The Andhra Agric. J 58(3):315-327, 2011

Reproductive Biology of Lotus

J S Minimol and K T Presannakumari
Department of Plant breeding and Genetics, College of Horticulture
Kerala Agricultural University, Thrissur, Kerala, India

ABSTRACT

Sacred lotus (*Nelumbo nucifera* Gaertn.) is a plant, where its all parts are used in one way or other in various ayurvedic preparations. A thorough knowledge of floral biology was studied which will help in further crop improvement. Flower of lotus is complete. An additional whorl called transitional petal was observed in all accession except Bramangalam, which was aborted stamen. The process of anthesis in sacred lotus completed in three days. Lotus flowers are with fertile stamen and stigma but 100 per cent cross pollinated due to self incompatibility. Pollen grains were round, triporate and yellow in colour with reticulate sculpturing on the exine.

Key words : Cantharophillous, Protogyny, Transitional petals, Triporate pollen

Sacred lotus (*Nelumbo nucifera* Gaertn), is an aquatic plant with creeping rhizomes, floating as well as upright leaves and colourful flowers standing high above the water. It is the only genera belonging to the family Nelumbonaceae. Lotus is historically and culturally significant. This legendary flower has at least 6000 years old association with Indian culture and religion. Owing to its very long and close association with history, culture, religion, literature and arts it is chosen as National flower of India. Lotus has immense therapeutic, ornamental and vegetable value. All most all parts of the plant are used in one way or other in various ayurvedic preparations. In spite of its importance, it has received only little attention of crop improvement workers. Knowledge about basic floral morphology and pollination mechanism is lacking in this plant which is very much essential for any crop improvement programme.

Keeping this in mind, the present study was taken up to under stand the floral morphology, pollination biology and thermogenesis in sacred lotus.

MATERIAL AND METHODS

Six different accessions collected from diverse ecological conditions *viz.,* Nagarkovil (pure water) from Kanyakumari district of Tamil Nadu, India, Bramangalam (clay) from Ernakulam district of Kerala, India, Chemmenda (kole area) from Thrissur district of Kerala, Nelliyampathy (high altitude), Chitoor (laterite tracts) ,both from Palakkad district of Kerala and Chandiroor (coastal clay) from Alleppy district of Kerala were used for the study. The accessions were evaluated under *ex situ* conditions in cement tanks of two feet diameter and three feet height in the Department of Plant Breeding and Genetics, College of Horticulture, Kerala Agricultural University, Thrissur, India. Clay and water level were maintained at uniform height in all the tanks throughout the experiment period.

Growth pattern of flower bud

Five flower buds from each type were tagged soon after their appearance at the surface of the mud. The growth of flower bud from visual appearance stage till opening was studied at periodic intervals in all the ecotypes selected. Time taken for opening from visual appearance of flower was also recorded.

Floral morphology

The descriptions of morphological features of flowers of different accessions were made after examining five fresh flowers from each accession.

Anther dehiscence and stigma receptivity

The colour and appearance of anthers were examined with hand lens at bihourly intervals in five fully matured flower buds of each type to find out the time of anther dehiscence.

Table 1. Growth pattern of flower buds of different accessions in Scared lotus

Accessions	Days to flower opening	Mean pedicel Length		Mean length of bud		Diameter of flower (cm)	Blossom life (days)
		At flower opening (cm)	At fruit maturity (cm)	Emergence (cm)	Maturity (cm)		
Nagarkovil	17	90.56	94.86	1.16	12.38	20.90	3
Bramangalam	12	71.32	75.94	1.62	10.04	17.72	3
Chemmanda	20	76.00	78.50	1.30	10.60	19.80	3
Nelliyampathy	20	96.80	99.00	1.10	11.90	20.00	3
Chittoor	18	90.60	94.82	1.18	11.00	19.85	3
Chandiroor	21	72.00	75.85	1.10	9.00	16.30	3
CD (0.05)	4.39	5.82	2.58	0.24	1.40	1.57	-
CV (%)	23.50	20.20	18.15	12.53	13.99	12.49	-

Table 2. Sepal and petal characters of six different accessions in Scared lotus.

