# POLLEN PRODUCTIVITY VARIATIONS IN *PINUS ROXBURGHII* AT THREE DIFFERENT ALTITUDES IN GARHWAL HIMALAYA

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**SHARMA, C. M. & KHANDURI, V. P. 2002. Pollen productivity variations in *Pinus roxburghii* at three different altitudes in Garhwal Himalaya.** In *Pinus roxburghii* the variations in the number of production units, namely, microsporophylls, strobili and strobili groups per tree at three different altitudes have shown variations in pollen production. The total pollen production per tree ranged from $1247.5 \times 10^9$ (at 1900 m asl) to $1888.5 \times 10^9$ (at 900 m asl). An exponential correlation was observed between the size of microsporophylls and the number of pollen grains they contain. The ratios between the number of pollen grains per microsporophyll and the number of microsporophylls per strobili group, the number of pollen grains per strobilus and the number of strobili per tree, as well as the number of pollen grains per strobili group and the number of strobili groups per tree showed a hyperbolic function.

Key words: Pollen production - anemophilous - microsporophyll - strobili - Himalaya - *Pinus roxburghii*

**SHARMA, C. M. & KHANDURI, V. P. 2002. Variasi pengeluaran debunga dalam *Pinus roxburghii* pada tiga altitud yang berbeza di Garhwal Himalaya.** Variasi dalam bilangan unit pengeluaran iaitu mikrosporofil, strobilus dan kumpulan strobilus bagi setiap pokok *Pinus roxburghii* pada tiga altitud yang berbeza menunjukkan variasi dalam pengeluaran debunga. Jumlah pengeluaran debunga bagi setiap pokok berjulat antara $1247.5 \times 10^9$ (pada 1900 m asl) hingga $1888.5 \times 10^9$ (pada 900 m asl). Korelasi eksponen dicerap antara saiz mikrosporofil dan bilangan biji debunga yang dikandungnya. Nisbah antara bilangan biji debunga bagi setiap mikrosporofil dan bilangan mikrosporofil bagi setiap kumpulan strobilus, bilangan biji debunga bagi setiap strobilus dan bilangan strobilus bagi setiap pokok, serta juga bilangan biji debunga bagi setiap kumpulan strobilus dan bilangan kumpulan strobilus bagi setiap pokok mempamerkan fungsi hiperbolik.

## Introduction

The quantity of pollen produced by an individual plant, and by the plant community, is not constant but varies both specifically and individually in relation to ecological parameters, especially with climatic changes. Flowering and pollen production under different environmental conditions are therefore, highly variable. The important characteristic feature of anemophilous plants is to produce copious amount of pollen grains. Moreover, a tree that is freely exposed, e.g. in a field, often produces as much pollen as one that grows in a dense stand, even if the latter reaches the upper stratum of the canopy. Pollen production areas within the same climatic region are roughly the same regardless whether they are forest-clad or covered with lower vegetation. Pollen production per species as affected by size class, vigour, climate, site and meteorological phenomena such as sunshine, temperature, wind direction, velocity and turbulence, have heen recognised and reviewed (Erdtman 1943, Hansen 1949, Faegri & Iversen 1950, Potter & Rowley 1960). The available literature on pollen production in gymnospermous taxa is limited, but Erdtman (1943), Pohl (1937b) and Sarvas (1962) reported a figure of $158 \times 10^3$, $152 \times 10^3 - 162 \times 10^3$ and $151 \times 10^3 - 164 \times 10^3$ pollen grains production per strobilus respectively in *Pinus sylvestris*, while Tormo *et al.* (1996) gave the figures of $20.9 \times 10^9 - 32.3 \times 10^9$ for pollen production per tree in *Pinus pinaster* from Spain. For the three different altitudes, we reported the pollen production figures for *P. roxburghii* known to be entirely anemophilous, and gave the production rates of pollen grains per microsporophyll, microsporophylls per strobilus, strobili per strobili group, strobili groups per branch, microsporophylls per tree and pollen grains per tree. This scope of study was chosen because of the immense importance of *P. roxburghii* to the economy of India. This species yields timber and resin that has multifarious uses in industries, and is distributed naturally in a wide range of habitats in the Himalayas between 450–2300 m asl in pure stands or in association with broad-leaved species.

