wall) is on the average about 6°. It has frequently been suggested[2,3,4] that the direction of protoplasmic streaming determines the orientation of spiral structure in the cell wall. Oort and Roelofsen[5] found that in the lower, non-growing part of the sporangiophore of *Phycomyces* spiral protoplasmic streaming indeed occurred, but were not able to observe oriented streaming at the actual zone where growth took place.

In an attempt to learn something about the nature of the "rotational vector" in the growth of cells of this type, the rates of elongation and of rotation of sporangiophores of *Phycomyces* were determined at 15° C. and at 25° C. The temperature coefficients for this interval were in 5 cases as follows: Q_{10} growth = 1.1, 1.1, 1.2, 1.6, 1.1; Q_{10} rotation = 2.5, 3.0, 2.4, 2.5, 1.6. Taken at their face value, these results indicate that the forces involved in twisting the cell have a significantly higher temperature coefficient than those concerned with its elongation. As a necessary consequence, moreover, the angle which the spiral makes with the long axis of the cell is greater at the higher temperature. For the five cells mentioned, the angles at 15° C. were 3.3°, 5.6°, 8.6°, 6.3° and 9.3°; at 25° C. these angles were, respectively, 10.8°, 15.6°, 15.6°, 11.6° and 11.1°. It is evident, therefore, that the steepness of the growth spiral is not structurally fixed, but that it can be (reversibly) altered by change of temperature. This supports the view that the spiral form of growth in these cells is indeed due to the resolution of two vectors.

Raising the temperature of the cells above 25° C. further increases the rate of rotation up to about 27.7° C. At this temperature rapid elongation of the cell continues, but rotation is greatly diminished in rate, frequently abolished altogether, or occasionally *reversed in direction.* No mention has been made so far of the direction of rotation. Oort[6] found that the majority of the cells grew upwards in the form of a "right-handed" spiral. This corresponds to what we call a left-handed thread on a screw. In the studies which are described here, most of the cells from a totally different stock of the same strain of fungus showed similar "right-handed" spiral growth.

The question as to what determines the direction of spiraling of cells or organisms is possibly a separate problem. It has frequently been approached by conducting a survey, sometimes extending into the cosmos, of the direction of spiraling found in nature.[7,8,9] Unfortunately, no satisfactory general explanation is forthcoming. The abolition of spiral growth or its reversal in *Phycomyces* by change of temperature suggests that relatively homely factors may control the direction as well as the magnitude of the process. The rapidity with which changes in the angle of spiraling may come about seems to argue against any interpretation in terms of altered proportions of different types of isomeric molecules. It is possible that the direction in which the protoplasm streams orients molecules which are being built into the wall,[10] and that at the higher temperatures the streaming protoplasm reaching the growing zone is not stably oriented. The suggestion that the rotational vector in spiral growth is streaming protoplasm is not intended to explain one unknown in terms of another: we know that there is movement and consequently force in protoplasmic streaming. If this idea were correct it would remain to discover what kinds of forces are at work in initiating and maintaining protoplasmic movement, but two problems would have been united. The experimental results briefly reported here show how relatively simple factors may profoundly modify the magnitude and direction of the rotational vector in spiral growth and suggest the value of experiments designed to test the rôle of protoplasmic streaming.

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EFFECT OF FLOWER PRODUCTION ON RATE OF GROWTH OF VEGETATIVE SHOOTS OF LONGLEAF PINE

WHILE working in a young stand (about 25 years old) of longleaf pine (*Pinus palustris* Miller) on April 8, 1931, I noticed a remarkable variation in the length of the terminal shoots. A close examination revealed that invariably those shoots which bore staminate strobili were short, while those which bore pistillate strobili or no strobili at all were quite long. The question suggested itself whether the production of the strobili may have had some influence on the rate of growth of the terminal shoots. Accordingly, 15 trees were numbered, and on each of these 10 to 20 terminal shoots were tagged with metal tags at different parts of the tree for a permanent record. The length of each shoot was measured from the base to the tip and the sex and number of strobili on each were recorded. On September 11 of the same year, the marked shoots were remeasured. The results appeared quite significant, suggesting a problem that has not yet received sufficient attention.

