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Pollen production in some terrestrial angiosperms

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Pollen production in terms of number per anther along with the particulars of anther number per flower and anther length was determined for 54 angiospermous plant species collected from different areas of Burdwan district, West Bengal. Pollen production varied widely from genus to genus and from species to species within the same genus of a family. There exists a correlation between pollen production and habit of plant. An increase in pollen production from herbs → shrubs → trees was observed and analysed. Variation in the number of pollen grains produced has been noticed in anemophilous, entomophilous and amphiphilous plant taxa. It is presumed that high-pollen producers are cross-pollinated, whereas low-pollen producers are either self-pollinated or apomictic.

A plant during its entire flowering period produces large amounts of pollen grains most of which are not involved in fertilization. These large amount of pollen released may float in air or water, and finally get deposited on the earth's surface[1]. It has been proved that pollen grains of some plant species are bio-pollutants as they cause various types of allergic diseases in human beings[2]. The knowledge of the quantitative production and methods of dispersal of pollen grains is significant as these factors, directly or indirectly, are involved in causing pollution of the environment, and, in the interpretation of data on the pollen content of the atmosphere, honey and sedimentary deposits[3]. These data also give some idea about the frequency of presence of particular plant pollen grains in the atmosphere and hydrosphere.

In flowering plants, pollen productivity is referred to as number of pollen grains produced per anther of the flower. The total production of pollen grains in a particular plant depends on number of anthers per flower and number of flowers per plant. This has significance in aerobiological work dealing with allergy problems. The allergenic pollens in the atmosphere if present in abundance in the air cause allergic symptoms according to Thommen's postulate[4]. The dispersal in air is controlled by factors such as morphology of the flowers, the season of flowering, and characters like anemophily, entomophily and amphiphilly. Various types of allergenic manifestation in human beings are related with dispersal of pollen grains in the air. It has been proved that plants known for high-pollen production are significant for causing pollen allergy problems. Pollen production in anemophilous plants has been studied by Reddi and Reddi[5]. Further, the pollen profile of a particular area reflects the pattern of vegetation of the area under investigation.

In this study, pollen production of 54 selected angiospermic plants profusely growing in Burdwan district, West Bengal, were investigated to establish their supposed role in pollen allergy problems. Pollen production was studied following the methods proposed by Nair and Rastogi[6] and Mandal and Chanda[2]. Pollen grains from the 54 selected angiospermic plant taxa were collected from different biozones of Burdwan district. Unopened flowers were collected between 8.30 and 9.30 a.m. From each flower one anther was crushed and dispersed uniformly in 50 drops of 50% glycerine. One drop of this mixture was placed on a slide and covered with a 18 × 18 mm cover glass. The number of pollen grains

