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Investigations into the Phenology and Reproductive Biology of Khejri (Prosopis Cineraria (L.) Druce)

Dr.Dipali Gupta[1*], Dr. Gajanand Modi[2]

[1*]Professor-School of Basic and Applied Sciences
[2]Associate Professor-School of Basic and Applied Sciences

***Corresponding Author:** Dr.Dipali Gupta
*Professor-School of Basic and Applied Sciences

Abstract
Khejri (Prosopis cineraria (L.) Druce) is a member of the Leguminosae family and the Mimosoideae subfamily. Rural communities actively promote the growth of Khejri in their agricultural fields due to its positive effects on grain yield and biomass production for storage. Known by various names such as the 'Golden Tree of Desert', 'Kalpvriksha' of the desert, 'King of the desert', 'Love Tree', and 'Pride of the Desert', it holds a significant multipurpose value. Understanding the phenology and breeding system is essential for any tree improvement program, as it aids in comprehending the species' evolutionary dynamics. The reproductive system regulates the range of genetic variability, thereby influencing adaptive changes. Pollination mechanisms impact various aspects such as seed set, fertility, gene flow, breeding systems, hybridization, and genetic makeup of tree populations.
Methods: During the 2014-15 period, ten Prosopis cineraria (L.) Druce trees growing in the research area at Bikaner, were randomly selected. Phenological observations were conducted at different phenophases on these selected trees. Breeding behavior was examined through selfing by covering the inflorescence with muslin cloth bags before opening, while an equal number of buds were left open in close proximity. Reproductive capacity was assessed based on the percentage of fruit setting in marked inflorescences.
Results: The average fruit set under self-pollination in Prosopis cineraria was found to be nil in this study, whereas it was 2.03 percent under open natural pollination. These findings corroborate previous studies indicating that Prosopis cineraria is a cross-pollinated species.

INTRODUCTION

The trees of *Prosopis* spp. are remarkably found growing in poor soil conditions and require relatively low moisture for survival (NAS, 1979). It holds an important place in the desert ecosystem (Jatasra and Paroda, 1981; Shankarnarayan *et al*.,1987). The tree is known locally as Jandi or Khejri (India), Jand (Pakistan) and Ghaf (Arabic). Its synonym is *Prosopis spicigera*. It belongs to the family Leguminosae and subfamily Mimosoideae. It is distributed mainly in dry regions of Southwest Asia and Africa (Khatri *et al*., 2010). In the most important areas of *Prosopis cineraria* distribution, the climate is dry to arid and rainfall shows considerable variation 100 to 600 mm annually with long dry season. It is seen at its best on alluvial soils consisting of various mixturesof sand and clay. The rural communities encourage the growth of Khejri in their agricultural fields, pastures and village community lands. Through experience, farmers haverealized its usefulness and learnt that it does not adversely affect crop yields; instead, it improves grain yield and storage biomass production (Kaul, 1967). It is being regarded as 'King of desert', 'Golden Tree of Desert', 'Love Tree' and 'Pride of the Desert', because every plant part of this versatile tree is utilized. This tree is so important in arid region that their number forms the major criterion for

the value of land (Singh *et al*., 1998). It is the true multipurpose species and often referred to in ancient literature as the 'Kalpvriksha' of the desert (Mahoney, 1990).

It provides fuelwood, fodder, small timber, medicines, gum and tannins and also helps in improving the soil fertilityand sand dune stabilization (Singh *et al*., 1998). This tree species is much valued as fodder tree. The fodder from its leaves, commonly known as loong is very nutritious, proteinrich (12-18% crude protein) and palatable to the animals (Bhandari *et al*., 1979; Bohra and Gosh, 1980). The wood issuitable for interior construction work such as column of huts, roofs, doors, windows *etc*. Wood is also used for agricultural hand tools. 40-70 kg fuel wood per tree can be obtained from 20^{th} to 30^{th} year of age group plant (Mann and Saxena, 1980). The unripe pods are used as a feed supplement (Brown, 1992), while mature pods are fed to livestock. Its pods contain 9-4 per cent crude protein and 6- 16 percent sugar. The bark is used in the cure of rheumatismand scorpion bite. It is a tree with great potential for agroBikaner systems as it is highly compatible with agricultural crops (Puri *et al*., 1994) due to its deep root system, monolayer canopy, nitrogen fixing ability and high efficiency of recharging the soil with organic matter (Toky and Bisht, 1992). Its branches are slender, glabrous and armed with somewhat compressed, straight and scattered prickles of 3-4 cm length. Flower is in the form of axillary spikes with the length of 7-11 cm, either solitary or in terminal panicles. Flower posses yellow corolla, attracting large number of insects including large number of *Apis florea* andnumerous other wild bees in the month of December and April (Gorain *et al*., 2012).

For any tree improvement programme, knowledge of phenology and breeding system is pre-requisite, which also helps in understanding the evolutionary dynamics of a species. The range of genetic variability is controlled by reproductive system, which in turn controls the adaptive change (Simmonds, 1962). Pollination mechanisms affect seed set, fertility, gene flow, breeding systems, hybridization and genetic constitutions of tree populations (Bangarwa, 1996).

