# 11. SYMMETRY OPERATIONS ON THE QUASI-CRYSTALLOID BIOPOLYMER SYSTEM OF THE SPOROPOLLENIN OF PHOENIX SYLVESTRIS LINN. FROM INDIA

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## Abstract

Partially degraded pollen of *Phoenix sylvestris* LINN. were investigated and exine was studied with the help of transmission electron microscopy. More or less radially oriented and comparatively large regular pentagon biopolymer units were observed on the tectal surface. This biopolymer unit was examined by using the rotation method. In the peripherial region of the pentagonal biopolymer unit peculiar Penrose units were also noticed.

*Key words:* Palynology, biopolymer symmetry, sporopollenin, *Phoenix sylvestris*.

## Introduction

During our joint research programme on the extant palm pollen from India experiments were conducted to partially degraded the exine of *Phoenix sylvestris*. Transmission electron microscopic observations on exine were published (KEDVES et al., 2000). During these studies a regular pentagonal unit was observed (KEDVES et al., l.c., fig. 1, Plate 7.4.) and was chosen for the symmetry operation studies. The aim of the present communication is to document the biopolymer symmetry in the exine of *Phoenix sylvestris* using rotation methods. This method was previously used to study the biopolymer symmetry in the walls of *Botryococcus braunii* KÜTZING isolated from Hungarian Upper Tertiary oil shales (KEDVES et al., 1995). The rotation method has, for the first times, been used to observe the biopolymer symmetry in recent palm pollen. These studies will be very useful in comparing the results from *Botryococcus* colonies and those the *Phoenix sylvestris*.

## Materials and Methods

The biopolymer unit which is the object of our present investigation (Plate 7.4., fig. 1, KEDVES et al., 2000) was obtained after a partial degradation of exine with 2-aminoethanol for 72 hours (experiment No.: 1/7-1316). The globular units of the observed regular pentagon are numbered and were studied for the symmetry operations in the same sequence. Two kinds of primary rotations (fivefold and tenfold) were carried out. The extreme secondary points ten and four were studied for two kinds of secondary rotations. Observations of the primary and secondary rotations are illustrated in Plates 11.1.-11.4. The secondary radial rotation

(R, cf. KEDVES, TÓTH and VÉR, 1993, 1995) was made for the points of symmetry of the tenfold rotation, the parallel (X, cf. KEDVES, 1989) for the points of symmetry of the fivefold rotation.

## Results

Fivefold primary rotation

C.P.5.A.5.5. (Plate 11.1.)

This rotation reinforced the regular pentagon. Around the pentagon ten points of symmetry appeared in two further pentagons. The first is composed by light units, this was followed by positive (dark) but not so characteristic ten points of symmetry. In this case we numbered these points of symmetry as 1/1 - 1/10. These points of symmetry form the boundary of the outer rotation area. At the peripheral region of the picture four points of symmetry appeared, which may be a part of another pentagon formed of the several points of symmetry, but in this case provisional designation has been used (2/1 - 2/4).

The above mentioned positive secondary points of symmetry were used for secondary rotations. The parallel axis method was used, so the axes of the secondary rotations are parallel to the primary PA axis.

Secondary fivefold rotations

C.S.X.$_{+1/1}$.5.5. (Plate 11.1.)

Two characteristic positive regular pentagons appeared. The position of the points of symmetry alternate. This is surrounded by a light star-like area, which is a characteristic rotation area. Around this area there are further points of symmetry both positive and negative.

C.S.X.$_{+1/2}$.5.5. (Plate 11.1.)

A characteristic dark pentagon appeared, which was surrounded by a light star-like area. At each side of light star-like area two dark points of symmetry were observed. Outside of these areas several further positive and negative points of symmetry appeared.

C.S.X.$_{+1/3}$.5.5. (Plate 11.1.)

Peculiar secondary picture appeared. A dark star is surrounded by a light area. At the sides of this light area there are dark points of symmetry forming a regular pentagon. In pentagonal arrangement five peculiar light fields of symmetry appeared. These fields are composed by a light central point further connected to three of the four smaller light points of symmetry. Similar but dark fields are in radial position to these light fields, forming a more or less regular large secondary rotation area.

C.S.X.$_{+1/4}$.5.5. (Plate 11.1.)

A more or less circular central dark field appeared after this rotation, which is surrounded by a very characteristic light star-like area. At the sides of this light star, characteristic dark points of symmetry are noticed. This regular area is surrounded by light and dark points of symmetry. These points are irregularly arranged, which may be due to the position of the original biopolymer unit.