Table 1. Selected plant taxa with flowering period

Plant with mode of pollination	Habit	Family	Flowering period
Aeschynomene aspera L. (E)	S	*Fabaceae*	June–Aug.
Amaranthus aspera L. (A)	H	*Amaranthaceae*	Feb.–Aug.
Anacardium occidentale L. (E)	T	*Anacardiaceae*	Feb.–Apr.
Andrographis paniculata (Burm. f.) Wall (A/E)	S	*Acanthaceae*	May–Sept.
Antigonon leptopus Endl. (E)	S	*Polygonaceae*	July–Sept.
Bauhinia acuminata L. (E)	T	*Caesalpiniaceae*	Feb.–Apr.
B. variegata L. (E)	T	*Caesalpiniaceae*	Jan.–Mar.
Boerhaavia repans L. (A/E)	H	*Nyctaginaceae*	Yr. round
Bryophyllum indicum Salisb. (A/E)	H	*Crassulaceae*	Dec.–Mar.
Canna indica L. (E)	S	*Cannaceae*	July–Dec.
Cassia tora L. (E)	S	*Caesalpiniaceae*	May–June
Centella asiatica (L.) Urbn. (E)	H	*Apiaceae*	Nov.–Apr.
Cereus hexagonus Mill. Gard. (E)	H	*Cactaceae*	May–Sept.
Cleome viscosa L. (E)	H	*Capparidaceae*	June–Oct.
Clerodendrum indicum (L.) O. Kuntze (E)	S	*Verbenaceae*	July–Oct.
C. japonicum (Thumb) E Sodect. (E)	S	*Verbenaceae*	Aug.–Oct.
Commelina bengalensis L. (E)	H	*Commelinaceae*	July–Sept.
Cresentia cujete L. (A/E)	T	*Bignoniaceae*	Mar.–June
Croton bonplandianum Baill. (E)	H	*Euphorbiaceae*	Yr. round
Datura metel L. (E)	S	*Solanaceae*	Mar.–Oct.
D. stramonium L. (E)	S	*Solanaceae*	Mar.–June
Delonix regia (Boj.) Ref. (E)	T	*Caesalpiniaceae*	Mar.–June
Dentella repens Forst. (E)	H	*Rubiacea*	Yr. round
Drosera indica L. (A)	H	*Droseraceae*	Sept.–Oct.
Evolvulus alsinoides Wall. (E)	H	*Convolvulaceae*	Mar.–Aug.
E. nummularius L. (E)	H	*Convolvulaceae*	Mar.–Aug.
Gloriosa superba L. (E)	H	*Liliaceae*	June–Nov.
Hamiltonia suaveolens Roxb. (A/E)	T	*Rubiaceae*	Jan.–May
Ipomoea fistulosa Mart. ex. Choisy (E)	S	*Convolvulaceae*	June–Oct.
Impatiens balsamina L. (E)	H	*Balsaminaceae*	Aug.–Oct.
Ipomoea pes-tigridis L. (E)	H	*Convolvulaceae*	June–Sept.
Jatropha carcus L. (E)	S	*Euphorbiaceae*	June–Sept.
J. gossypifolia L. (E)	S	*Euphorbiaceae*	June–Oct.
Lantana camara L. (E)	S	*Verbenaceae*	June–Sept.
Martynia annus L. (A/E)	S	*Martyniaceae*	June–Nov.
Nerium indicum Mill. (E)	S	*Apocynaceae*	Mar.–Aug.
Oldenlandia corymbosa L. (E)	H	*Oxalidaceae*	Aug.–Oct.
Opuntia dillenii L. (E)	S	*Cactaceae*	June–Aug.
Oxalis corniculata L. (A/E)	H	*Oxalidaceae*	Aug.–Oct.
O. latifolia H.B. & K. (A/E)	H	*Oxalidaceae*	Sept.–Nov.
Peperomia pellucida Kunth. (A)	H	*Piperaceae*	Apr.–Sept.
Petunia hybrida Lindl. (E)	H	*Solanaceae*	Oct.–Feb.
Pilea microphylla L. (A)	H	*Urticaceae*	May–July
Polygonum barbatum L. (A)	H	*Polygonaceae*	June–Aug.
Ruellia tuberosa L. (A/E)	H	*Acanthaceae*	Oct.–Feb.
Solanum evianthum D. Don. (A/E)	S	*Solanaceae*	Major part of the year
S. indicum L. (A/E)	S	*Solanaceae*	Oct.–Feb.
S. nignum L. (E)	H	*Solanaceae*	Yr. round
S. xanthocarpum L. (E)	H	*Solanaceae*	Major part of the year
Tabernaemontana coronaria Willd. (E)	S	*Apocynaceae*	Apr.–Dec.
Tephrosia purpurea Pers (E)	H	*Fabaceae*	July–Sept.
Vitex negundo L. (E)	T	*Verbenaceae*	Feb.–Aug.
Wahlenbergia gracilis Schrad. (A)	H	*Campanulaceae*	Nov.–Mar.
Xyris indica L. (A)	H	*Xyridacea*	Dec.–Feb.

Abbr. A = Anemophilly, E = Entomophilly, A/E = Anemophilly/Entomophilly, H = Herbs, S = Shrubs, T = Trees.

present in this area was counted with an average of 5 drops for each species of plant. This average was multiplied by 50 to obtain the number of pollen grains produced per anther and therefore the number of pollen grains produced per flower. The pollen count was made for 10 anthers from different flowers of a single individual as well as of several plants. The plant materials selected are presented in Table 1.

