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Pollen Production and dispersion in Pinus roxburghii

Vinod Prasad Khanduri

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Abstract - Pollen dispersion and frequency of flowering were studied in natural population of Pinus roxburghii Sargent at altitudes between 1600 and 1900 m asl in the Tehri forest division of Garhwal Himalaya. Temporal variations for pollen cone and male strobilus production were observed with a year of bumper production. An individual tree produced $14.96 \times 10^{11} \pm 2.64 \times 10^{11}$ pollen grains with the range of variation in the population between $12.95 \times 10^{11}$ and $19.09 \times 10^{11}$ pollen grains. Dispersion of pollen grains from the fringe of forest declines sharply with distance. The results eventually imply that a segregation barrier of 640 m would be minimal for the management of chir-pine seed orchard at the study location.

Key words: Chir-pine, pollen cone, gene flow, Himalaya

1. Introduction

Pinus roxburghii Sargent, commonly known as Chir-pine or Himalayan Long needle pine, covers a wide range of distribution in Himalaya as pure forests between 450 -2300 m. asl. The species also occurs in association with other coniferous and broad-leaved species, such as Cedrus deodara (Roxb.) G.Don, Lyonia ovalifolia (Wall.) Drude, Myrica
esculanta Buch.-Ham. ex D. Don, Pinus wallichiana A. B. Jacks, Quercus leucotrichophora A. Camus ex Bahadur and Rhododendron arboreum Sm. etc. towards its upper limit, and Anogeissus latifolia (Roxb. ex DC.) Wall. ex Bedd., Bauhinia variegata L., Ougeinia oojinenses (Roxb.) Hochr. and Shorea robusta Gaertn. towards the lower limit. At upper elevations it favors warmer slopes and drier spurs. Several characteristics such as high regeneration potential (Kumar and Bhatt, 1990), ability to inhabit on degraded habitats (Joshi, 1990), fast growth (Misra and Lal, 1984), straight cylindrical bole and high volume returns (Singh, 1979) and capability to yield substantial quantity of resin (Deshmukh, 1966) make this species a valuable reserve in Himalayan region. It has immense significance in the Indian economy, since the resin it yields has varied uses in a variety of industries.

The conversion from the vegetative to the reproductive stage is one of the important morphogenetic events in the lifespan of a long lived tree species. It carries multiple changes in the metabolism, and stimulates numerous decisive processes linked with the commencement of sexual reproduction and alternation of generation (Chailakhyan, 1968). During alteration from vegetative to reproductive phase, the cells accountable for the development of sex organs attain extremely diverse biochemical capacities than those of the vegetatively growing apical meristems (Zeevaart, 1976; Chailakhyan, 1979), resultant to which formation of reproductive buds begin and the initiation of reproductive structures of different sexes sets in. Further, the male and female plants/flowers also differ from each other in possessing a few specific macromolecules, which constitute the molecular markers or probes of differentiation (Jaiswal and Kumar, 1983).
Pines are anemophilous and monoecious, that is the male and female reproductive structures are borne on the same tree but are separated in space. Wind-borne pollen offers homogeneity among populations and undertakes that most patterns of geographic variation will be clinal (Ledig, 1998). The outlook of pollen supply directs to incredible outcome that each tree is expected to be pollinated largely by its neighbour. For example, Colwell (1951) calculated that more than 90% of the pollinations on a known tree would come from the adjoining trees on its windward side. Contrary to this, Koski (1970) found that a single Pinus sylvestris L. tree would account about 10% of the pollen received by a close neighbour. Although half of the pollen received by a given tree in P. sylvestris stands, perhaps derives from trees within a 50 m radius, that area would confine at least 25-30 trees (Koski, 1970). Thus gene flow, through pollen exchange in Pinus is so great that recombination is maximized within a population, and random genetic drift which leads to segregation among populations, is retarded. High levels of recombination produce required variation to adjust to altering conditions. Dispersion of pollen is an inactive process which depends on pollen production values of a tree, sunshine, wind, humidity, rain, etc. Pollen production varies from tree-to-tree, location-to-location, year-to-year, species to species and age of the tree. Gene movements in forest trees entails both pollen and seeds (Smouse and Sork, 2004), which is responsible to genetic connectivity among individuals in populations and established genetic diversity in the population (Sork and Smouse, 2006). Pollen dispersion is the movement of male gamete and its pattern significantly influence the genetic structure and effective size of plant populations (Sousa and Hattemer, 2003). Additionally, the extents of pollen immigration also determine the rate of contamination to a isolated population. Pollen gene flow is one
of the most important factors influencing genetic structure of wind pollinated forest trees (Burczyk et al., 2004). Wind borne pollen of broadly distributed tree species has the potential to travel dozens or hundreds of kilometers (Lindgren et al., 1995; Di-Giovanni et al., 1996; Rogers and Levetin, 1998). However, sterile or unviable pollens which are light in weight can move for long distances (< 2 km) (Erdtman, 1943). Such distant dispersal of pollen is not of much interest in pollination ecology, but the area of huge pollen deposition from the source is of great interest (Faegri and van der Pijl, 1979). Therefore, it is important to know the successful long distance dispersal of pollen grains or what is the distribution of effective pollen distances. An attempt has been made in this communication to discover the effective pollen distribution distances and pattern and level of pollen output per tree in *P. roxburghii* during four consecutive years.

