sue, are capable of forming new cells which, under the proper stimulus, will develop into root primordia and eventually into new roots.

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PRESIDENT SNYDER: If there are any questions I will be glad to answer them during the question period.

MODERATOR COGGESHALL: The second speaker on the symposium this morning is Mr. James Wells, Wells Nursery, Inc. Red Bank, New Jersey. He will speak to us on Wounding of Cuttings as a Commercial Practice. I also understand Mr. Wells has some slides which he will show at a later date in the program, not this morning. Mr. Wells!

MR. JAMES WELLS: I dislike reading a paper, but when faced with this august assembly I don't think there is any alternative because I want to know precisely what I said.

WOUNDING CUTTINGS AS A COMMERCIAL PRACTICE

JAMES S. WELLS

The practice of wounding plant material as an aid to successful rooting is not a recent development. Textbooks of last century, describing methods to use for layering, say that the stem should be bent into a sharp U where it is fixed to the ground, and that for best results, the stem should be "nicked" at this point. This, of course, is a wound. Burbidge [2], in his book published in 1875, indicates the need for ringing the stem of many plants which are to be propagated by marcottage, a method which may more readily be recognized today as air layering. Old time growers recommended the splitting of the base of carnation stems and Sheat [10] mentions this for cuttings of *Daphne odora*.

Yet, despite the general acceptance of wounding in one form or another in old gardening journals, it is only recently that the method has been tested and applied in a scientific manner to the propagation of a wide range of plant materials.

In searching through the literature, I was not able to find many references until 1932. Day [4], then wrote a most interesting paper in which he showed that the rooting of cuttings of California Privet (*Ligustrum ovalifolium*), *Chaenomeles,* and Muscat grapes was greatly improved by wounding. His results appeared to indicate that wound had a definite effect upon the rapidity and quantity of water absorbed by the unrooted cutting, and furthermore, that the water absorption through the wound was also affected by the application of a film of clay to the wounded surface. Further tests indicated that it was apparently the finely divided state of the clay particles which produced this effect because similar results were obtained with finely powdered lime.

In 1938, Stuart and Marth [12] published an excellent paper on the rooting of *Ilex opaca* in which they showed that a far better root system was produced when the cuttings were wounded. This result was confirmed by Chadwick and Swartley [3] in 1941.

Two reviews on propagation include brief references to the value of wounding. R. J. Garner [7], in a technical bulletin published in 1944, gives a brief review, while Thimann and Behnke [13], in 1947, give a more complete table of results reported to date. Immediately prior to the last war the Dutch growers in Boskoop were testing the practice widely, and in the first year book of the Boskoop Trial Grounds, [5] published in 1941, there are some most interesting and valuable reports. Work has continued at Boskoop to the present, and for a really definitive survey I can refer you to a most excellent report published this year by the Boskoop Trial Grounds [8], for it combines up-to-date records on wounding together with optimum timing, mediums and hormone treatments.

Now, what are the practical aspects of wounding? First, what do we mean by wounding? A wound can take many forms and it would appear that there is hardly a variation which has not been tried somewhere. Bridgers [1] lists a number of wounds which were tested on rhododendrons, but generally speaking, we are concerned with two types — the so-called light wound, and a heavy wound. The light wound is made by drawing the tip of a sharp knife blade down the base of the stem of the cutting for a distance of about one and a half inches. The cut is not deep, and usually goes through the outer bark and soft cells beneath to touch, but not to deeply penetrate the central woody tissue. This type of wound can be made by the propagator with a knife used for trimming the cutting, but a simple tool can

