THE EFFECT OF DIFFERENT FUELS ON THE QUALITY OF BOILED WATER

By

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CONTENTS

INTRODUCTION

This thesis consists mainly of the procedure followed in the seting up of and the results obtained from a research experiment, the object of the experiment being to determine whether or not there is any difference in the effect on plant growth of water boiled over a wood fire as compared to water boiled over a coal fire, a gas fire, or an electric fire.

The fact that such a phenomena was believed to exist was brought to my attention by Dean Earl G. Mason, who had received his information from Mr. George M. Cornwall, editor of "The Timberman". Since Dean Mason's belief was that Mr. Cornwall had obtained what few facts he had from a conversation with a German of unknown identity, who was supposed to have carried out an experiment of this kind, we did not think it possible to secure any detailed procedure of the formerly performed experiment. Therefore, the only information we had to begin with was that plants treated with water boiled over the various types of heat mentioned had shown a marked difference in growth and that those treated with water boiled with wood as fuel had produced a much more rapid growth.

Being Foresters and feeling that any such facts, no matter how fantastic they might appear on the surface, if they could be proved, would be invaluable for the promotion of the use of our forest products, the following described experiment was performed, not with the expectation of definitly proving any such facts in the short time available, but merely hoping, should any significance result, to create enough interest in the subject to encourage further experimentation.

After the completion of this experiment, an article on the subject was found in the editorial of "The Timberman", Volume XXXIX, No. 12,

October 1938, which, it is felt, gives far more significance to the facts we had at the time the experiment was performed. Although, in the main this article paralleled much of the material already stated on the subject and object of this thesis, the following excerpt from it is being presented to give a clearer concept of what we have tried to accomplish.

"On a recent visit to this country, Dr. J. A. von Momroy, technical advisor to the German Four-Year Wood Utilization Plan, reported the following information recently discovered about the use of wood fires in Germany: Heat appears to possess definite characteristics as apart from volume and intensity. Exactly what these properties are is not yet known. Just as there is white light, blue light, yellow light, and so on, there appear to be types of heat which exert different influences upon substances subjected to it. To illustrate: Identical quantities of ordinary water were boiled with electric current, gas flame, coal fire, and wood fire. These samples were then used to test comparative growth of tree seedlings placed in them. Seedlings placed in the water boiled over the wood fire showed a much more rapid growth than those placed in water boiled over electricity, gas, or coal. Growth from water boiled with electricity was the slowest. While many more experiments must be made before any real conclusions can be drawn, it is significant that this phenomenon was observed with remarkable regularity."

PREPARATORY RESEARCH

As before stated, we did not have any of the details of the procedure followed in former experiments on this subject, so it was necessary to secure much information before an experiment could be set up. It was found that Dr. W. M. Atwood of the Botany Department at Oregon State College had had considerable experience in testing a great many influences upon plant growth. After interviewing him regarding any such experiments that indicated any similarity to the desired results, it was concluded that water cultures had proven to be the best method of testing effects on plant growth where it was necessary to eliminate as many of the variable influences as possible in order to secure any significance from the resulting difference in growth. He also stated that it had been found necessary to set up more than one culture of each material being tested, regardless of the number of samples contained in the culture, as added precaution against the chance variable influences that always affect growth of plants. He suggested three cultures for each type of water in this case.

Some type of plant seed that would sprout rapidly and grow rather rapidly was needed in order to get measurable results in the short time available,regardless of the method used, and since water cultures were to be used, the fact that most plants will remain alive for only a few weeks in water was a major consideration in the choosing of a fast growing plant. Any species of spring wheat was suggested by Dr. Atwood.

Most of the information needed on setting up water cultures was obtained from B. M. Duggar's book, "Plant Physiology", and the rest was supplied by Dr. Atwood. This was followed very carefully and is embodied to a large extent in the detailed explanation of the procedure followed in

setting up the experiment.