2. Materials and Methods

This study was conducted during four consecutive years in January, February and March, 2013, 2014, 2015, and 2016, in the chir-pine forests of Ranichauri, Tehri Forest division at altitude range of 1600 and 1900 m asl (Latitude 30° 18’ N, Longitude 78° 24’ E) (Fig 1). The study location is situated in the central part of Western Himalaya. The mean annual temperature and total annual rainfall at the study location is 14.2±2.06°C and 1785.00 mm, respectively.

Assessment of reproductive phenology

To monitor the development of pollen and seed cones, long shoots containing pollen and seed cone buds were randomly sampled from twenty-five different trees at weekly intervals from mid-January to Mid-February; and two times per week between mid-February and March, until pollination ended. To observe pollen development, individual
microsporangia were dissected from the fresh pollen cones of several trees. Individual microsporangia were squashed in acetocarmine on microscope slides, cover slips were applied and the slides were heated to intensify staining (Johansen, 1940) and the pollen grains were assessed using binocular microscope.

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Twenty five candidate trees from the natural forest were selected and marked by yellow paint. These trees were considered as a representative individuals for every year of sampling. The trees were selected with the criteria of height, diameter and maturity on the basis of check tree or comparison tree method. The selected candidate trees represent the whole study area of about 10 hectare. In order to estimate the production traits in each candidate tree, first the main branches were counted, and then a sample of ten branches were selected randomly, and all the pollen cones were counted. Further, fifty pollen cones, scattered throughout the tree were harvested and the number of pollen strobili per pollen cone were counted for each tree. Apart from each pollen cone, pollen strobili were chosen from the lower, middle and upper parts, and the numbers of microsporangia were counted manually. The assessment pollen grains were done on five microsporangia from different pollen strobili of each tree which had been previously measured. Basically, the method used was that of Molina et al. (1996). In order to estimate total production of pollen grains per tree, first the total number of microsporangia per tree were calculated by multiplying the total number of pollen cones by the average number of pollen strobili per pollen cone, and then by the average number of microsporangia per pollen strobilus. The result was then multiplied by the average number of pollen grains produced per microsporangium.
Statistical analysis

The effect of years and altitudes on the number of Pollen cones and pollen strobili per tree, microsporangia and pollen grains per tree were analyzed by means of split-plot ANOVA with nesting. Years and altitudes were examined as fixed effects. Counts were log transformed in order to improve normality of residuals and to reduce heteroscedasticity (Sokal and Rohlf, 1995). ANOVA was performed using the SPSS version 14.

Observations on the pollen dispersion

Pollen dispersion through the air was recorded by using jelly coated microscopic slides. Ordinary microscopic slides covered with thin coat of petroleum jelly or Vaseline, were used as pollen traps. The slides were mounted vertically on wooden roads of 1.5 m height and were placed to all around the source tree at geometrically increasing distances that is, 0, 05, 10, 20, 40, 80, 160, 320, and 640 m. The pollen trap or slide was unprotected and exposed to the air throughout the period of observations. The slides were set out between 9:00 – 10:00 am from the fringe of the forest in two possible directions (horizontal and uphill direction) and collected after 24 hours. The pollen count was made directly from exposed glass slides under a binocular microscope, the area counted per slide was fixed that is 1 cm² (1 cm × 1 cm). The experiment was repeated in open conditions so as to assess the efficiency of pollen flow inside the forest.

