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The Periodicity of Spore Release from a Conifer, a Liverwort, and a Bracket Fungus

Field observations of pollen and spore release from plants are relatively rare. This study represents a continuing attempt to gather this basic information from a variety of native plants in the Pacific Northwest. The Kramer-Collins samplers were set up primarily to observe pollen release from *Tsuga* at the actual source, but interesting data were also obtained from nearby sporulation of *Ganoderma* and the liverwort *Cephalozia*. The samplers were set up for a 10-day period, but the seven days presented in this paper represent the peak period of pollen release from *Tsuga*. Data are also mentioned from a similar experiment at a lower elevation. An attempt was made to correlate the hourly fluctuations in spore release with temperature, relative humidity, cloud conditions, and precipitation.

Study Sites

This study was done between May 8 and 18, 1968, at the junction of Coal Creek and Glacier Creek (elevation ca. 3500 ft), Mt. Baker National Forest, Whatcom County, Washington. The primary canopy vegetation types in the area were *Tsuga heterophylla* (Raf.) Sarg., *Pseudotsuga menziesii* (Mirb.) Franco, *Alnus rubra* Bong, and *Salix scouleriana* Barr. At slightly higher elevations *Abies amabilis* (Dougl.) Forbes and *Alnus sinuata* (Regel) Rydb. were also present. *Cephalozia media* Lindb. was quite common on mossy logs in the vicinity. Basidiocarps of *Ganoderma applanatum* (Pers. ex Wallr.) Pat. were distributed from ground level to 20-30 ft high on standing dead *Tsuga*. At least 25 basidiocarps were noted within a 50-ft radius of the sampling apparatus.

Additional experiments were carried out in the Lake Louise region of Whatcom County (elevation ca. 500 ft). Sampling at this site was done on *Alnus rubra* and *Thuja plicata* D. Don.

Methods

Sampling was done with two Kramer-Collins samplers operated by 12-volt D.C. storage batteries (Kramer and Pady, 1966). The samplers operate volumetrically, sampling approximately 10 cu ft (228 liters) of air each hour taken in four equal samples. Each sample is superimposed on a single hourly band. The bands are located on a silicone grease-coated glass slide which ultimately results in a slide with 24 bands, one for each hour per day. The slides were changed at approximately 0700 hours PDT each day. Each sampler was placed under a pollen-shedding *Tsuga heterophylla* tree at ground level in sampler 1 and 1 meter higher in sampler 2. Sampler 1 was directly under a pollinating tree and at sampler 2 the male strobili were placed directly adjacent to the sampler inlet. A representative spore sample of the hourly band was counted, and a correction factor applied to express the data

in spores/cu ft/hour. Temperature and relative humidity were taken with a Bendix hygrothermograph located in a protective box at the sampling site. Notations on precipitation and cloud cover were taken at the Glacier ranger station located 3.5 air miles from the sampling site. No data were available for wind speed and direction at the sampling site.

The pollen and spores collected in the air were compared with materials collected in the vicinity for positive identification. Voucher specimens for the plants studied are deposited in the herbarium at Western Washington State College.

Results

Tsuga. At the Glacier Creek site well-defined peaks were noted on three days: May 9, 10, and 11 (Fig. 1). These peaks occurred only when the relative humidity