Table 2. Pollen production in herbs

Plant	No. of anthers/flower	Length of anther (mm)	Average no. of pollen/anther	Log pollen/anther	Average no. of pollen/flower
Amaranthus aspera L.	5	1.5–2	1137	3.05	5685
Boerhaavia repens L.	5	1.2–2.3	5190	3.71	25950
Bryophyllum indicum Salisb.	6	3–3.2	6868	3.83	41208
Centella aciatica (L.) Urbn.	5	2–2.5	1036	3.01	5180
Cereus hexagonus Mill. Gard.	110	3–3.5	2359	3.37	259490
Cleome viscosa L.	4	1.5–2.2	928	2.96	3712
Commelina benghalensis L.	6	1.7–1.9	832	2.92	4992
Croton bonplandianum Baill.	15	1.3–1.8	348	2.54	5220
Dentella repens Forst	5	1.5–1.8	212	2.32	1060
Drosera indica L.	5	1–1.25	750	2.87	3750
Evolvulus nummularius L.	5	1.2–1.4	267	2.42	1335
E. alsinoides Wall.	5	1.3–1.6	411	2.61	2055
Gloriosa superba L.	6	2.5–3.2	11292	4.05	67752
Impatiens balsamina L.	4	2.5–3	856	2.93	3424
Ipomoea pes-tigridis L.	5	3–3.5	26428	4.42	132140
Oldenlandia corymbosa L.	5	1.7–2.2	282	2.45	1410
Oxalis corniculata L.	10	1.2–1.8	536	2.72	5360
O. latifolia H.B. & K.	10	1.4–1.6	812	2.90	8120
Perperomia pellucida Kunth	4	1.8–2.2	720	2.85	2880
Pilea microphylla L.	4	0.7–0.9	302	2.48	1208
Petunia hybrida Lindl.	5	3–4.5	18375	4.26	91875
Polygonum barbatum L.	8	3–3.6	126	2.10	1008
Ruellia tuberosa L.	4	2.75–3.2	2360	3.37	9440
Solanum xanthocarpum L.	5	3.5–4.8	36783	4.56	183915
S. nigrum L.	5	2.5–2.8	24101	4.38	120505
Tephrosia purpurea Pers.	7	2.2–2.4	322	2.50	2254
Wahlenbergia gracilis L.	5	1.2–2.5	288	2.45	1440
Xyris indica L.	5	2.2–2.5	302	2.48	1510

Table 3. Pollen production in shrubs

Plant	No. of anthers/flower	Length of anther (mm)	Average no. of pollen/anther	Log pollen/anther	Average no. of pollen flower
Aeschynomene aspera L.	10	2.7–3.5	5117	3.70	51170
Andrographis paniculata (Burm.f.) Wall.	2	2.8–3.2	2321	3.36	4642
Antigonen leptopus Endl.	8	1–1.75	12235	4.08	97880
Canna indica L.	1	7–7.5	4037	3.60	4037
Cassia tora L.	5	5–5.5	5729	3.75	28645
Clerodendrum japonicum (Thumb.) Sodect.	4	3–3.2	9097	3.95	36388
C. indicum (L.) O. Kuntze	4	3.2–3.5	11137	4.04	44548
Datura metel L.	5	5.5–6.5	3133	3.49	15665
D. stramonium L.	5	5–5.5	4563	3.65	22815
Ipomoea fistulosa Mart. ex Choisy	5	6–6.5	96426	4.98	482130
Jatropa carcus L.	5	3–3.2	2713	3.43	13565
J. gossypifolia L.	5	2–3.5	1496	3.17	7480
Lantana camara L.	5	2.5–2.8	326	2.59	1630
Martynia annua L.	2	3–3.6	10906	4.03	21812
Nerium indicum Mill	5	1.4–2.2	205	2.31	1025
Opuntia dillenii L.	70	2.5–2.8	1556	3.19	108926
Solanum indicum L.	5	3–3.2	13223	4.12	66115
S. evianthum D. Don	5	2.5–3.2	27568	4.44	137840
Tabernaemontana coronaria Willd.	5	2–2.2	544	2.73	2720

Tables 2, 3 and 4 show the pollen production figures obtained for the 54 angiospermic species. Table 2 shows that among herbs, *Cereus hexagonus* produced 259490 pollen grains per flower followed by *Solanum xanthocarpum* (183915), *Ipomoea pes-tigridis* (132140) and *Solanum nigrum* (120505) and lowest pollen production was noticed in the herbs; *Pilea microphylla* (1208), *Evolvulus nummularius* (1335), *Oldenlandia corymbosa* (1410), *Wahlenbergia gracilis* (1440) and *Xyris indica* (1510). Table 3 revealed that among shurbs, *Ipomoea fistulosa* produced maximum number of pollen grains (482130) per flower followed by *Solanum evianthum*

Table 4. Pollen production in trees

Plant	No. of anthers/flower	Length of anther (mm)	Average no. of pollen/anther	Log pollen/anther	Average no. of pollen flower
Anacardium occidentale L.	10	2–2.5	1236	3.09	12360
Bauhinia variegata L.	5	4–5.2	168889	5.22	844445
B. acuminata L.	5	5–5.4	133720	5.12	668600
Cresentia cujete L.	4	5.5–5.9	129601	5.11	518404
Delonix regia (Boj) Raf.	7	4–4.6	14262	4.15	99834
Hamiltonia suaveolens Roxb.	5	3–3.2	4957	3.69	24785
Vitex negundo L.	4	1.25–2.2	1120	3.04	4480

