

BEAUFORTIA

SERIES OF MISCELLANEOUS PUBLICATIONS

ZOOLOGICAL MUSEUM - AMSTERDAM

No. 17

1952

MAY 26

Growth-Inhibiting Substances in the Roots of *Fuchsia hybrida* and of *Pelargonium zonale*

by
ANTH. STOLK

1. INTRODUCTION.

Scientific research concerning growth inhibitors, which has been pursued for several decades already, dealt mainly with the effect of these substances on the germination process. WIESNER (1894) demonstrated the presence of a growth inhibitor in the slime of the mistletoe (*Viscum album*) which prevented the germination of a great variety of seeds. OPPENHEIMER (1922) supplemented the analysis by placing seeds on the pulp of ripe tomatoes and he observed a strong inhibitive effect as a result of this treatment. In addition, however, he found that the inhibiting substance is thermolabile and insoluble in ether or alcohol. REINHARD (1933) corroborated Oppenheimer's results for the most part. According to this author, however, the inhibiting agent in tomato juice is thermostabile, and it is not destroyed by boiling, neither by neutralisation or by diluting the juice 50 times. In other fleshy fruits such as apples, pears and quinces KÖCKEMANN (1934) detected inhibiting substances capable of preventing the germination of *Lepidium* seeds. These substances were reported to be sensitive to peroxide and to alkali, thermostabile and soluble in water and in ether, but insoluble in petroleum ether. On the other hand, the inhibiting agent extracted by LEHMANN (1937) from the exocarp of buckwheat is thermolabile. In *Helianthus annuus* and *Avena sativa*, finally, RUGE (1939) demonstrated the presence of an inhibitor that reduces the speed of germination to a considerable extent. FRÖSCHEL's investigations on *Trifolium* and *Beta* will be dealt with in 4.

This survey is not quite exhaustive, but clearly demonstrates that the inhibiting agent should not be regarded as a definite, well-defined chemical substance which is always the same in every individual case, but as a group of substances with analogous activities but most probably with widely divergent physical and chemical properties. Following KÖCKEMANN (1934) we can classify the inhibiting substances into two groups, as follows :

1. inhibiting substances in the testa or in the seed, and
2. inhibiting substances in the mesocarp of pulpy fruits.

For the first group I suggest the term autochtone inhibiting substances, for the second group the term allochtone inhibiting substances. In the first group I include the agents excreted by cuttings and inhibiting the growth of the roots of cuttings. See in this connection 4.

The incidence of inhibitors in the germination process, i.e., in sexual reproduction, has been irrefutably proved. One might wonder if certain inhibiting agents are involved in other physiological processes, e.g., if these substances can be demonstrated in vegetative reproduction.

This last question was the starting point of this investigation.

2. MATERIAL AND METHOD.

The experiments were carried out at Rotterdam during the summer and autumn of 1943, in a room facing South-West. The material used consisted of cuttings of *Fuchsia hybrida* and *Pelargonium zonale* which were as identical as possible. The *Fuchsia* cuttings were obtained from Maassluis and from Utrecht (Hortus Botanicus), the *Pelargonium* cuttings (variety Paul Grampel) from Schiedam and from Utrecht (Hortus Botanicus). They were placed in suitable jars by means of pieces of perforated cardboard. The contents of the jars are given in table 1.

Type of container	Contents in ml	Symbol
small	11 — 17	S
large	450 — 500	L
very large	1000 — 1500	VL

Table 1. Contents of containers used for the experiments on root inhibiting substances. In addition, the symbol used for each type is indicated.

For the sake of completeness I mention that all cuttings were cut off from the mother plants by means of scissors so as to obtain similar cutting planes, as HUBERT, RAPPAPORT AND BEKE (1939) indicate that in *Vitex Agnus-Castus* the lesion near main and lateral branches has a favourable effect on the percentage of cuttings striking root and on the average amount of roots formed per cutting.

I started from the assumption that the inhibiting agent eventually excreted by the cuttings taking root would attain a higher concentration in small jars than in larger ones and that, accordingly, the effect on the growth of roots would not be the same in the different jars. In order to analyse this effect I used the following criteria :

1. the presence or absence of roots,
2. the speed of growth of the roots, and
3. the speed of growth of the roots after a change in the nutrient solution.

The estimation of the length of the roots was carried out by means of a pair of compasses and a brass ruler.

The following list summarizes the nutrient solutions with the symbols used to indicate them for convenience sake in this paper.

- 1. F-water = fresh tap water.
- 2. Fu-water = *Fuchsia* water, i.e., water in which a considerable number of *Fuchsia* cuttings has been standing for a long time.
- 3. P-water = *Pelargonium* water, i.e., water in which a considerable number of *Pelargonium* cuttings has been standing for a long time.

