Botany. — *Report on Fervorization of Plant Nutrient-Substrata.* By A. RADERMACHER and Z. KLAS, with the collaboration of Prof. V. VOUK. (Laboratory for Plant-physiological Research of the University of Zagreb, Yugo Slavia, Director Prof. V. VOUK.) (Communicated by Prof. G. VAN ITERSON Jr.)

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In this communication we give a short account of the behaviour of some plants in nutrient-substrata which have been heated to a high temperature. This heating of nutrient-substrata has been applied for a long time in plant-physiological, and especially in micro-biological, investigations. Generally this treatment has been called sterilization. For reasons which shall be given later, we suggest for this treatment the term *fervorization* [1]). Hereinafter, therefore, by fervorization shall be understood the heating of plant nutrient-substrata to a high temperature.

In the sense of this definition, soils, nutrient-solutions, water, and salts were fervorized and then used for the cultivation of plants. We reserve for ourselves the right to publish a more detailed report concerning these experiments in another place.

The incentive to our research was V. VOUK's (1) work on sterilization of cultures with brown coal. By virtue of his experiments, which took place at the laboratory for plant-physiological research of the University of Zagreb, Prof. VOUK stated, with special emphasis, that sterilization of the soil highly increases the yield.

I. *General remarks on the method of investigation.*

From a study of earlier work on the influence of heat on nutrient media it follows that an analysis was generally made in three directions, the aim being to explain the effect of heat sterilization by chemical, physical, or micro-biological changes in the soil.

The chief defect of this research work hitherto would seem to lie in the circumstance that all the factors possibly being active have not been examined separately. Only in one case time- and temperature-factors have been separately examined (without, however, yielding a result). It seemed important to us to examine the influence of heat on the nutrient salt components. This required the use of the classic water-cultures. Hereby one of the components which is regarded as being an essential factor in the influence of heat, the micro-biological one, is excluded. This makes it easier to interpret the results of the experiments.

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[1]) Fervor, latin: siedende Hitze, i.e. heating to the boiling temperature; ferve facere: to heat to the boiling temperature.

This method of physiological analysis with the aid of nutrient-solutions was the right one, as the first experiments already showed. By heating the v. d. Crone's nutrient-solution in the autoclave, and charging such a nutrient-solution with young *Sinapis alba* plants, we at once obtained the same increase of the yield, as had been formerly observed after the heating of soils. This striking result led us to a new interpretation of the influence of heat. As in our water-cultures we had almost entirely excluded the micro-biological influence of heat sterilization the result in our case was evidently *an effect of the high temperature and not of the absence of living germs.*

That the treatment of soils by high temperatures not merely leads to a micro-biological change, but also effects a change in other qualities of the soil, had already been observed by CZERMAK [1]). In his publication he therefore qualifies sterilization as "lediglich die Wirkung der Hitze auf die physiologischen Bodeneigenschaften".

For the heating of nutrient media, which generally leads to changes of a chemical, a physical and, also, a micro-biological nature, we should like to introduce the term "fervorization". The new state of the media is indicated collectively by the term *fervor-state.* This fervor-state induces an effect on plants which we will designate *fervor-effect.* This effect is manifested in different ways.

Further consideration of the experiments with water-cultures logically led us to divide the influence of heat on the nutrient-solution into the influence on the nutrient-salts and that on the water. Here, too, the first experiment showed that our way of reasoning was the right one. From this experiment and from other ones it followed that by mixing previously *fervorized water* with the unfervorized salts of the v. d. Crone-solution, the same fervor-effect was obtained, as was shown by the fervorized nutrient-solutions and by the fervorized soils.

The technic of our experiments was generally similar to that of heat sterilization, i.e. the substrata were heated in the autoclave to 137° C with a pressure of $2\frac{1}{2}$ atm. during a certain time. Difficulties were experienced when the substratum had to be heated to 70° C and 100° C. The temperature of 100° C was reached in the autoclave without pressure, and that of 70° C by making a water bath in the autoclave.

In the following pages some of the experiments on the influence of fervorization on the development of plants will be briefly communicated.

II. *Experiments on the influence of fervorization of soils.*

In the literature there is already mentioned that the so-called sterilization increases the crop yield. In our experiments we wished to investigate the causes of this effect more thoroughly. Further, we endeavoured to answer some questions related to the germination, the growth of shoots, and the

[1]) CZERMAK, Landw. Versuchs. Stat. **76**, p. 91.

crop at various life periods of the plants, former investigations of different writers having, as a rule, been restricted to the first phase of development only. Furthermore, we wished to examine more exactly the effects of different temperatures in the presence of moisture, whereby the duration of the fervorization was to be reckoned with. We mainly wished to determine the duration of heating, and the temperature giving the most favourable effect.