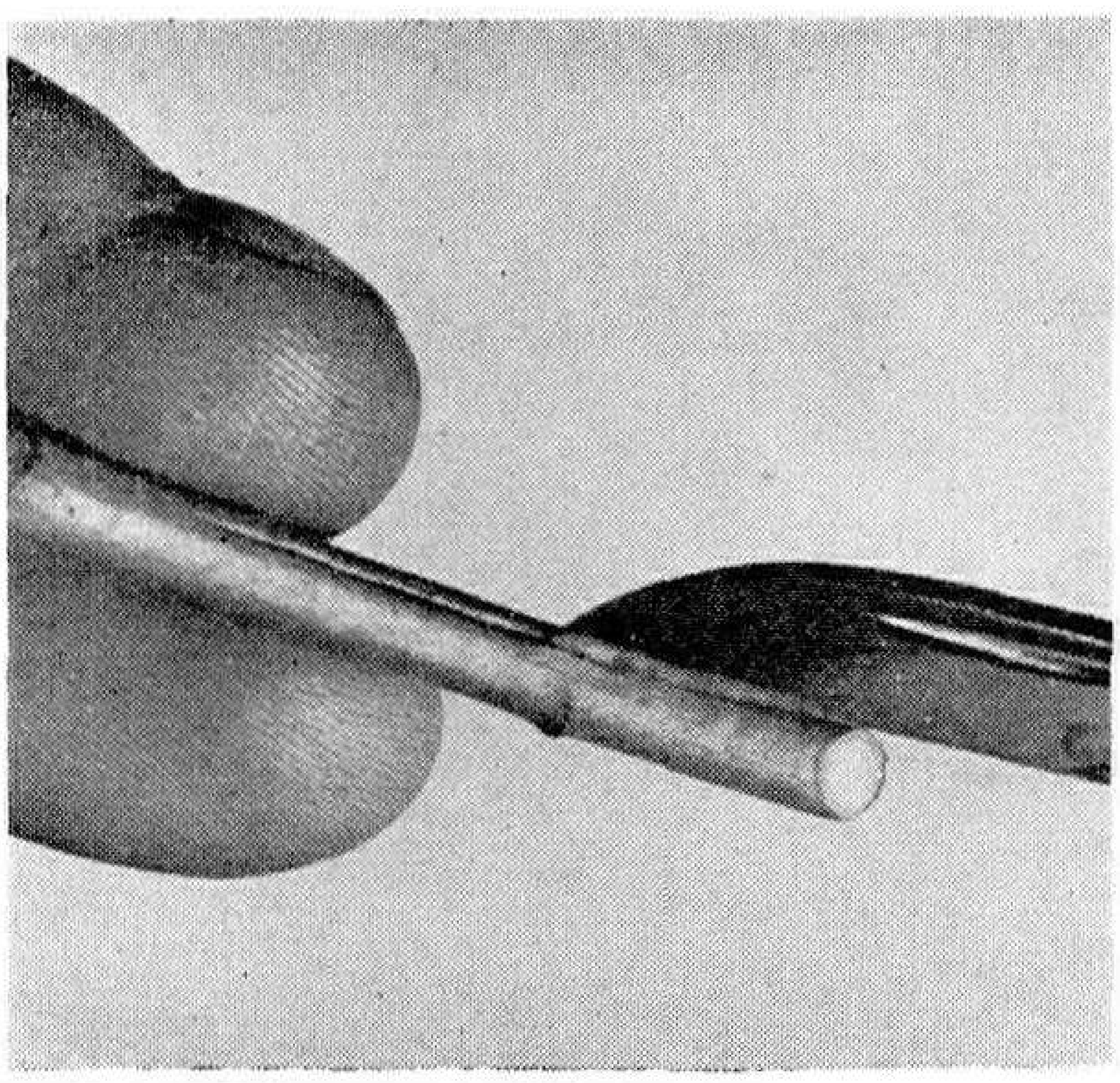

Figure 1. Making a light wound.