Accessions	Mean No. of sepals $flower^{-1}$	Mean length of sepals (cm)	Mean breadth of sepals (cm)	Colour of petal	Mean No. of petal $flower^{-1}$	Mean length of petal (cm)	Mean breadth of petal (cm)	Angle at tip of petal
Nagarkovil	5	1.69	1.11	Pink	36	10.77	5.37	108°
Bramangalam	3	1.54	0.92	Pink with dark pink at the edge	18	9.07	5.00	111°
Chemmanda	5	1.28	0.78	Pink	24	8.98	4.52	112°
Nelliyampathy	5	1.42	0.64	Light pink	30	10.14	5.62	102°
Chittoor	5	1.45	0.62	Light pink	12	10.04	4.48	101°
Chandiroor	5	1.28	0.58	Pink	15	6.70	4.50	118°
CD (0.05)	-	0.26	0.20	-	10.19	1.76	1.04	NS
CV (%)	-	12.53	12.89	-	27.34	13.99	20.20	24.45

Table 3 Transitional petal characters of six different accessions in Scared lotus.

Accessions	Mean No. $flower^{-1}$	Mean length (cm)	Mean breadth (cm)	Angle at tip
Nagarkovil	72	7.50	2.54	85.80°
Bramangalam	Nil	-	-	-
Chemmanda	47	7.36	2.16	91.40°
Nelliyampathy	52	7.36	2.52	97.80°
Chittoor	95	6.50	2.18	91.30°
Chandiroor	68	7.28	2.60	92.00°
CD (0.05)	17.80	0.27	0.22	NS
CV (%)	19.57	10.18	9.92	18.58

4 Androecium character of six different accessions in Scared lotus.

Accessions	Mean No. of stamen flower^{-1}	Mean length of filament (cm)	Mean length of anther lobe (cm)	Mean length of append-age (cm)	No. of carpels receptIcle^{-1}
Nagarkovil	137	1.50	1.02	0.37	13
Bramangalam	147	1.58	1.06	0.39	12
Chemmanda	85	1.32	1.00	0.30	7
Nelliyampathy	131	1.40	1.06	0.44	7
Chitoor	130	1.50	1.02	0.37	12
Chandiroor	120	1.58	1.06	0.30	13
CD (0.05)	7.56	0.18	NS	NS	2.3
CV (%)	18.90	7.10	8.50	9.80	14.50

Table 5. Gynoecium characters of six different accessions in Scared lotus.

Accessions	No. of carpels receptacle^{-1} (cm)	Diameter of receptacle (cm)	
		Just after anthesis	At maturity
Nagarkovil	13	2.62	5.10
Bramangalam	12	1.66	4.32
Chemmanda	7	1.20	4.00
Nelliyampathy	7	1.80	3.70
Chitoor	12	1.26	3.90
Chandiroor	13	1.58	4.10
CD (0.05)	2.3	0.48	0.98
CV (%)	14.5	12.58	12.50

Table 6. Pollen characters of six different accessions in Scared lotus.

Accessions	Type	Colour as appeared to naked eye	Mean fertility (%)	Mean size (µm) x 100	Pollen unit	Nuclear condition
Nagarkovil	Round, triporate	Yellow	95	62.4	Monad	Uninucliate
Bramangalam	Round, triporate	Yellow	95	63.2	Monad	Uninucliate
Chemmanda	Round, triporate	Yellow	96	63.4	Monad	Uninucliate
Nelliyampathy	Round, triporate	Yellow	96	62.8	Monad	Uninucliate
Chitoor	Round, triporate	Yellow	95	62.6	Monad	Uninucliate
Chandiroor	Round, triporate	Yellow	96	62.4	Monad	Uninucliate
CD (0.05)	-	-	NS	NS	-	-
CV (%)	-	-	9.8	15.6	-	-

Fig 1. Growth Pattern of flower bud in Sacred lotus.

Fig 2. Closed Flower after whorl opering in Sacred lotus.

Fig 3. Fully opened flower in Sacred lotus.