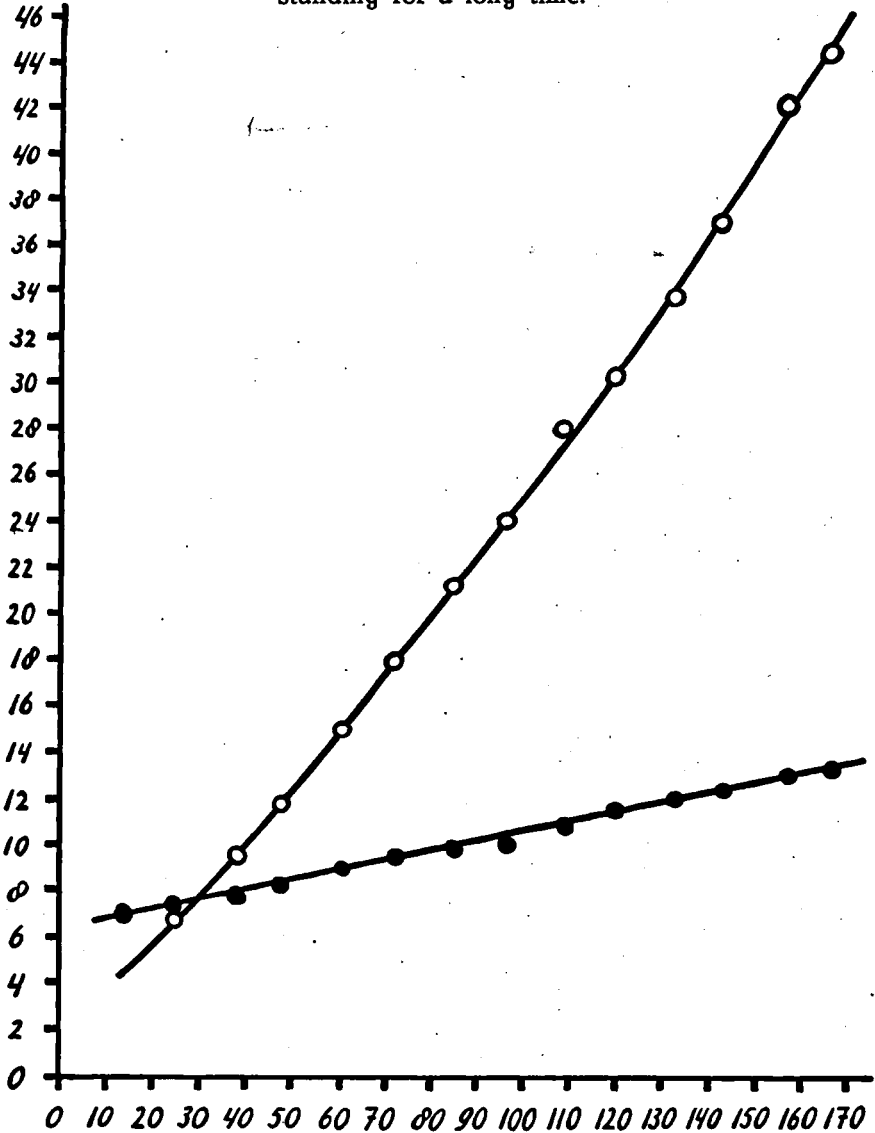


Diagram 1. Increase in length of *Fuchsia* root in a large container and in a small one (upper and lower curve, respectively). Abscissa : time in hrs. ; ordinate : root length in mm. In the large container the *Fuchsia* root appears to grow more rapidly than in the small one.

4. Fu 100-water = *Fuchsia* water, kept at a temperature of 100° C. for about 15 minutes.
5. P 100-water = *Pelargonium* water, kept at 100° C. for 15 to 45 minutes.

The *Fuchsia* water has a yellow colour, the *Pelargonium* water is brown; both smell rather unpleasantly and froth fairly strongly when shaken. After heating at 100° C. the colour remains the same, whereas the smell disappears. Also the capacity of frothing is retained.

If small containers with *Fuchsia* or *Pelargonium* cuttings had lost water by suction and/or evaporation, they were replenished with Fu-water or P-water, respectively.

When preparing Fu 100- and P 100-water the heated Fu- and P-water was made up to the original amount by adding fresh water. After cooling,

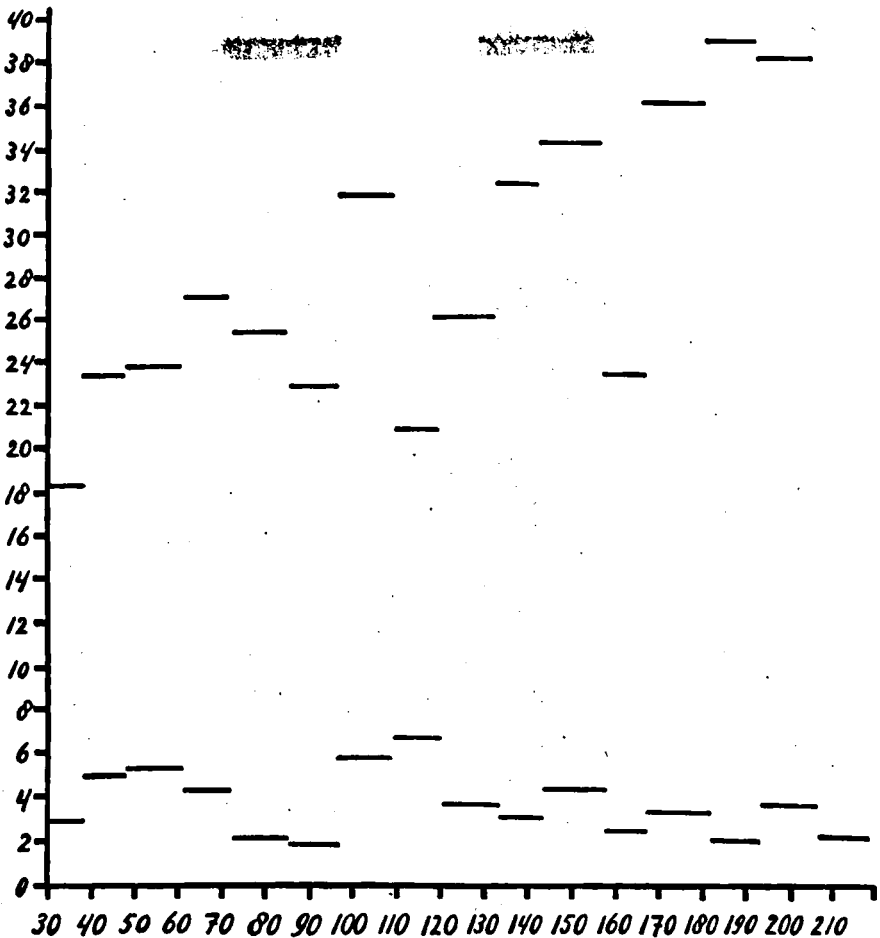


Diagram 2. Speed of growth of *Fuchsia* root in large container and in a small one (upper and lower diagram, respectively). Abscissa: time in hrs.; ordinate: speed of growth of the individual periods in units of 10 μ per h.

the water was vigorously shaken with air in order to restore the original oxygen content of the water. The F-, Fu- and P-water were also supplied with sufficient oxygen by shaking or by aerating it, so that in the various tests the amount of oxygen could not possibly be the limiting factor.