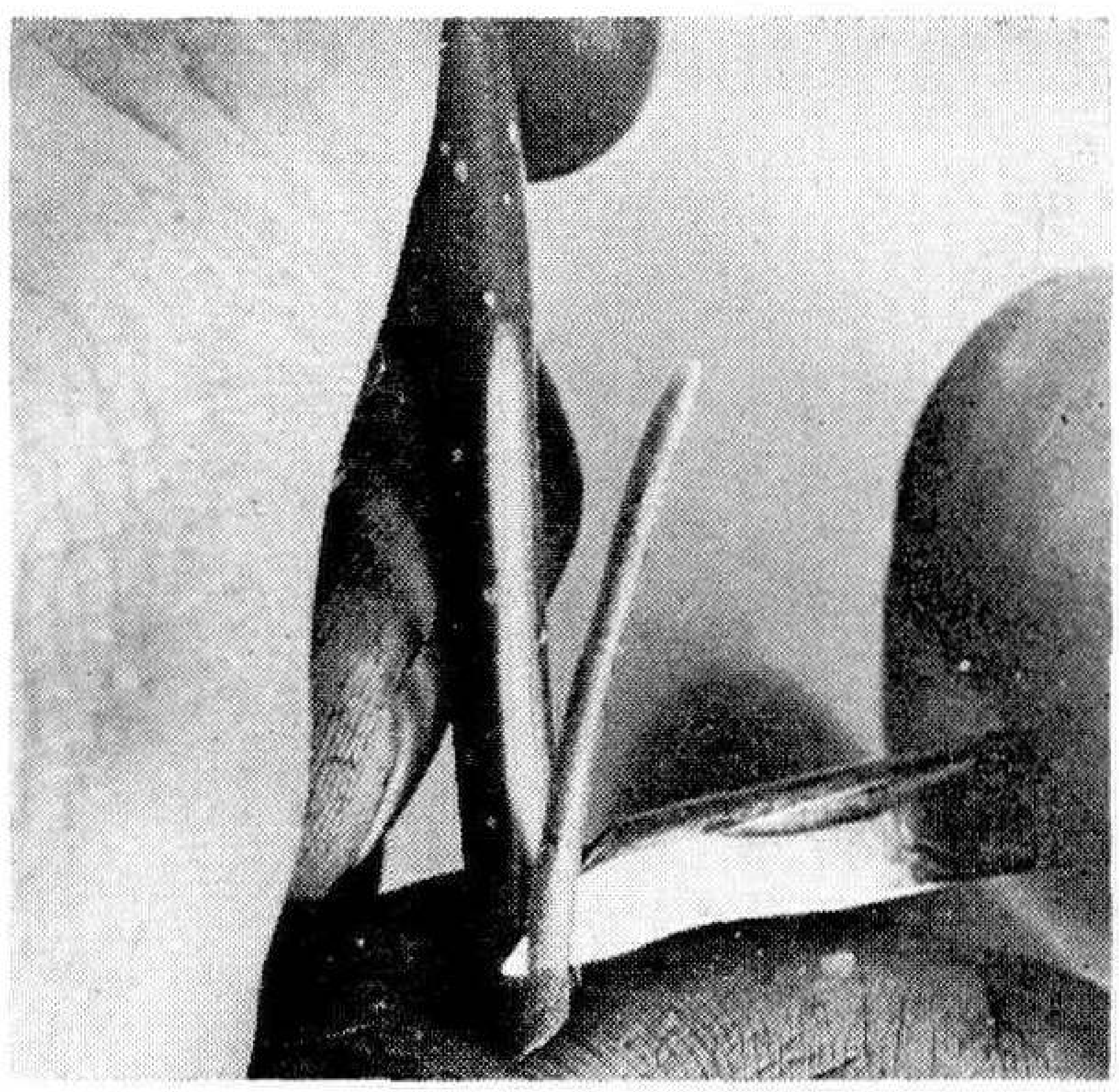

Figure 2. Making a heavy wound.

also be constructed for this purpose by soldering together four single edge razor blades.

A heavy wound is made by removing a thin slice for a distance of about an inch from the side of the stem of the cutting with a sharp knife, cutting through the outer bark and the soft cells beneath to reveal, but not to cut into, the central woody tissue. This heavy wound is sometimes applied twice to opposing sides of the same stem ,and this is known as a double heavy wound.

Why do we wound? Let me say at once that in my opinion wounding will not root any cutting which would otherwise not have rooted, if given sufficient time. It has little effect upon the ultimate percentage of rooting, but it does have a most definite and immediate effect upon the vigor, quality and quantity of roots produced, upon the speed of rooting, and, because of all these things, upon the percentage of plants ultimately produced. I need hardly remind you that, interesting as figures of percentage rooting may be, they can be misleading. A cutting with one small root loosely attached might be considered rooted for statistical purposes; but for practical purposes, it is not. Here then lies the value of wounding. Let me quote an example.

Stuart and Marth [12] treated a number of cuttings of *Ilex opaca* by splitting the base of the stem for a distance of a quarter of an inch with two right angle cuts. The cuttings were then treated with indolebutyric acid at .01% for 18 hours. All cuttings so treated were strongly rooted in 23 days.

We wound, therefore, first to speed up the rooting process; second, to increase the number of roots produced; and third, to improve the points of attachment between the root system and the cutting.

I first came into contact with wounding when I paid a very brief visit to Boskoop in 1946. At the time, the Trial Grounds had been running tests for some years and their first yearbook [5], dated 1941, gave some interesting reports on tests made that year. Example: Cuttings of *Chamaecyparis lawsoniana erecta* were taken on April 18th, and examined on August 26th. The unwounded control had rooted 30% while the wounded batch had rooted 90%.

CHAMAECYPARIS LAWSONIANA ERECTA

	Taken April 18th, 1941	
	Lifted August 26th, 1911	
	Medium Peat and sand	
	Cuttings in the greenhouse	
Control	No treatment	30% rooted
Control	Wounded	90% rooted

By 1942, almost all plants were being tested in Boskoop by wounding, and the yearbook [6] for that year gives much information as to the value of this treatment. Cuttings of *Juniper* pfitzer taken on October 23rd, and lifted on February 4th, showed 43% well rooted on the control, but 93% well rooted when the cuttings had been wounded.