## Materials and methods

Sample consists of three stands of *P. roxburghii* growing in natural habitats at each of the three diferent altitudes (total nine trees, latitude 29° 20' to 30° 15' N and longitude 78° 10' to 79° 20' E), namely, Ashtabakra (900 m asl), Sumari (1400 m asl) and Ransi (1900 m asl) in the district of Pauri Garhwal, India (Figure 1). The trees were in good health and well shaped, and were measured for tree height, diameter at breast height (dbh), crown length and crown diameter, as per MacDicken *et al.* (1991). Further details regarding the study are presented in Table 1.

### *Number of strobili groups, strobili and microsporophylls*

The *P. roxburghii* has a high number of strobili groups arranged mostly on the main branches of the crown. First the main branches were counted and then a sample of five branches (representative) were selected randomly and a count was made of all their strobili groups. Following this, 20 strobili groups scattered throughout the tree were selected and the number of strobili per strobili group was counted for each tree. Then a strobilus was chosen from the upper, middle and lower parts of each of the 20 strobili group selected and the number of microsporophylls in each strobilus was counted manually.

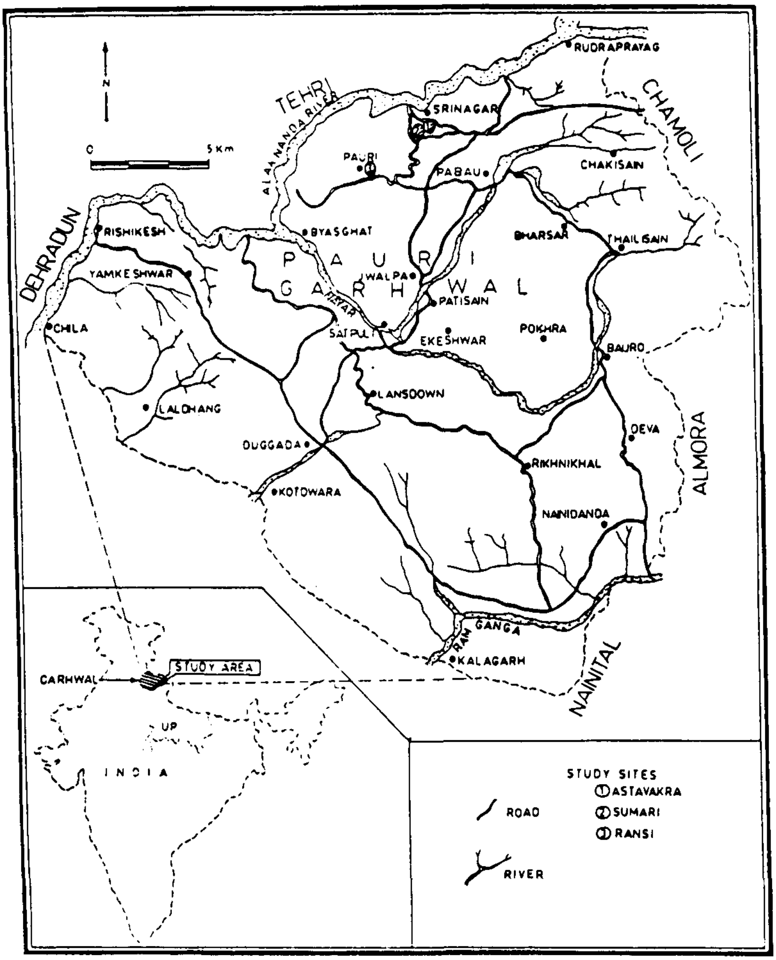


**Figure 1** Location map of the study area

**Table 1** Details of the study area

| Locality (altitude) | Mean annual temp. (°C) | Total rainfall (mm) | No. of trees per ha | Other species | Environment |
|---|---|---|---|---|---|
| Ashtabakra (900 m) | 22.10 ± 1.76 | 1495.9 | 190 | None in tree layer | Rural |
| Sumari (1400 m) | 19.75 ± 1.98 | - | 160 | None in tree layer | Rural |
| Ransi (1900 m) | 14.65 ± 2.06 | 1635.0 | 250 | • *Quercus Leucotrichophora*<br>• *Rhododendron arboreum*<br>• *Cupressus torulosa*<br>• *Pinus wallichiana* | Rural/Traffic |

### *Number of pollen grains per microsporophyll and estimate of the total pollen production*

Five microsporophylls from different strobili of each tree were obtained to count the pollen grains following the methods of Cruden (1977) and Tormo *et al.* (1996). For this purpose the microsporophylls were derived from closed strobili and kept in 70% ethanol. These microsporophylls were washed in distilled water and kept in test tubes after proper measurements of length. They were further taken apart using a glass rod and the pollen grains were then suspended in 1 ml of distilled water. From this concentrate, five drops of 10 μl were taken out and the pollen grains were counted under the microscope.