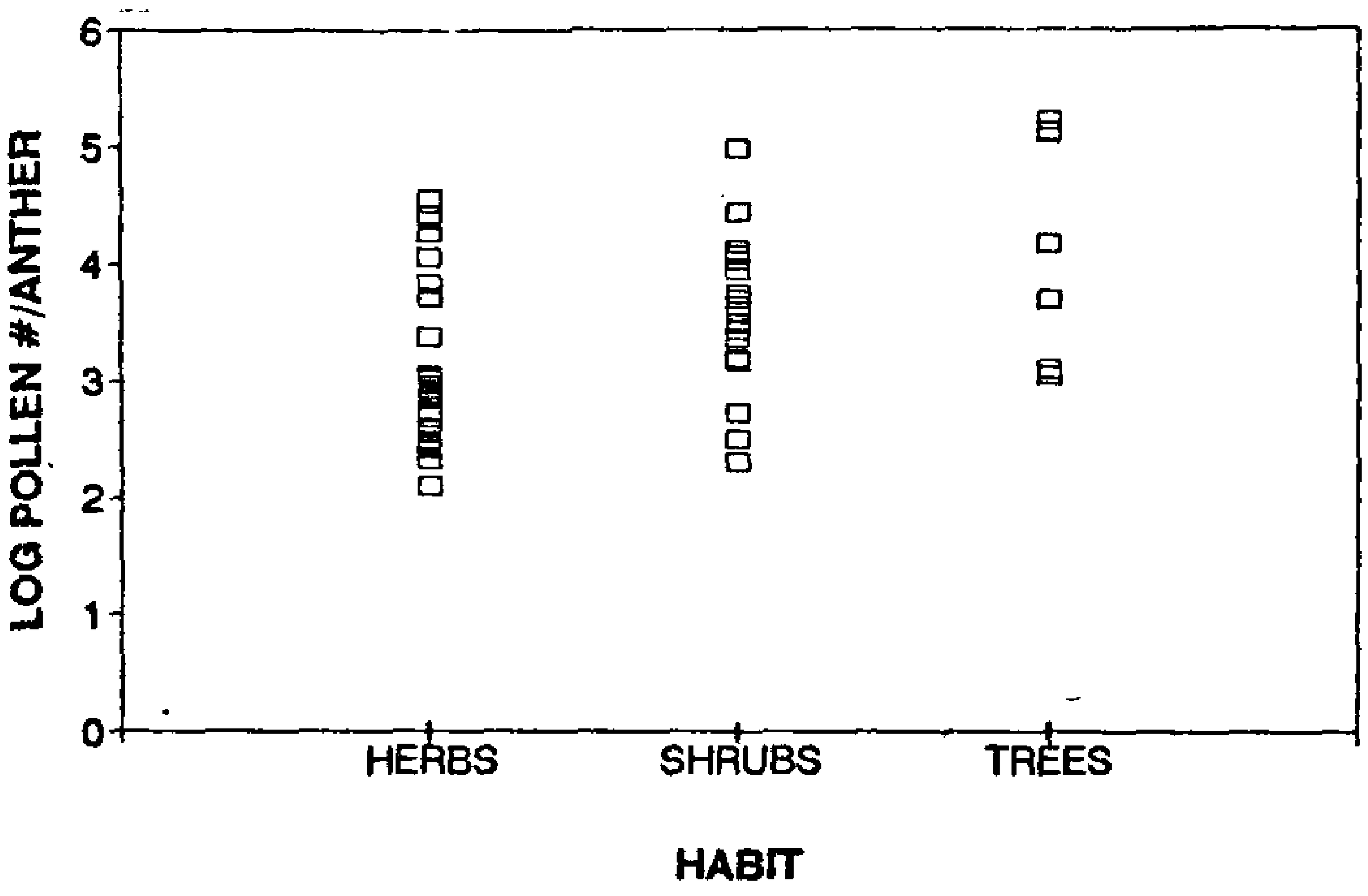

Figure 1. Pollen production in some terrestrial angiosperms.