Finally, some explanation of the diagrams would not be out of place. The speed of growth-time diagrams are built up of successive periods of growth of which the mean speed of growth is shown. This speed of growth was expressed in units of 10μ per hour. One should avoid interpreting the differences in level of the periods of growth as real and sudden increases and decreases of the speed of growth, the periods being discontinuous as a result of the fact that the mean speed of growth was estimated.

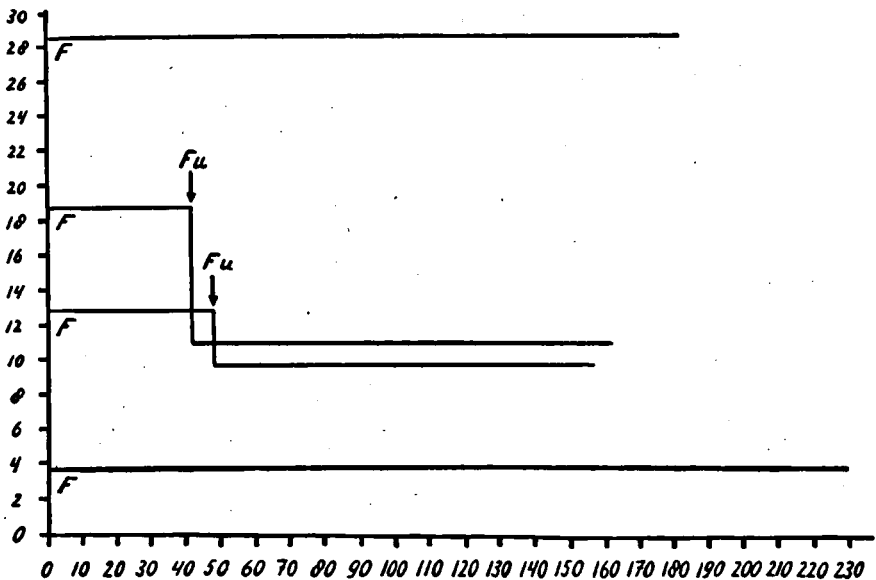


Diagram 3. Mean speed of growth of *Fuchsia* roots. Above: in a large container. Bottom: in a small container. In the middle: decrease of the mean speed of growth of two roots as a result of inhibition by *Fuchsia*-water. The inhibition appears to be of a different intensity. Explanation of the symbols: F = fresh water, Fu = *Fuchsia* water. Abscissa: time in hrs.; ordinate: mean speed of growth in units of 10μ per h.

Some diagrams also show the relation between the speed of growth and time, but in these instances the mean speed of growth was estimated for every whole period during which the cutting remained in the same medium.

A change in the environmental conditions is indicated in the diagrams by an arrow and a letter. The symbol Fu , for instance means that the cutting was placed in Fu-water, $P100$ that it was placed in boiled P-water. The symbol without an arrow at the beginning of a diagram indicates the solution in which the cutting was standing at that time. There is no change of medium in this case, changes only being indicated by an arrow.

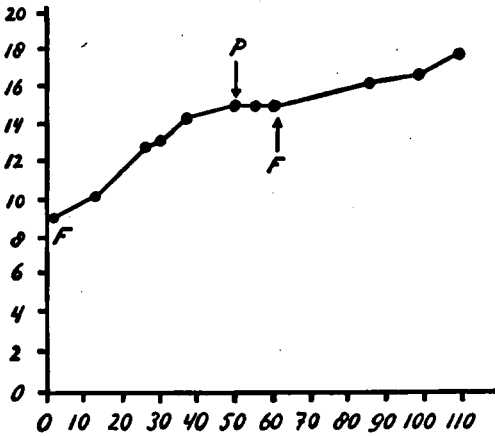


Diagram 4. Increase in length of *Pelargonium* root. *Pelargonium* water completely inhibits growth. Fresh water causes renewed growth, but the speed of growth does not attain the same value as before the application of *Pelargonium*-water (reversibility of the inhibition process).
Explanation of the symbols: F = fresh water, P = *Pelargonium* water. Abscissa: time in hrs.; ordinate: root length in mm.

Diagram 5. Speed of growth of *Pelargonium* root before and after the application of *Pelargonium* water. *Pelargonium* water causes a decrease of the speed of growth to the zero level. Fresh water causes an increase in speed of growth (reversibility of the inhibition process). Explanation of the symbols: F = fresh water, P = *Pelargonium* water. Abscissa: time in hrs.; ordinate: speed of growth in units of 10μ per h.

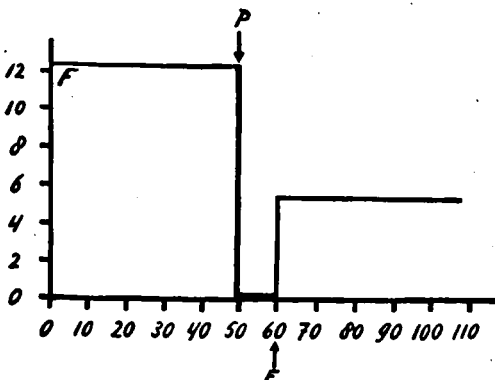
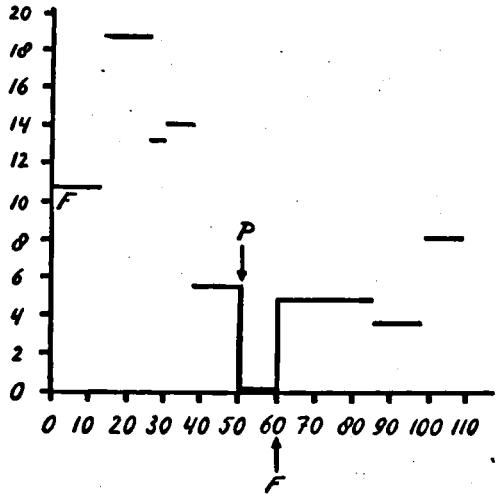