For estimation of total production of pollen grains per tree, first the total number of microsporophylls per tree was calculated by multiplying the total number of strobili groups by the average number of strobili per strobili group, and then by the average number of microsporophylls per strobilus. The result was multiplied by the average number of pollen grains produced per microsporophyll. For each tree an estimate was also made for the production of pollen grains per microsporophyll per meter of the diameter of tree crown.

### *Calculation of the correlation coefficients*

The correlation between the length of microsporophylls and the production of pollen grains per microsporophyll as well as between ten pairs of ratios of production, which are; grains/microsporophyll, grains/strobilus, grains/strobili group, grains/tree, microsporophylls/strobilus, microsporophylls/strobili group, microsporophylls/tree, strobili/strobili group, strobili /tree, and strobili groups/tree were calculated as outlined by Freese (1967) to establish the relationship between different indices.

## Results

Height and diameter of the tree and crown of each tree studied are presented in Tables 2 and 3. The number of strobili groups, strobili, microsporophylls and pollen grains per microsporophyll deviated considerably in trees of different altitudes. The number of strobili groups per terminal branch varied from 487 ± 84.12 (1900 m asl) to 704 ± 101.37 (900 m asl), whereas the number of strobili per strobili group varied from 98.6 ± 10.92 (900 m asl) to 119.0 ± 27.47 (1400 m asl), microsporophylls per strobilus from 101.1 ± 12.14 (1900 m asl) to 121.0 ± 10.43 (900 m asl) and number of pollen grains per microsporophyll from 5304 ± 24.33 (1900 m asl) to 6871 ± 43.95 (1400 m asl) in the representative trees (Table 2).

**Table 2** Production data of strobili groups per branch, strobili per strobili group, microsporophylls per strobilus and pollen grains per microsporophyll (average ± S.E.) for each tree at three different altitudes

| Altitude/ Tree no. | Height (m) | Dbh (cm) | No. of branches | No. of strobili groups/branch (N = 5) | No. of strobili/strobili group (N = 20) | No. of microsporophylls/ strobilus (N = 20) | Length of microsporophyll (mm) (N = 5) | Pollen grains/ microsporophyll (N = 5) |
|---|---|---|---|---|---|---|---|---|
| 900 m asl | | | | | | | | |
| 1 | 31 | 60.45 | 43 | 704 ± 101.37 | 98.6 ± 10.92 | 101.2 ± 4.48 | 2.9 ± 0.18 | 5982.6 ± 42.59 |
| 2 | 32 | 61.25 | 39 | 620 ± 98.26 | 103.4 ± 13.65 | 121.0 ± 10.14 | 3.0 ± 0.15 | 6242.6 ± 61.26 |
| 3 | 34 | 66.82 | 54 | 515 ± 119.35 | 112.8 ± 12.59 | 109.4 ± 12.89 | 2.7 ± 0.16 | 5358.0 ± 38.13 |
| 1400 m asl | | | | | | | | |
| 1 | 32 | 62.45 | 42 | 520 ± 86.15 | 101.2 ± 12.57 | 110.2 ± 8.48 | 3.0 ± 0.18 | 6871.0 ± 43.95 |
| 2 | 33 | 63.85 | 45 | 509 ± 86.15 | 108.4 ± 14.37 | 116.0 ± 12.43 | 2.7 ± 0.21 | 5418.0 ± 28.33 |
| 3 | 35 | 67.42 | 47 | 495 ± 104.17 | 119.0 ± 21.47 | 104.2 ± 18.47 | 2.9 ± 0.26 | 5943.6 ± 30.47 |
| 1900 m asl | | | | | | | | |
| 1 | 30 | 60.42 | 41 | 510 ± 70.14 | 102.1 ± 10.15 | 112.0 ± 7.17 | 2.4 ± 0.17 | 5215.0 ± 21.32 |
| 2 | 31 | 62.82 | 43 | 492 ± 76.23 | 107.1 ± 11.14 | 119.1 ± 10.14 | 2.7 ± 0.15 | 5304.0 ± 24.33 |
| 3 | 33 | 68.45 | 45 | 487 ± 84.12 | 112.1 ± 12.12 | 101.1 ± 12.14 | 3.0 ± 0.21 | 6231.0 ± 37.34 |