In this communication we deal with experiments which have only been carried out with a soil which has been qualified as field-soil. This is a loamy, clayey, heavy soil, which had been taken from the experimental fields of the Botanical Gardens, the pH of which was 8.22. For the cultivation of plants we mixed 5 parts of this soil with 1 part of sand. The experiments were carried out with MITSCHERLICH's vessels.

a. *The influence on germination.* Seeds of *Sinapis alba* were bought, from which specimens of similar size were selected before they were put into the ground. 30—50 seeds were sown in rows at the same depth. The soil was fervorized twice, each time during 1 hour, at 137° C in the autoclave. For the purpose of comparison, seeds were also sown in unfervorized soil. Normal germination was equal to 70—80 %.

The results are given in Table I, in which the germination in unfervorized soil is put equal to 100 %. The results refer to 4 experiments.

TABLE I. Germination in 2 × 137° C fervorized field-soil after 4, 8 and 14 days, expressed in percentages. Number of germinated seeds in unfervorized field-soil = 100 %.

Number and date of experiment	4 days	8 days	14 days
1. (10.XII.38. — 10.VI.39)	37.50	101.67	
2. (31.XII.38. — 10.VI.39)	3.12	128.41	
6. (1.VI.39. — 5.VII.39)	47.06	163.63	156.25
7. (20.VI.39. — 4.VII.39)	32.20	113.92	113.92

If we examine the Table, we are first of all struck by the fact that on the fourth day of germination, a distinct retardation is seen, i.e. in fervorized soil on the whole there germinated far less than 50 % of the seeds which germinated in the unfervorized soil. After 8 days there was a considerable change. The percentage of germination in fervorized soil not only reached that in unfervorized soil, but even more or less surpassed it. After a further period of cultivation the results showed no change. Thus, the higher figure for the germination of *Sinapis alba* in fervorized soils may always be expected at the end of the experiment.

The *fervor-effect on germination, therefore, consists in a retardation of the germination in the beginning, and later on in an increase of the* *germination*. To arrive at a general conclusion with regard to the fervor-effect on germination these experiments will have to be made with the greatest variety of seeds.

Another interesting fact was observed in these germination experiments. In the first retardative phase of the fervor-effect the seedlings, especially the cotyledons of the germinated seeds, were generally smaller, though greener (better production of chlorophyll), and they produced more anthocyan at the underside. In addition it was noticed that the roots formed in this retardative phase were of a heterogeneous character. The root system in the fervorized soil showed a more or less rich ramification, more root-hairs and less growth of the tap-root. The tap-roots of the plants in normal soil, on the contrary, were long and thin, with few lateral roots and they produced many root-hairs. Similar facts had already been observed by RUSSEL and PETHERBRIDGE [1]). This difference in growth of the roots is a remarkable phenomenon, but, nevertheless, the roots of the seedlings in fervorized soil (Fig. 1 on Plate I) looked healthy, as might be concluded from the strong development of the root-hairs. Perhaps the stronger growth of plants in fervorized soil in the later stages of the development is partly due to the strong formation of the root system. Indeed the further discussion of the fervor-effect, especially that in nutrient-solutions, will show that, as a rule, the fervor-effect expresses itself more strongly in the development of the root system than in that of the shoot.

b. *The influence on the development of shoots.* Tables II and III show the fervor-effect on the development of shoots by heating at 137° C during 2 × one hour. Observations were made during the whole development of the plant till the flowering. In Table II the fervor-effect refers to the height

TABLE II. Fervor-effect on the height of shoots in 2 × 137° C fervorized field-soil, expressed in percentages. Height of shoots in unfervorized field-soil = 100 %.

Number and dates of experiments	20 d.	40 d.	62 d.	102 d.	113 d. Final height
8. (20.VI.39 — 13.X.39)	85.71	103.54	102.08	121.21	127.06

TABLE III. Fervor-effect on the dry weight of the shoots in 2 × 137° C fervorized field-soil, expressed in percentages. Dry weight in the unfervorized field-soil = 100 %.

Number and dates of experiments	20 d.	40 d.	62 d.	102 d.	113 d.
8. (20.VI.39 — 13.X.39)	—	134.40	146.54	259.34	345.47

1) E. J. RUSSEL and PETHERBRIDGE, Journ. of Agric., Vol. **19**, No. 10, p. 909.

of shoots and in Table III to the dry weight of shoots. In both Tables it can be seen that the fervor-effect is visible after 40 days. Generally it may be said that, during the early development of the shoot, there is but little difference between plants in fervorized and in unfervorized soil to the advantage of the latter, and many negative experimental results of former investigators (e.g. MERKENSCHLAGER) [1]) may be associated with this fact. Only in five weeks old cultures there are distinct differences to be seen in the height of plants in favour of those in fervorized soil. Moreover the effect expresses itself not only in a greater height but also in a generally strong, vegetative growth, and especially in the greater proliferance of the leaves, as is shown by the dry weight. As can be seen in Table III the dry weight of the crop increases from the 40th till the 113th day from 134.40 % to 345.47 %. The fervor-effect, therefore, is extraordinarily high. The crop increases to over $2\frac{1}{2}$ times the normal. The same result was obtained in some experiments concerning the crop of seeds, on which we shall report in another place.

c. *The influence of the duration of fervorization.* Table IV shows the experimental results of the effect of the duration of fervorization at 137° C. These values refer to the height of shoots, to the fresh weight and to the dry weight. If, first of all we compare the rows of the end-effect (printed in bold type) after 113 days, the general result appears to be that the

TABLE IV. Fervor-effect in 1 × 137° C, 2 × 137° C, 3 × 137° C, 4 × 137° C and 8 × 137° C fervorized field-soil after 51, 62, 102 and 113 days, expressed in percentages. Height and weight in the unfervorized field soil = 100 %.