C.S.X.$_{+1/5}$.5.5. (Plate 11.1.)

A central light small pentagon appeared, which is further surrounded by five similar small light pentagons. Five dark points of symmetry around these light areas are present. These dark points of symmetry are a little elongated, but arranged in a regular pentagon. Several further more or less elongated light and dark points of symmetry surround this pentagon.

C.S.X.$_{+1/6}$.5.5. (Plate 11.1.)

Elongated or twin points of symmetry characterize this secondary rotation. Further, the outermost large pentagon composed of five globular dark units is clearly seen. Surrounding this a large rotation area is observed, but the whole area is not covered in the picture.

C.S.X.$_{+1/7}$.5.5. (Plate 11.1.)

A very characteristic large light rotation area characterize this rotation. The central small light star-like pentagon is surrounded by five wedge-like dark units of symmetry. Similar types of points follow this pentagon, but the units of the edges are more globular. More or less globular or radially ellipsoidal points of symmetry form another pentagon, which is "embedded" in the light rotation area. This light rotation area is delineated but dark elongated or fusioned points of symmetry are also seen.

C.S.X.$_{+1/8}$.5.5. (Plate 11.1.)

An unusual light rotation area appeared around the central rotation point. This light area of a pentagonal symmetry is surrounded by ten dark more or less characteristic points of symmetry. Five dark points of symmetry form a large outer pentagon. These dark units are surrounded by light irregular fields.

C.S.X.$_{+1/9}$.5.5. (Plate 11.1.)

A dark regular pentagon field appeared after this rotation. At the edges of this pentagon more or less dark globular points of symmetry are present. Further five, not so characteristic irregular "points" of symmetry appeared. This rotation area is bordered by a light rotation area.

C.S.X.$_{+1/10}$.5.5. (Plate 11.1.)

A dark central pentagon is surrounded by five light irregular points of symmetry. This is followed by five characteristic dark points of symmetry which are connected with further smaller dark globular or irregular units of the regular pentagon field. A large regular outermost rotation area with five dark points of symmetry close to this large biopolymer unit is noticed.

C.S.X.$_{+2/1}$.5.5. (Plate 11.1., plate 11.2., fig. 1)

Several dark and light points of symmetry appeared after this secondary rotation. These are bordered with a large pentagon composed of twenty dark points of symmetry. The light globular units surrounding the central units are not so characteristic informing the real pentagonal structure. Around this area at the sides there are five pentagonal units, but the outermost two points of symmetry are very characteristic. But one of the basic units is a little clear than others. This is because of the arrangement of the biopolymer system. The three others represent a component of the pentagonal area. In the peripherial region one can presume the pentagonal structures.