The influence of wounding alone on the percentage of well rooted plants is clearly indicated by a series of tests which I carried out in

1946, immediately after coming to this country [15]. The purpose was to determine whether cuttings with a heel would root better than those without a heel, and whether wounding on either type of cutting would improve rooting. To these series of tests were added additional treatments with various strengths of hormone powders. The plants tested were *Juniper* pfitzer, *Juniper stricta, Thuja globosa,* and *Thuja pyramidalis.* There was a clear picture on all of these plants which can best be illustrated by the following results picked from a mass of information:

JUNIPER PFITZER — Treated with IBA 3 mg/g
Taken December 27th, 1946 — Lifted February 26, 1947
Medium — Half peat, half sand — Bottom heat of 70° F. In greenhouse 8 weeks

With a heel	40% well rooted
Without a heel	56% well rooted
Without a heel, light wound	81% well rooted

JUNIPER STRICTA — No treatment
Taken January 8, 1947 — Lifted February 27, 1947
Medium — Half peat, half sand — Bototm heat of 70° F. In greenhouse 6 weeks 1 day

With a heel	8% well rooted
With a heel and wounded	16% well rooted
Without a heel and wounded	24% well rooted

Combine these effects with a hormone treatment and the same picture is to be seen. For instance,

JUNIPER STRICTA — Treated with 5 mg/cc concentrated dip IBA
Taken January 8, 1947 — Lifted February 27, 1947
Medium — Half peat, half sand — Bottom heat of 70° F. In greenhouse 6 weeks 1 day

With a heel	36% well rooted
With a heel and wounded	52% well rooted
Without a heel and wounded	84% well rooted

THUJA PYRAMIDALIS — Treated with IBA 3 mg/g
Taken January 14th, 1947 — Lifted March 6th, 1947
Medium — Half peat, half sand — Bottom heat of 70° F, In greenhouse 7 weeks

Wth a heel	36% well rooted
With a heel and wounded	68% well rooted
Without a heel and wounded	84% well rooted

There is, therefore, a clear influence from wounding alone, and secondly, an even greater influence when wounding is combined with a suitable hormone treatment.

Why does wounding improve rooting? There seems to be no clearcut answer, for many factors are involved. It was thought at one