	Field-soil experiment 8 (20.VI.39. — 13.X.39)											
	Height of shoots				Fresh weight of shoots				Dry weight of shoots			
	51 d.	62 d.	102 d.	113 d.	51 d.	62 d.	102 d.	113 d.	51 d.	62 d.	102 d.	113 d.
1 × 137° C	130.77	133.33	122.71	**136.76**	192.63	165.11	130 85	**220.07**	283.90	165.81	131.27	**240.95**
2 × 137° C	105.28	102.08	121.21	**126.47**	156.81	126.53	323.11	**352.10**	147.82	146.51	259.31	**345.47**
3 × 137° C	100.00	110.42	146.97	**135.29**	157.27	124.87	321.79	**368.98**	160.87	141.86	293.07	**362.03**
4 × 137° C	97.43	122.91	151.51	**136.76**	117.13	123.85	401.14	**483.12**	106.52	124.65	302.65	**417.99**
8 × 137° C	130.77	118.75	157.57	**144.11**	186.38	131.02	277.43	**364.01**	186.95	138.23	230.35	**337.52**

fervorization effect expresses itself more in the increase of the plant-mass than in the height. As for the influence of the duration of fervorization on the height of shoots, the greatest effect was observed at 8 × 137° C, and with regard to fresh and dry weight there seems to be an optimum between 3 × 137° C and 4 × 137° C (Figures on Plate II).

[1]) MERKENSCHLAGER, Sinapis alba, München 1925.

The photo shows us one series of these experiments, and proves that the optimum has already been reached more or less after fervorizing three times during 1 hour at 137° C. The difference is most apparent if one compares the result with that of the 1 and 2 × fervorization. Anyhow the optimum was not yet reached when the soils were fervorized 2 ×, as we generally did in our experiments. This holds good only for the plant here examined (*Sinapis alba*), and for the soil which was used.

d. *The influence of the temperature of fervorization.* We observed the fervor-effect for the first time after heating in the autoclave at 137° C, and therefore we were very much interested to know, whether it would be possible to obtain the effect at a lower temperature, especially at temperatures below 100° C, i.e. temperatures also to be met with under natural circumstances.

The results of our experiments are combined in Tables V and VI, and if we compare the bold typed end-effects for the height of shoots, the fresh

TABLE V. Fervor-effect in 1 × 70° C, 1 × 100° C, 1 × 137° C fervorized field-soil after 62 and 102 days, expressed in percentages. The values for the unfervorized field-soil = 100 %.

Field-soil experiment 8 (20.VI. — 13.X.39)						
	Height of shoots		Fresh weight		Dry weight	
	62 d.	102 d.	62 d.	102 d.	62 d.	102 d.
1 × 70° C	116.66	**125.75**	148.03	**111.77**	160.46	**114.58**
1 × 100° C	122.90	**124.24**	136.24	**139.32**	154.18	**132.81**
1 × 137° C	133.33	**122.71**	165.11	**130.85**	165.81	**131.27**

TABLE VI. Fervor-effect in 2 × 70° C, 2 × 100° C and 2 × 137° C fervorized field-soil after 62 and 102 days, expressed in percentages. The values for the unfervorized field-soil = 100 %.

Field-soil experiment 8 (20.VI. — 13.X.39)						
	Height of shoots		Fresh weight		Dry weight	
	62 d.	102 d.	62 d,	102 d.	62 d.	102 d.
2 × 70° C	116.66	**118.18**	74.32	**161.62**	92.10	**169.28**
2 × 100° C	150.00	**122.72**	74.53	**156.42**	222.79	**125.79**
2 × 137° C	102.08	**121.21**	126.53	**323.11**	146.51	**259.31**

and the dry weight, we cannot fail to observe that the effect of fervorization at 70° C is already perceptible, though it is not nearly so strong as that of fervorization at 137° C.

It is clear that in both series of experiments 2 × fervorization appears to be considerably more effective than 1 × fervorization. We may conclude to the possibility that fervorization takes place under natural circumstances, i.e. when the heating of the soil by the sun lasts a long time. The effect is the resultant of a time- and a temperature-component. (Figures on Plate III.)

The results of the experiments on fervorization of soils may be summarized as follows:

1. The fervor-effect on germination appears in two phases. In the beginning there is a retarded germination, lasting only for a few days and, after about 7—8 days, changing into a phase of stimulated growth. Further the retarding phase expresses itself in a delay in the development of the shoot, in an increase in the formation of chlorophyll and anthocyan, and especially in the ramification of roots and the formation of root-hairs.