Fig 4. Withering of petals in Sacred lotus after full opening.

Fig 5. Five sepals of Sacred lotus.

Fig 6. Gradation of patals in Sacred lotus.

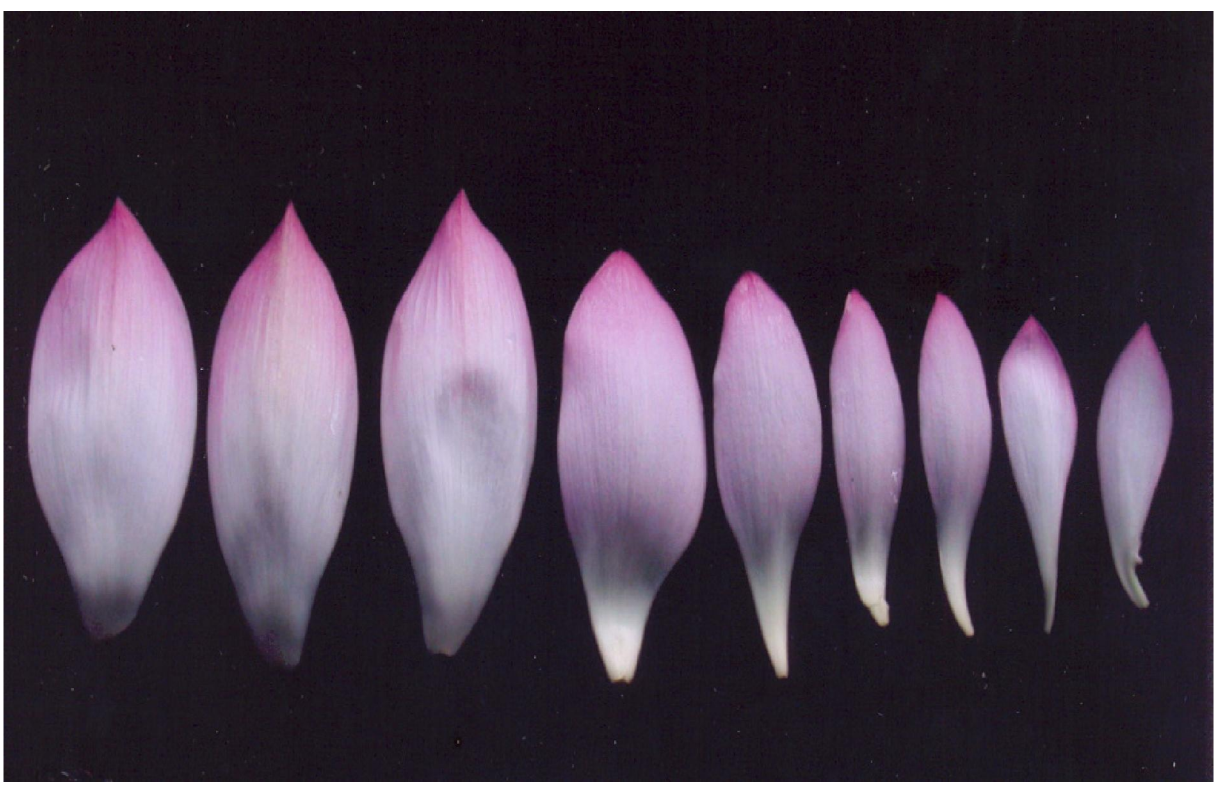

Fig 7. Transitional petals (sterile stamens) in Sacred lotus.

Fig 8. Bramangalam flower with devoid of transitional petals in Sacred lotus.

Fig 9. Stamens in Sacred lotus.