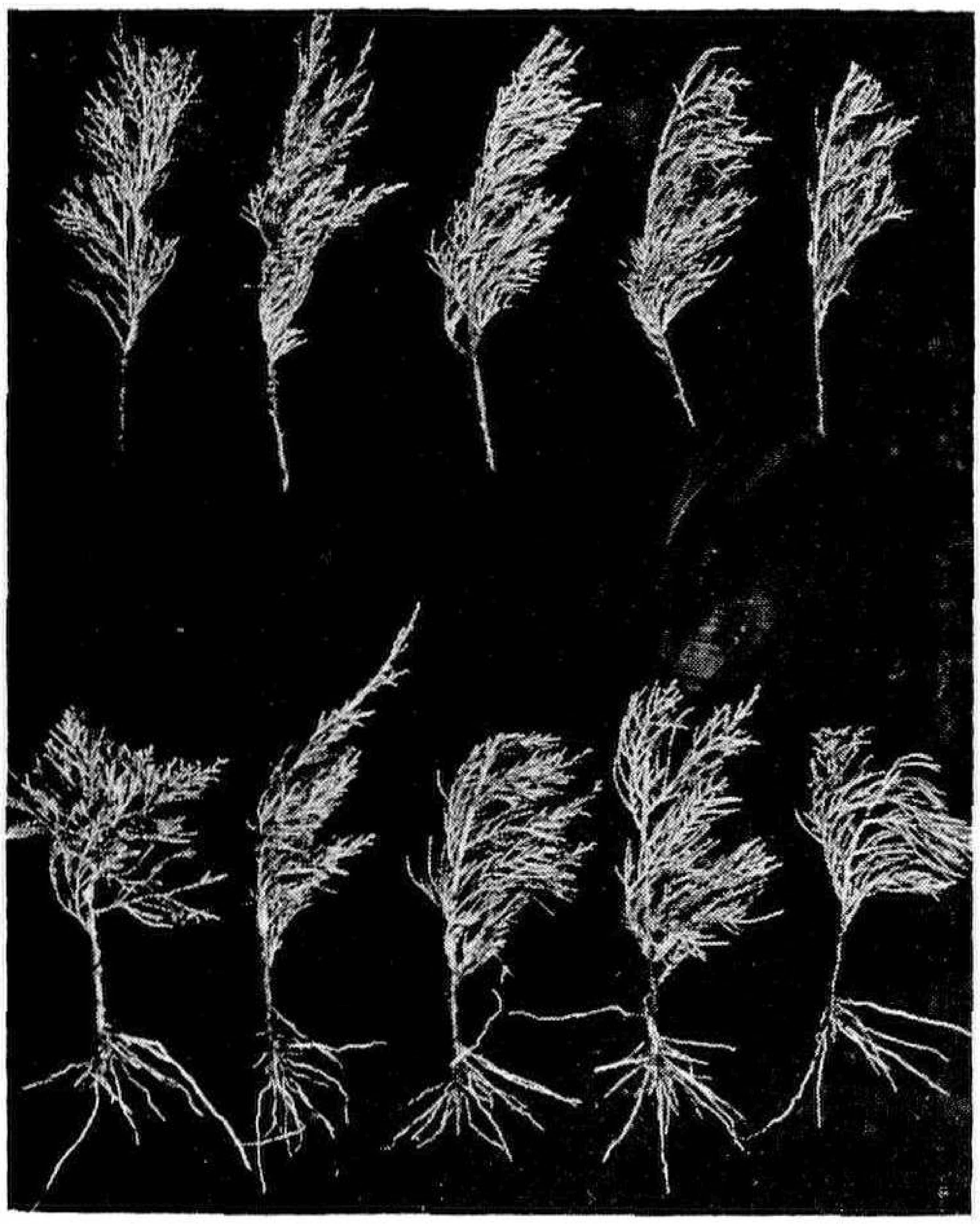

Figure 3. The influence of wounding upon rooting. Upper row—not wounded; lower row—wounded.