Since the water was to be boiled, most of the nutritive value would be taken out, and as it was desired to keep the plants living for several weeks (longer than they could live on the food stored in the wheat kernel, which is nearly two weeks), it became necessary to supply some type of nutrition to the cultures. Pfeffer's Nutrient Solution was chosen for this purpose, because it could be easily mixed in such a manner that each culture would receive exactly the same amount, thereby eliminating any chance of introducing other variables.

A list of the equipment needed for the experiment was prepared (see appendix) and a detailed working plan of the proposed procedure was set up and followed very closely as given in the succeeding sections of this thesis.

PROCEDURE FOR SETTING UP THE EXPERIMENT

Sprouting the Wheat

One-half pound of spring wheat (kept for test purposes) was secured from the Farm Crops laboratory.

Enough of this wheat to fill the jar about one-fourth full was placed in the jar, as shown in Figure 1 on the following page, and the device attached to the tap as indicated by the diagram. It was necessary to let the water run very slowly to prevent the wheat from rising to the top and clogging the overflow tube. Water was allowed to run through the wheat continuously for sixteen hours to wash away any impurities that might be clinging to the wheat kernels.

The wheat was then drained and spread out in shallow, sprouting dishes made of pottery. Another dish of the same type was inverted over each one containing the wheat. The sprouting dish was then placed in a