Mathematical treatment of pollen dispersion data

Pollen dispersion distances are best presented in terms of a curve. Bateman (1947) found that the function \( F=\text{Fo}e^{-kD} \) fitted dispersion data well (Formula 1, below). In this formula \( F \) and \( \text{Fo} \) are pollen frequencies at distance \( D \) and 0, respectively, and \( e \) is the
base of the natural logarithms. If the curve is reduced to a straight line, the quantity k is the slope.

\[ F = f(D) = F_0 e^{kD} \]  

The logarithmic transformation of \( \log_{10}e \) is:

\[ \log F = \log F_0 - (\log_{10}e)^kD \]
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3. Results

The first step in sexual reproduction is the initiation of floral buds. In \textit{Pinus roxburghii} pollen cone bud initiation was recorded in the last week of January with 26-33 days required for complete maturation. However the initiation of ovulate strobili was recorded in the first week of March, reaching full receptivity within one week and remaining receptive for up to 5 days.

The number of pollen cones, pollen strobili, microsporangia and pollen grains per microsporophyll oscillated considerably among trees in the population and varies considerably from one year to the next. The number of branches which produced the pollen cones per tree in the years 2013, 2014, 2015, and 2016 varied from 27 to 48. The diameter and height of the selected trees was oscillating between 71.00 cm and 86.00 cm and 34 and 41 m, respectively. The number of pollen cones per terminal branch and pollen strobili per pollen cone varied from 498 \( \pm 21.52 \) (year 2015) to 734.0 \( \pm 114.37 \) (year 2014) and 79.4 \( \pm 14.24 \) (year 2015) to 121.15 \( \pm 15.12 \) (year 2014), respectively. Among the four studied years, the year 2014 was recorded as the highest production year.
as compared to that of 2013, 2015 and 2016. The number of microsporangia per pollen strobilus oscillated from 109.2 ±6.47 to 129.13 ± 14.14. Similarly the number of pollen cones and pollen strobili per tree varied from $19.18 \times 10^3$ to $35.30 \times 10^3$ and $2489.58 \times 10^3$ to $3278.56 \times 10^3$, also in the years 2015 and 2014, respectively. The number of microsporangia per tree deviated from $325637.22 \times 10^3$ in the year 2015 to $383656.9 \times 10^3$ in the year 2014, respectively, averaged among the representative trees for the studied years. The production of pollen grains per microsporangium deviated between $5269.72 \pm 61.24$ to $6901 \pm 122.17$. Ultimately the number of pollen grains per tree ranged between $1295.9 \times 10^9$ in the year 2015 and $1908.51 \times 10^9$ in the year 2014.

In *P. roxburghii*, the number of pollen cones, pollen strobili, microsporangia and pollen grains per tree varied considerably in years and within the population. The analysis of pollen production per tree revealed significant year (F=44.45, p=0.0014), individuals (F=68.24, p=0.0001), and year x individuals (F=29.94, p=0.0076), interactions. There were also significant differences among years, individuals and year x individuals interactions in number of pollen cones (F=16.25, p=0.0025, F=28.46, P= 0.0001and F=9.78, p=0.0056, respectively), pollen strobili (F=19.56, p=0.0034, F=37.62, P= 0.0001and F=14.37, p=0.0047, respectively) and microsporangia (F=32.25, p=0.0024, F=54.74, P= 0.0001 and F=19.62, p=0.0062, respectively) per tree.

The data on pollen migration from the source revealed that the pollen frequencies were highest in all directions near the source trees. The distribution of the majority of pollen grains from the source was observed up to 40 m towards uphill and horizontal directions. The frequencies of pollen grains to the source frequency at these distances were 28.83 and 23.34, respectively. The results also revealed that the pollen grains could...
travel up to 320 m and 640 m in the uphill and horizontal directions, respectively (Fig. 2).
The averages of pollen to source frequency at these distances were 2.35% and 2.16% respectively.

4. Discussion

Flower formation starts when a vegetative meristem suddenly changes its pattern of division to produce beginnings of floral organs and appendages. This change is influenced by a number of factors, however, specifics are lacking on the internal control, which cause one meristem to produce a flower and another to remain vegetative (Schopmeyer, 1974). Climatic factors influence the anthesis, androecia protrusion and anther dehiscence, and hence pollen release, in a different way in *P. roxburghii* air temperature must exceed (20°C) and relative air humidity must remain below 85% to begin the process of anthesis. However, high relative air humidity favours androecial protrusion. Anther dehiscence and pollen release are also affected by relative air humidity. Anthesis also shows a diurnal periodicity, every day from 0600 hr to 1800 hr, however, anthesis is not affected by the presence or absence of the light at all (Khanduri and Sharma, 2000).