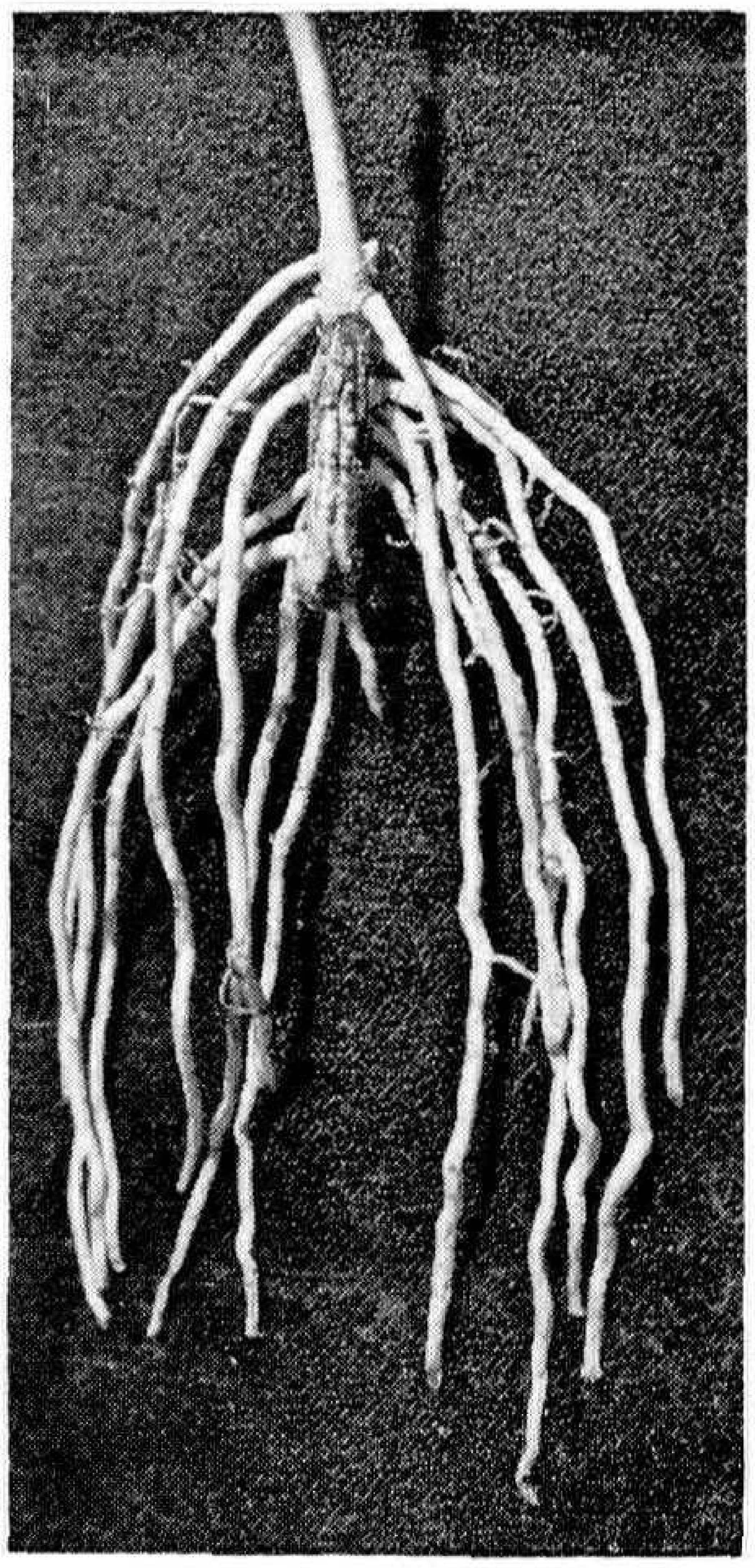

Figure 4. Roots emerging adjacent to heavy wound.

time that a "wound hormone" was produced by the plant which stimulated healing, suberin and callus formation, and thus encouraged rooting. I do not think that this theory has ever been proven. Day [4] showed that the wound clearly influenced the uptake of water by the unrooted cutting and that this water intake was further enhanced by treating the wound surface with a clay-like material. Talc which is used as a carrier for most hormone powders no doubt has a similar effect. The effect of wounding upon the water economy of unrooted cuttings is now being investigated by Dr. Snyder at Rutgers, and we may expect some interesting information from the tests now under way. Snyder [11] also suggests another possible reason for the value of wounding. Many plants have a band of thick walled cells, external to the point of origin of the root. The root grows outward to these cells but cannot grow through them. Some roots may emerge from the base of such a stem, but the number is necessarily limited. A wound, on the other hand, allows free egress for the newly formed roots. It seems to me that the wounding of a cutting must certainly allow for the more rapid and complete penetration of a hormone treatment into the base of the cutting and this has been proven by the effect of wounding upon cuttings of *Taxus Browni*. In tests which I carried out in 1955, the wounding of cuttings of *Taxus Browni* followed by a fairly strong hormone treatment produced an excessive and unnatural root system, while the same treatment applied to unwounded cuttings produced an adequate and more normal rooting system. In parenthesis I would add here that the whole *Taxus* group appear to be plants upon which wounding is not really necessary.

I believe that the real value of wounding lies in two clear areas. The first is the improvement of the root system on a plant which normally produces a somewhat sparse root system. In this group practically all of the conifers must be included. Those of you who have wounded and compared the root system on *Juniper* pfitzer with unwounded cuttings will know what I mean. The second area in which it is of real value is to aid in the rooting of really difficult subjects, and as an example, I would give rhododendrons. Now is seems so commonplace at this time to root rhododendrons that you may wonder why I place this plant in the difficult category. But, it is no longer difficult because we have learned how to grow them. A review of the methods was given in our first proceedings [14]. In order to root rhododendrons and obtain a good percentage of sound root systems well attached to the cutting, we have to use every aid at our command, including, in particular, wounding. We must take cuttings of the right kind at the right time. We must wound them with a double heavy wound. We must treat them with an appropriae hormone powder and set them in the right medium. We must provide a continuously and carefully controlled set of conditions by the use of mist, bottom heat, and good drainage; and if we do this in the proper manner, good rooting will result. Omit any one of these factors and rooting becomes poor. We can wound and not treat with hormones and rooting is uneconomically slow. We can treat with hormone powders and not wound and results will be poor. We can do both of these things

