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Short Communication

Pollen production in *Pinus roxburghii* Sargent

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Pinus roxburghii, an anemophilous tree is characterised by high pollen production, as the vector of pollination it employ is extremely haphazard and not specific. Although a tree's total production of pollen grains is influenced by various factors [1], which also varies from one year to the next [2], it is most important to have an estimate of the total production of pollen per tree, not only from an aerobiological but also from a breeding stand point, as the production of seeds often depends on the production of pollen [3, 4]. Therefore, Holm [5] has demonstrated that, by adding a supplementary amount of pollen to *Betula sp.* an increase in the quantity of seed produced can be obtained.

The available literature on pollen production in Gymnospermous taxa is still meagre. However, some workers [6-11] gave the figures of pollen production per microsporophyll, strobili, strobili groups and branch in some anemophilous species. Fewer are the studies which give information about the total amount of pollen produced per tree [12-14] principally due to the arduous task of quantifying the total number of anthers per plant [15]. We report here the pollen production figures for Pinus *roxburghii*, an anemophilous tree species and give particulars regarding anther number, anther length, tree height and dbh, crown length and diameter and correlation of these indices alongwith approximate age of the trees.

Ten representative trees (first five young i.e., 20-25 years old and rest five 50-60years old) were selected in the natural chir-pine forest of Ashtabakra (900 m. asl.) in Pauri Garhwal (lat. 29° 20' to 30° 15'N and long. 78° 10' to 79° 20' E). Only those isolated trees were selected which were good in shape and sound in health. The height, dbh and dimensions of the crown, of those trees were further measured.

The *Pinus roxburghii* has a high number of strobili groups arranged mainly on the main branches of the crown. First the main branches were counted and then a random sample of five branches was selected and a count was taken of all their strobili groups. In all, twenty strobili groups, scattered throughout the tree, were selected and the number of strobili per strobili group were counted for each tree. A strobilus was chosen from the middle part of each strobili and the number of microsporophylls were counted manually. The data obtained are presented in Table 1.

The pollen grains were counted as per Cruden [16]. In order to estimate total production of pollen grains per tree, first the total number of microsporophylls per tree were calculated by multiplying the total number of strobili groups with 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. To establish the relationship between different indices, the correlation coefficients were calculated as per Freese [17].

The dimensions of the trees studied (tree height, dbh, crown length and crown diameter) appear in columns 2 and 3 of table 1 and 2 respectively. The number of strobili groups, strobili, microsporophylls and pollen grains per microsporophyll varies considerably from tree to tree. The number of strobili groups per terminal branch varies from 113.2 ± 11.81 to 1346.8 ± 262.51, whereas number of strobili per strobili group from 77.6 ± 17.65 to 137.8 ± 11.16, number of microsporophylls per strobilus from 101.2 ± 4.49 to 145.4 ± 4.52 and number of pollen grains per microsporophyll from 5046 ± 27.95 to 6851 ± 23.95 in the representative trees.

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The total production of strobili groups per tree ranged between 3400 to 60600 (Table 2). Similarly the total number of strobili per tree between 389.4 $\times$ 10^3 to 5709.09 $\times$ 10^3, microsporophylls per tree between 46414.1 $\times$ 10^3 to 577759.42 $\times$ 10^3. The total number of pollen grains per tree varied from 239.29 $\times$ 10^9 to 3456.52 $\times$ 10^9. The total production of pollen grains per tree, when divided by the diameter of the tree crown, an estimate of the quantity of pollen grains produced per tree, regardless of the size of the tree crown, was obtained. This value deviated from 427.25 $\times$ 10^8 in tree number 1, to 3323.58 X 10^8 in tree number 7 (Table 2). The total production of the strobili groups, strobili, microsporophylls and pollen grains per tree in tree numbers 1 and 7 were minimum and maximum respectively due to the smallest and largest dimensions of the crown.

Correlation between the number of pollen grains per microsporophyll and the length of microsporophyll.