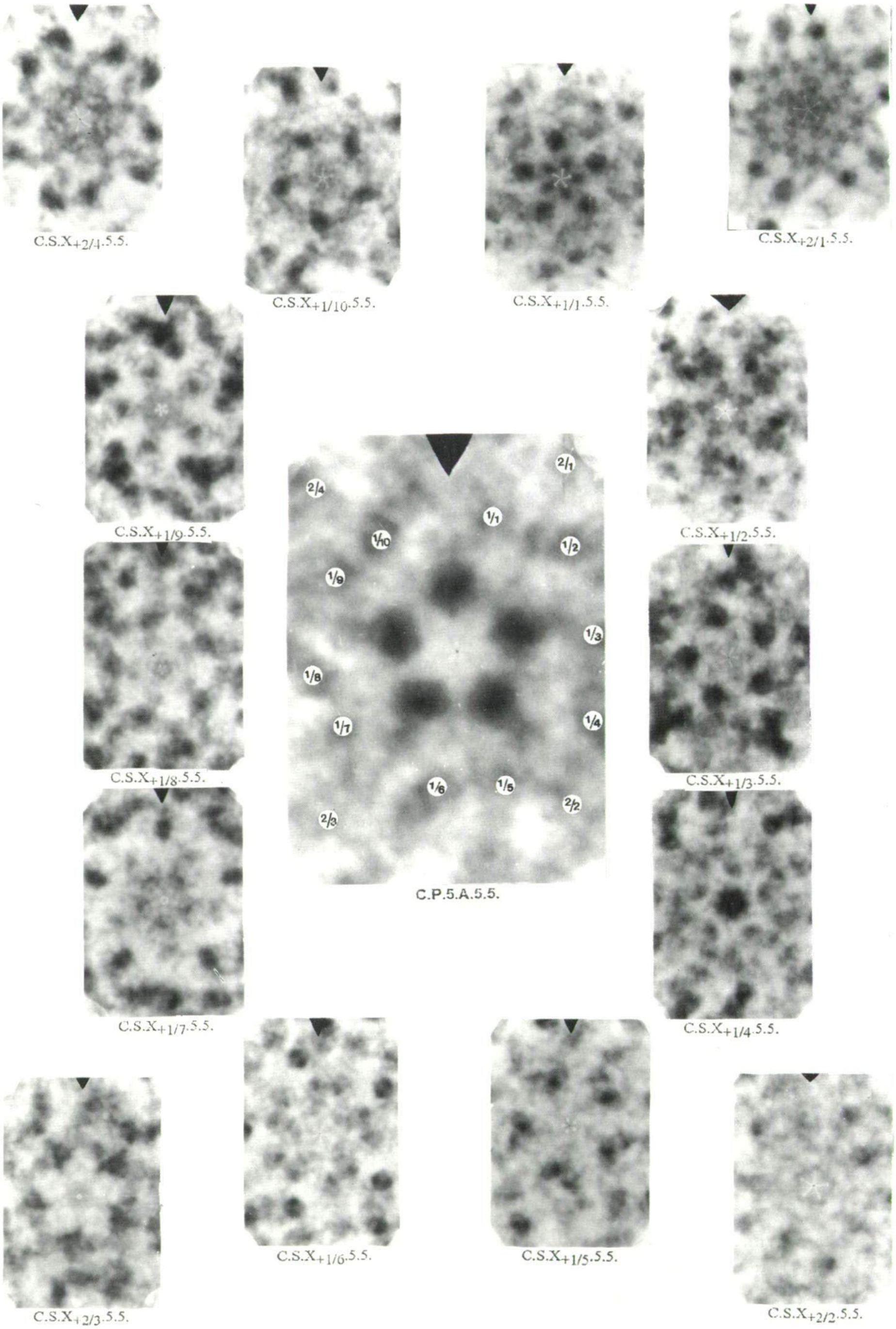
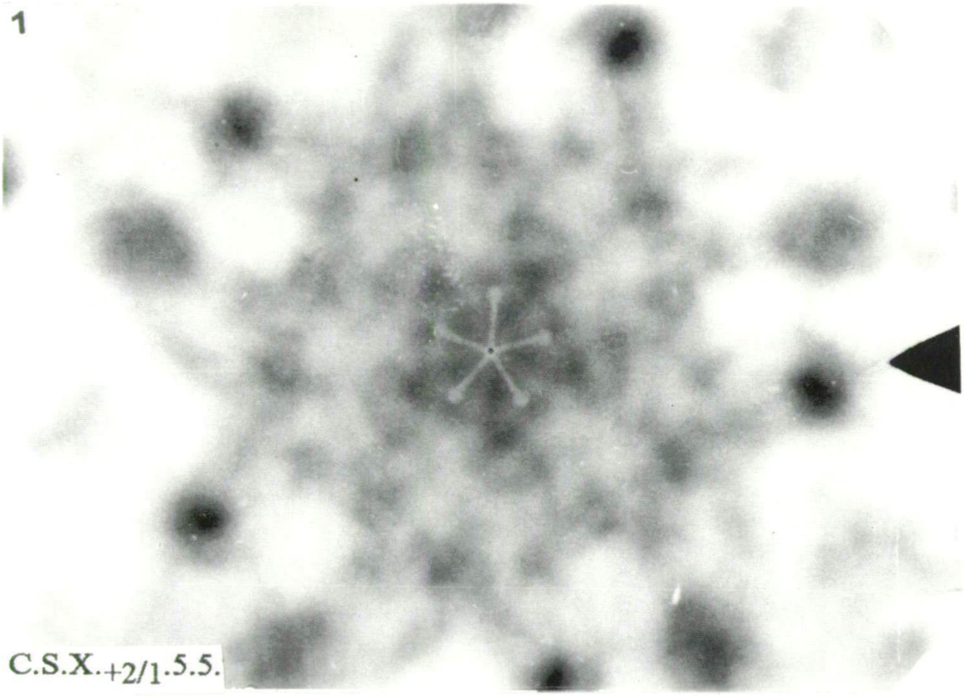



Plate 11.1.