The analysis of pollen production clearly indicate that there is temporal and tree to tree variation in pollen production in *P. roxburghii*, which ultimately suggest that climatic conditions along with genetic makeup of individual tree plays a significant role in this variation. The bumper pollen yield was observed in the years 2014.

In forest trees, determination of the extent of pollen migration is important because trees are sessile and the gene flow of interest is valuable to know the background of external pollen sources into the seed orchards. Gene flow from unselected, background
pollen sources into a seed orchard results pollen contamination, which affects the genetic quality of seed yield. The intensity of pollen contamination varies with the species, mating pattern of the species, synchrony in reproductive phenology of the trees of within and outside-seed orchard, size of seed orchard and its background population, the extent of isolation and environmental conditions. A number of studies have reported pollen contamination for several species with the rate of contamination varying from almost 0 (El-Kassaby and Ritland, 1986) to 90% (Fast et al., 1986; Kaya et al., 2006). The rate of contamination may vary from one year to the next for example in Douglas-fir seed orchard the contamination rate in one year was 44% and in the next consecutive year was 89 % (Fast et al 1986). Contrary to this, regular level of contamination between 69 and 71% over a period of three years was recorded in a Norway spruce seed orchard (Fast et al 1986). Contamination affects genetic gain, genetic quality and genetic diversity by different ways, as by increasing pollen contamination the Genetic gain of the seed crop decreases (Wheeler and Jech, 1986) and genetic diversity increases up to a certain level (Lindgren and Mullin, 1998). High level of pollen contamination may either increase or decrease the genetic diversity of seed crop resultant on the conspecific population and its genetic characteristics (Adams and Kunze, 1996). Under the condition of absolute pollen contamination (100%), half of all genes come from the parents within the orchard because the pollens are the male component of reproductive success (Funda and El-Kassaby, 2012).

The scattering pattern of pollen grains in the population implies successful seed set through mixed mating, as the outcrossing rate in *Pinus* is reported to be high at population level (Sharma et al., 2012). The decrease in pollen concentration with
increasing distance imply reduction in percentage seed set with increasing distance as noted in Douglas fir (Wright, 1953). The amount of pollen scattered over long distances is small in comparison to the magnitude of pollen formed by an individual. The distance wind dispersed pollen travels has been the matter of several investigations and it can be confirmed that a single pollen grain could be carried long distances, however, it is uncertain that it would be viable after such journey (Bateman, 1947). Dispersal varies greatly due to wind, height of vegetation, length of period of release, etc., and the area of pollen coverage could vary between a few and some hundred meters, and under exceptional circumstances be more than a kilometer (Raynor et al., 1969). The results of this study revealed large pollen pool in the population due to copious pollen production per tree, which proclaimed high levels of pollen dispersal for Pinus roxburghii. The estimates of average pollination distances varying between 320 and 640 m. This suggests that trees in Pinus roxburghii mate with a large number of conspecific distributed over a large area in their vicinity. The pollen dispersal distance estimates from this study appear larger than other coniferous tree species, such as 91.4 m for Pinus edulis Engelm., 45.7 m for Pseudotsuga menziesii (Mirb.) Franco, 100.6 m Picea abies (L.) H. Karst., 213.2 m for Cedrus atlantica (Endl.) Manetti ex Carrière. (Wright, 1952), 152.4 m for Pinus elliottii Engelm. (Wang et al. 1960), and 190 m for Cedrus deodara (Roxb. ex D. Don) G. Don (Khanduri and Sharma, 2002). A segregation barrier of 600 m in Pinus roxburghii was also observed by the author at Pauri Garhwal District (Khanduri, 2012). The decline in the frequency of pollen deposition with increasing distance from a pollen source is an issue of utmost importance in the setting up and management of a seed orchard. For example Wright’s (1952) data on Pinus edulis Engelm (Pinyon tree) and
Wang et al. (1960) data on *Pinus elliottii* Engelm (Slash pine), showed a rapid decline in pollen deposition with increasing distances. The occurrence of pollen of Pinyon at 91.4 meter was 1 percent of the frequency at the pollen source, and in the case of Slash pine, it was 2 - 5 percent of the source frequency at 152.4 meter.