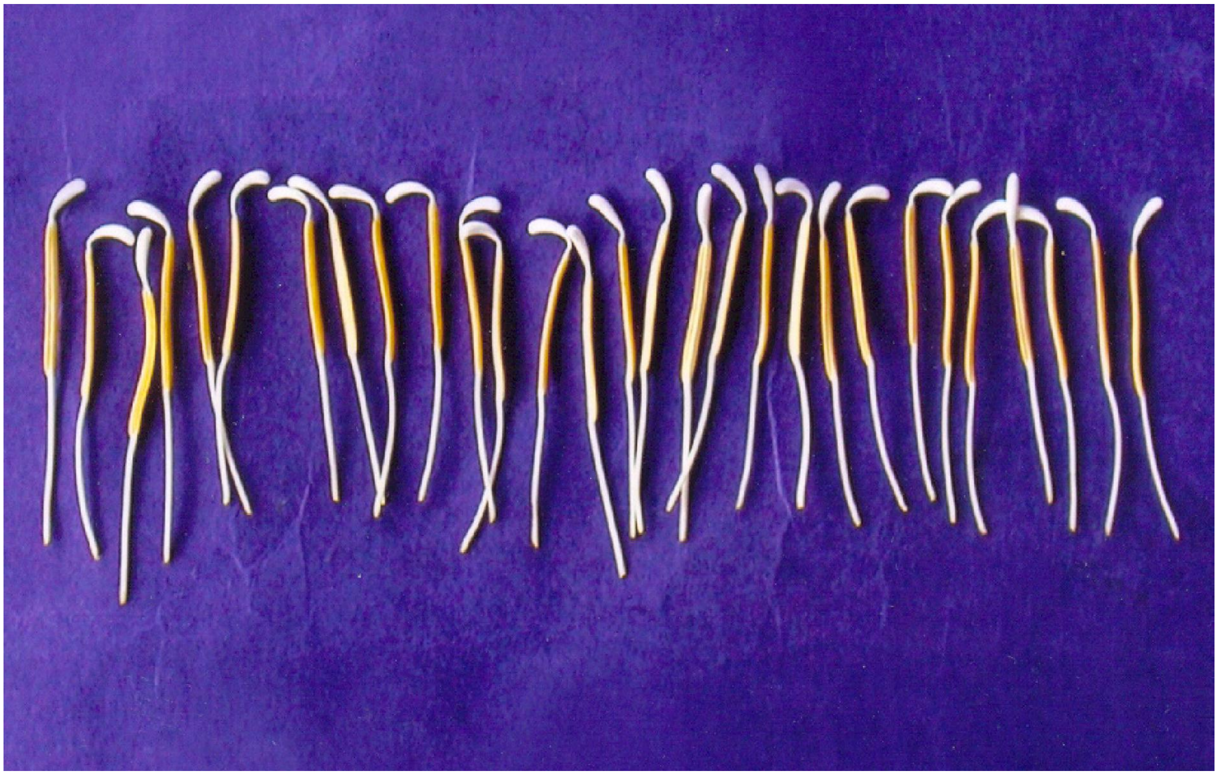

Fig 10. Gynoecium with deep cavities in Sacred lotus.

Fig 11. The morphology of pollen grains in Sacred lotus.