Fivefold primary rotation picture (1,000.000x) and secondary rotation pictures (500.000x).



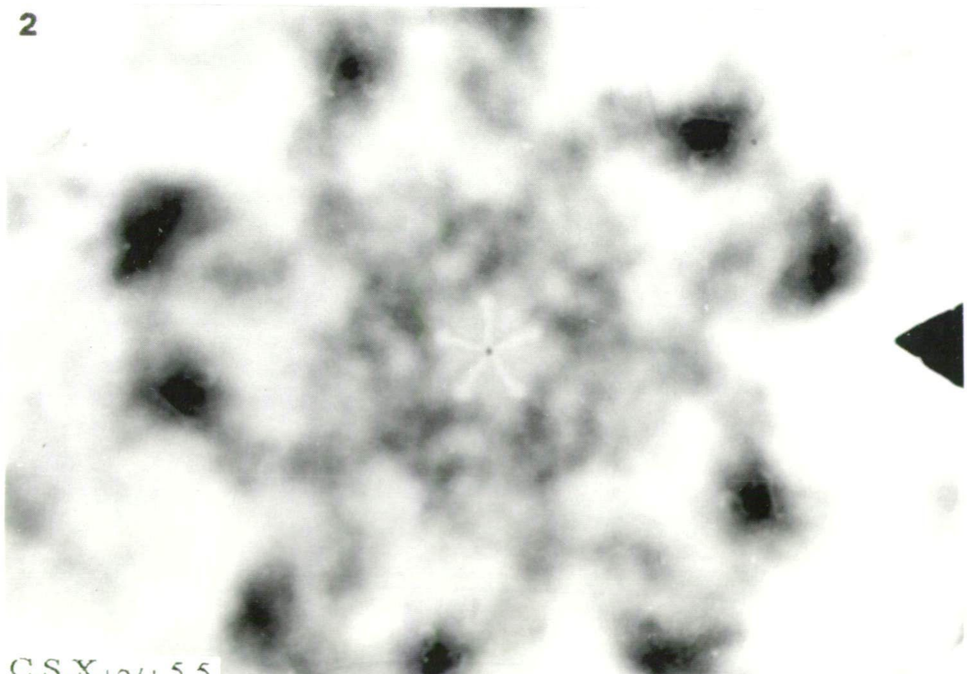




Plate 11.2.

1,2. Secondary rotation pictures (2.000.000x).

C.S.X.$_{+2/2}$.5.5. (Plate 11.1.)

A light star-like inner area appeared after this rotation. This is surrounded by a dark one, which is composed of anastomosing globular units, five at the apices and other five at the sides. This is followed by a light and dark zone surrounded by network zone. Beneath this zone pentagons similar to the basic biopolymer unit are also observed. In the outermost rotation zone there are large dark globular biopolymer units.

C.S.X.$_{+2/3}$.5.5. (Plate 11.1.)

Five small dark points of symmetry appeared after this rotation, which are enclosed with a light zone. At the edges of the peculiar central pentagon large dark points of symmetry are noticed. There are further dark units of irregular form after this dark zone. This is surrounded by five light elongated irregular elements which border the outermost rotation area.

C.S.X.$_{+2/4}$.5.5. (Plate 11.1., plate 11.2., fig. 2)

As a result of this rotation an interesting Penrose unit is noticed. Probably this is the first rotation picture which represents the quasi-crystalloid structure in space. In the centre there is pentagon dodecahedron unit, which is further surrounded by five pentagonal structures.

Tenfold primary rotations

C.P.5.A.5.10. (Plate 11.3.)

Around this rotation centre a light, more or less circular zone appeared. This is followed by a dark zone composed of ten anastomosing points of symmetry. Further ten light and ten dark points of symmetry are observed. Around this dark zone at the edges of this rotation picture there are four more or less characteristic dark points of symmetry. The points of symmetry are numbered as 5/1-5/4.

Secondary radial rotations

C.S.5.R$_{3+1/1-10}$.5.5. (Plate 11.3.)

Dark elongated areas arranged in a whorl fashion appeared in the centre after the rotation. Within this dark whorl area there are five light points of symmetry, which are made up of two or three units. This dark area is surrounded with a light zone. More or less radially oriented points of symmetry are around this star-shaped field. These 10 points form a pentagonal structure.

C.S.5.R$_{3+2/1-10}$.5.5. (Plate 11.3.)

Five curved dark elongated elements of symmetry appeared, which are embedded in a light pentagonal rotation area. Around this area there are ten dark points of symmetry which may be in the outermost rotation area. Different kinds of irregular elements are also seen around this area.

