EVIDENCE OF A FACTOR ASSOCIATED WITH ACTIVELY FUNCTIONING TISSUES WHICH GIVES TO SUGAR-CANE PLANTS RESISTANCE TO THE INVASION OF FUNGI AND OTHER MICROORGANISMS.

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It is with hesitation that one discusses in publication such a broad subject as the resistance of plant tissues to the invasion of micro-organisms, based on what seem to be very simple observations. It is reassuring, however, to recall the fundamental and broad conclusions of Jacques Loeb, drawn from his very simple quantitative experiments with *Bryophyllum*. If one recalls also the fundamental conclusions in animal physiology obtained by Claude Bernard from pathological cases, confidence is regained to present the following evidence; an indication also that in some instances pathological cases in plants may contribute to an advancement in the knowledge of plant physiology.

The Normal Development of Sugar-Cane Roots.

Sugar-cane is propagated on a plantation scale by cuttings of the cane stem. These cuttings, usually consisting of three or four nodes, are planted horizontally in the ground, and rootlets arise from areas at each node known as root bands; subsequently, an aerial shoot develops from the single bud which exists at each node. Normally such an aerial shoot feeds upon the parent stalk cutting for a period of 1 or 2 months; during this period the cutting has put forth small roots from the root bands of the nodes so that the aerial shoot receives its mineral food through the cutting. The aerial shoot does not form its own roots for a considerable period after germination.

In a month or two, depending on environmental factors, the aerial shoot normally forms its own roots and the seed cutting gradually

is invaded by fungi and other microorganisms and gradually loses its function in supporting the aerial shoot.

This development is shown in Fig. 1; the letter *N* denotes the nodes, *B* the buds, one at each node; above each node is a flat narrow band

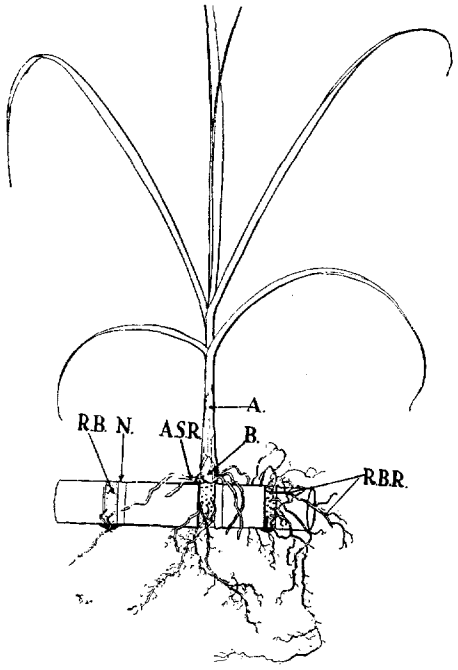


FIG. 1. A diagrammatic illustration of the parts of a sugar-cane plant arising from a stem cutting. *N* denotes a node of which there are three in the illustration. At each node is a root band indicated by the letters *R.B.* From such root bands the cutting sends out roots which are labelled *R.B.R.* in the illustration. At each node is a single bud denoted *B.*, and in the illustration the central one of these has germinated resulting in the aerial shoot *A*. The aerial shoot, after some time for its development, forms its own roots indicated by the letters *A.S.R.*, which are independent of the roots formed from the cutting. Drawing by Twigg Smith.

known as the root band shown in the figure as *R.B.* From the root bands, *R.B.R.* shows the root band roots developing. *A* shows the aerial shoot and *A.S.R.* the aerial shoot roots which are formed at a considerable period after germination has taken place.

A Suggestive Pathological Condition.

In Hawaii a disease of sugar-cane known as Pahala blight occurs. In some of the phases of this disease the aerial shoot seems incapable of forming its own roots and feeds through the seed cutting; instances have been observed in which the seed cutting functioned for 12 months after planting, with no formation of roots by the aerial shoots. The seed cutting in such cases did not succumb to soil fungi such as invade seed cuttings under usual conditions. Non-blighted, healthy stools of cane adjacent to affected stools, however, developed roots from their aerial shoots and in such cases the seed cuttings were invaded with microorganisms, the tissues were entirely rotted, and the cuttings no longer functioned in supporting growth of the aerial shoot. Such observations were uniform on some twenty or thirty shoots of cane affected with Pahala blight which were examined, and an almost equal number of healthy stools dug up and inspected.