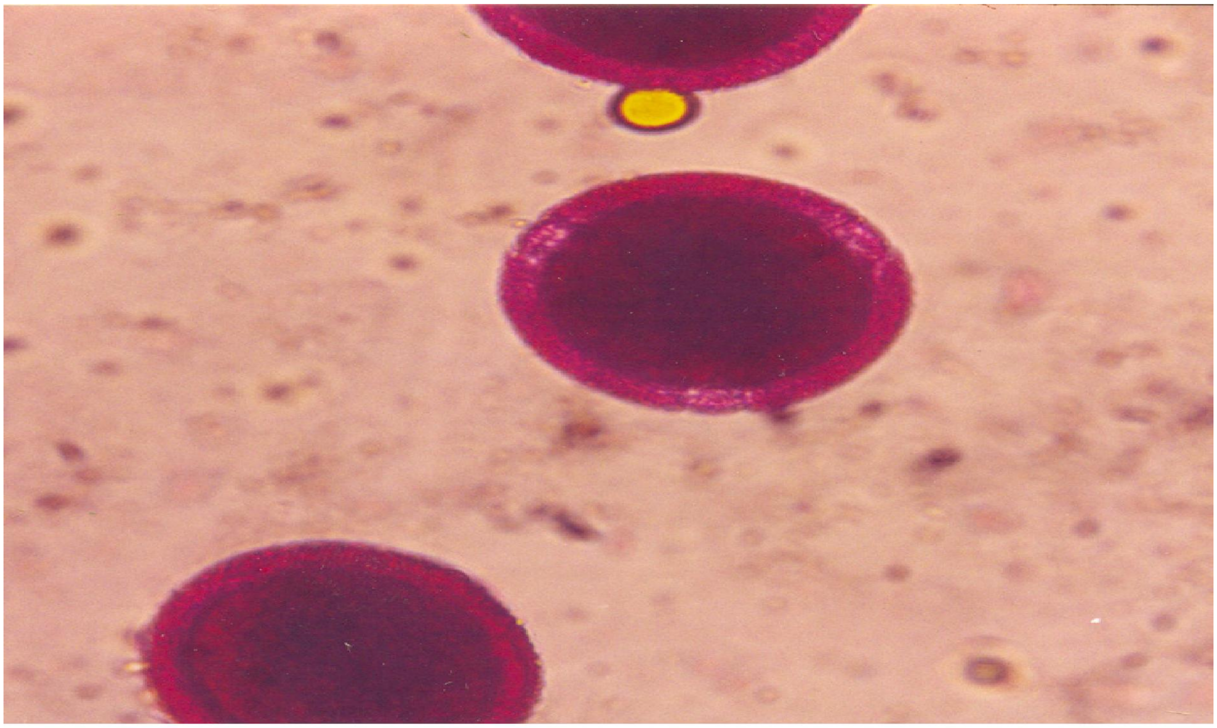

Fig 12. Stigmatic surface with honey due secretion in Sacred lotus.