C.S.5.R$_{3+3/1-10}$.5.5. (Plate 11.3.)

Five dark points of symmetry appeared after this rotation. These points of symmetry are surrounded with a small light zone. This zone is connected with ramifying light zones. These light zones surround five dark more or less spike forming dark zones.

These dark zones are composed by about six globular units of symmetry an outermost similar zone may also be presumed.

C.S.5.$R_{3+4/1-10}$.5.5. (Plate 11.3.)

A central pentagonal dark zone appeared, which is composed of anastomosing globular units. The number of these globular elements is about ten. A relatively large circular light zone around this pentagon is present. This zone is probably composed of anastomosing globular light elements. There are five radially oriented light ramifying processes in this zone. This zone is encircled by a dark zone followed by another light zone.

C.S.5.$R_{3+5/1-10}$.5.5. (Plate 11.3.)

Dark, five radially oriented points of symmetry appeared after this rotation. Concave triangular light zones surrounding the dark elements form a more or less pentagonal rotation area. Around this area there are several light rotational elements of irregular shapes are seen.

C.S.5.$R_{3+6/1-10}$.5.5. (Plate 11.3.)

A light star-shaped zone appeared after this rotation. The sides of this light area are surrounded with five elongated dark rotation elements forming a pentagon which is surrounded with a relatively large light area. There are ten globular light points of symmetry connected to this area. In the outer region of the network light elements surround this large light pentagonal rotation area.

C.S.5.$R_{3+7/1-10}$.5.5. (Plate 11.3.)

A small dark star-shaped area surrounded by a light zone represents the inner rotation area. Ten very characteristic dark globular points of symmetry follow the light pentagon. Five light, more or less irregular elements of symmetry follow the inner dark pentagon.

C.S.5.$R_{3+8/1-10}$.5.5. (Plate 11.3.)

A small dark pentagon appeared after this rotation. This is surrounded by a light zone. Five dark points of symmetry are the direction of the edges of the pentagon. The light zone is connected to five outer large points of symmetry. Between the large light points there are ten dark points of symmetry which sometimes anastomose. Outside the peripheral rotation area there are further light and dark points of symmetry which sometimes anastomose.

C.S.5.$R_{3+9/1-10}$.5.5. (Plate 11.3.)

A small light pentagon area appeared after this rotation. This is surrounded by five dark points of symmetry. This is surrounded by a relatively large light area. From the edges of this pentagon light more or less irregular rotation fields are in radial direction. Outside of this rotation area there are five light originally pentagons, with a dark point of symmetry in the centrum.

C.S.5.$R_{3+10/1-10}$.5.5. (Plate 11.3.)

Five irregular radially oriented light fields surrounded by five characteristic dark points of symmetry appeared after this rotation. Around this dark pentagonal zone at the sides there are further dark points of symmetry.