2. The fervor-effect on the development of the shoot is expressed not so much in the development of height as in the generally stronger vegetative growth of all parts of the plant above the ground, particularly in the stronger development of the leaves. The fervor-effect is also noticeable in the development of flowers and seeds, as 2—2½ times greater crops are obtained.

3. The intensity of the fervor-effect is dependent on the duration of fervorization and also on the temperature. Maximal fervorization applied to *Sinapis alba* in the case of the soil used here (loamy, clayey, heavy soil) at 137° C is about 3—4 times fervorization during 1 hour. The fervor-effect is seen, to a lesser degree, after heating at a temperature of 70° C.

All these results refer to *Sinapis alba* only.

III. *Experiments on the influence of fervorization of nutrient-solutions.*

In this communication we deal with the fervorization of v. d. Crone's nutrient-solution. This is one of the best known nutrient-solutions, often succesfully applied in physiological research of the higher plants (BENECKE) [1]). For these researches it received special consideration because it contains an important undissolved residue. We also made some experiments with other nutrient-solutions, to which we shall refer in a more detailed publication.

Zea Mais (pure line isolated by Prof. Dr. TAVČAR, Zagreb–Maksimir), *Vicia Faba, Solanum lycopersicum, Sinapsis alba, Fagopyrum esculentum* and *Tagetes erecta* were our test plants. Some of the chief results of these researches will be communicated in the following tables. The values obtained with the normal unfervorized v. d. Crone's nutrient-solution are put equal to 100 %. Here we shall merely note that there is no great difference between the value of pH of the fervorized (varying from 5.08

[1]) BENECKE, Zeitschrift f. Bot. **1**, 235 (1909).

to 6.80) and that of the unfervorized v. d. Crone's nutrient-solution (pH 6.48).

According to the values in table VII all the test plants, with regard to the increase in height and in crop show a distinct fervor-effect. This was most marked in the height of shoots and in the total dry weight. Furthermore, we draw the attention to the high dry weight of the roots. Admittedly

TABLE VII. Results of the cultivations in 2 × 137° C fervorized v. d. Crone's nutrient-solution, expressed in percentages. The values for the unfervorized v. d. Crone's nutrient-solution = 100 %.

	Height of shoots	Length of roots	Fresh weight of shoots	Dry weight of shoots	Dry weight of roots	Total dry w.
Zea Mais (21.IV. — 17.VII.1939)	106.59	152.17	103.99	104.38	182.83	114.16
Vicia Faba (28.IV. — 27.VI.1939)	421.05	238.20	290.38	214.55	225.00	216.06
Sinapis alba II (29.IV. — 12.VI.1939)	208.79	—	114.85	123.80	225.92	131.05
Solanum lycopersicum (30.IV. — 28.VI.1939)	342.04	101.61	188.34	200.00	306.45	220.25
Tagetes erecta II (25.VIII. — 6.IX.1939)	293.29	137.03	228.13	211.70	404.71	231.42

the test plants did not all react uniformly. For the height of shoots, *Vicia Faba*, *Solanum lycopersicum* and *Tagetes erecta* showed about 3—4 times higher values in the fervorized solution than in the unfervorized solution, and for the total dry weight more than the double values. The abnormal height of *Vicia Faba* is especially remarkable. *Sinapis alba* generally is slightly less responsive to fervorization. The fervor-effect of *Zea Mais* was the smallest; this may have been so owing to the small quantity of nutrient-solution.

Tables VIII and IX show the results of fervorization at different temperatures and of different duration. The values refer, as in the preceeding Tables, to the height and to the crop. If these values in Table VIII are compared with each other, it is evident that when fervorizing once at temperatures of 70° C, 100° C and 137° C, the fervor-effect clearly appeared at 137° C. At 70° C it is hardly perceptible and expresses itself distinctly only in the dry weight of the roots. (Figures on Plate II.)

We obtained about the same result with fervorization at 100° C. The fervor-effect was strongest with *Sinapis alba* and weakest — probably for the above mentioned reason — with *Zea Mais*.

As regards Table IX, here we see a similar result as in Table VIII, i.e. the fervor-effect appeared strongest at 2 × 137° C. At 2 × 70° C and at 2 × 100° C the values fluctuate. But, if we compare the results of 1 × 137° C and 2 × 137° C, the increase of the fervor-effect at 2 × 137° C is striking.

TABLE VIII. Results of the cultivations in 1 × 70° C, 1 × 100° C and 1 × 137° C fervorized v. d. Crone's nutrient-solution, expressed in percentages. The values for the unfervorized v. d. Crone's nutrient-solution = 100 %.