**Table 3** Total production data for each tree

| Altitude/ Tree no. | Crown Height | Crown diameter | Strobili group ($\times 10^3$) | Strobili ($\times 10^3$) | Microsporophylls ($\times 10^3$) | Pollen grains ($\times 10^9$) | Microsporophylls/strobili group | Pollen grains/strobili group ($\times 10^3$) | Pollen grains/ strobilus ($\times 10^3$) | Pollen grains/ meter of crown diameter ($\times 10^8$) |
|---|---|---|---|---|---|---|---|---|---|---|
| 900 m asl | | | | | | | | | | |
| 1 | 15.0 | 8.6 | 30.3 | 2984.8 | 302 063.7 | 1807.1 | 9978.3 | 59 696.6 | 605.4 | 2101.3 |
| 2 | 16.6 | 9.1 | 24.2 | 2500.2 | 302 525.7 | 1888.5 | 12 511.4 | 78 103.8 | 755.4 | 2075.3 |
| 3 | 15.7 | 8.2 | 27.8 | 3137.0 | 343 484.3 | 1838.8 | 12 340.3 | 66 119.4 | 586.2 | 2242.4 |
| 1400 m asl | | | | | | | | | | |
| 1 | 15.3 | 8.7 | 21.8 | 2210.2 | 243 564.9 | 1673.5 | 11 152.2 | 76 627.6 | 757.2 | 1923.6 |
| 2 | 16.0 | 9.8 | 22.9 | 2482.9 | 288 016.6 | 1560.5 | 12 574.4 | 68 128.1 | 628.5 | 1592.3 |
| 3 | 15.8 | 8.4 | 23.3 | 2768.5 | 288 481.4 | 1714.6 | 12 399.8 | 73 699.7 | 619.3 | 2041.2 |
| 1900 m asl | | | | | | | | | | |
| 1 | 14.8 | 8.4 | 20.9 | 2135.7 | 239 203.7 | 1247.5 | 11 439.7 | 59 657.9 | 584.1 | 1485.1 |
| 2 | 15.4 | 7.9 | 21.2 | 2266.2 | 269 976.1 | 1431.9 | 12 761.2 | 67 685.4 | 631.9 | 1812.5 |
| 3 | 15.7 | 8.2 | 21.9 | 2457.8 | 248 578.6 | 1548.9 | 11 342.9 | 70 677.3 | 630.2 | 1888.9 |

### *Total production*

In *P. roxburghii* the amount of pollen production varied considerably at different altitudes. Primarily the number of strobili groups per tree was higher in the trees of lower altitudinal site (900 m asl) and lower at the higher altitudinal site (1900 m asl). This pattern determined the total production of strobili per tree and microsporophylls per tree at all the three altitudes. This in turn varied the values of total pollen production per tree and pollen grains per meter of crown diameter at all the three altitudes. It can therefore be concluded that *P. roxburghii* produced higher pollen production per tree at the lower altitudinal site but lower pollen production at the higher altitudinal site (Table 3).

The total production of strobili per tree varied between $2135.7 \times 10^3$ (1900 m asl) to $3137.0 \times 10^3$ (900 m asl), microsporophylls per tree between $239\ 203.7 \times 10^3$ (1900 m asl) to $343\ 484.3 \times 10^3$ (900 m asl) and total number of pollen grains per tree from $1247.5 \times 10^9$ (1900 m asl) to $1888.5 \times 10^9$ (900 m asl). The total production of pollen grains per tree for each meter of crown diameter varied from $1485.1 \times 10^8$ at 1900 m asl to $2242.4 \times 10^8$ at 900 m asl.

### *Correlation between the number of pollen grains per microsporophyll and the length of the microsporophyll*

The length of microsporophylls in *P. roxburghii* averaged between $2.04 \pm 0.17$ to $3.02 \pm 0.18$ mm (Figure 2). After observing 45 microsporophylls of nine trees (five microsporophylls of each tree), we achieved a significant positive correlation ($r = 0.8045$, $p = 0.000$ probability level) between the length of the microsporophyll (independent variable, x) and total number of pollen grains per microsporophyll (dependent variable, y). A higher value of regression coefficient $r^2 = 0.6992$, $p = 0.000$ probability level) was recorded between the length of microsporophylls and the decimal logarithm of the number of pollen grains, which indicated the exponential ratio between the two. The linear regression calculated between the length of the microsporophylls (x) and the number of pollen grains they contain (y) yielded the equation $\log y = 3.4559 + 3.0072x$.