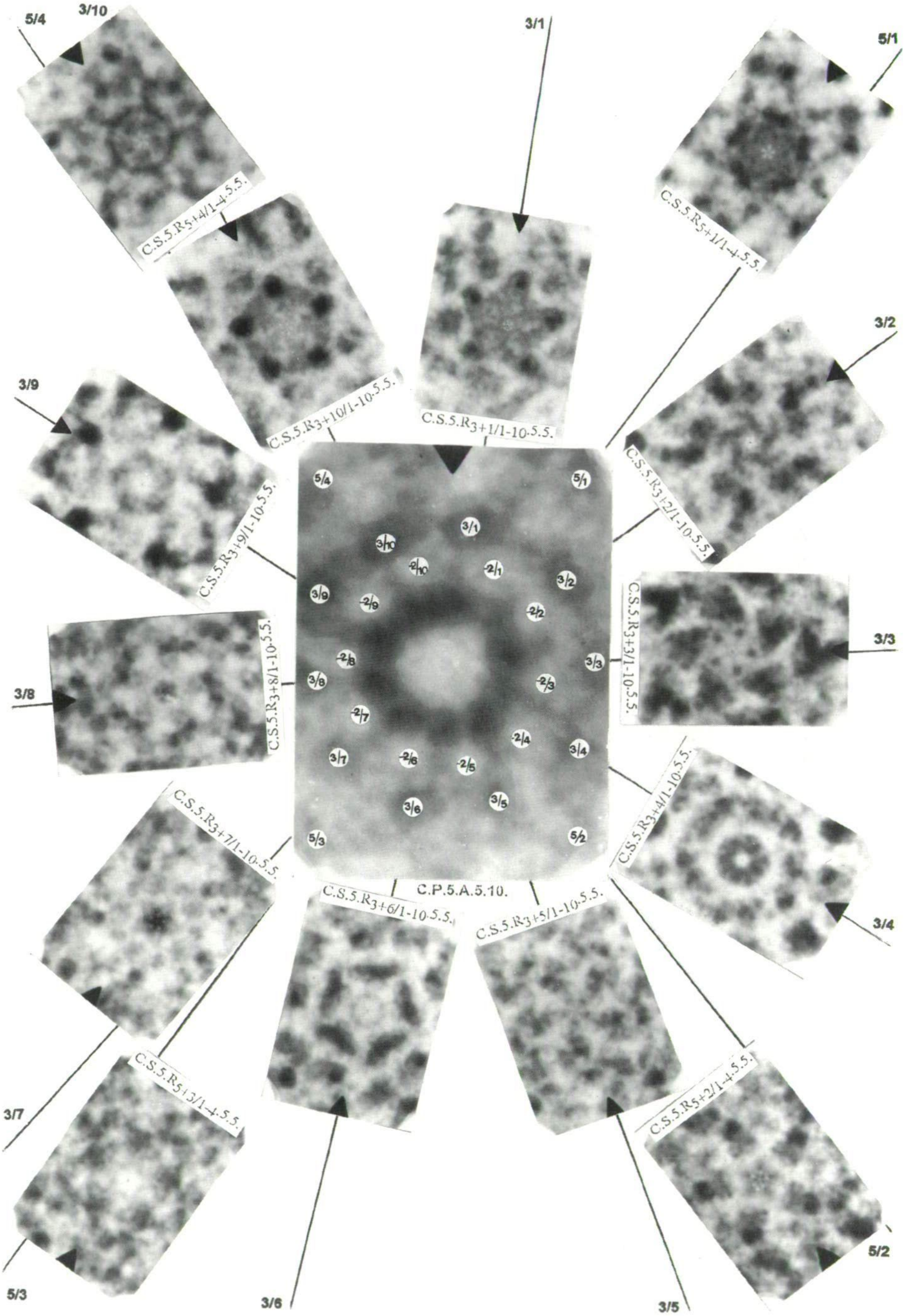
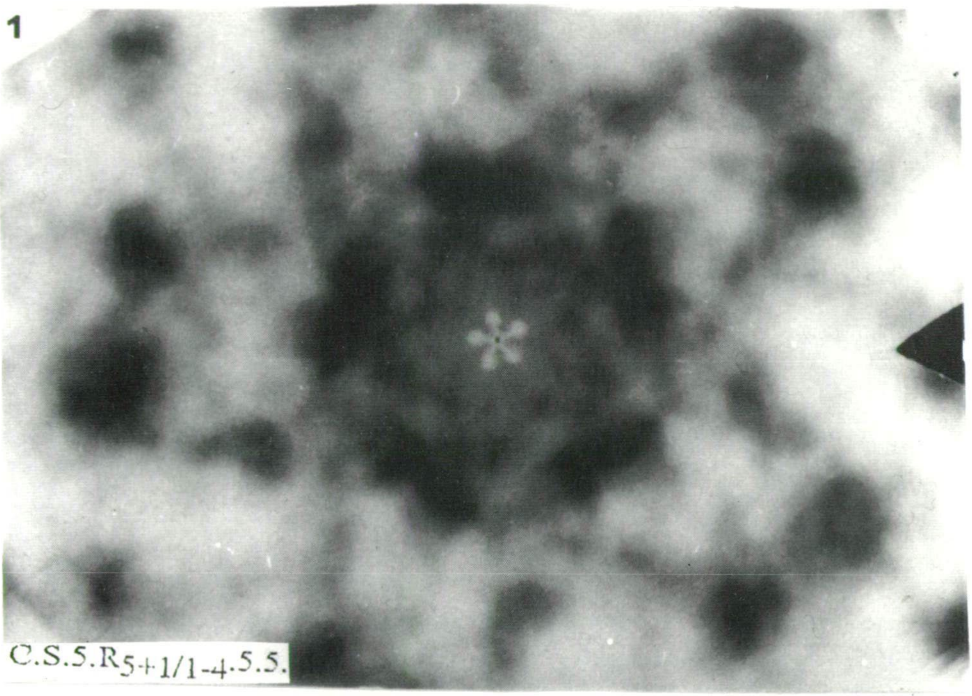



Plate 11.3.