	Height of shoots			Length of roots			Fresh weight of shoots			Dry weight of shoots			Dry weight of roots			Total dry weight		
	70°	100°	137°	70°	100°	137°	70°	100°	137°	70°	100°	137°	70°	100°	137°	70°	100°	137°
Zea Mais (21.IV, — 17.VII.1939)	71.43	109.89	79.12	86.96	121.74	117.39	94.99	81.82	65.95	85.77	67.58	70.17	107.57	100.50	120.71	88.48	71.68	76.46
Vicia Faba (28.VI. — 27.VI.1939)	96.48	83.16	249.12	114.65	114.61	175.28	109.62	102.35	194.39	97.18	83.10	158.69	122.22	150.00	172.22	100.80	92.77	160.65
Sinapis alba II (29.IV. — 12.VI.1939)	125.94	160.67	252.30	—	—	—	118.59	131.25	125.96	124.50	137.96	111.61	203.70	203.70	150.00	130.13	142.63	114.34
Solanum lycopersicum (30.IV. — 28.VII.1939)	109.09	103.41	256.82	104.84	106.45	108.06	91.75	94.85	196.21	98.48	95.45	205.30	109.68	116.13	232.26	100.61	99.39	210.43

TABLE IX. Results of the cultivations in 2 × 70° C, 2 × 100° C and 2 × 137° C fervorized v. d. Crone's nutrient-solution, expressed in percentages. The values for the unfervorized v. d. Crone's nutrient-solution = 100 %.

	Height of shoots			Length of roots			Fresh weight of shoots			Dry weight of shoots			Dry weight of roots			Total dry weight		
	70°	100°	137°	70°	100°	137°	70°	100°	137°	70°	100°	137°	70°	100°	137°	70°	100°	137°
Zea Mais (21.IV. — 17.VII.1939)	72.53	72.53	106.59	132.61	123.91	152.17	96.51	64.29	103.99	72.54	66.93	104.38	117.17	80.81	182.83	78.10	68.66	114.16
Vicia Faba (28.IV. — 27.VI.1939)	78.95	143.86	421.05	82.02	132.58	238.20	72.20	201.97	290.38	68.54	138.03	214.55	63.89	225.00	225.00	108.03	150.60	216.06
Sinapis alba II (29.IV. — 12.VI.1939)	137.66	185.36	208.79	—	—	—	137.62	112.42	114.85	130.03	119.41	123.80	155.55	159.26	225.92	131.84	122.24	131.05
Solanum lycopersicum (30.IV. — 28.VII.1939)	104.55	129.55	342.04	133.87	119.35	101.61	90.61	137.32	188.34	103.79	144.70	200.00	96.77	138.71	306.45	102.45	143.56	220 25

The experiments show that in fervorizing nutrient-solution, time- and temperature-components are of equally great significance as in the fervorization of soils. As further variations of time and temperature components were not made, it is impossible to say anything about the optimum of the influences of these components.

It was established that:

1. By fervorization of the v. d. Crone's nutrient-solution at 137° C, distinct fervor-effects were obtained with *Vicia Faba, Solanum lycopersicum, Tagetes erecta* and *Sinapis alba.*
2. *The fervor-effect of cultures in the v. d. Crone's nutrient-solution is the same as in soil-cultures.* It appeared in the height of the plants and in the weight of the crop, but more especially in the dry weight of the roots.
3. It appears that also in this case duration and temperature of the fervorization are of importance. Hitherto the strongest fervor-effect was obtained by fervorizing twice during 1 hour at 137° C (Figures on Plate III).

IV. *Experiments on the influence of fervorization of the water.*

In continuation of the physiological analysis of the fervorization, experiments were made in which the two components of the v. d. Crone's nutrient-solution, i.e. the salts and the water were fervorized separately. The distilled water was fervorized twice during one hour at 137° C and, after cooling down to roomtemperature, the salts were added. These experiments, carried out with *Sinapis alba, Fagopyrum esculentum* and *Tagetes erecta,* had very remarkable results (Table X).

It appeared *that fervorization of the water was sufficient to produce the fervor-effect.* From the Table, as well as from the photos (Figures on Plate IV), it follows that the fervor-effect of the fervorized water was more or less equal to that of the fervorized v. d. Crone's nutrient-solution.

TABLE X. Fervor-effect in 2 × 137° C fervorized water with unfervorized v. d. Crone's nutrient-salts, expressed in percentages. The values for the unfervorized v. d. Crone's nutrient-solution = 100 %.

	Height of shoots		Length of roots		Fresh weight of shoots		Dry weight of shoots		Dry weight of roots		Total dry weight	
	H_2O, 2×137° + Cr. S.	Cr., 2×137°	H_2O, 2×137° + Cr. S.	Cr., 2×137°	H_2O, 2×137° + Cr. S.	Cr., 2×137°	H_2O, 2×137° + Cr. S.	Cr., 2×137°	H_2O, 2×137° + Cr. S.	Cr., 2×137°	H_2O, 2×137° + Cr. S.	Cr., 2×137°
Sinapis alba (14.V. — 4.VII.1939)	249.41	279.68	—	—	77.49	110.56	106.51	139.96	90.99	92.79	104.94	134.88
Fagopyrum esculentum (24.V. — 17.VII.1939)	179.20	217.11	77.01	121.84	138.02	156.20	150.69	160.64	336.11	347.22	160.38	170.39
Tagetes erecta II (25.VII. — 6.XI.1939)	276.47	293.29	122.22	137.03	238.12	228.13	180.05	211.70	364.70	404.71	198.81	231.42

It is expressed in the height as well as in the crop of the plants. *Sinapis alba* showed noticeably smaller crops than *Fagopyrum esculentum* and *Tagetes erecta*. Both of the last-mentioned plants exhibit the fervor-effect especially in the dry weight of root, which was strikingly large in contrast to that of *Sinapis alba*.