The average length of the microsporophylls (Table 1) varied between 1.9 ± 0.11 and 3.2 ± 0.14 mm. A positive significant correlation ($r = 0.8001$, $p \leq 0.001$) has been observed between the length of the microsporophylls and total number of pollen grains produced per microsporophyll. If we calculate the correlation between the length of microsporophylls and the decimal logarithm of the number of pollen grains, we obtain a higher value ($r = 0.8346$, $p \leq 0.001$), which indicates an exponential ratio between the two. When the number of pollen grains per microsporophyll was regressed on the length of the microsporophyll, it was found to be highly significant ($p \leq 0.001$). By calculating coefficient of determination it was found that about 64 percent of the variation in the former was associated with the latter character.

Correlation between the crown length, crown diameter, tree height and the production of strobili groups, strobili, microsporophylls and pollen grains:

The total production of strobili groups, strobili, microsporophylls and pollen grains are all correlated, as one is multiplied by the next to obtain the total production (Table 3).

The length of the tree crown has a positive significant correlation ($p \leq 0.05$) with the total number of strobili groups, strobili, microsporophylls and pollen grains per tree. Moreover, the highest significant positive correlation ($p \leq 0.01$) has been observed between diameter of the tree crown and the production of strobili groups, strobili, microsporophylls and pollen grains. The height of the tree on the other hand, though has a positive correlation, it is not significant ($p \geq 0.05$) and weaker than that with the crown length and diameter.

The information on the total pollen production per tree is useful in order to estimate the number of pollen grains that could be in the air during a certain season, and to understand the pollination behaviour of any species. It can also be used as an estimate of the production of seeds (12, 18), as efficiency of anemophilous pollination decreases with the reduction in the concentration of airborne pollen [19].

Erdtman [7] and Pohl [6] gave values of pollen production per strobilus for *Pinus sylvestris* as 158 x 10^3 and 152-162 x 10^3 respectively. Whereas, Molina *et al.* [14] had reported the values of pollen production for *Pinus pinaster* between 244 $\times$ 10^3 and 280 $\times$ 10^3 per strobilus, between 3600 $\times$ 10^3 and 4500 $\times$ 10^3 per strobili group and 2.09 $\times$ 10^{10} to 3.23 $\times$ 10^{10} pollen grains per tree. However, in this study the pollen production values for *Pinus roxburghii* ranged

Table 1. The production of strobili groups/branch, strobili/strobili group, microsporophylls/strobilus and pollen grains/microsporophyll in relation to tree height and dbh in *P. roxburghii*

Tree No.	Height (m)	Diameter dbh (cm)	No. of branches	No. of strobili groups/branch	No. of Strobili/strobili group	No. of microsporophylls/ Strobilus	Microsporophylls length (mm)	Pollen grains/ microsporophyll
1	20	34.20	29	134.0 ± 11.77	100.2 ± 10.74	119.2 ± 3.07	2.3 ± 0.19	5155.00 ± 21.32
2	20	42.16	34	481.6 ± 44.21	106.4 ± 10.08	104.2 ± 2.44	2.7± 0.16	5318.00 ± 28.23
3	21	35.00	32	359.1 ± 67.24	77.6 ± 17.65	117.0 ± 2.78	2.9 ± 0.17	5952.67 ± 30.41
4	21	35.79	30	113.2 ± 11.81	120.4 ± 6.47	134.2 ± 3.98	2.6 ± 0.13	5225.00 ± 27.21
5	22	36.99	32	313.4 ± 50.77	129.2 ± 17.12	142.8 ± 3.60	3.1 ± 0.12	6628.00 ± 20.24
6	30	60.45	43	723.0 ± 101.37	95.6 ± 10.92	105.0 ± 2.30	2.0 ± 0.21	5070.00 ± 28.53
7	31	59.47	45	1346.8 ± 262.51	94.2 ± 5.24	101.2 ± 4.49	2.9 ± 0.18	5982.63 ± 42.59
8	31	61.25	54	218.2 ± 34.22	103.4 ± 13.65	109.4 ± 2.89	3.0 ± 0.15	6232.61 ± 37.37
9	32	62.84	34	620.4 ± 56.30	137.8 ± 11.16	121.0 ± 10.43	3.2 ± 0.14	6851.00 ± 23.95
10	33	66.82	47	212.4 ± 14.92	112.8 ± 12.59	145.4 ± 4.52	1.9 ± 0.11	5046.00 ± 27.95