### *Correlation between the ratios of grains/microsporophyll, grains/strobilus, grains/strobili group, grains/tree, microsporophylls/strobilus, microsporophylls/strobili group, microsporophylls/tree, strobili/strobili group, strobili/tree, and strobili groups/tree*

When correlated differentially with each other, the production units showed a significant ($p < 0.05$) positive and linear correlation between the number of grains per microsporophyll vs. grains per strobilus (0.7324), grains per strobilus vs. grains per strobili group (0.8048), grains per tree vs. microsporophylls per tree (0.6989), strobili per tree (0.7141) and strobili groups per tree (0.7208); microsporophylls per tree vs. strobili per tree (0.8690) and strobili groups per tree (0.7978); and between the strobili per tree vs. strobili groups per tree (0.8842). The details are given in Table 4.

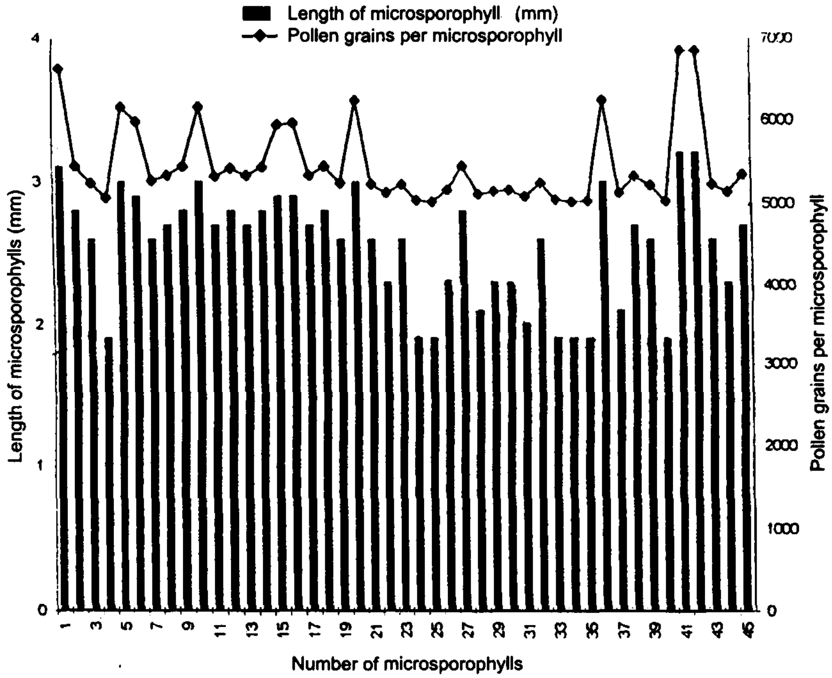


**Figure 2** Relationship between the number of pollen grains per microsporophyll and the length of microsporophylls

After calculating logarithms between each production unit the aforementioned correlations were maintained but this time negative significant correlations were also obtained. For example the number of pollen grains per microsporophyll decreased significantly with increasing numbers of microsporophylls per strobilus, number of microsporophylls per strobili group and hence microsporophylls per tree. Similarly, the number of pollen grains per strobilus decreased significantly when there was an increase in the number of strobili per strobili group, strobili per tree and strobili groups per tree. In the same way, the number of grains per strobili group decreased significantly when the number of strobili per tree or strobili groups per tree increased. The number of microsporophylls per strobilus decreased significantly when the number of strobili per tree or the number of strobili groups per tree increased. The negative correlations were also obtained between the number of microsporophylls per strobili group and between the number of strobili groups per tree, and also between the number of strobili per strobili group and the number of strobili groups per tree. This type of ratio which is obtained by using logarithmic values, and in which by increasing one value the other decreases, carries out a hyperbolic function.