Diagram 6. Mean speed of growth of *Pelargonium* root before and after the application of *Pelargonium* water. *Pelargonium* water causes a decrease in speed of growth to the zero level. Fresh water causes an increase in speed of growth (reversibility of the inhibition process). Explanation of the symbols: F = fresh water, P = *Pelargonium* water. Abscissa: time in hrs.; ordinate: mean speed of growth in units of 10μ per h.

3. DISCUSSION OF THE RESULTS.

The results will be discussed in the following order, using the various criteria as a guiding principle.

CRITERION 1: The presence or absence of roots.

Table 2 shows the percentages of cuttings taking root in a number of experiments, in this case classified according to the various kinds of jars. In the first horizontal row the types of containers are indicated by the symbols VL, L and S (very large, large and small, respectively). The following rows show alternately the number of cuttings and the percentages for three series of experiments with *Fuchsia* and two with *Pelargonium*. All cuttings of one series of experiments had been cut and placed in the jars at the same time. The percentage indicates the amount of cuttings that had struck root.

The following example may serve as an illustration. In the experiment II Fu the percentage for VL was 75, because 3 out of 4 *Fuchsia* cuttings placed in very large containers formed roots. The last four horizontal rows show the overall numbers and percentages of all *Fuchsia* and *Pelargonium* cuttings, respectively.

		VL	L	S	Commencing date
Experiment I Fu	N	2	2	2	4.8.1943
	P	100%	100%	50%	
Experiment II Fu	N	4	2	4	16.9.1943
	P	75%	100%	0%	
Experiment III Fu	N	3	8	5	22.9.1943
	P	33.3%	25%	0%	
Experiment IV P	N	3	4	3	9.8.1943
	P	66.7%	75%	0%	
Experiment V P	N	3	5	5	22.9.1943
	P	33.3%	20%	0%	
Total Fu mean	N	9	12	11	
	P	66.7%	50%	9.1%	
Total P mean	N	6	9	8	
	P	50%	44.4%	0%	

Table 2. Percentage of cuttings of *Fuchsia* and *Pelargonium* taking root in containers of different sizes.

Fu = *Fuchsia*; P = *Pelargonium*; VL = very large container; L = large container; S = small container; N = number of cuttings; P = percentage.

As regards the results of these experiments, the following comments can be made. In the first place the percentage of cuttings taking root is lower in all experiments with small containers than in those with large containers; in the 2nd to the 5th experiment inclusive it amounts to 0, in the first to 50%. This difference has to be ascribed in my opinion to the average temperature, which was highest in the first experiment because this one was carried out in the summer. Also the differences between the 4th and the 5th experiment with *Pelargonium* in very large and large containers, have to be explained in the same way. For the sake

of completeness the commencing dates of every experiment are mentioned separately in the last vertical column.

The overall mean of the percentages of all containers of a certain type gradually decreases from the very large to the small ones in the experi-

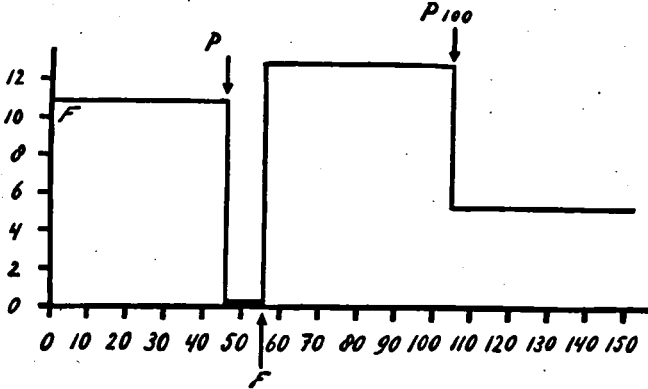


Diagram 7. Mean speed of growth of *Pelargonium* root. A case in which after inhibition by *Pelargonium*-water the application of fresh water causes a mean speed of growth greater than before the inhibition. *Pelargonium*-water kept at 100° C. for some time, also causes a decrease of the mean speed of growth, but this decrease appears to be less than the one caused by *Pelargonium*-water. Explanation of the symbols: F = fresh water, P = *Pelargonium* water, P 100 = *Pelargonium* water kept at 100° C. for some time. Abscissa: time in hrs.; ordinate: mean speed of growth in units of 10 μ per h.

