

32 annual rings for the total number of years of the tree's age, and these stood out with unusual clearness. In addition, however, during the two years of defoliation above referred to, three other rings were observable although somewhat less clearly. A reference to the Weather Report records gave the explanation of these narrower annual rings. When the tree was 15 years old there occurred after the leaves were formed frosts on two successive nights which were so severe as to cause defoliation. After this leaves were again formed but later in the same year were destroyed by insects, a thing which rarely occurs with *Liriodendron tulipifera*. These two defoliations caused the formation of two rings or midsummer growths in the tree in its fifteenth year, which were not so distinct as the usual annual rings. The formation of two rings in one season is exceptional, but it shows, as stated by Jost, that a relation exists between defoliation and annual ring formation. When the tree was 23 years old it was again defoliated early in the season by frost which caused an extra ring to form. This was less distinct than the annual rings. These same midsummer growth formations were visible in some maple trees that were in the same locality, but they were less distinct than those mentioned for *Liriodendron*.

Various and numerous theories have been advanced concerning annual ring formation but as yet the real causes are unknown. Mechanical explanations have failed but the teleological viewpoint deserves study. While some facts are known concerning annual ring formation in temperate zones extremely little is known concerning annual ring formation in tropical trees. The first case of growth rings on record in a monocot has recently been reported by Chamberlain¹ for *Agave ferox* which grows in South Africa. In view therefore of the production of the midsummer growths as recorded in this paper, controlled experiments, although they would be costly to perform, should be carried out in order to determine the physiological facts involved in this important question.

STUDIES ON POLLEN—IV.

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Since my third contribution to this subject I have investigated the germinal behavior of more than a score of different pollens not heretofore considered in this series of studies. The more one progresses in this line of investigation, as in many others, the more one finds to be done in the various interesting and important phases of the subject. It is also clear that in many respects corrections of previous work needs attention and re-investigation from different angles. Improvements in the methods of research in this subject are constantly required as the work has progressed. The petri dish method has practically supplanted the procedures usually employed. A temperature arrangement has been devised which has definitely advanced this field of investigation. Too little attention has been paid heretofore to conditions controlling pollen

¹ Chamberlain, C. J. Growth Rings in a Monocotyl. Bot. Gaz., 72, 293-304, 1921.

behavior in the plant concerned. Therefore a study of pollen behavior, as far as possible, has been made in the field in certain cases for the sake of comparison with the laboratory experimentation. It is expected to extend this phase of the work.

Since my third paper on this topic I have increased the number of plants to 561. In all cases thus far the pollen has been tested in the various solutions referred to in my last paper. As yet no specimen has been found which for number of germ tubes produced is as prolific as *Malva crispa* referred to in my previous paper¹. Some of the pollen reported in this paper refused to germinate under any of the laboratory conditions that were provided while in other cases germination occurred under precisely the same arrangements. In this last study no case of more than one pollen tube from a single grain has been observed. *Primula obconica* showed luxurious germination in most cases and under ordinary conditions is a favorable specimen for investigation. This was notable in as much as below and immediately above 10 per cent of cane sugar active germination was observed, but at 10 per cent none occurred in the specimens studied. This corroborates the findings heretofore brought out in certain other cases mentioned during these studies and it deserves further attention. There arises here also certain questions concerning the difference in the amount of time required for the commencement of germination aside from the influence of membranal variation. This I have found to be very different in the various pollens studied and constitutes a considerable problem in itself.

PROTOPLASMIC STREAMING.

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The idea of this chemical study in *Rhizopus nigricans* was to ascertain the behavior of the plant when plasmolysed in different degrees and the response of the protoplasmic movements when in this condition. It is well known that some plants when plasmolysed by certain substances may remain living for only a short time while others will live for weeks in this condition². It is the intention to carry out this study by using various representatives from the six groups of metals as well as certain organic substances such as sugar and glycerine.

In the first experiments a 20 per cent solution of cane sugar was used. In these experiments a rather sudden plasmolysis resulted, in the time it was maintained, in a slowing of the streaming from a speed of three mm. per minute to one-tenth mm. per minute. When the normal hydrostatic pressure was restored the normal velocity of protoplasmic streaming above mentioned in these specimens was finally restored. In the series of specimens experimented with in this way, however, three hours elapsed before the normal speed was regained. The question still remains as to whether or not a full cessation of streaming could be

¹ Andrews, F. M. Studies on pollen—III. Proc. Ind. Acad. Sci., 1920, p. 155-156.

² Pfeffer, W. Pflanzenphysiologie 2te Aug. 1904, Bd. II, p. 330.