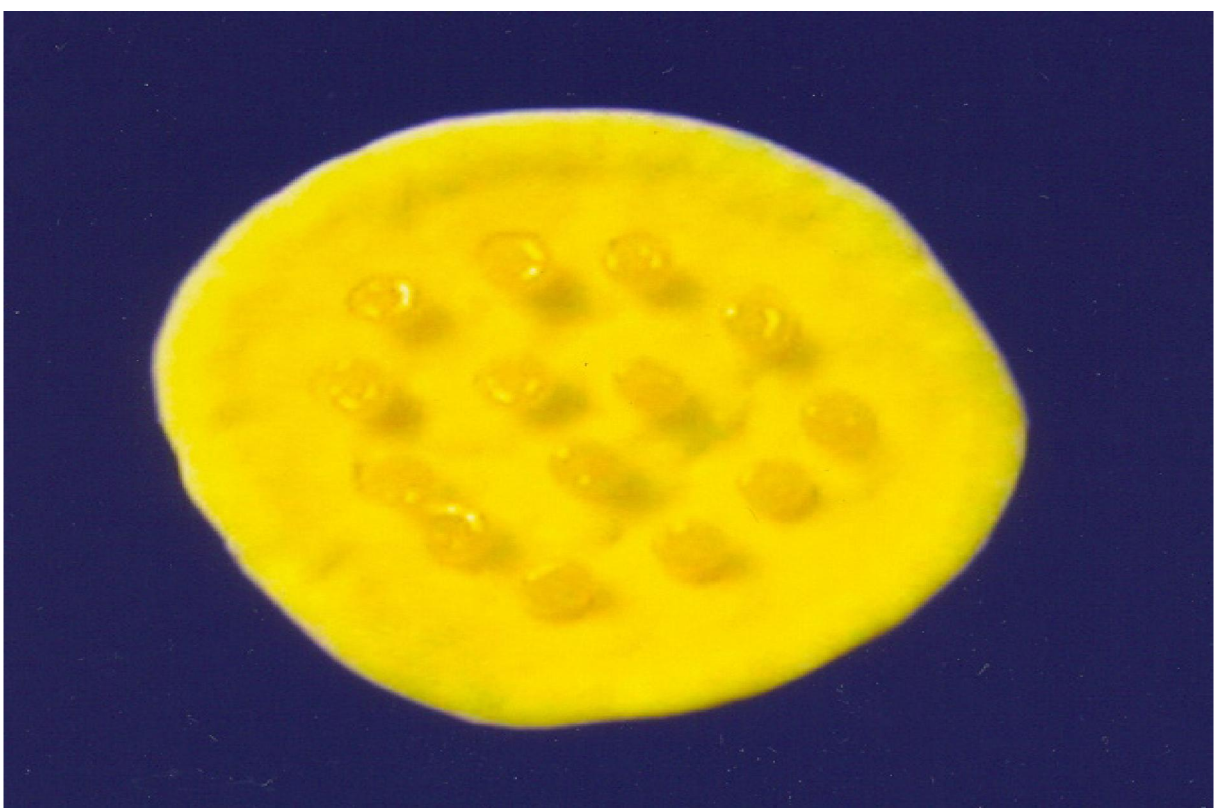

Fig 13. The loss of receptivity of stigmatic surface (Blackening) increasing from peripery to innerside.

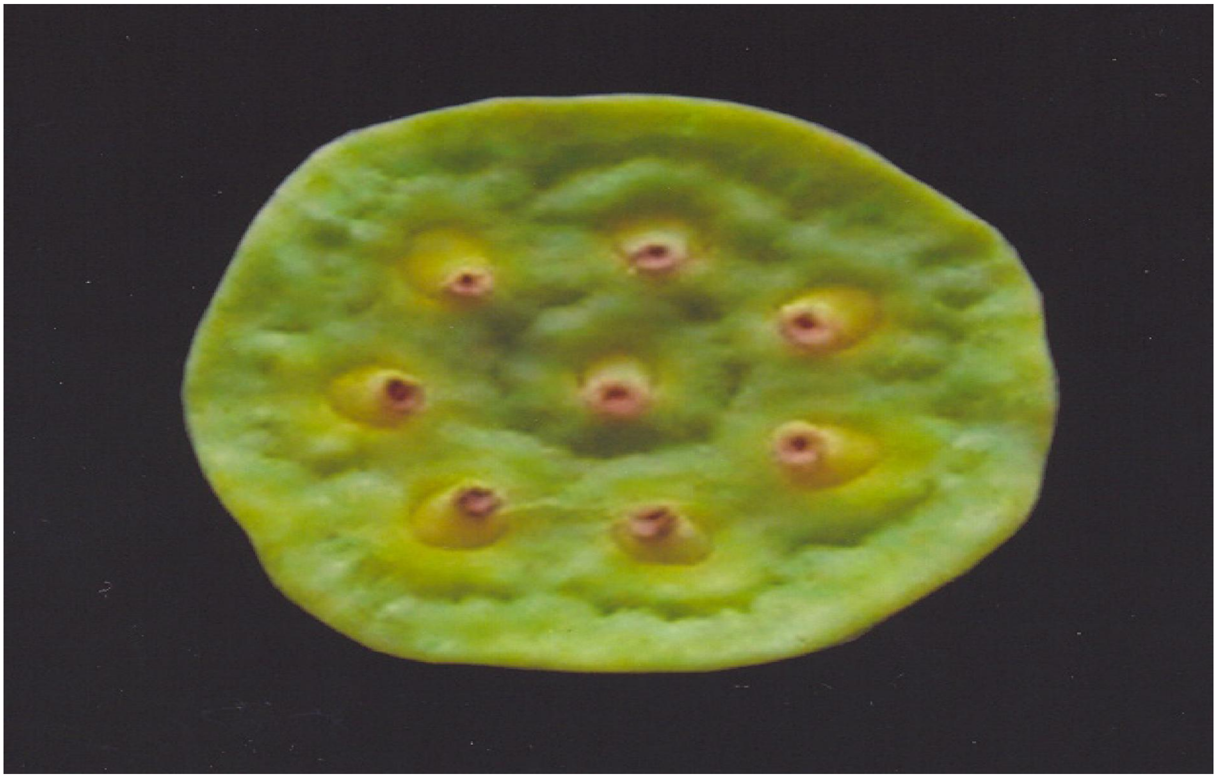

Fig 14. Protected bud in Sacred lotus.

