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ENDURANCE OF EXTREME CONDITIONS AND ITS RELATION TO THE THEORY OF ADAPTATION

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Current theories lead us to expect the adaptation of plants to extreme drought or to extreme moisture, but they can hardly account for endurance of both extremes by the same individual. If such cases are found, it would seem that we must explain them by some peculiarity of the protoplasm which is not the result of adaptation. This however raises the question whether the same sort of explanation may not apply in other cases whose adaptive nature is not usually regarded as open to question.

Individuals which can endure extreme drought and extreme moisture are found among the lower plants. Some years ago the writer observed a similar case among the higher plants. The plant is a species of Tradescantia (apparently *T. fluminensis* Vell.) which grows vigorously in a saturated atmosphere, which can live submerged in water for some time, but which was nevertheless able to go without water for nearly two years: during this long period it received no moisture (except what could be absorbed from the air).

Some years ago the writer observed that pieces of this plant continued to grow when lying on a laboratory table. Curious to know how long they could live under these conditions, he placed some of them on a table before a north window without soil or other supply of moisture. Here they continued to live for nearly two years.[1] It should be noted that the air was not unusually moist. The laboratory was, on the contrary, rather dry (being situated in the third story and containing no soil or other source of moisture). The experiments were carried on at Berkeley, California. The following table shows the humidity and temperature during the greater part of the period of

[1] 1 year, 11 months, and 2 days.

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the experiments (taken from the report of the Students' Observatory, University of California):

1907	Mean Relative Humidity	Mean Temperature
Sept	88.3	59.0° F.
Oct	88.7	58.0
Nov	86.8	53.0
Dec	89.3	49.8
1908		
Jan	90.1	48.2
Feb	88.6	46.8
Mar	85.0	49.9
April	84.0	54.2
May	84.0	54.9
June	85.0	56.7
July	88.0	58.6
Aug	88.0	57.8
Sept	86.0	58.3
Oct	84.0	55.6
Nov	90.0	51.1
Dec	89.5	44.0
1909		
Jan	92.0	49.8
Feb	90.0	48.2
Mar	88.0	48.1
April	85.0	54.0
May	77.0	54.4
June	84.0	58.2
July	80.0	60.2

The humidity of the air of the laboratory was less than that given in the table.

During the experiment each piece produced several new leaves. As may be observed in figure 1, these are much below the normal in size. The new leaves were formed at the expense of the older ones, which gradually died and thus furnished material which was transported to the tip of the stem and utilized in new growth.

The amount of growth is surprising when we consider how little material can be stored in the old stem and leaves. The plant shown in the photograph weighed at the start 2.1 gm. while at the end of the exposure to drought it weighed 0.22 gm. or 10.5 percent of the original weight. This loss is somewhat less than the average. In one plant the loss amounted to 95 percent, but it remained alive and subsequently grew well when placed under normal conditions. The plant shown in the photograph was 11 cm. in length at the start. At the time the photograph was taken it measured 28 cm. Hence its gain in length during exposure to drought was 17 cm. or 150 percent.

After nearly two years of this extreme drought the plants were placed in bottles (with the lower ends of the living portions dipping in water) and transferred to a greenhouse at Cambridge, Massachusetts, where they were placed in moist soil. All of them grew vigorously, producing stems and leaves of normal size and appearance.

Some of them were placed in a saturated atmosphere in which they continued to

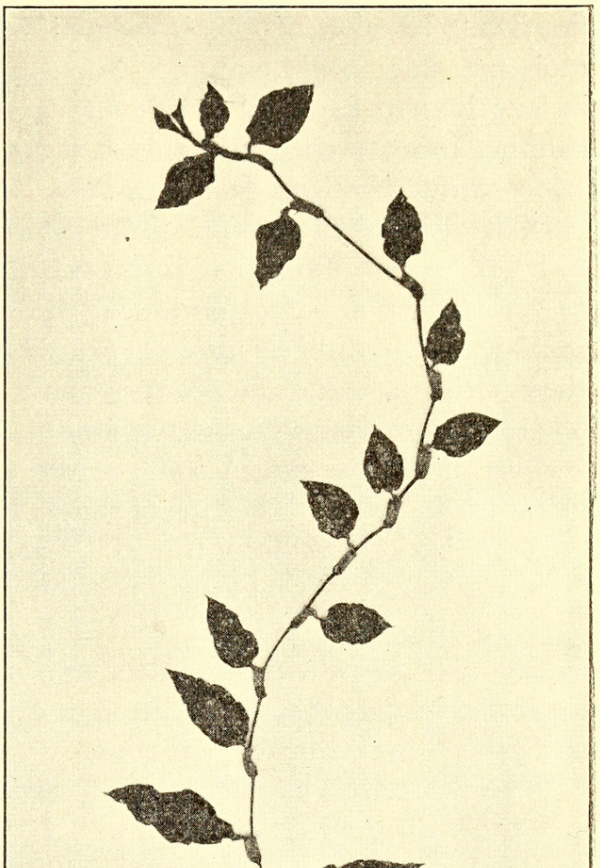

FIG. 1. Piece of Tradescantia which remained for nearly two years without soil or water. The six larger leaves at the base were present at the start. The others were formed after the plant was deprived of water and soil. During this period the plant lost 89.5 percent of its weight while at the same time it gained 150 percent in length. Subsequently it was placed in a saturated atmosphere where it grew vigorously: finally it was submerged in running water for a month, at the end of which time it was still alive.

flourish. In view of this it seemed desirable to ascertain how much moisture they could endure. For this purpose pieces eighteen inches in length were fastened at one end and anchored in a small, rapidly running brook during the month of August. The temperature of the water varied from 20° to 25°C.

Care was taken to keep all the pieces constantly submerged but not to let them sink more than an inch below the surface. The proximity to the surface and the motion of the water (which was aërated by a small waterfall directly above) ensured a fair supply of oxygen. Under these circumstances the plants grew a little (the average growth was one tenth of an inch during the month) but no new leaves were formed and all the leaves except some of the very youngest became pale and yellowish in color. The tips of some of the plants were still alive when the experiment was discontinued. Undoubtedly the plants would have done still better if it had been possible to supply more oxygen to them.

It is therefore evident that the same individual could live for nearly two years without water and afterward grow vigorously in a saturated atmosphere; in addition, it could live for a month under water and grow a little during that time.

The writer has had occasion to study other cases[2] which can not be explained by gradual adaptation. It would seem that in these cases the explanation must be sought in physical and chemical peculiarities of protoplasm which arise without reference to adaptation. It is quite possible that this kind of explanation should find more extensive application and that many cases now regarded as adaptations may prove to be fictitious.

Summary

A species of Tradescantia lived for nearly two years without soil or water: it afterward grew vigorously in a saturated atmosphere and was finally placed under water for a month, during which time it grew slightly and was alive at the end of the experiment.

The explanation of such cases must be sought in physical or chemical conditions of the protoplasm which arise without reference to direct adaptation. It would seem that the same kind of explanation may apply to many cases which are now regarded as adaptations.

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[2] *Cf.* Osterhout, W. J. V. Univ. Calif. Publ. Bot. **2**: 227. 1906. Bot. Gaz. **55**: 446. 1913.