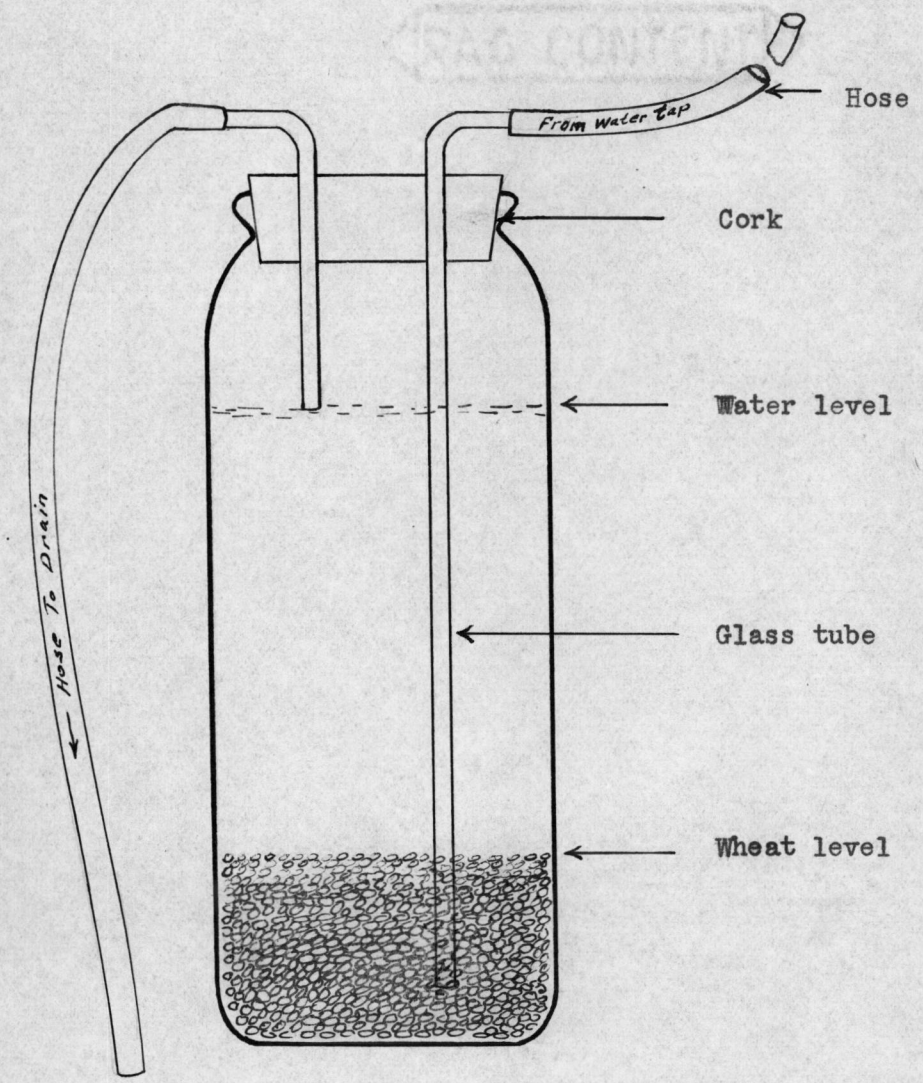

Fig. 1 DEVICE FOR WASHING WHEAT

shallow pan of water (the sprouting dishes are just permeable enough to allow enough water to soak through and keep them good and moist on the inside) and then placed in a normally warm room for three days until shoots and roots were well started.

Preparation of Nutrient Solution

The following chemicals were added to 750 cc of tap water that had been placed in a thoroughly sterilized pyrex flask.

Calcium Nitrate	4.0	Grams
Potassium Nitrate	1.0	"
Magnesium Sulphate	1.0	"
Potassium Dihydrogen Phosphate	1.0	"
Potassium Chloride	0.5	"
Ferric Chloride	Trace	

The formula for this solution recommends that it be used with from three to seven liters of water. This amount, when applied to the number of cc of water in the cultures set up, represented a proportion of 4.5 liters.

Labeling Process

A . . . . . Flask of Pfeffers Nutrient Solution

I . . . . . Flask of straight tap water

II . . . . . Flask of water boiled over a wood fire

III . . . . . Flask of water boiled over a coal fire

IV . . . . . Flask of water boiled over a gas fire

V . . . . . Flask of water boiled over an electric fire

1 . . . . . Cultures of tap water

2 . . . . . Cultures of water boiled over a wood fire

3 . . . . . Cultures of water boiled over a coal fire

4 . . . . . Cultures of water boiled over a gas fire

5 . . . . . Cultures of water boiled over an electric fire

Obtaining and Boiling Water

Enough water was drawn from the tap, into a large container, to set up fifteen water cultures using 200 cc of water each and allowing plenty for evaporation during the boiling process.

Exactly 900 cc of this water were then placed in each of the four 1000 cc pyrex flasks, which were exactly alike and which had each been thoroughly sterilized. These flasks were then labeled according to the predetermined labeling process.

The amount of tap water required for setting up the check cultures of tap water was placed in a sterilized milk bottle, labeled, corked, and set aside and the water in the four flasks was boiled on the respective types of heat, as indicated by the labels, for exactly fifteen minutes each.

The boiling process was recorded as follows:

Water boiled over a wood fire

Time heat was applied	7:45 A. M.	30 Minutes
Time boiling began	8:15 A. M.	
Time boiling began	8:15 A. M.	15 Minutes
Time boiling stopped	8:30 A. M.	
Time cooling started	8:30 A. M.	1 Hour 45 Minutes
Time stopper was applied	10:15 A. M.	

Total time cooled (with stopper in bottle) before using 75 Hrs.

Water boiled over a coal fire

Time heat was applied	2:38 P. M.	37 Minutes
Time boiling began	3:15 P. M.	
Time boiling began	3:15 P. M.	15 Minutes
Time boiling stopped	3:30 P. M.	
Time cooling started	3:30 P. M.	1 Hour 45 Minutes
Time stopper was applied	5:15 P. M.	

Total time cooled (with stopper in bottle) before using 72 Hrs.

Water boiled over a gas fire

Time heat was applied	3:20 P. M.	31 Minutes
Time boiling began	3:51 P. M.	
Time boiling began	3:51 P. M.	15 Minutes
Time boiling stopped	4:06 P. M.	
Time cooling started	4:06 P. M.	1 Hour 45 Minutes
Time stopper was applied	5:51 P. M.	