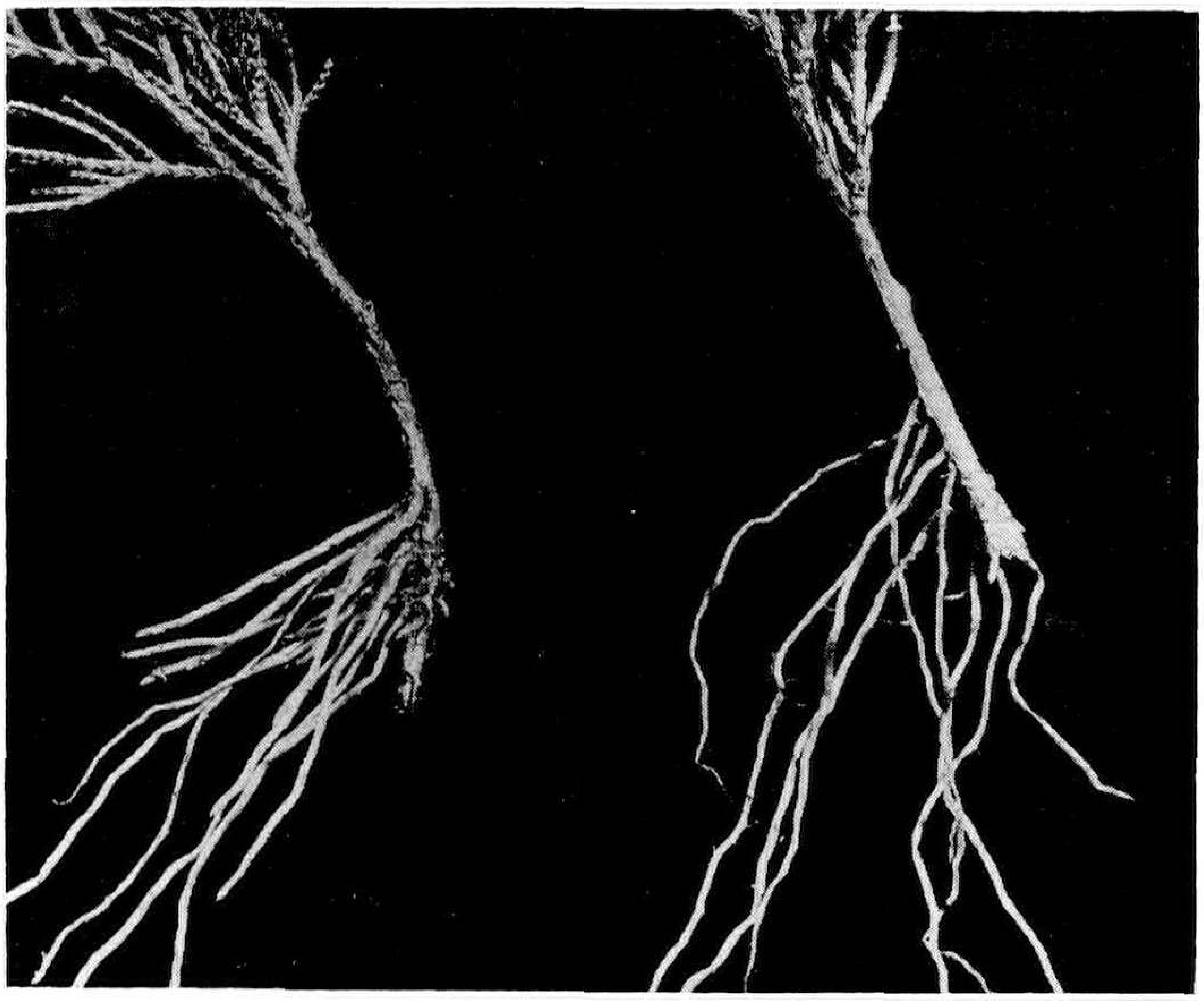

Figure 5. Roots emerging from a heavy wound.

and not provide mist or some other means of control of water loss, and obtain low percentages. If we take the wrong kind of cutting at the wrong time, and do everything else, the results are equally poor. So, here we have a plant in which a whole series of requirements have to be accurately met if we are to propagate it successfully. As suggested by Nearing [9], wounding is a vital and integral part of this chain of events. Without it we could not possibly succeed.

It is interesting to note here that the depth of the wound is apparently of some importance on rhododendrons. In 1959 we ran a series of tests on cuttings of *Rh Catawbiense* Boursault to determine the effect on the root system of a very shallow, a medium, and a very deep wound. The wound in all cases was the so called double heavy wound, wherein two slices were removed from the base of the cutting. The only difference was in the depth of the cut. On the very shallow wound, only the thinnest possible shaving was removed, and certainly none of the central woody tissue could be seen. On the medium wound the cuts were made down to, but not into, the central woody tissue, while on the deep wound the cuts went quite deeply into the woody center. Cuttings were then all treated with similar hormone powders and inserted on December 17th. They were lifted for evaluation in February 16th. Rooting was evaluated numerically on the basis of quantity and state of development. In all tests there was a clear indication that the very deep wound was detrimental and while in most cases all cuttings finally rooted 100%, the quality of the rooting was clearly superior on those given a very shallow or a medium wound.

I am glad to be able to add to this brief paper part of the list compiled and published this year by the Trial Grounds at Boskoop, Holland. This table lists a wide range of plants, recording the best time to take the cuttings; the best mediums to use; whether the cuttings should be wounded or not; and the optimum hormone treatment for successful propagation. You will see from this list that a very substantial number respond to wounding.