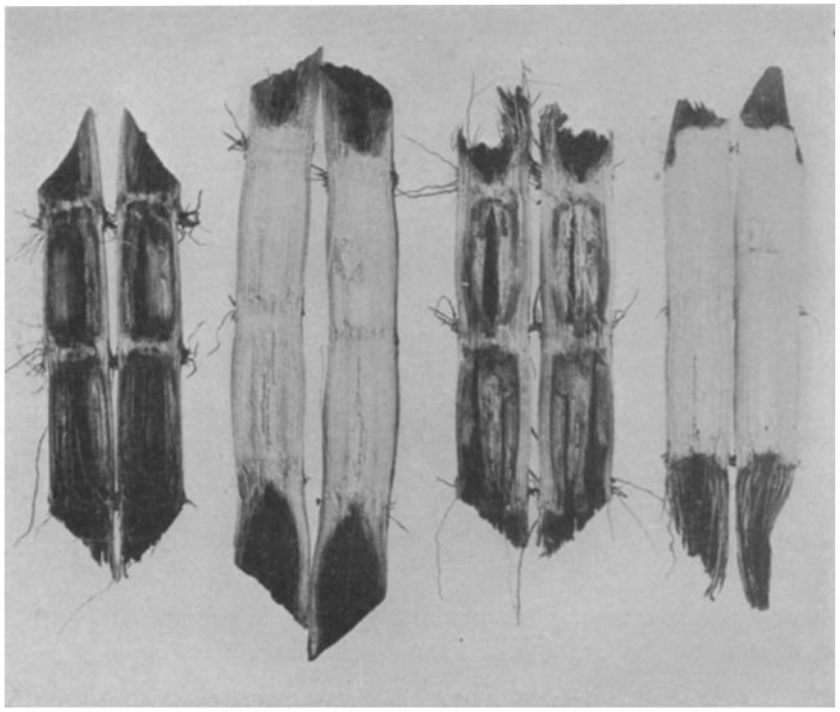
The question arises in these cases, of course, whether the freedom from invasion by microorganisms was a cause or an effect; this question is eliminated by a coincident experiment with normal cane mentioned in the following paragraphs.

An Experiment with Normal Cane.

At this Experiment Station a study was being conducted at the same time on the function of the roots from the root bands of seed cuttings in connection with the growth of aerial shoots. In potted cane plants the aerial shoots were maintained free from the soil and all roots from the aerial shoots were pruned off as they arose. The aerial shoots were thus forced to draw their mineral supply through the seed cuttings and the roots from the root bands of the seed cutting. At the end of 6 months it was found that the aerial growth took place just as well in those plants forced to feed through the seed cutting as in normal plants as controls under identical conditions, which formed their later roots as usual from the aerial shoots. The roots of the plants were then washed out and examined.

In all cases where no roots were allowed to develop from the aerial shoots, the plant had continued to be supported from the seed cutting and the invasions of fungi and other microorganisms in these func-

tioning cuttings were inhibited. In the control cane plants, where roots had been allowed to develop normally from the aerial shoots, the seed cuttings were entirely invaded by microorganisms and had rotted away. This difference in the two classes of cuttings is shown



1 2 3 4

FIG. 2. Cuttings 1 and 3 are from plants in which aerial shoots were allowed to form their own roots; Cuttings 2 and 4 are from plants under identical conditions, the roots of which, however, were excised at their inception, thus forcing feeding through the cutting and the roots from the root cutting. Cuttings 2 and 4, therefore, were actually functioning and as the photograph shows completely resisted invasions of fungi and microorganisms such as invaded Cuttings 1 and 3. The photograph was taken about 200 days after the planting of the cuttings.

in Fig. 2. In the figure, seed Cuttings 1 and 3 are from stools in which the roots from aerial shoots were allowed to develop normally and function in the support of the plant. Cuttings 2 and 4 are from stools in which aerial shoot roots were pruned off as they developed,

thus causing the aerial shoots to depend for their support on the seed-piece cuttings and the roots developed from the root bands of the cuttings. There were six replications of plants with excised roots, and controls.

DISCUSSION.

The conclusion which would seem to be deduced from these phenomena is that there is a factor, or there are several factors, in actively functioning plant tissues, or at least in the tissues of sugar-cane plants, which give to such tissues resistance to the invasion of low-grade fungi and other microorganisms. A review of the discussions on resistance and immunity in plants by Appel (1), Biffen (2), Butler (3), Cook and Taubenhaus (4), Freeman (5), Orton (6), and Stakman (7), shows no previous clear-cut evidence in the literature pointing to such a conclusion, although undoubtedly there has been belief in such resistance by many students in the plant industries and students of plant pathology.

In explanation of this resistance one may advance very simple physical factors such as the greater turgor of actively functioning cells as compared to those in non-functioning tissues. Other explanations may lie in the realm of substances formed by the aerial shoots which normally flow to the roots giving them resistance to fungus invasion; when the normal roots from the aerial shoots are inhibited, such substance may, in passing to or through the seed cutting, contribute to its resistance. Such explanations, however, are at present entirely in the realm of conjecture; there remains, however, the seemingly clear-cut evidence that there is a factor in actively functioning plant tissues which causes resistance to the invasions of low-grade microorganisms under conditions in which non-functioning tissues are quickly invaded. Many of the conjectures as to the reason for this could be readily put to proof in institutions devoted to non-commercial research.

BIBLIOGRAPHY.

1. Appel, O., Disease resistance in plants, *Science*, 1915, xli, 773.
2. Biffen, R. H., Studies in the inheritance of disease resistance, *J. Agric. Sc.*, 1907, ii, pt. 2, 109.
3. Butler, E. J., Fungi and disease in plants, Calcutta, 1918, 114.

4. Cook, M. T., and Taubenhaus, J. J., The relation of parasitic fungi to the contents of the cells of host plants. I. The toxicity of tannin, *Delaware Agric. Exp. Station Bull. 91*, 1911; II. The toxicity of vegetable acids and the oxidizing enzyme, *Delaware Agric. Exp. Station Bull. 97*, 1912.
5. Freeman, E. M., Resistance and immunity in plant diseases, *Phytopathology*, 1911, i, 109.
6. Orton, W. A., The development of farm crops resistant to disease, *Yearbook U. S. Dept. Agric.*, 1908, 453.
7. Stakman, E. C., Relation between *Puccinia graminis* and plants highly resistant to its attack, *J. Agric. Research*, 1915, iv, 193.