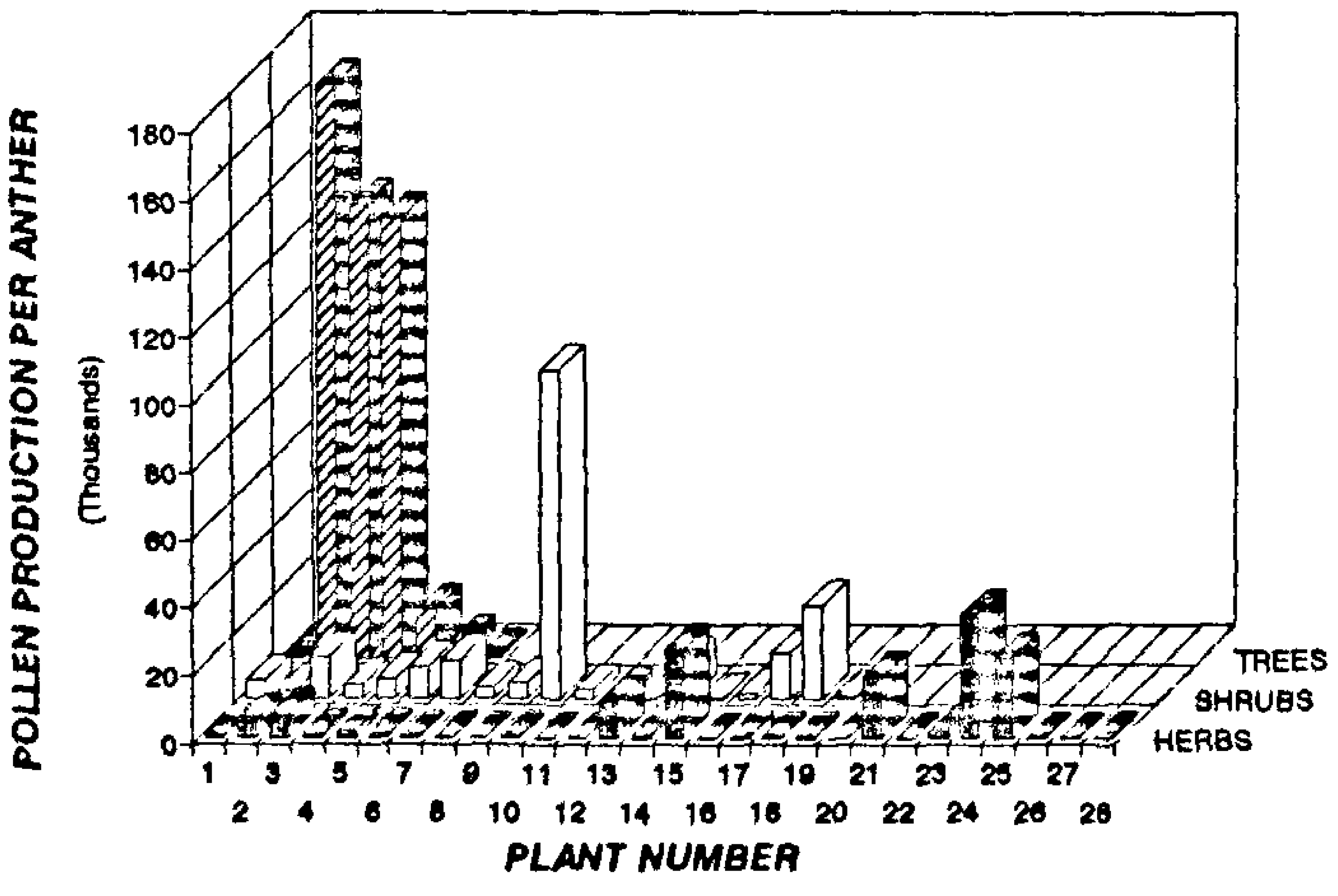

Figure 2. Pollen production per anther in some terrestrial angiosperms.

(137840), *Opuntia dillenii* (108920) and lowest pollen production was noticed in *Nerium indicum* (1025), followed by *Lantana camara* (1630), *Canna indica* (4037) and *Andrographis paniculata* (4642) pollen. Table 4 deals with the tree species; *Bauhinia variegata* showed highest pollen production of 844445 followed by *Bauhinia acuminata* (668600), *Cresentia cujete* (518404) and *Delonix regia* (99834), and the lowest number was recorded in *Anacardium occidentale* (12360), *Vitex negundo* (4480) and *Hamiltonia suaveolens* (24785). It has been observed that pollen production in terms of number per anther and also per flower varies widely from genus to genus, species to species and even within the same genus.