Table 7. Stigma receptivity in six different accessions

Accessions	Time of start of receptivity	Total duration of receptivity
Nagarkovil	32 hours before flower opening	83 hours
Bramangalam	32 hours before flower opening	82 hours
Chemmanda	32 hours before flower opening	82 hours
Nelliyampathy	32 hours before flower opening	83 hours
Chittoor	32 hours before flower opening	82 hours
Chandiroor	32 hours before flower opening	82 hours

Table 8. Extend of fruit set in different ecotypes under different treatment

Accessions	Mean fruit set (%)		
	Protected	Unprotected	Emasculated but unprotected
Nagarkovil	0	44.40	46.20
Bramangalam	0	36.10	36.50
Chemmanda	0	88.80	87.40
Nelliyampathy	0	38.20	36.80
Chittoor	0	41.66	42.00
Chandiroor	0	50.67	49.60

Stigmatic surface was also examined for any change in colour and appearance in the same bud at same intervals of time to find out stigma receptivity.

Palynology

The morphology, size and fertility of the pollen grain of each accession were determined following standard procedures using pollen collected from newly opened flowers. The pollen grains were acetolysed according to the method described by Erdtman(1960) and the sculpturing were examined under microscope. Classification was done following the procedure suggested by Moore and Webb (1978). Fertility of pollen was assessed on the basis of staining with acetocarmine glycerin mixture as suggested by Radford *et al.* (1974) The pollen grains which are well filled and stained were counted as fertile and others were sterile. Observations were taken from two fields of each of the five slides prepared for each accession. The values were expressed as percentage. Pollen diameter was examined using an ocular micrometer after calibration. The observations were taken from 100 pollen grains of each accession and mean was computed.

RESULT AND DISCUSSION

Growth pattern of flower bud and flowering biology

The growth pattern of flower bud (Plate1) of six different accessions *viz.,* Nagarkovil, Bramangalam, Chemmenda, Nelliyampathy, Chitoor and Chandiroor are presented in Table 1.

The mean number of days to flower opening from the appearance of bud at mud surface varied from 12 days in Bramangalam to 21 days in Chandiroor. However, Bramangalam alone was found to differ significantly from the other accessions, which were on par. The pedicel length varied from

71.32 cm in Bramangalam to 96.0 cm in Nelliyampathy. A slight increase in pedicel length varying from 2-4 cm was observed in different accessions at the time of maturity of fruit indicating that elongation of pedicel continues even after flower opening. Bramangalam, though was having the biggest bud at the time of emergence did not retain that superiority at full maturity of bud. The biggest fully matured buds (12.38 cm) and fully opened flowers (20.90 cm) were observed in the accession Nagarkovil. The flower size of Chemmenda, Nelliyampathy and Chitoor were on par with that of Nagarkovil. Irrespective of the accession, blossom life was only three days. Hence for the production of large flowers the accessions Nagarkovil, Nelliyampathy, Chitoor and Chemmenda can be preferred.

The process of anthesis in sacred lotus was observed to be completed in three days.The flower opening started 10-15 days after the appearance of bud. On the first day of flower opening, the floral whorls are just loosened, keeping the flowers in half opened condition. The loosening of whorls occurs by a sudden jerking movement of the petals which took place between 8.00 am to 8.30 am .The flower remained in that condition upto 10.30 am to 11.00 am and closed again (Plate 2).

On the next day, it opened fully and the opening starts by 5.30 am and completed by 7.00 am (Plate 3).Withering of the floral parts starts on the third day of flower opening (Plate 4).

Floral morphology

The flowers were found to be solitary, ebracteate, pedicellate, actinomorphic and complete.

Floral formula is $O^{0}\ K_{3-5}\ C_{á}\ A_{á+á\ staminode}\ G_{7-13}$

The comparisons of morphological feature of flower of the six different accessions are presented in Table 2 to 6 and depicted in plates 5 to 8.

Sepals are five in number and green in colour (Plate 5) in all ecotypes studied except Bramangalam. The accession Bramangalam registered only three sepals. Among the accessions studied Nagarkovil was having the biggest sepals with 1.69 cm length and 1.11 cm breadth (Table 2).