MATERIALS AND METHODS

The investigation on the phenology, floral biology and breeding system were carried out during 2014-15 on ten randomly selected trees of *Prosopis cineraria* (L.) Druce (Table 1) growing at the research area of BikanerDepartment of Bikaner (20° 10′ N lat., 75° 46′ E long., alt. 215 m msl), situated in the arid region of North-Western India. The climate is subtropical monsoonic with an average annual rainfall of 350-400 mm, 70-80 per cent of which occurs during July to September. The phenological observations were made on the selected trees at different phenophases observations were recorded on development and type of inflorescence, flower development, peak period of flowering, breeding behaviour and fruit set. Several inflorescences on different trees were observed for flower initiation, flower opening time, stigma receptivity period, peak period of flowering and flower cessation. To observe the time of anthesis, three randomly selected branches on three trees were tagged during April 2015 and the numbers of buds opening at different hours of day were noted from 0600 h to 1500 h. For observing the time of flower opening, fully mature buds on the selected branches, which were likely to open the following morning, were tagged in the afternoon of the same day and the immature buds on the same branches were removed. Beginning at 0600 h, the number of fully open flowers was noted at one hour interval upto 1500 h and after that next observation was taken at 0600 h on next day. All the opened flowers after each interval were plucked to avoid the possibility of recounting. The pollen morphology and viability study was done by mounting pollens in 1 per cent acetocarmine stain. For pollen stainability, pollen from freshlyopened flower of a randomly selected tree was dusted on a clean slide and 1-2 drops of acetocarmine solution were added to the pollen mass. The slides were then left for 10- 15 minutes to allow the pollen to take the stain. The deeply stained normal looking grains were recorded as stainable, which are usually considered viable. Unstained pollen grains were recorded as non-viable. The observations were repeated for five days.

RESULTS AND DISCUSSION

The critical observations on leaf fall pattern in *Prosopis cineraria* indicated that defoliation started during the month of November and continued till end of January. The new leaves started appearing in late

February. There was complete defoliation before the initiation of new vegetative growth and the new leaves started coming up after all the leaves had shed off. Panicle initiation was started in the first week of March in the randomly selected trees and continued till 2nd of April (Table 2). Observations on flowering habit indicated that bud begins to appear as small protruding structures with the commencement of new leaves. Inflorescence was a raceme panicle, which was often axillary.Maximum well developed buds were observed on all the

Table 1: Morphological characters of trees used in phenology and reproductive biology.

Tree No.	Total height (m)	gbh (cm)	Clear bole height (m)	Canopy spread (m) height (m)	Approximate Age (yrs)	Crown E-W	Crown N-S
1	8.6	115	3.0	5.4	20	10	9
2	9.2	108	3.8	5.2	20	6	5
3	6.8	88	1.8	5.0	16	5	7
4	5.7	63	1.3	4.2	16	2	5
5	7.7	92	2.4	5.2	15	7	9
6	8.2	99	1.8	6.3	20	8	6
7	10.0	109	4.0	5.8	21	8	10
8	8.4	96	2.8	5.4	20	6	7
9	9.6	106	3.9	5.6	21	9	7
10	7.8	94	2.6	5.1	15	6	8
Range	5.7- 10	63-115	1.3-4	4.2- 5.6	15- 21	2- 10	2- 10
Mean	8.2	97	2.7	5.3	18.4	6.7	7.3

selected trees from April 7 to April 23. The floral buds started to open from first week of April to third week of April. The flowering pattern was asynchronous *i.e.* new flowers were developing at different times on the same tree. The trees were in full bloom from second week of April to third week ofMay. Peak period of flowering varied from 13 to 24 days. Flowering gets completed by first week of June. Duration of flowering varied from 27 to 49 days. On all the marked trees, natural fruit setting was noticed during April end. There wereminor variations for these observations among different plants during the same season. It appears that microclimatic changes and genetic makeup of plants caused such variations. Earlier, Dhillon *et al. (2003) in Prosopis cineraria,* Dhillon *et al.* (2004) in *Azadirachta indica,* Dhillon *et al.,* (2009) in Karanj (*Pongamia pinnta*) and Puttaswamy *et al.* (2012) in *Jatropha curcas* conducted similar studies on this aspect. The results of present study and earlier reports suggested to complete the task of reproductive biology before initiation of tree breeding programme in a particular tree species.

The period of pod development and maturity ranged from 28 to 46 days (Table 2). The pod maturity was observed from May 23 to June 4. Duration of panicle initiation to pod maturity varied from 56 to 93 days on the randomly selectedtrees.

The observations regarding the time of flower opening were recorded from 0600-1500 h at one hour interval. The data are summarized in Table 3. Flower opening started between 0600-0630 h and maximum flowering, ranging from

84.38 to 93.82 per cent was recorded between 0800-0900 h.Maximum buds opened up to 1100 h, however anthesis continued till noon hours. Such observations have also beenreported by Chauhan and Singh (2001) in *Terminalia arjuna*and Jose and Pandurangan (2012) in *Ochreinauclea missionis.*

The data of observations on pollen morphology and stainability are presented in Table 4. Pollens were roundin shape. It was observed from the data that pollen viability in 0.1 per cent acetocarmine ranged from 86.21 to 94.00 per cent.