Tenfold primary rotation picture (1,000.000x) and secodary radial rotation pictures (500.000x).

1




2

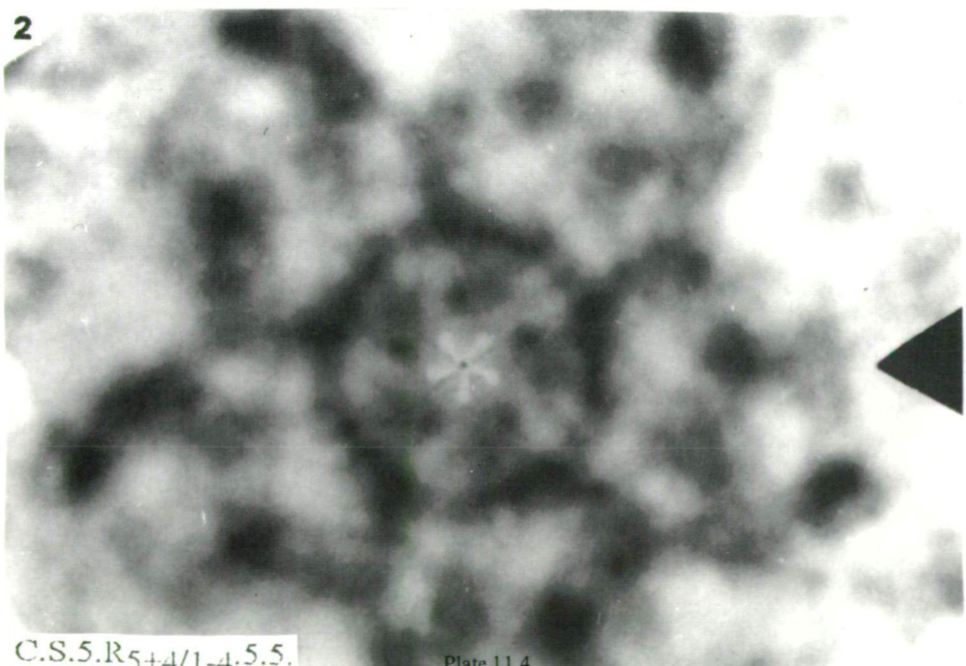



Plate 11.4.

1,2. Secondary rotation pictures (2,000.000x).

C.S.5.$R_{5+1/1-4}$.5.5. (Plate 11.3., plate 11.4., fig. 1)

Around the center two pentagons composed of dark points of symmetry are seen. These central units are connected to five other pentagons which are connected by apices to the central unit. This rotation resulted into very interesting Penrose biopolymer structure.

C.S.5.$R_{5+2/1-4}$.5.5. (Plate 11.3.)

In the rotation centre a dark pentagon appeared which is surrounded by a light zone. The light zone is connected to further light units, which may be pentagons in another space configuration.

C.S.5.$R_{5+3/1-4}$.5.5. (Plate 11.3.)

An interesting rotation area appeared after this rotation. In the centre there is a light star-shaped field, its edges shows further five points of symmetry. Radially around the inner rotation area there are five characteristic dark points of symmetry. Five irregular light rotation elements follow this and further five more or less globular points of symmetry close to this rotation area are present. This characteristic pentagonal area is surrounded with further rotation elements, which may compose the outer rotation zone.

C.S.5.$R_{5+4/1-4}$.5.5. (Plate 11.3., plate 11.4., fig. 2)

This rotation also resulted into a very interesting Penrose unit of the quasi-crystalloid biopolymer skeleton. The central unit is surrounded with five seemingly characteristic pentagon dodecahedrane unit. These results have been reported for the first time in these kind of researches.

## Discussion and Conclusions

1. The points of symmetry of the five- and tenfold primary rotations are not so characteristic.

2. The pictures of the two kinds of the secondary rotations illustrate the peculiar secondary points of symmetry or different kinds of elements having resembling trends in organization patterns. More or less similar kinds of disposition of the points of symmetry are noticed.

3.1. A central pentagon dodecahedron unit is seen surrounded by five pentagon dodecahedron biopolymer system (Plate 11.2., fig. 2, plate 11.4., fig. 2).