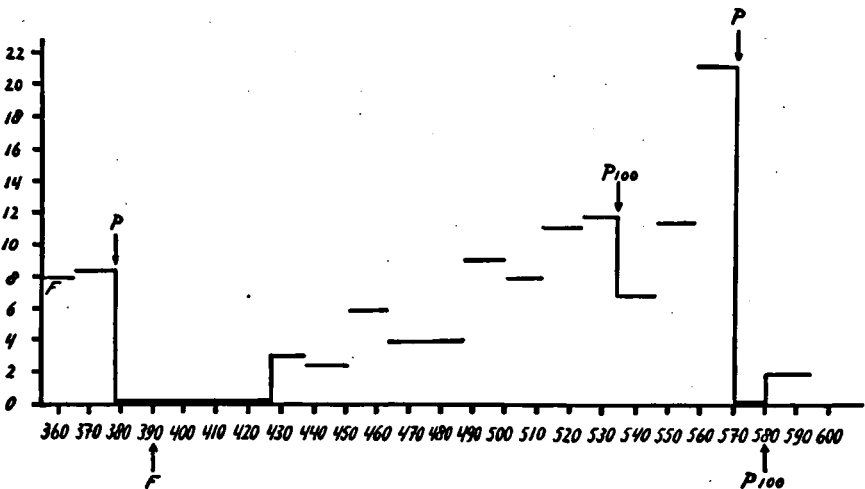


Diagram 8. Speed of growth of *Fuchsia* root inhibited by *Pelargonium*-water (aspecificity of inhibiting substance). The cessation of growth after the first application of *Pelargonium*-water is apparently a result of so strong an inhibition that even after the application of fresh water no growth occurs for some time. The inhibition caused by P 100-water is much less intense. The cessation of growth after the second application of *Pelargonium*-water is immediately finished by the application of P 100-water. Explanation of symbols: F = fresh water, P = *Pelargonium* water, P 100 = P-water, heated at 100° C. for some time. Abscissa: time in hrs.; ordinate: speed of growth in 10 μ per h.

ments with *Fuchsia* as well as in those with *Pelargonium*. In the individual experiments this percentage is not always higher for the very large jars than for large ones. The percentages were equal for very large and large containers in the first experiment, but in the second experiment the percentage was higher in the large jars than in the very large ones. I do not claim, therefore, that in very large vessels the cuttings strike roots better than in large ones, but I am of the opinion that it is highly probable that in small jars the process of root formation is strongly inhibited.

The formation of lateral shoots and leaf primordia, on the other hand, took place in the normal way in both the large vessels and the smaller ones. This process does not seem to be inhibited. The formation of lateral shoots being of a complicated nature, a further analysis could not be made.

The question of the possible cause of root inhibition I shall leave unanswered for the time being. I shall return to it in a following section.

Table 3, compiled from data from the first experiment with *Fuchsia*, shows the number of hours after which the first roots became discernable in the various containers. This number is on the average higher in the smaller jars than in the larger ones, but in my opinion it is so much subject to variation that it does not allow for positive conclusions.

Experiment I Fu	Fu 1	Fu 2	Fu 4	Fu 6	Fu 7	Fu 5
Number of the cutting.						
Type of container	VL	L	S	VL	L	S
Appearance of first root in hrs. after the commencement of the experiment	385	493	—	397	275	408

Table 3. First appearance of roots on *Fuchsia* cuttings in containers of different sizes. Fu = *Fuchsia*; VL = very large container; L = large container; S = small container.

CRITERION 2: The speed of growth of the roots.

The speed of growth of the roots depends on the size of the container and, consequently, on the available amount of water. If the increase in length of *Fuchsia* root in a large container is compared with that in a small one, it appears to be considerably higher in the first case (diagram 1). Obviously the speed of growth is also higher in the large container (diagram 2) and, accordingly, the mean speed of growth as well (diagram 3). Diagram 3, for instance, shows that the mean speed of growth of two individual *Fuchsia* roots amounts to 286 μ per hour in a large jar and only attains 37 μ per hour in a small one, i.e., the growth is about 7.7 times slower.

From this experiment, which could be repeated with a great number of *Fuchsia* roots, the following preliminary conclusion can be drawn. The different speed of growth is caused by an inhibiting factor present in the water. There is a certain relation between the amount of water and the intensity of the inhibition, the latter being slight in a great deal of water and strong in a small amount of water.

Similar results were obtained with *Pelargonium* roots, but as in small jars the *Pelargonium* cuttings hardly ever struck root, a comparison as was made in the experiments with *Fuchsia* was out of the question. I had to confine myself to a comparison of the speed of growth of roots in larger containers. The diagrams of these experiments are omitted because they are essentially the same as those with *Fuchsia*.

CRITERION 3: The speed of growth in relation to the nutrient solution.

The experiments reported so far gave me the impression that *Fuchsia* and *Pelargonium* cuttings excrete a substance into the water which inhibits the formation of roots. This inhibitor would attain a higher concentration in a small quantity of water than in a large amount and consequently cause a stronger inhibition in the small containers. It became interesting to find out if a rapidly growing root from a large container, after having been transferred to a smaller jar, starts growing more slowly. It is not necessary to place the cutting in the small container itself, because the roots can grow in the small containers as unhindered by the glass wall as in a larger one, so that it is sufficient to place the cutting in water from a small container instead of in the jar itself. In order to obtain that water in considerable quantities and with a high concentration of the inhibiting substance, a great number of cuttings was placed in a container filled with water. In this way *Fuchsia*- and *Pelargonium*-water was obtained. It was then possible to estimate the speed of growth of a root in both fresh water and in water containing the inhibitor.

Diagram 4 illustrates the growth of a *Pelargonium* root. For some time the root was growing in fresh water, reaching a higher speed of growth in the last period than in the first. The cutting was subsequently placed in *Pelargonium*-water and stayed in this medium for 10 hrs. The growth was completely inhibited after this change in nutrient solution. After having been placed in fresh water again, the speed of growth increases, but at first it does not attain the value it had before the transfer to *Pelargonium*-water. Diagram 5 shows the relation between speed of growth and time, diagram 6 that between mean speed of growth and time. The mean speed of growth was originally 123μ per h., but was reduced to the zero level by the action of the *Pelargonium*-water. After the application of fresh water the mean speed of growth could reach the 54μ per h. level.

A similar result was obtained in an experiment represented in diagram 7. In addition, this diagram shows the peculiarity that the mean speed of growth after the action of *Pelargonium*-water for 10 hrs, could be restored to a higher level (128μ per h.) than the original one (109μ per h.).

We have found that *Pelargonium*-water is able to inhibit the growth of *Pelargonium* roots. Diagram 3 indicates that *Fuchsia*-water shows an inhibiting action on the *Fuchsia* root. However, the inhibitive action of *Fuchsia*-water is much less than that of *Pelargonium*-water. The *Fuchsia*-water is not able to produce a complete inhibition of the growth of roots as the *Pelargonium*-water often does.