[2] L. Dippel, *Abh. Naturf. Ges. Halle,* 10: 55, 1868.
[3] E. Strassburger, "Ueber den Bau und das Wachstum der Zellhäute," Jena, 1882.
[4] G. van Iterson, *Hand. 23e Ned. Nat. en Geneesk. Congres,* 4, 1931.
[5] A. J. P. Oort and P. A. Roelofsen, *Proc. Acad. Sci. Amsterdam,* 35: 898, 1932.
[6] *Loc. cit.*
[7] H. Günther, *Biol. Cent.,* 39: 513, 1919.
[8] Th. Schmucker, *Beih. Bot. Cent.,* 41: 51, 1925.
[9] G. van Iterson, *loc. cit.*
[10] *Ibid.*

TABLE I

No. trees studied	Aver. diam. breast-high	No. shoots studied	Sex on shoots	Aver. length of shoots Apr. 8, 1931 mm	Aver. length of shoots Sept. 11, 1931 mm	Aver. length of leaves Apr. 8, 1931 mm	Aver. length of leaves Sept. 11, 1931 mm	Shoots dead, May, 1932 No.	Shoots dead, May, 1932 Per cent.	No. strobili on shoots Max.	No. strobili on shoots Min.	No. strobili on shoots Aver.
15	19.0 cms	51	Vegetative	68.4	102.4	0	302.2	3	6	—	—	—
		18	Pistillate	93.0	162.0	0	318.0	0	0	2	1	1.5
		89	Staminate	36.6	74.1	0	283.5	28	31	72	2	19.2

In Table I are given the measurements of the shoots and the sex of flowers they bore. Those which bore no strobili were for convenience designated as vegetative shoots. The results show that in all the 89 shoots bearing the staminate strobili the amount of the growth they had made was very small. In the early spring the shoots bearing the pistillate strobili were the largest and were nearly three times as long as those bearing the staminate strobili. Those bearing no strobili, or the vegetative shoots, were at the start about two thirds the length of those bearing the pistillate strobili and about twice as long as those bearing the staminate strobili. At about the end of the growing season the stems produced by the shoots bearing the pistillate strobili (which by now had been pollinated) were twice the length of the stems produced by those bearing the staminate strobili, while the stems produced by the vegetative shoots were about one and one half times as long as those produced by the male-bearing.

Another point of interest is the relation between the number of staminate strobili and the size of the shoot that bore them. In all cases it was evident that the shoots bearing the smaller number of staminate strobili were larger than those bearing the larger number of male flowers. In other words, the amount of growth made by the shoots bearing the staminate strobili varied inversely with the number of the strobili. This would indicate that the production of the staminate strobili caused a retardation in the growth of the terminal shoots bearing those strobili. On the other hand, the production of the pistillate strobili apparently caused a stimulation of the growth of the shoots that bore them, for in all cases those bearing the pistillate strobili were larger than those which bore no strobili. Field observation of mature trees showed, however, that the upper branches of the trees which were vigorous bore pistillate strobili, while those on the lower part of the tree bore the staminate strobili, suggesting that staminate strobili were produced on weaker branches. This then suggests the question of whether the slow growth of the shoots bearing the staminate strobili was due to their natural weak condition or whether the shoot actually suffered a retardation in growth produced by the staminate strobili. In other words, the question is: "Which is the cause and which the effect?"

A point in favor of the theory that the production of the pistillate strobili cause a stimulation in the growth of the shoot is shown by the greater growth of the needles on the shoots bearing the pistillate strobili than on those bearing the staminate strobili or on the vegetative shoots (see Table I).

It was also found by the end of the summer that while none of the pistillate shoots died, 6 per cent. of the vegetative shoots and 31 per cent. of the shoots bearing staminate strobili had died due to insect infection.

In August, 1932, the area was again visited and observation made on the tagged shoots in order to determine whether the development of the pistillate cones after fertilization might retard the terminal growth of that branch during the development of the cones. It was found that six of the branches bearing the pistillate cones had long new shoots. Five of the pistillate cones examined during 1931 were destroyed by insects, but the terminal growth of that year (1932) was as long as during the previous year. However, as many of the tips of the branches bearing the staminate strobili in 1931 showed no growth in 1932, no further notes were made.

In conclusion, it may be stated that the question of the effect of flower production on the rate of growth of terminal shoots of pine is an open one and presents an excellent problem for further investigation.

L. J. PESSIN
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