3.2. The secondary pentagon dodecahedron units are connected at one of the sides of the central pentagon dodecahedron.

3.3. The resulting two dimensional pictures have proved very useful in establishing the molecular arrangement of the quasi periodic biopolymer network in the three dimension.

3.4. Irregularly arranged biopolymer units were observed in pollen wall of *Phoenix sylvestris*. The rotation pictures also show its irregular arrangement.

3.5. The allergenic *Ambrosia (Asteraceae)* pollen grains also exhibit irregular arrangement of biopolymer units (KEDVES et al., 1999). Some palm pollen grains are also allergenic e.g.: *Livistona*, CHEN and HUANG, (1980), *Phoenix canariensis* CHABAUD, LA-SERNA RAMOS et al., (1989), *Astrocaryum mexicanum* LIEBM. ex MART., *Chamaedorea ernesti-angusti* H. WENDL. in OTTO et DIETR., *Chamaedorea tepejilote* LIEBM. ex MART., *Geonoma oxycarpa* MART., *Reinhardtia gracilis* (H. WENDL.) DRUDE ex

DAMER var. *gracilior* (BURRET) H. MOORE, SOCORRO LOZANO-GARCIA and MARTINEZ HERNÁNDEZ (1990), *Areca catechu, Phoenix hanceana*, HUANG, (1998). From India: Bombay, *Cocos nucifera, Borassus flabellifer*, PRASAD and TRIPATHI (1986); following AGASHE and MANJUNATH (1991), p. 13: "New types of allergens which are not tested for allergies in Bangalore like *Mimosa, Dodonaea, Phoenix, Casuarina* and *Cocos* were recorded in significant numbers." The allergenic character of these pollen may thus be linked with the biopolymer organization in pollen walls and may be one of the factors for causing allergy. The future studies will throw more light on this aspect.

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## References

AGASHE, S.N. and MANJUNATH, K. (1991): Pollen calendar of Jnanabharathi Campus, Bangalore University, Bangalore: A suburban locality near Bangalore. - 6th National Conf. on Aerobiology, Abstracts, 12,13.

CHEN, S.-H. and HUANG, T.-C. (1980): Aeropalynological Study of Taipei Basin, Taiwan. - Grana *19*, 147-155.

HUANG, T.-C. (1998): Airborne Pollen Grains and Spores in Taiwan. - Taipei, Taiwan R.O.C.

KEDVES, M. (1989): Méthode d'étude des biopolymères de la paroi pollinique à structure quasi-cristalloïde. A method of investigation of the quasi-crystalloid structure of the pollen wall biopolymers. - Revue de Micropaléontologie *32*, 226-234.

KEDVES, M., BORBOLA, A., TRIPATHI, S.K.M. and MADHAV KUMAR (2000): Transmission electron microscopic studies on partially degraded pollen grains of *Phoenix sylvestris* LINN. - Plant Cell Biology and Development (Szeged) *12*, 93-103.

KEDVES, M., PÁRDUTZ, Á., MADARÁSZ, M. et HORVÁTH, A. (1999): Microscopie électronique à transmission de l'exine partiellement dégradée de grains de pollen *d'Ambrosia artemisiifolia*. - XVIème Symposium de l'A.P.L.F., Liège, Résumés, 70.

KEDVES, M., TÓTH, A. and VÉR, A. (1993): Radial fivefold rotation: A new method in the study of the biopolymer organization of the sporoderm. - XV. Int. Bot. Congr., Yokohama, Abstracts, 28.

KEDVES, M., TÓTH, A. and VÉR, A. (1995): Radial fivefold rotation: A new method in the study of the biopolymer organization of the sporoderm. - Plant Cell Biology and Development (Szeged) *6*, 44-59.

LA-SERNA RAMOS, I., MENDEZ PEREZ, B., DOMINGUEZ SANTANA, M.D. and ACEBES GINOVES, J.R. (1989): Contribución al atlas aeropalinológico de la Comarca de Santa Cruz-La Laguna (Tenerife: Islas Canarias) - IV. - Bol. Soc. Brot. Ser. 2, *62*, 155-182.

PRASAD, R.K. and TRIPATHI, D.M. (1986): Dominant aero-allergens in Bombay. - 3rd Internat. Conf. on Aerobiology, Abstracts, 74.

SOCORRO LOZANO-GARCIA, M. del and MARTINEZ HERNÁNDEZ, E. (1990): Palinologia de la estacion de biologia tropical Los Tuxtlas Parte I Especies Arbóreas. – Publicaciones especiales del Instituto de Biologia *3*, 1-61.