The shiny stigma was considered receptive. It was found that the stigma receptivity occured between 0800 to 1100 h.It was further confirmed through the visits of honey bees (*Apis cerana indica* and *A. dorsata*), wasps (*Polister spp*.) and lady bird beetle (*Coccinella septempunctata*) during 0800 to 1100 h. The best way to find out the nature of pollination in a species is to examine fruit/ seed setting under self pollination vis-a-vis natural open pollination. In present study of *Prosopis cineraria*, the average fruit set under self pollination was nil whereas it was 2.03 per cent in open natural pollination. No fruit setting in self pollination suggested self incompatibility in *Prosopis cineraria* (Table 5).In *Tectona grandis* the extent of self incompatibility varied from 96-100 percent (Bryndum and Hedgeart, 1969). The results of present study suggested the cross pollinating nature in *Prosopis cineraria*.

Table 2: Phenological data on flowering and fruiting in *Prosopis cineraria* during 2014

Tree No.	Date of panicle initiation	Commencement of flowering	Peak period of flowering	Duration of flowering (days)	Date of cessation of flowering	Duration of panicle initiation to first pod maturity (days)	Duration of pod development (days)	Date of pod maturity	Duration of panicle to pod maturity (days)
1	Mar. 13	Apr. 3	May 16	24	Apr. 27	46	46	Apr. 23	83
2	Mar. 4	Apr. 7	May 10	26	Apr. 27	54	39	Apr. 23	93
3	Mar. 24	Apr. 9	May 4	16	Apr. 25	33	37	May-7	65
4	Mar. 18	Apr. 3	May 5	13	Apr. 16	29	33	May-5	68
5	Apr. 2	Apr. 9	May 13	15	Apr. 24	23	33	May-7	56
6	Mar. 20	Apr. 8	May 1	13	Apr. 21	32	34	May-8	59
7	Mar. 29	Apr. 14	May 10	16	Apr. 26	28	31	May-8	59
8	Mar. 10	Apr. 14	May 10	16	Apr. 26	38	38	Jun. 4	84
9	Mar. 31	Apr. 9	May14	15	Apr. 24	24	44	Jun. 6	89
10	Mar. 22	Apr. 15	May16	21	Apr. 26	35	29	May-7	58
Range	Mar.4 - Apr. 2	Apr. 7- Apr. 15	May 10- May 16	13- 24	Apr. 25- Apr. 27	23- 46	29- 46	May-23- Jun.4	56- 93

Table 3: Time of flower opening in *Prosopis cineraria.*

Date of observation	No. of buds observed	Per cent flower opened					
		6-7 a.m.	7-8 a.m.	8-9 a.m.	9-10 a.m.	10-11 a.m.	11-12 Noon
20/4/2015	320	65.31	78.75	84.38	13.44	1.88	-
21/4/2015	306	73.86	83.00	91.38	10.13	1.96	0.98
22/4/2015	210	67.62	78.57	85.71	9.52	0.79	-
23/4/2015	252	71.83	85.32	93.82	9.92	-	0.40
24/4/2015	114	71.92	84.21	92.05	6.14	-	-
25/4/2015	142	71.83	80.99	86.06	4.23	0.70	0.70

(-) No flower opening.

Table 4: Pollen stainability in *Prosopis cineraria.*

Date of observation	Total pollens (No.)	Stainable pollens (No.)	Non-stainable pollens (No.)	Pollen viability (%)
08/05/2015	100	94	6	94
09/05/2015	87	75	12	86.21
10/05/2015	85	76	9	89.41
11/05/2015	162	150	12	92.59
12/05/2015	96	84	12	87.5
Mean				89.94

Table 5: Fruit setting percentage under controlled (self) and open pollination in *Prosopis cineraria.*

Tree No.	No. of floral buds		No. of fruit setting under		Fruit setting percentage	
	Open pollination	Self pollination	Open pollination	Self pollination	Open pollination	Self pollination
1	2726	3720	40	Nil	1.47	Nil
2	575	469	12	Nil	2.09	Nil
3	1022	737	22	Nil	2.15	Nil
4	1284	953	28	Nil	2.18	Nil
5	1162	878	23	Nil	1.98	Nil
6	1152	977	21	Nil	1.82	Nil
7	1049	949	24	Nil	2.29	Nil
8	2340	2150	48	Nil	2.05	Nil
9	1059	971	23	Nil	2.17	Nil
10	2124	1768	45	Nil	2.12	Nil
Mean					2.03	

CONCLUSION

This study confirms previous studies that *Prosopis cineraria*is a cross pollinated species. In present study of *Prosopis cineraria*, the average fruit set under self pollination was nil whereas it was 2.03 per cent in open natural pollination.

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