Agnihotri and Singh[7] studied the pollen production in 10 species of Indian grasses to establish a correlation between size of the pollen grains and length of the anthers with the pollen production in a taxon, confirming our earlier observation. Mandal *et al.*[1] stated that pollen production per flower in a taxon is not only dependent on size of the anther or size of the pollen grain but is also controlled by other factors like periodicity, response to light and nutrient availability. Terrestrial species produce large quantities of pollen compared to aquatic ones[1]. The aquatic plants are mostly adapted for self-pollination, and are propagated not only by seeds but also by root stalks and stolons. So the rate of production of pollen grains and the number of flowers produced in these plants are lesser than those of terrestrial plants.

The present study confirms that pollen production increases with habit, i.e. from herbs to shrubs to trees (Figures 1 and 2). Pohl[8] gave the figure of pollen production per anther, flower, inflorescence and annual production which averages to many millions for square metres of ground covered. Smart *et al.*[9] explained that variation in pollen production by an individual plant might be genetically fixed. At the same time, Joppa *et al.*[10,11] reported that among the cultivated species, diploid plants produced more pollen than the tetraploids. Variation in pollen production has also been reported by other workers[6,7,12–15].

The present study is thus helpful from the following points of view:

1. The quantitative estimation of pollen produced is one of the essential prerequisites in dispersal biology[2]. This has significance in the interpretation of data on the pollen content of the atmosphere, honey and sedimentary deposits[3].
2. Pollen grains have been proved to be a source of respiratory allergy[2]. According to Thommen's postulate[5], which is accepted by aerobiologists and al-

lergists, the allergenic pollen in the atmosphere cause allergy symptoms if pollen are found in great abundance in air and pollen are buoyant and transportable, wind-pollinated and the plants producing these pollen are widely distributed. Obviously, the plants known for high-pollen productivity and are wind-pollinated are more significant for pollen allergy problems in human beings. Hence for any studies on the botanical aspect of respiratory allergy, data on the pollen incidence have to be correlated with those of pollen productivity.

3. Assured reproductive success of a plant species may be brought about by several ways: increased probability of the male and/or female gametic success in fertilization, faster and ensured development of seed, etc[14]. A plant during its flowering period produces large amounts of pollen grains, most of which are not involved in fertilization and instead remain suspended in air as pollen grain, before settling on the ground or water surface. Cross-pollinated plants usually produce greater number of pollen grains than self-pollinated ones, thus increasing the probability of success of fertilization.
4. Although aquatic plants produce less quantity of pollen grains compared to terrestrial plants, the pollen released by the aquatic plants affects the water environment. Consequently, a knowledge of quantitative production and methods of dispersal of pollen grains are significant as these factors, directly or indirectly, are involved in causing pollution in the environment.
5. Survey of the deposition of pollen grains of a particular area and production of pollen grains of a plant can sometimes be used as an index of the vegetation pattern of that area.

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Late Quaternary sea level changes in western India: Evidence from lower Mahi valley

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The Mahi and Kothiyakhad are two recently established marine formations from the Late Quaternary continental succession of the lower Mahi valley, Gujarat. These formations have yielded fairly rich assemblages of foraminiferids, confirming their marine origin. The Mahi Formation indicates that the first major transgression of about 7–8 m high took place around 240 Ka in the Mahi valley during Late Quaternary. However, the second transgressive phase at ~ 4,000 years BP, represented by the Kothiyakhad Formation, is to be viewed in the light of the tectonic uplift in recent times. Results of radiocarbon dating of bottom and top mud layers of Kothiyakhad section indicate that the sea-level was high up to 2,000 years BP.

THE Mainland Gujarat across which the Mahi river flows, comprises a huge thickness (100–500 m) of partially indurated sediments of diverse origin. These have been investigated in the past for their detailed lithologic, stratigraphic, sedimentological characteristics and depositional environments[1–4]. The emphasis so far has been on the processes and agents of deposition and the climatic variations. No concrete evidences for Late Quaternary sea-level changes have been recorded from the Mainland Gujarat. Studies from the off-shore region of the west coast are however better documented which provide evidence in support of the Late Quaternary sea-level changes[5–8], and similar evidences are required from the mainland to address this problem.

Our studies on geomorphic, stratigraphic and micropalaeontologic aspects of the lower Mahi valley (Figure 1) provide records of high sea-levels during Middle Pleistocene (~ 240 Ka BP) and Holocene (~ 4,000 years BP).