Total time cooled (with stopper in bottle) before using 22 Hrs.

Water boiled over an electric fire

Time heat was applied	9:20 A. M.	34 Minutes
Time boiling began	9:54 A. M.	
Time boiling began	9:54 A. M.	15 Minutes
Time boiling stopped	10:09 A. M.	
Time cooling started	10:09 A. M.	1 Hour 45 Minutes
Time stopper was applied	11:54 A. M.	

Total time cooled (with stopper in bottle) before using 75 Hrs.

An attempt was made to allow as nearly as possible the same amount of time for bringing the water to a boil in each flask, but this was too difficult to accomplish without experimenting for some time with the different types of heat.

Heat using wood and coal for fuel was obtained from the same stove, which had always been used with wood for fuel. However, before using for coal heat, the stove was thoroughly cleaned out and heated with coal for fuel for several hours to allow any chance of the effects from the wood fuel to influence the boiling process.

No noticeable difference was noted in the way in which the water boiled over the wood, gas, and electric heat, but considerable difference did occur in the manner in which the water boiled over the coal heat. Although the fire was many times hotter than it had been during the boiling process with wood as fuel, it took seven minutes longer to bring to a boil and the force of the heat seemed to lift the entire mass of water, causing it to break in one huge bubble whereas in the cases of the other types of fuels there was a steady flow of many smaller bubbles.

The water was allowed to cool under, as nearly as could be obtained, the same conditions.

Setting up the Cultures

The 30 glass tumblers and 15 cork stoppers were first thoroughly sterilized.

Exactly 200 cc of water were then measured into each of 15 of these culture glasses (three with tap water, three with water boiled over a wood fire, three with water boiled over a coal fire, three with water boiled over a gas fire, and three with water boiled over an electric fire). It was necessary to keep each respective three culture glasses carefully separated since they were not yet labeled. Exactly 40 cc of the

Pfeffers Nutrient Solution were next added to each glass after thoroughly shaking each time before measuring into the graduate cylinder.

Wheat seedlings were then taken from the sprouting dishes and five of them very carefully placed into small holes in the stopper for each culture glass. The seedlings were choosen very carefully to obtain as nearly as possible equal growth of roots and shoots for the 75 seedlings.

It was necessary to keep the sprouting dishes covered while arranging each set of five as the very fine tender roots dry out in an exceedingly short time.

The seedlings were placed in the stopper in such a way that the wheat kernel was held firmly in the stopper with the roots extending downward and the shoots upward.

The stoppers were then placed in the culture glasses in such a way as to have all of the roots extending into the water and to have the water up to the stoppers but not against them.

The black paper wrappers, which had previously been labeled according to the method before listed, were then placed over each glass being careful to shut out all light for precaution against water mold, green algae, and other types of fungi.

The remaining 15 tumblers were then inverted over the cultures to be left for three or four days until the seedlings had obtained more growth and strength.

The cultures were arranged on a normally warm closed-in sleeping porch in a north light in such a manner as to secure equal light and other conditions.

CARE OF THE CULTURES DURING THE GROWTH OF THE SEEDLINGS

Daily Attention

Each culture was moved into the place of another one every day in such a manner that each culture occupied an exact spot exactly the same length of time. This was continued throughout the entire time that the plants remained in the culture glasses, thereby eliminating as nearly as possible the chance that any differences in room conditions would have an effect on the resulting growth.

A casual inspection was made of each sample in each culture as a precaution against the development of fungi growth.

Three days after setting up the cultures the seedlings had reached a growth of approximately $2\frac{1}{2}$". They appeared to be in a healthy condition and had begun to darken in color, so the inverted tumblers were removed from each culture.

Weekly Inspection

The cultures were set up on Tuesday afternoon and every succeeding Tuesday afternoon thereafter throughout the length of the experiment a thorough inspection was made of each culture by lifting the stopper of each one and carefully examining each plant.