With regard to fervorization of the salts, so far, one experiment has been carried out, but we do not consider the results sufficiently definitive.

It was established that *previous fervorization of the distilled water at 137° C to which the v. d. Crone's nutrient-salts are added is sufficient to produce the fervor-effect.*

General summary. If, at the end of our communication, we cast a restrospective glance, it seems to us that a new line of investigation has been established. As a matter of fact there exists already an extensive literature on the benefit of heating of soils — the so-called soil sterilization (RICHTER, KÖNIG, DIETRICH, SCHULZE, CZERMAK, RUSSEL and PETHERBRIDGE, BEWERLEY, a.o.) — and the results of those investigations have already been put into practice. We observe, however, that the cause of the amelioration of the soil was not clear hitherto. It was shown by our experiments with nutrient-solutions that this amelioration is not merely the result of sterilization, but also of general changes in the state of the nutrient substratum, caused by heating. To bring this effect to the fore we proposed the term "fervorization".

Heat sterilization is neither equivalent to chemical sterilization nor to sterilization by freezing. The results of the micro-biological cultures in moist soil sterilized by heat must be judged with caution, for they include not only the normal growth of the cultures but also the growth influenced by fervorization. Therefore it seems important to compare cultures on substrata, sterilized by chemicals, by freezing, and by heat.

We are quite alive to the fact that the investigations which we have described must be supplemented in many ways. Nutrient substrata and salts will have to be examined on their behaviour in connection with a far greater variety of plants.

Above all it will be necessary to throw more light upon the changes caused by the fervorization of water. We consider the investigation of this problem a task for chemists and physicists, whereas for physiologists it is of interest to examine whether fervorized water exercises influence on other phenomena of life.

Finally, it should be remembered that fervorization possibly takes place under natural circumstances. The great fertility of the otherwise poor soil in the tropics may be partly due to the fervorization of the soil caused by the radiation of heat rays by the sun. There may be similar conditions in other climates.

PLATE I.

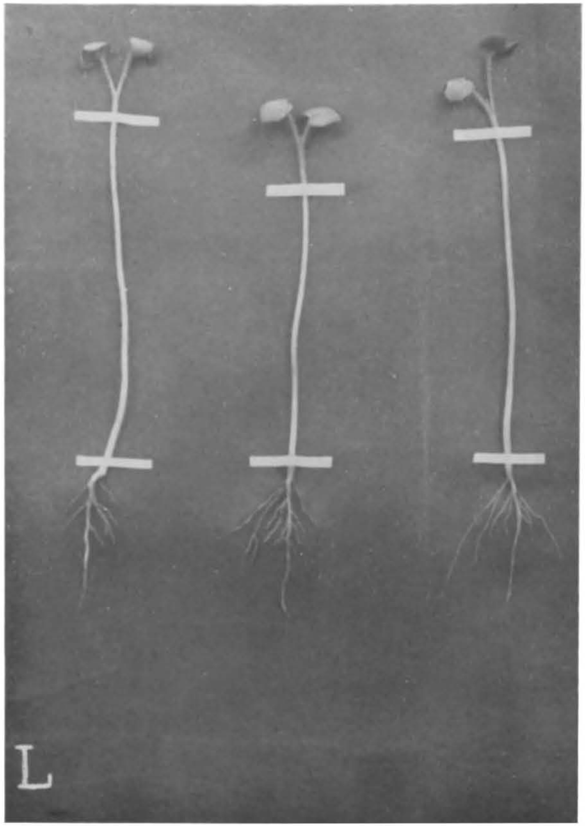


Fig. 1. 3 young seedlings of *Sinapis alba* in 2 × 137° C fervorized garden-mould.