Table 2. The production of strobili, strobili groups, microsporophylls and pollen grains per tree in relation to crown length and crown diameter in *P. roxburghii*

Tree No.	Crown length (m)	Crown diameter (m)	Strobili group ($\times 10^3$)	Strobili ($\times 10^3$)	Microsporo-phylls ($\times 10^3$)	Pollen grains ($\times 10^6$)	Microsporo-phylls/strobili group	Pollen grains/ strobili group ($\times 10^3$)	Pollen grains/ strobilus ($\times 10^3$)	Pollen grains/ meter of crown dia. ($\times 10^8$)
1	5.2	5.6	3.9	389.4	46414.10	239.29	11943.84	61566.17	614.48	427.25
2	7.4	5.8	16.4	1742.2	181541.41	965.44	11086.88	58960.03	554.14	1664.60
3	6.8	5.6	11.5	891.7	104331.24	621.05	9079.2	54044.29	696.46	1109.00
4	5.3	5.7	3.4	408.9	54871.70	286.71	16157.68	84423.88	709.20	503.00
5	8.2	7.4	13.2	1709.2	244068.2	1617.68	18449.76	95773.01	856.34	2186.05
6	16.2	8.4	31.1	2972.1	312071.55	1582.20	10038.00	50892.66	532.35	1883.60
7	17.4	10.4	60.6	5709.9	577759.42	3456.52	9533.04	75032.65	605.44	3323.58
8	15.0	7.8	11.8	1218.3	133286.4	830.72	11311.96	70503.04	681.85	1065.02
9	16.6	9.1	21.1	2906.7	351710.7	2409.57	16673.80	114232.2	828.97	2647.90
10	15.7	8.0	7.9	1126.1	163729.12	826.18	16401.12	82760.05	735.14	1032.70

Table 3. Correlation between strobili groups (inflor.), Strobili (flowers), microsporophylls (anthers) and pollen grains per tree with crown length, crown diameter and the tree height in the studied trees

Variables	Crown length				Crown diameter				Tree height			
	r	F	cd	p	r	F	cd	p	r	F	cd	p
Strobili groups/tree	0.6265	5.1680	0.3925	<0.05	0.7852	12.8457	0.6165	<0.01	0.4614	2.1635	0.2129	>0.05
Strobili/tree	0.6782	6.8144	0.4599	< 0.05	0.8437	19.7696	0.7118	<0.01	0.5180	2.9342	0.2683	>0.05
Microsporophylls/tree	0.7165	8.4399	0.5134	< 0.05	0.8904	30.6042	0.7928	<0.01	0.5680	3.8113	0.3226	>0.05
Pollen grains/tree	0.6690	6.4823	0.4476	< 0.05	0.8586	22.4498	0.7372	<0.01	0.5232	3.0160	0.2737	>0.05

r = Correlation Coefficient
F = Analysis of Variance (ANOVA)
R^2 = Coefficient of Determination
p = Level of Significance

between 532×10^3 to 856×10^3 per strobilus, between 50892×10^3 to 114232×10^3 per strobili group and 2.39×10^{11} to 3.46×10^{12} pollen grains per tree.

The correlation between the size of the anthers and the quantity of pollen grains they contain has already been demonstrated by other authors (9, 11). However, this ratio is not linear, but rather exponential. The existence of a hyperbolic ratio between the relative productions of the different aspects of production (anther, flower, inflorescence, tree) leads us to believe that in the anemophilous arboreal species, there is a constant value for pollen production. As the number of pollen grains per anther, anther per flower, flower per inflorescence and inflorescences per tree varies considerably, there is a tendency to compensate by increasing one or reducing other, so that the resulting product is generally within some defined margins, which was also supported by the findings of Molina *et al.* (14). Thus some species would have a tendency to increase the number of inflorescences in order to compensate for the small number of flowers per inflorescence or anthers per flower or grains per anther.

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