One might wonder if *Fuchsia* roots are also inhibited by *Pelargonium*-water, in other words, is the action of *Pelargonium*-water a specific or an inspecific one? Diagrams 8 and 9 clearly demonstrate that *Fuchsia*

roots are also inhibited by *Pelargonium*-water and that, accordingly, the inhibiting action is an aspecific process. The inhibitions represented in diagram 9 vary widely as regards their intensities.

In order to analyse the inhibiting agent more thoroughly, the water containing the inhibitor was heated to 100° C. The exposure to this temperature lasted about 15 min. in the case of *Fuchsia*-water and from about 15 to about 45 min. in the case of *Pelargonium*-water. The oxygen

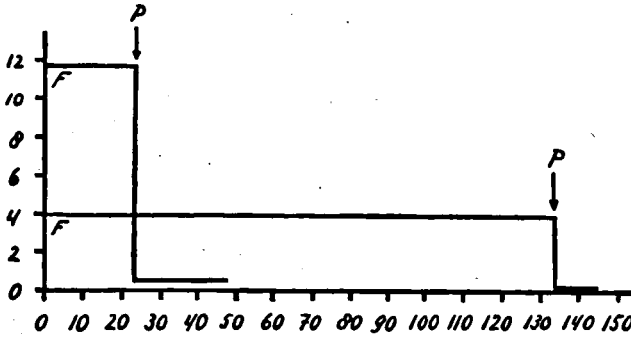


Diagram 9. Mean speed of growth of two *Fuchsia* roots inhibited by *Pelargonium*-water (aspecificity of inhibiting substance). The inhibitions appear to have different intensities. Explanations of symbols: F = fresh water, P = *Pelargonium* water. Abscissa: time in hrs.; ordinate: mean speed of growth in units of 10 μ per h.

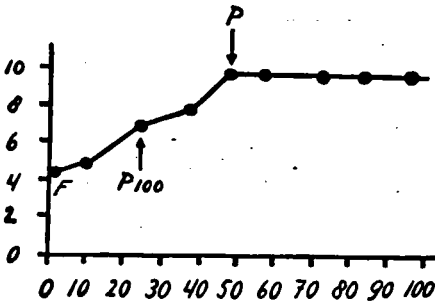
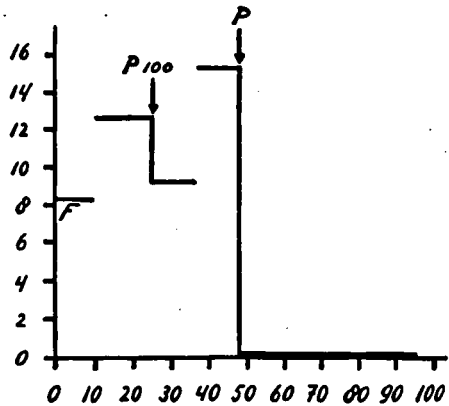


Diagram 10. Increase in length of *Fuchsia* root after consecutive application of P 100-water and *Pelargonium*-water. In P 100-water the growth continues (thermolability of inhibiting agent), in *Pelargonium*-water the growth is completely inhibited. Explanation of symbols: F = fresh water, P 100 = *Pelargonium* water, heated to a temperature of 100° C. for some time. Abscissa: time in hrs., ordinate: root length in mm.

Diagram 11. Speed of growth of *Fuchsia* root, treated consecutively with P 100-water and *Pelargonium*-water. In P 100-water the growth continues, although with a slightly smaller speed of growth (thermolability of inhibiting substance). After the application of *Pelargonium*-water the speed of growth is reduced to the zero level. Explanation of symbols: F = fresh water, P = *Pelargonium* water, P 100 = *Pelargonium* water treated at 100° C. for some time. Abscissa: time in hrs.; ordinate: speed of growth in units of 10 μ per h.



concentration was adjusted after cooling by shaking or by aerating the liquid. The Fu 100- and P 100-water obtained in this way was used for several experiments.

Diagram 10 shows that a *Fuchsia* root after having been placed in P 100-water continues growing at practically the same rate as in fresh water. After transfer to *Pelargonium*-water the growth ceases completely. The relation between speed of growth and time is given in diagram 11, the relation between mean speed of growth and time in diagram

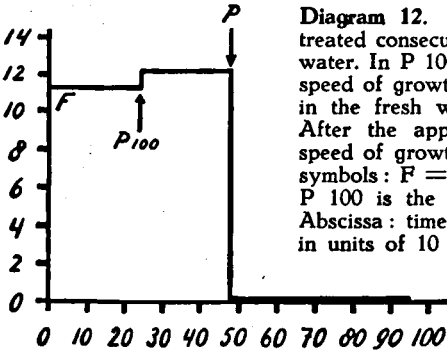


Diagram 12. Mean speed of growth of *Fuchsia* root, treated consecutively with P 100-water and *Pelargonium*-water. In P 100-water the growth continues with a mean speed of growth that is even slightly higher than the one in the fresh water (thermolability of inhibiting agent). After the application of *Pelargonium*-water the mean speed of growth is reduced to zero level. Explanation of symbols: F = fresh water, P = *Pelargonium* water and P 100 is the same, treated at 100° C. for some time. Abscissa: time in hrs.; ordinate: mean speed of growth in units of 10 μ per h.