5. Conclusions

In *P. roxburghii*, the occurrence of pollen at 640 m was 2.16 percent of the source frequency, which implies that a segregation barrier of 640 m could be used for the establishment of a chir pine seed orchard.

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Fig. 1. Location map of the study site

Fig. 2. Pollen dispersion from source tree in two directions
Pollen Production and dispersion in *Pinus roxburghii*

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The logarithmic transformation of $\log_{10}e$ is:
\[
\log F = \log F_0 - (\log_{10} e)^{kD} = \log F_0 - 0.4343kD
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3. Results

The first step in sexual reproduction is the initiation of floral buds. In *Pinus roxburghii* pollen cone bud initiation was recorded in the last week of January with 26-33 days required for complete maturation. However, the initiation of ovulate strobili was recorded in the first week of March, reaching full receptivity within one week and remaining receptive for up to 5 days.

The number of pollen cones, pollen strobili, microsporangia and pollen grains per microsporophyll oscillated considerably among trees in the population and varies considerably from one year to the next. The number of branches which produced the pollen cones per tree in the years 2013, 2014, 2015, and 2016 varied from 27 to 48. The diameter and height of the selected trees was oscillating between 71.00 cm and 86.00 cm and 34 and 41 m, respectively. The number of pollen cones per terminal branch and pollen strobili per pollen cone varied from 498 ±21.52 (year 2015) to 734.0 ±114.37 (year 2014) and 79.4 ±14.24 (year 2015) to 121.15 ±15.12 (year 2014), respectively. Among the four studied years, the year 2014 was recorded as the highest production year as compared to that of 2013, 2015 and 2016. The number of microsporangia per pollen strobilus oscillated from 109.2 ±6.47 to 129.13 ± 14.14. Similarly, the number of pollen cones and pollen strobili per tree varied from 19.18 x 10^3 to 35.30 x 10^3 and 2489.58 x 10^3 to 3278.56 x 10^3, also in the years 2015 and 2014, respectively. The number of
microsporangia per tree deviated from 325637.22 x 10³ in the year 2015 to 383656.9 x 10³ in the year 2014, respectively, averaged among the representative trees for the studied years. The production of pollen grains per microsporangium deviated between 5269.72 ±61.24 to 6901 ±122.17. Ultimately the number of pollen grains per tree ranged between 1295.9 x 10⁹ in the year 2015 and 1908.51 x 10⁹ in the year 2014.

In *P. roxburghii*, the number of pollen cones, pollen strobili, microsporangia and pollen grains per tree varied considerably in years and within the population. The analysis of pollen production per tree revealed significant year (F=44.45, p=0.0014), individuals (F=68.24, p=0.0001), and year x individuals (F=29.94, p=0.0076), interactions. There were also significant differences among years, individuals and year x individuals interactions in number of pollen cones (F=16.25, p=0.0025, F=28.46, P= 0.0001and F=9.78, p=0.0056, respectively), pollen strobili (F=19.56, p=0.0034, F=37.62, P= 0.0001and F=14.37, p=0.0047, respectively) and microsporangia (F=32.25, p=0.0024, F=54.74, P= 0.0001 and F=19.62, p=0.0062, respectively) per tree.

The data on pollen migration from the source revealed that the pollen frequencies were highest in all directions near the source trees. The distribution of the majority of pollen grains from the source was observed up to 40 m towards uphill and horizontal directions. The frequencies of pollen grains to the source frequency at these distances were 28.83 and 23.34, respectively. The results also revealed that the pollen grains could travel up to 320 m and 640 m in the uphill and horizontal directions, respectively (Fig. 2). The averages of pollen to source frequency at these distances were 2.35% and 2.16% respectively.

4. Discussion
Flower formation starts when a vegetative meristem suddenly changes its pattern of division to produce beginnings of floral organs and appendages. This change is influenced by a number of factors, however, specifics are lacking on the internal control, which cause one meristem to produce a flower and another to remain vegetative (Schopmeyer, 1974). Climatic factors influence the anthesis, androecia protrusion and anther dehiscence, and hence pollen release, in a different way in *P. roxburghii*. Air temperature must exceed \(20^\circ C\) and relative air humidity must remain below 85% to begin the process of anthesis. However, high relative air humidity favours androecial protrusion. Anther dehiscence and pollen release are also affected by relative air humidity. Anthesis also shows a diurnal periodicity, every day from 0600 hr to 1800 hr, however, anthesis is not affected by the presence or absence of the light at all (Khanduri and Sharma, 2000).