Petals are obovate, slightly boat shaped and arranged in a spiral fashion on the floral axis. Whorls showed gradation in size with the outer most whorls having short petals (Plate 6).Petal size was the highest for Nagarkovil (10.77 cm length and 5.37 cm breadth). Nagarkovil also showed the highest number of petals (36 / flower) (Table 2). The flowers also possessed transitional petals which are actually sterile stamen (Plate 7 and Table 3) among the ecotypes studied, Bramangalam (Plate 8) was devoid of transitional petal.

Stamens were numerous ranging from a mean value of 85 in Chemmanda to 147 in Bramangalam (Table 4). Each stamen consisted of a filament, long bilobbed basifixed yellow anther lobes and white coloured connective extending beyond the length of anther lobe. The connective had a pearl coloured club shaped appendage at the distal end (Plate 9). Difference in the length of stamens among the accessions was found to be due to difference in the length of the filament.

Gynoecium was found to be apocarpous with several uniovulate carpels placed separately in deep cavities in the receptacular tissue (Plate 10). The carpels ranged from 7- 13 per flower depending upon the accessions (Table 5). The receptacle was round in outline with a depression at the centre. The stigma was seen projecting slightly above the receptacle.

In all ecotypes a two to three fold increase in diameter of the receptacle was observed after anthesis.

Anther dehiscence and Palynology

The anther dehiscence was found to occur between 7.15 am to 7.30 am on the second day of flower opening in all accessions. The anther dehisced through longitudinal slits, starting from the inner most whorls.

The morphology, size and fertility of the pollen grains of six different accessions under evaluation are presented in Table 6 and Plate 11. Irrespective of the accessions, the pollen grains were found to be round, triporate and yellow in colour with reticulate sculpturing on the exine. Very high pollen fertility about 90-95 per cent was observed. The accessions did not differ significantly in the size of the pollen grains. The pollen grains are viable for only 30-35 minutes.

Stigma receptivity

The details of stigma receptivity in different ecotypes are presented in the Table 7. Stigma was found to be receptive 32 hours before flower opening and the receptivity was retained until third day of flower opening up to 11am. The peripheral lobes became receptive first. A honey due like secretion was found on the stigmatic surface during the receptive period (Plate 12). The loss of receptivity could be identified by the blackening of stigmatic surface (Plate 13). The loss of receptivity proceeded from the periphery to the centre.

Pollination biology

Extent of fruit set in protected bud (Plate 14), unprotected bud and emasculated but unprotected bud is furnished in Table 8. There was no fruit set in protected buds where as high fruit set was recorded in unprotected as well as emasculated but unprotected buds. This clearly indicates that sacred lotus is adapted to cross pollination and no self pollination takes place even though flowers are bisexual and fertile. Absence of seed set upon selfing may be due to self incompatibility mechanism operating in the flowers.

Observation on insects visiting the flower revealed the presence of wide range of insects mainly beetles and bees. Hence it can be concluded that insects are acting as agents for cross pollination and the flowers can be considered as cantharophillous (Ke *et. al*., 1987).

The study of the floral morphology and anthesis, pollination mechanism of sacred lotus with immensely helpful in future crop improvement programmed in lotus.

LITERATURE CITED

Erdtman G. The acetolysis method. A revised description. *Svensk. Bot. Tidsk*., 54 (4), 561-564.

Moore P D and Webb J A 1978. *All Illustrated Guide to Pollen Analysis*. Hodder and Stoughton, London, p.160 .

Radford A E, Dickison W C, Massey J R and Bell CR 1974. *VascularPlant Systematics*. Happer and Rao Publishers, London, p 466.
Fig 3. Fully operred flower in Scared lotus.

Ke X, Zhang W, Zhang H, Xu D and Jinag Z 1987. Experiments in the use of honeybees for the pollination of lotus seed crop. *Journal of Fujian AgriculturalCollege* 16 (2),169-171.

(Received on 01.11.2010 and revised on 18.12.2010)