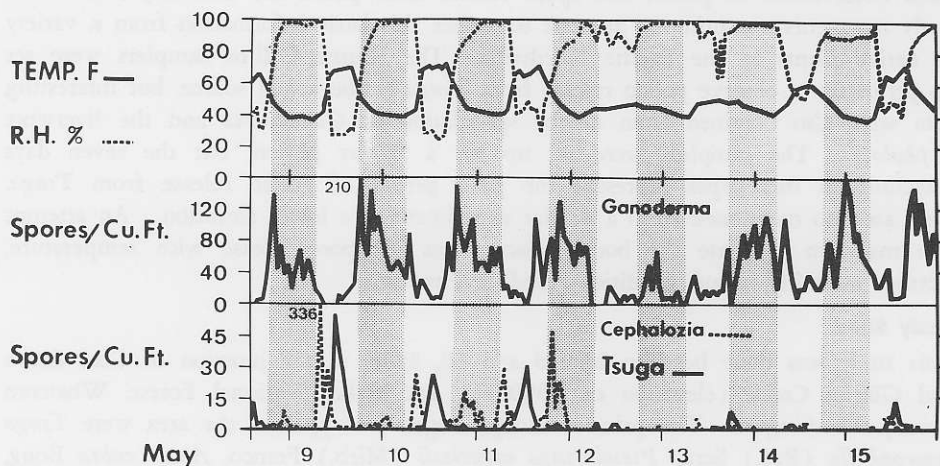


Figure 1. Hourly environmental data and volumetric spore counts from *Ganoderma*, *Cephalozia* and *Tsuga*.

was at the lowest point for the day. The peaks in spore numbers came at 1200 hours on May 9 and 10 and 1300 hours on May 11 when the relative humidity was at 29, 26, and 43 percent, respectively. An identical experiment carried out on *Alnus rubra* and *Thuja plicata* in the Lake Louise area of Whatcom County indicated a very similar pattern of release, but in this case the exact release time for each species was sometimes several hours apart. Visual observations of *Tsuga* strobili showed some pollen the morning of May 12, but a rainy period starting on the previous night essentially terminated pollen release for the duration of the observations.

Ebell and Schmidt (1959) studied pollen release from *Thuja plicata*, *Tsuga heterophylla*, and others. Using a nonvolumetric technique they found 90 percent of all pollen released during the 0800-2200 hours with the maximum release period occurring between 1000 and 1600 hours. In addition they noted the peaks were more closely related to each particular site rather than a characteristic pattern of release for each species. This variation in the daily afternoon peaks was thought to be an environmental reaction. Ogden, Hayes, and Raynor (1969) recorded pollen release from *Phleum*, *Zea*, *Ricinus*, and *Ambrosia* in cultivated plots. They showed that although the mean peak and duration of pollen release varied for each species, the pollen-shedding period was generally during the hours when relative humidity was lowest and wind speeds and/or atmospheric instability increased, except for

Pbleum which began releasing pollen during the night. Similar observations on pollen release from *Humulus lupulus* L. were made by Brooks and Puri (1963) and on *Plantago lanceolata* L. by Mathews (1965).

Visual observations of the male strobili of all species studied indicated a probable hygroscopic mechanism in which the microsporangia remain closed until drying conditions prevailed. Bianchi, Schwemmin, and Wagner (1959) reported that dehiscence and extension of the anthers in *Ambrosia* were induced by changes in temperature and relative humidity that commonly occur in the field following sunrise. Ogden, Hayes, and Raynor (1969) noted that no relationship was found between temperature and pollen emission except as temperature causes changes in relative humidity.

Cephalozia. On May 8 there was a weak peak of 10 spores/cu ft at 2300 hours when the relative humidity was 100 percent. The peak that occurred on May 9 was at 0800 hours with 100 percent relative humidity just prior to a sudden drop in relative humidity and a rise in temperature. A minor peak also occurred at 0100 hours May 10 of eight spores/cu ft two hours after the relative humidity reached 100 percent. Two additional peaks occurred at 0900 hours and 2000 hours of 26 and 20 spores/cu ft, respectively. These peaks again occurred when the temperature and relative humidity were actively changing, specifically at a relative humidity of 85 and 88 percent. The data from May 12 were similar to May 11, showing peaks at 0700 hours and 1900 hours of 28 and 45 spores/cu ft. These peaks occurred at 100 and 68 percent relative humidity again when the temperature and relative humidity were undergoing active changes. The rainy period which began on May 12 coincided with a termination of any large numbers of *Cephalozia* spores in the atmosphere although a few spores were noted on May 13, 14, and 15.

Cephalozia bicuspidata, its mechanism of sporangium dehiscence, and reaction of elators to drying conditions were considered by Ingold (1965). These data showed that *Cephalozia bicuspidata* will only release its spores while the environmental conditions are actively changing. This apparent sensitivity to environmental change results in two peaks per day, one in the morning and the other in the evening when temperature and relative humidity are showing the greatest fluctuation. The evening peak is quite puzzling because in the laboratory the elators of these liverworts only show their hygroscopic activity under drying conditions.