The analysis of pollen production clearly indicate that there is temporal and tree to tree variation in pollen production in *P. roxburghii*, which ultimately suggest that climatic conditions along with genetic makeup of individual tree plays a significant role in this variation. The bumper pollen yield was observed in the years 2014.

In forest trees, determination of the extent of pollen migration is important because trees are sessile and the gene flow of interest is valuable to know the background of external pollen sources into the seed orchards. Gene flow from unselected, background pollen sources into a seed orchard results pollen contamination, which affects the genetic quality of seed yield. The intensity of pollen contamination varies with the species, mating pattern of the species, synchrony in reproductive phenology of the trees of within and outside-seed orchard, size of seed orchard and its background population, the extent
of isolation and environmental conditions. A number of studies have reported pollen contamination for several species with the rate of contamination varying from almost 0 (El-Kassaby and Ritland, 1986) to 90% (Fast et al 1986, Kaya et al 2006). The rate of contamination may vary from one year to the next for example in Douglas-fir seed orchard the contamination rate in one year was 44% and in the next consecutive year was 89 % (Fast et al 1986). Contrary to this, regular level of contamination between 69 and 71% over a period of three years was recorded in a Norway spruce seed orchard (Fast et al 1986). Contamination affects genetic gain, genetic quality and genetic diversity by different ways, as by increasing pollen contamination the Genetic gain of the seed crop decreases (Wheeler and Jech 1986) and genetic diversity increases up to a certain level (Lindgren and Mullin 1998). High level of pollen contamination may either increase or decrease the genetic diversity of seed crop resultant on the conspecific population and its genetic characteristics (Adams and Kunze, 1996). Under the condition of absolute pollen contamination (100%), half of all genes come from the parents within the orchard because the pollens are the male component of reproductive success (Funda and El-Kassaby, 2012).

The scattering pattern of pollen grains in the population implies successful seed set through mixed mating, as the outcrossing rate in Pinus is reported to be high at population level (Sharma et al. 2012). The decrease in pollen concentration with increasing distance imply reduction in percentage seed set with increasing distance as noted in Douglas fir (Wright, 1953). The amount of pollen scattered over long distances is small in comparison to the magnitude of pollen formed by an individual. The distance wind dispersed pollen travels has been the matter of several investigations and it can be
confirmed that a single pollen grain could be carried long distances, however, it is uncertain that it would be viable after such journey (Bateman, 1947). Dispersal varies greatly due to wind, height of vegetation, length of period of release, etc., and the area of pollen coverage could vary between a few and some hundred meters, and under exceptional circumstances be more than a kilometer (Raynor et al., 1969). The results of this study revealed large pollen pool in the population due to copious pollen production per tree, which proclaimed high levels of pollen dispersal for Pinus roxburghii. The estimates of average pollination distances varying between 320 and 640 m. This suggests that trees in Pinus roxburghii mate with a large number of conspecific distributed over a large area in their vicinity. The pollen dispersal distance estimates from this study appear larger than other coniferous tree species, such as 91.4 m for Pinus edulis Engelm., 45.7 m for Pseudotsuga menziesii (Mirb.) Franco, 100.6 m Picea abies (L.) H. Karst., 213.2 m for Cedrus atlantica (Endl.) Manetti ex Carrière. (Wright, 1952), 152.4 m for Pinus elliottii Engelm. (Wang et al. 1960), and 190 m for Cedrus deodara (Roxb. ex D. Don) G. Don (Khanduri and Sharma, 2002). A segregation barrier of 600 m in Pinus roxburghii was also observed by the author at Pauri Garhwal District (Khanduri 2012). The decline in the frequency of pollen deposition with increasing distance from a pollen source is an issue of utmost importance in the setting up and management of a seed orchard. For example Wright’s (1952) data on Pinus edulis Engelm (Pinyon tree) and Wang et al’s (1960) data on Pinus elliottii Engelm (Slash pine), showed a rapid decline in pollen deposition with increasing distances. The occurrence of pollen of Pinyon at 91.4 meter was 1 percent of the frequency at the pollen source, and in the case of Slash pine, it was 2 -5 percent of the source frequency at 152.4 meter.
5. Conclusions

In *P. roxburghii*, the occurrence of pollen at 640 m was 2.16 percent of the source frequency, which implies that a segregation barrier of 640 m could be used for the establishment of a chir pine seed orchard.

References


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