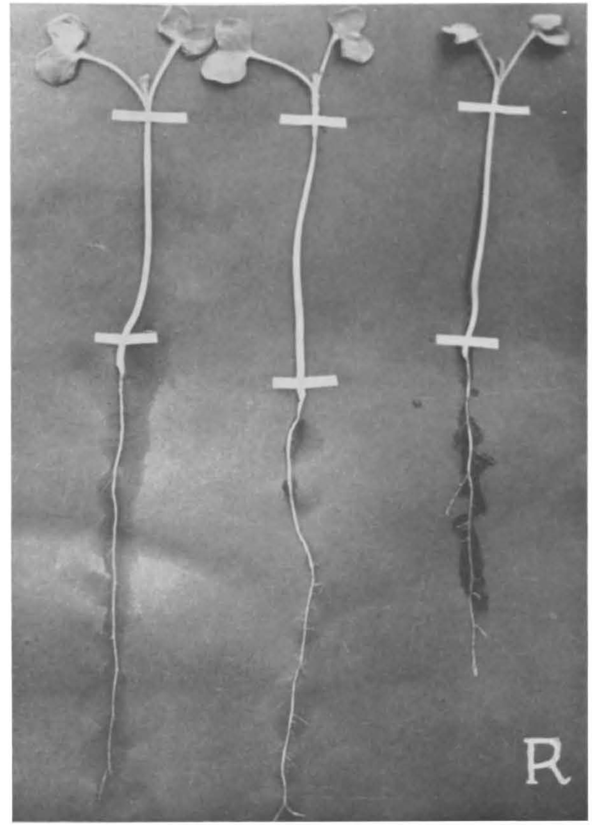
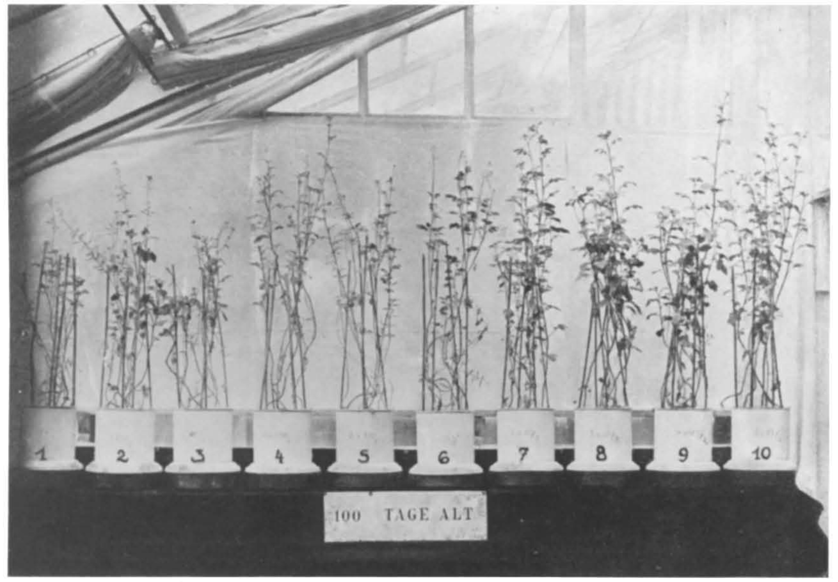


Fig. 2. 3 young seedlings of *Sinapis alba* in unfervorized garden-mould.

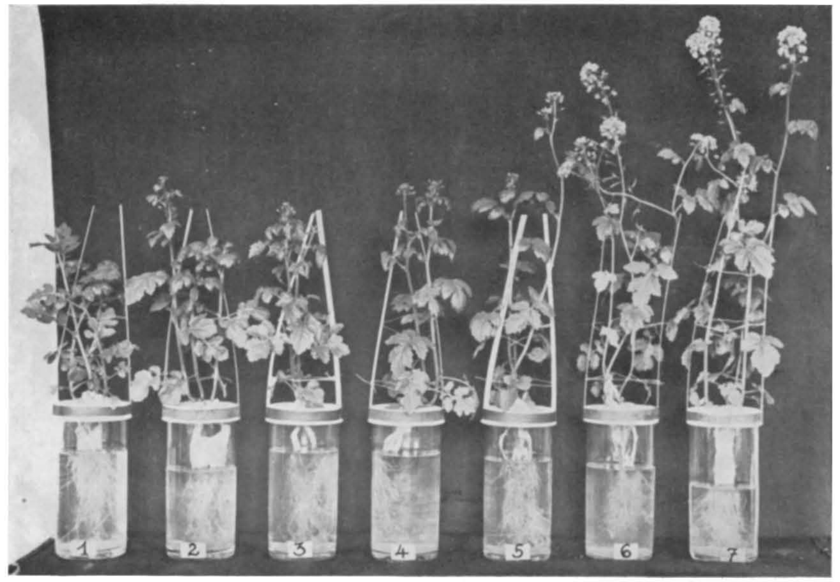
PLATE II.

Sinapis alba in fieldsoil. 77 days old. From l. to r.: 1 = normal, 2 = 1 × 137° C, 3 = 2 × 137° C, 4 = 3 × 137° C, 5 = 4 × 137° C and 6 = 8 × 137° C.