To conclude, if you are having difficulty in propagating any plant from cuttings, it is well to consider how best to marshall the many aids at our disposal — one by one — until you have assembled sufficient "propagating power" to achieve success. Wounding is one of the most important of these aids, for on many plants it can make the difference between indifferent failure and resounding success.

Name	Time	Medium	Wound	Hormone Treatment
Acer. palm atropurpureum	May-June	4P IS	H	IBA 2%
Acer. palm Dissectum	May-June	2P IS	H	NA .1%
AZALEA Mollis	May-June	P	L	
BERBERIS JULINAE	Oct.-Nov	2P IS	H	IBA 1%
" Thun atro nana	Aug.	2P IS	L	IBA 1%
CAMMELLIA JAPONICA	April or July	4P IS	H	IBA 1%
Chaenomeles Simonii	June-July	2P IS	H	IBA 1%
CHAMAECYPARIS obtusa nana gracilis	Oct-March	4P IS	L	IBA 100 mg/l
" Pisifera Boulevard	Oct.-March	4P IS	L	IBA 100 mg/l
CLEMATIS jackmanii	May-June	2P IS	L	NA .01%
CORNUS FLORIDA RUBRA	July	2P IS	H	IBA 1%
COTINUS COGGYRIA RUBRIFOLIUS	May-June	2P IS	L	IBA 1/2%
COTONEASTER HORIZONTALIS	July	IP 2S	L	IBA 2%
" PRAECOX	July-Aug	2P IS	L	IBA 2%
CRYPTOMERIA JAP. BANDAI SUGI	Sept.	2P IS	L	NA 25 mg/l
CYTISUS PRAECOX	Sept.	IP 4S	L	NA 50 mg/l
DAPHNE SOMERSET	Aug.-Sept	IP 4S	L	IBA 1%
ILEX AQUIFOLIUM	July-Aug.	2P IS	H	IBA 1% or IBA 2%
ILEX OPACA	July-Sept	2P IS	H	IBA 2%
JUNIPER STRICTA	Oct.-March	4P IS	L	IBA 2%
JUNIPER PROCUMBENS	Oct.-March	2P IS	L	NA 25 mg/l
" SINENSIS MOUNTBATTEN	Oct.-March	2P IS	L	NA 25 mg/l
" VIRGINIANA GLAUCA	Oct.-March	2P IS	L	NA 100 mg/l
MAGNOLIA DENUDATA	July	2P IS	H	IBA 2%
" SOULANGEANA	July	2P IS	H	IBA 1%
" STELLATA	June-July	4P IS	H	IBA 2%
METASEQUOIA CLYPTOSTROBOIDES	July	2P IS	H	NZ .1%
PHILADELPHUS CORONARIUS AUREUS	June	2P IS	H	IBA 1%
PICEA PUNGENS KOSTERI	Aug.	2P IS	H	None
PRUNUS CISTENA	June	2P IS	H	IBA 1/2%
PYRACANTHA LLANDII	Aug.	2P IS	H	IA 1/2%
RHODODENDRONS	July	P	H	IBA 2% Many varieties are listed. Treatments range from 1/2% IBA to 4% IBA
SPIREA ARGUTA	May-June	4P IS	L	IA 50 mg/l
THUJA OCC. VARS	Oct.-April	4P IS	L	NA 50 mg/l
VIBURNUM BURKWOODII	June-July	IP IS	H	IBA 1%
WISTERIA SINENSIS	July	2P IS	H	IA ½%

It should be remembered that this data is correct for plant materials and conditions in Boskoop, Holland. Timing, optimum treatment and optimum medium may have to be adjusted to local conditions.

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MODERATOR COGGESHALL: Thank you very much, Jim.

We will now go on to the next speaker, Dr. Sidney Waxman, University of Connecticut, Storrs, Connecticut, who will speak on the subject of Physiology of Evergreen Cuttings from Collection Through Rooting. Dr. Waxman!

DR. SIDNEY WAXMAN: I, too, do not like to read from a paper, but I have a feeling I will be sticking my neck out on some of these statements I am going to make and I would rather be confined to those statements than any I might make beyond that.

THE PHYSIOLOGY OF AN EVERGREEN CUTTING FROM THE TIME IT'S TAKEN UNTIL THE TIME IT IS ROOTED

SIDNEY WAXMAN
Plant Science Department
Storrs Agricultural Experiment Station
University of Connecticut

To thoroughly cover such a topic as this, the physiology of evergreen cuttings from time of taking to time of rooting would, of course, take considerably more time than 20 minutes. When I accepted the request of our program chairman to give this talk, I didn't realize just