this ultimately attract the insects, birds and other agents to depend on these type of species and act as agent of pollination, due to this noticeable activity eventually influence on the pollination process of the species. The cross pollination of *C. decidua* is entomophilic in nature, insect visitors which played main role in pollination are from Apidae and Papilionidae. Some important insects with their scientific names are mentioned in Table 8. Out of all the insect visitors, the honey bees played a major role and the next was Mormon butterfly and bumble bees. These insects visit the flowers all the day but the maximum activity was observed between 5.00 PM to 7.00 PM and during 6.00 AM to 9.00 AM which coincided with

Fig. 7. Pollination studies in *C. decidua* a. Emasculation b. Hand pollination c. Tagging d. Bagging

Table 7. Modes of pollination and percent fruit set in *C. decidua*

Mode of pollination	No. of flower pollinated	No. of fruit set	Fruit set percentage	Overall pollination percentage
		Self pollination		
i) Autogamy	60	10	17.00	20
ii) Geitonogamy	60	14	23.00	
		Cross pollination		
i) Open pollination	60	43	72.00	62
ii) Hand pollination	60	31	52.00	

Table 8. Agents of pollination in *C. decidua*

Common name	Scientific name	Order	Family	Nature
Honey bees	*Apis mellifera*	Hymenoptera	Apidae	Pollen collector and pollinator
	A. Cerana indica			
	A. dorsata			
Bumble bees	*Bombus spp.*		Vespidae	
Wasps	*Polistes orientalis*			Nectar robber
Ant	*Anoplolepis gracilipes*		Formicidae	Nectar robber
	Camponotus parius			
	Polyrhachis spp			
Hoyer flies	*Episyrphus balteatus*	Diptera	Syrphidae	
	Metasyrphus confrator			
Mormon butterfly	*Papilio polytes*	Lepidoptera	Papilionidae	Pollen collector and pollinator
Sun bird	*Cinnyris osea*	Trochiliformes	Nectariniidae	Nectar robber
Red-vented bulbul	*Pycnonotus cafer*	Passeriformes	Pycnonotidae	Nectar robber and seed disperser

the time of anthesis and dehiscence of anthers. The mode of cross pollination reveals that these insects sat on the anthers in search of nectar and during this process, the pollen grains stuck to their abdomen, mouth parts, legs and thorax etc., and in most cases the whole ventral side of the insect body appeared to be loaded by pollen. After sucking, the insect left that flower and visited another flower and during this process pollen which were present on the ventral side of the body of the insects stuck to the stigma of the other flower thus cross pollination occurs. It is fascinating to note that insects like Wasp's (*Polistes orientalis*), Ant (*Anoplolepis gracilipes, Camponotus parius, Polyrhachis spp*), Hoyer flies (*Episyrphus balteatus* and *Metasyrphus confrator*), sun bird and red vented bulbul are not pollen carrier but are nectar robbers. Similar observation was done by Sharma (2020) in his study and noted that on the basis of their visitation rate, pollen load on their body parts, *Apis mellifera, Apis cerana* and *Mormon butterfly* are found to be the most efficient pollinators. However, Wasps, Ant and sunbird act as a nectar robber.

Conclusion

Reproductive biology of *Capparis decidua* (Kair) which exhibits foliation and flowering during January to November it is a complete, hermaphrodite, and zygomorphic flower, having diversity in the flower colour (light red, scarlet red, and yellow colour). The species is entomophilic and cross-pollination in nature which are pollinated by insect visitors from the Apidae and Papilionidae families. Anthesis takes place between morning and evening hours. Anthers reach maturity and undergo dehiscence by 20–30 minutes after anthesis. Pollen are prolate, tricolporate, trilobed, with costae, and possess sparsely granulated colpal membranes. The green surface is considered as receptive stage while a dull and brown appearance signifies non-receptiveness of stigma. Fruit set successes can be achieved when flowers are pollinated during the time of anthesis. The observed stages are very much suitable to carry out breeding studies in *Capparis deciduas*.

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