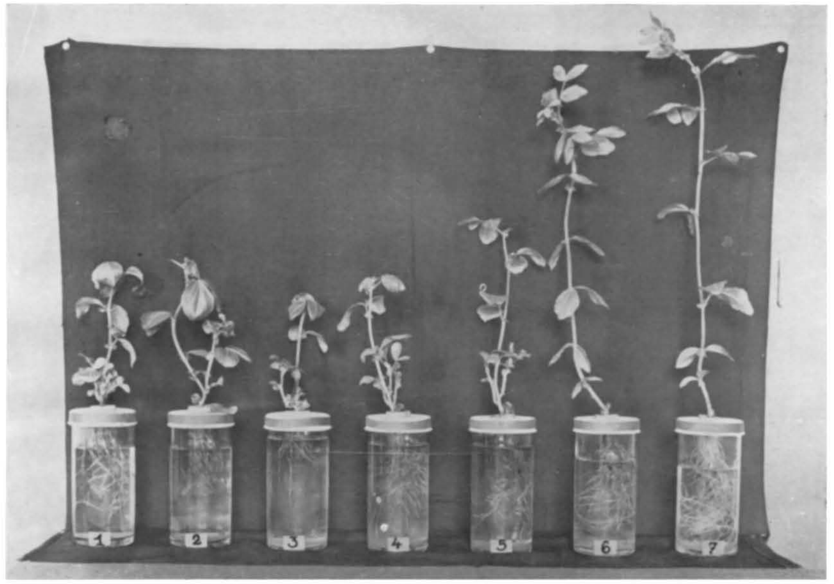


The whole row of the same culture after 100 days. 1 = normal, 2 = 1 × 70 C, 3 = 2 × 70° C, 4 = 1 × 100° C, 5 = 2 × 100° C, 6 = 1 × 137° C, 7 = 2 × 137° C, 8 = 3 × 137° C, 9 = 4 × 137° C and 10 = 8 × 137° C.

PLATE III.

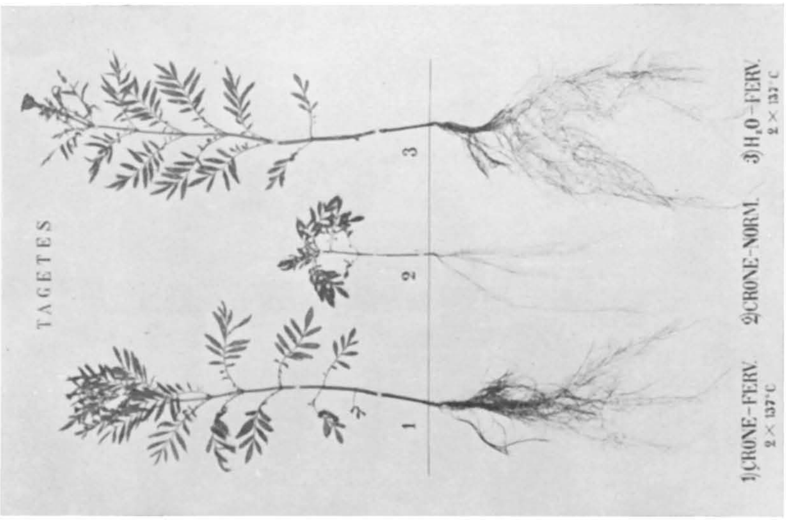


Sinapis alba in v. d. Crone's nutrient solution. 39 days old. From l. to r.: 1 = normal, 2 = 1 × 70° C, 3 = 2 × 70° C, 4 = 1 × 100° C, 5 = 2 × 100° C, 6 = 1 × 137° C, 7 = 2 × 137° C.

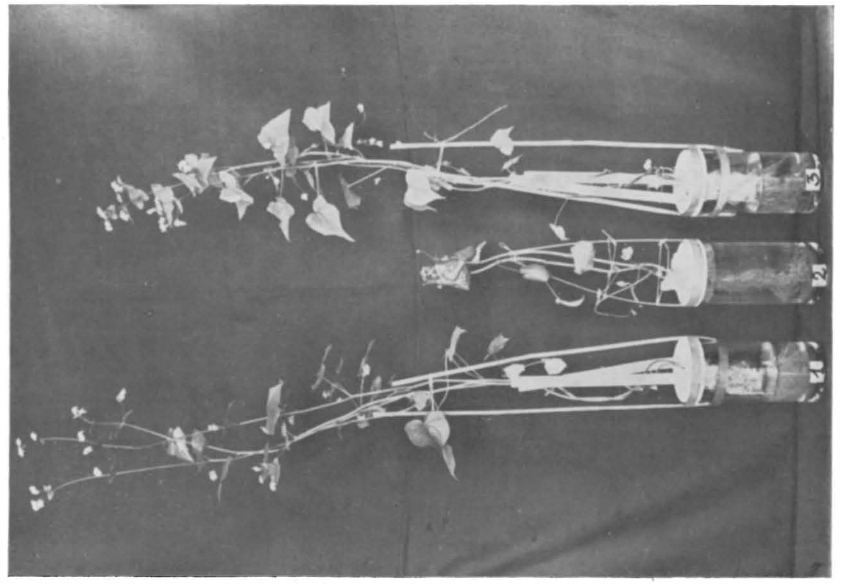


Vicia Faba in v. d. Crone's nutrient solution. 40 days old. From l. to r.: 1 = normal, 2 = 1 × 70° C, 3 = 2 × 70° C, 4 = 1 × 100° C, 5 = 2 × 100° C, 6 = 1 × 137° C, 7 = 2 × 137° C.

PLATE IV.



Tagetes erecta in v. d. Crone's nutrient solution. Final effect after 74 days.



Fagopyrum esculentum in v. d. Crone's nutrient solution. From l. to r.: 1 = 2 × 137° C, 2 = normal, 3 = H_2O, 2 × 137° C + v. d. Cr. salts (unfervorized).