**Table 4** Correlation coefficients between the production rates of pollen grains (grn.), microsporophylls (micr.), strobili (str.) and strobili group (str. grp.) per superior production unity. (Each pair of data represents correlation coefficient r and probability p)

| Variables | log (grn./micr.) | log (grn./str.) | log (grn./str. grp.) | log (grn./tree) | log (micr./str.) | log (micr./str. grp.) | log (micr./tree) | log (str./str.grp.) | log (str./tree) |
|---|---|---|---|---|---|---|---|---|---|
| log (grn./str.) | 0.7324<br>*0.8647* | - | - | - | - | - | - | - | - |
| log (grn./str. grp.) | 0.5987<br>*0.9338* | 0.8048<br>*0.8000* | - | - | - | - | - | - | - |
| log (grn./tree) | 0.4955<br>*0.3014* | 0.4074<br>*0.3854* | 0.4262<br>*0.2654* | - | - | - | - | - | - |
| log (micr./str.) | - 0.3671<br>*0.3222* | 0.3450<br>*0.2484* | 0.1819<br>*0.3632* | - 0.1632<br>*0.0495* | - | - | - | - | - |
| log (micr./str. grp.) | - 0.4526<br>*0.6895* | 0.1346<br>*0.5513* | 0.4311<br>*0.7307* | - 0.0913<br>*0.1496* | 0.7124<br>*0.5682* | - | - | - | - |
| log (micr./tree) | - 0.2647<br>*0.6889* | - 0.1632<br>*0.8176* | - 0.0807<br>*0.6291* | 0.6989<br>*0.5212* | 0.1088<br>*0.1695* | 0.2071<br>*0.4108* | - | - | - |
| log (str./str. grp.) | - 0.2901<br>*0.3355* | - 0.3383<br>*0.2594* | 0.2774<br>*0.3776* | 0.0056<br>*0.0525* | - 0.2081<br>*0.9779* | 0.5297<br>*0.5868* | 0.1681<br>*0.1778* | - | - |
| log (str./tree) | - 0.0874<br>*0.3580* | - 0.3416<br>*0.4517* | - 0.1477<br>*0.3173* | 0.7141<br>*0.9062* | - 0.3809<br>*0.0631* | - 0.1191<br>*0.1835* | 0.8690<br>*0.5995* | 0.3081<br>*0.0667* | - |
| log (str. grp./tree) | 0.0509<br>*0.4738* | - 0.2179<br>*0.5836* | - 0.3174<br>*0.3173* | 0.7208<br>*0.7454* | - 0.3312<br>*0.0948* | - 0.4141<br>*0.2575* | 0.7978<br>*0.7498* | - 0.1586<br>*0.0910* | 0.8842<br>*0.8358* |

## Discussion

The efficiency of wind pollination is generally assumed to decrease as the concentration of airborne pollen decreases (Regal 1982, Whitehead 1983). This low efficiency may be due to low pollen production by individuals, large distances between conspecifics and poor pollen dispersal. These conditions are assumed to affect both ovule fertilisation and seed production negatively (Allison 1990). Therefore, since the production of seeds often depends on the production of pollen, it is most important to have an estimate of the total pollen production per plant (Faegri & Iversen 1989, Cour & van Campo 1980).

As each strobilus usually possessed a number of microsporophylls, and each shoot many flowers, the figures for total production reached enormous dimensions. Forest trees produce great quantities of pollen. A male strobilus of *P. contorta* contains almost 600 000 pollen grains, and a shoot may contain 8–9 million grains (Ho & Owens 1973). The environmental factors influencing the pollen production of a variety of deciduous trees, spruce and pine were reported by Scamoni (1955). The author reported considerable variations in pollination period, amount of pollen and the year of maximum pollen production among several species.

The variations in pollen production rates observed in the present study were also reported by other workers from India (Nair & Rastogi 1973, Agnihotri & Singh 1975, Janaki & Subba 1980, Subba & Reddi 1986) and other countries (Pohl 1937a, b, Erdtman 1943, Sarvas 1962, Smart *et al.* 1979). Smart *et al.* (1979) suggested that such variations can be related to the mode of reproduction.

The level of pollen production in a particular species is a function of its genotype (Subba & Reddi 1986) and the amount of pollen grains per microsporophyll may be genetically fixed (Joppa *et al.* 1968). In *P. roxburghii,* the trees which grow naturally under different altitudinal conditions showed variations in pollen production because the total production of microsporophylls, strobili and strobili groups per tree varied considerably from lower to higher altitudes. The variation in pollen production in this species at different altitudes may be attributed to the variations in environmental conditions.

The sizes of the microsporophylls and the number of pollen grains they contained were compared and correlated in different species by several workers (Agnihotri & Singh 1975, Subba & Reddi 1986). As per the data of the present study this ratio is exponential and can be calculated by the formula: $y = 2857.09 + 1016.74^x$.

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