Ganoderma. May 8 through May 11 were relatively warm days with no precipitation. The hourly maxima in spore numbers were quite similar for each of the first four days during this period. The night of May 8 showed a major peak in spore numbers of 120 spores/cu ft at 1900 hours when the relative humidity was 90 percent; another minor peak of 60 spores/cu ft occurred at 0300 hours on May 9. The spore numbers during the daytime temperature maximum and the low in relative humidity during May 9 declined to none or a trace as they did on the succeeding two days when similar conditions prevailed. The peaks on the night of May 9-10 were at 1800, 2100, and 0700 hours, and were 210, 160, and 98 spores/cu ft when the relative humidity was 80, 98, and 100 percent, respectively. As on the night of May 8-9 the early evening peak was the major one. The peaks in spore numbers for May 10-11 fell into a similar pattern with the major peak recorded at 7 P.M. and minor peaks at 2300, 0500, and 0700 hours. The afternoon of May 12 was the beginning of a rainy period and showed a 3 P.M. peak of 98 spores/cu ft when the relative humidity was 48 percent; subsequent night peaks did develop,

however, at 1900, 0200, and 0400 hours. May 12, 13, and 14 were rainy and the temperature and relative humidity were relatively constant. The spore numbers on May 12-13 showed a tendency for a night peak but were ill defined. During May 13 there was a dip in the relative humidity at 1400-1600 hours with a peak at 1700 hours of 72 spores/cu ft. The nighttime spore numbers on this night were relatively uniform, not showing the early-evening peak that seems to be prominent when the temperature and relative humidity fluctuate sharply during a 24-hour period. This pattern was re-established on May 14 through May 28 as dry weather conditions were re-established.

In studying spore release at the source, Haard (1967) and Riley (1952) found that a second early-morning peak is sometimes evident. These data showed a similar second peak on May 8 through 11, but it was ill defined. De Groot (1968), on the other hand, found a single nighttime peak in *Ganoderma* spores when sampling was carried out remote from the spore source. The data from his paper showed an intermediate situation probably because of the extremely high number of *Ganoderma* basidiocarps in the vicinity.

Discussion

The mechanism of pollen release from *Tsuga heterophylla* is apparently moisture dependent. This dry weather release pattern has been observed in many plant genera. These data show an identical pattern of pollen release in *Thuja*, *Tsuga*, and *Alnus*. The precise time of peak numbers in pollen grains varies from genus to genus and also from site to site (Ebell and Schmidt, 1959). Field observations of pollen strobili of these genera have supported previous observations (Bianchi, Schwemmin, and Wagner, 1959) that the microsporangium wall is hygroscopic and actually ejects the pollen as the walls contort under drying conditions.

Ingold (1959, 1965) and others have studied the mechanisms of spore discharge in the bryophytes, but these data are the first observations of spore release from a liverwort under field conditions. Since *Cephalozia* shows two peaks per day rather than one as the author expected, more field observations of this liverwort and other bryophytes are in order.

Spore release and dispersal from the species of *Fomes* and *Ganoderma* have been studied by Haard (1967), De Groot (1968), and Riley (1952). These observations tend to support previous data on spore release and dispersal from these fungi. It is interesting to compare the single nighttime peak as recorded by De Groot (1968) and the double peak recorded by Haard (1967) and Riley (1952). In the author's opinion this is an intermediate situation between the two, the former being a measurement of atmospheric dispersal and the latter the pattern of spore release at the source.

Summary

Two Kramer-Collins air samplers were placed in close proximity to *Tsuga heterophylla*, *Cephalozia media*, and *Ganoderma applanatum* for seven days. Hourly sampling showed three distinctly different diurnal patterns in spore release. Under normal dry weather conditions, *Ganoderma* produced broad night peaks. *Tsuga* released pollen during the early afternoon hours when the relative humidity was at the lowest point. *Cephalozia* produced as many as two peaks per day, one in the early morning and the other in the early evening approximately 12 hours apart. Under intermittent rainy conditions, *Ganoderma* spores were detected in a weak diurnal pattern; *Cephalozia* and *Tsuga* were barely detectable.

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