12. The last diagram shows that after a transfer to P 100-water the speed of growth even increases. Before the transfer to P 100-water the mean speed of growth amounted to 113 μ per h., afterwards to 122 μ per

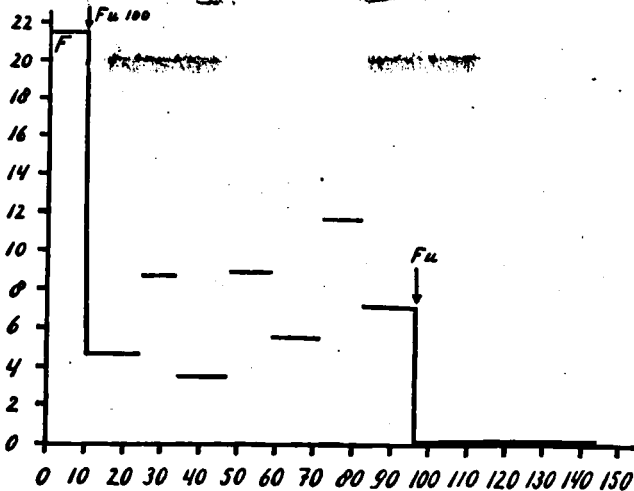


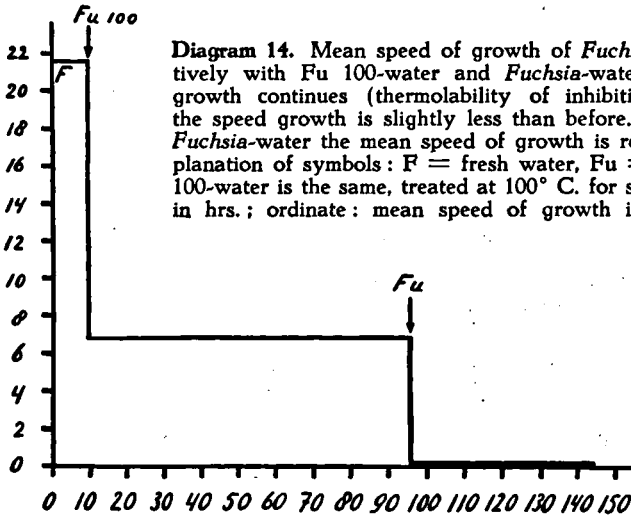
Diagram 13. Speed of growth of *Fuchsia* root, treated consecutively with Fu 100-water and *Fuchsia*-water. In Fu 100-water the growth continues (thermolability of inhibiting agent), although the speed of growth is somewhat less than before. After the application of *Fuchsia*-water the speed of growth is reduced to zero level. Explanation of symbols: F = fresh water, Fu = *Fuchsia* water and Fu 100-water is the same, treated at 100° C. for some time. Abscissa: time in hrs.; ordinate: speed of growth in units of 10 μ per h.

h. Also in the experiment represented in diagram 7 the *Pelargonium* root continues growing, although the speed of growth is less. It should be borne in mind, however, that the *Pelargonium*-water inhibits growth almost completely.

In a number of tests with P 100-water a small decrease in speed of growth was found. It is not necessary, in this connection, to show these results in a diagram.

Also the *Fuchsia*-water appears to be inactivated by heating at 100° C. Diagrams 13 and 14 for instance teach us that in Fu 100-water the *Fuchsia* root keeps growing, although the speed of growth is considerably less, whereas unheated *Fuchsia*-water produces complete inhibition.

Diagram 8, finally, demonstrates the results of a prolonged experiment in which the root keeps growing in P 100-water. In this speed of growth diagram the speed of growth decreases in the beginning, but increases considerably afterwards. Untreated *Pelargonium*-water completely inhibits again. P 100-water, applied a second time, increases the speed of growth, but not to such an extent as it did the first time.



From these experiments with *Fuchsia* and *Pelargonium* the following conclusions can be drawn:

In a boiled, cooled and aerated inhibiting liquor the roots do not cease growing. The inhibitor is decomposed by boiling, but the coloured matter remains unaltered. The inhibiting action therefore cannot be ascribed to an effect of the coloured substance, neither to oxygen deficiency.

4. COMPARISON OF THE RESULTS WITH THE LITERATURE ON THE SUBJECT.

As the investigations carried out thus far had been limited to substances inhibiting germination and no data concerning substances inhibiting root growth were available. I can necessarily only compare the results of my work with those obtained from the substances inhibiting germination.

In the first place I wish to draw the attention to the fact that my

results are in several respects conformable to those obtained by FRÖSCHEL (1939), who on account of experiments with *Trifolium* and *Beta* made a distinction between inhibition and self-inhibition. Self-inhibition or auto-inhibition means that the germination is inhibited by substances produced by the same plant species, inhibition means that the inhibiting agent is produced by a different species.

If in my experiments the *Pelargonium* root is inhibited by a substance produced by *Pelargonium* roots and the *Fuchsia* root by an inhibiting substance produced by *Fuchsia* roots, the inhibiting process has to be considered to be also self-inhibition, but if by analogy with FRÖSCHEL'S experiments *Pelargonium*-inhibitor effects the *Fuchsia* root, then this is a case of inhibition *sensu stricto*.

FRÖSCHEL (1939, page 102) draws the following conclusion: "Not only the reduced percentage of germination but also the decreased speed of growth is characteristic of the effect of inhibiting agents". I can completely corroborate this statement, if "percentage of germination" is substituted by "percentage of cuttings striking root". In addition, my conclusion that the inhibitor is not associated with coloured substances, tallies with FRÖSCHEL'S findings, the inhibitor being decomposed by boiling whereas the colour of the liquid remains unchanged. I also found, as FRÖSCHEL did, a certain reversibility of the inhibiting process.

As regards the effect of the temperature, however, our results are at variance. Whereas FRÖSCHEL'S inhibiting substance is thermostabile, my *Fuchsia* and *Pelargonium* inhibitors have to be considered to be thermolabile. Neither could I demonstrate FRÖSCHEL'S "reversing effect" (plants obtained from inhibited seeds by addition of water show speed of growth that is about quadrupled) in *Fuchsia* or in *Pelargonium*.

I did find an increase in speed of growth after a 10 hours treatment with *Pelargonium*-water (the increase in speed of growth was about 20 μ per h.), but on the other hand in another case the speed of growth after the inhibiting treatment with *Pelargonium* water lasting 10 hrs. attained the same value as before the inhibition period and in a third case after an inhibiting treatment with *Pelargonium*-water lasting 25 hrs. it remained considerably less than before.

It is not impossible, in my opinion, that after a treatment for less than 10 hrs., followed by a transfer to fresh water, the speed of growth may increase considerably as compared with that before the inhibition. For experiments of this kind more data are required than I had at my disposal owing to the conditions prevailing at that time.

As the most essential difference between the inhibiting agent studied by FRÖSCHEL and my *Fuchsia* and *Pelargonium* inhibitors I regard their different behaviour with regard to the temperature. More thermolabile inhibiting agents have been reported in the literature. In table 4 I have assembled a number of thermostabile and thermolabile inhibiting substances.

The results obtained by OPPENHEIMER (1922) and REINHARD (1933), in spite of the fact that these workers used the same plant species for their experiments, are even controversial.

I wish to touch upon the autochtone character of the inhibiting substances. It was mentioned in the introduction what the word "autochtone" means in this connection. According to the definition given the

inhibitors of *Pelargonium* and *Fuchsia* must belong to the autochtone inhibiting substances because they are secreted by the same plant species in which they inhibit root formation. The definition of "self-inhibition" implies the meaning of "autochtone" in this connection.

As regards the accelerated growth after application of fresh water, (or P 100-water) to an inhibited culture, the following remarks can be made. I feel sure that this acceleration is caused by the elimination of the cause of the inhibition. Whether every acceleration of growth should be considered to be a result of an elimination of the inhibiting agent still remains an open question. For this point the reader is referred to a publication by VON VEH (1936) on the nature and the meaning of inhibition of developmental processes in plants.

Author	Source of inhibiting substance	Nature of inhib. subst.	Behaviour towards high temperature
OPPENHEIMER (1922)	fruit pulp of tomato	inhibiting germination	thermolabile
REINHARD (1933)	fruit juice of tomato	ibid.	thermostabile
KÖCKEMANN (1934)	fruit pulp of apple, quince, pear, tomato	ibid.	thermostabile
LEHMANN (1937)	exocarp of buckwheat	ibid.	thermolabile
FRÖSCHEL (1940)	<i>Beta</i>	ibid.	thermostabile
STOLK (1952)	<i>Fuchsia</i> and <i>Pelargonium</i>	inhibiting root growth	thermolabile

Table 4. Survey of various types of inhibiting substances.

Finally, it should be mentioned that I was not able to distinguish two processes in root formation as GEIGER-HUBER (1938) did. According to this worker the process of root formation is to be separated into :

1. the formation of root primordia, which is stimulated by the application of a growth promoting substance ;
2. the initial growth of these primordia and the subsequent longitudinal growth of the young roots which processes are reported to be inhibited by the application of a growth promoting substance or are only stimulated at a very low hydrogen ion concentration.

My experimental technique was not refined enough to allow for such a distinction.

5. SUMMARY OF RESULTS.

1. *Pelargonium* cuttings excrete a substance inhibiting the growth of *Pelargonium* roots and *Fuchsia* cuttings produce a substance inhibiting the growth of *Fuchsia* roots : auto-inhibition.
2. The inhibiting substance from *Pelargonium* also inhibits *Fuchsia* roots and acts specifically : inhibition sensu stricto.

3. The inhibiting substance from *Fuchsia* is weaker in its action than the one from *Pelargonium*.
4. Both the *Fuchsia* and *Pelargonium* inhibitors are thermolabile, the inhibiting capacities get lost after a treatment at 100° C.
5. If the inhibition has not been lasting for too long a period, it can be stopped by a transfer of the cuttings to fresh water. The inhibition is therefore a reversible process.
6. The inhibiting substance from *Fuchsia* cuttings has no perceptible influence on the formation of lateral shoots.

6. LITERATURE CITED.

FRÖSCHEL, P. —

- 1939 Onderzoekingen over de physiologie van de kieming. I Remstoffen. *Natuurwetenschappelijk Tijdschrift* 21, 93—116.
1940 Untersuchungen zur Physiologie der Keimung. Zweite Mitteilung. (Hemmstoffe, Fortsetzung). *Biologisch Jaarboek Dodonaea* 7, 73—116.

GEIGER-HUBER, M. —

- 1938 Die Bewurzelung von Stecklingen als hormon-physiologisches Problem (Vorläufige Mitteilung). *Verhandlungen der Schweiz. Naturforschenden Gesellschaft* 183—185.

HUBERT, B., J. RAPPAPORT en A. BEKE —

- 1939 Onderzoekingen over de beworteling van stekken. *Mededelingen der Landbouwhoogeschool en der Opzoekingsstations van den Staat te Gent, Deel VII*, 3—103.

KÖCKEMANN, A. —

- 1934 Ueber eine keimungshemmende Substanz in fleischigen Fruechten (vorläufige Mitteilung). *Berichte der deutschen botanischen Gesellschaft* 52, 523—526.

RUGE, U. —

- 1939 Zur Physiologie der genuinen keimungshemmenden und keimungsbeschleunigenden Stoffe von *Helianthus annuus*. *Zeitschrift für Botanik* 33, 529—571.

VEH, K. VON —

- 1936 Experimenteller Beitrag zur Frage nach Wesen und Bedeutung pflanzlicher Entwicklungshemmungen. *Berichte der deutschen botanischen Gesellschaft* LIV, 135—155.

WIESNER, J. —

- 1894 Pflanzenphysiologische Mitteilungen aus Buitenzorg. IV. Vergleichende physiologische Studien über die Keimung europäischer und tropischer Arten von *Viscum* und *Loranthus*. *Sitz. ber. d. Wien. Akad. d. Wiss., math.-naturw. Kl., Abt. I*, 103, 401.