Fungi Attack

During the first thorough weekly inspection, an attack of fungi was discovered on two of the wheat kernels in one of the cultures of water boiled over the gas fire and on one seedling in each of two of the cul-

tures of water boiled over the electric fire.

Acting on the advice of Dr. Atwood, these infected seedlings were removed and burned and each of the 71 remaining seedlings were very carefully removed from the stoppers, thoroughly washed in water left over from the respective types of boiled water corresponding to the cultures from which they were removed, and then replaced in their respective stoppers.

In washing these seedlings, it was necessary to remove, wash, and replace only one seedling at a time to prevent any drying out of the roots.

The kernels of wheat were still attached to each seedling and on replacing each seedling in its respective stopper, after washing it, it was placed in the stopper in such a manner that the wheat kernel remained about 1/8 inch above the stopper. This made it necessary to place a small amount of cotton loosely in the hole in the stopper around the roots to prevent the seedling from slipping down against the stopper. By preventing any contact between the wheat kernel and the cork stopper, moisture that was continually drawn up into the stopper by the roots was kept off the kernel, allowing it to dry out. This apparently prevented any further attack of fungi.

Attaching Wire Supports to the Cultures

By the end of the first week, after setting up the cultures, the plants had reached an approximate average height of 6 inches and had begun to bend over from their own weight. To hold them in an upright position, wire supports were attached to each culture glass, as may be seen in Figure 2.

These wire supports were made with two supporting loops, one loop approximately 4 inches above the top of the culture glass to take care of the present growth, and the second loop approximately 8 inches above the top

of the culture glass to allow for future growth.

Photographing the Experiment

A picture, Fig. 2, was taken of the growing cultures exactly three weeks after the experiment was set up. An attempt was made to show the difference in height growth existing between the respective sets of cultures by stretching a dark colored cord against the light background at a carefully measured parallel distance above the level of the table. However, due to lack of experience in photography, the camera was not set at the proper angle and the cord failed to indicate, in the picture, the differences that did exist at that time.

OBTAINING AND RECORDING THE RESULTS OF THE EXPERIMENT

Dismantling the Cultures

During the thorough inspection at the end of the fourth week after setting up the experiment, it was discovered that quite a number of the plants were starting to die back from the tips of their shoots, so it was decided to discontinue the experiment.

The plants were carefully removed from the cultures, by following the same sequence that was employed in setting them up to allow exactly the same time of occupancy in the cultures.

As the plants were removed from each culture glass, they were laid out on a paper that had been previously prepared for this purpose, Fig. 3, and tied in a bundle. The three bundles were then tied together, tagged with a number corresponding to the culture from which they had been removed, and attached to the paper by pressing the tips of the roots

Fig. 2. CULTURES AT END OF THIRD WEEK: Tap water (1), water boiled over a wood fire (2), water boiled over a coal fire (3), water boiled over a gas fire (4), water boiled over an electric fire (5).

against the paper.

When the plants had been removed from each culture glass, the solution remaining in each glass was carefully measured and the amount recorded along with the number of plants removed from each glass, Table I.

This procedure was followed until the five sets of cultures had been dismantled.

The paper to which the plants had been attached was then carefully photographed, Figure 3, to indicate the extent of both root and top growth secured in the four-week period.

The plants were then removed from the paper, separated into the bundles, as taken from each culture glass, and placed in paper sacks which had been carefully labeled by the same method as employed in Table I.

Drying the Plants

The paper bags containing the plants were placed in a warm room and allowed to air dry for thirteen days, at which time the plants were becoming very brittle.

Weighing the Plants

The bundles of plants from each culture glass were very carefully weighed separately and then the three bundles from each set of cultures were weighed together and the resulting weight checked against the totaled weights for the three.

The weights were recorded, Table II, by employing the same method of labeling as used in Table I. Before recording, the weights were computed to represent five plants for each culture in each case although

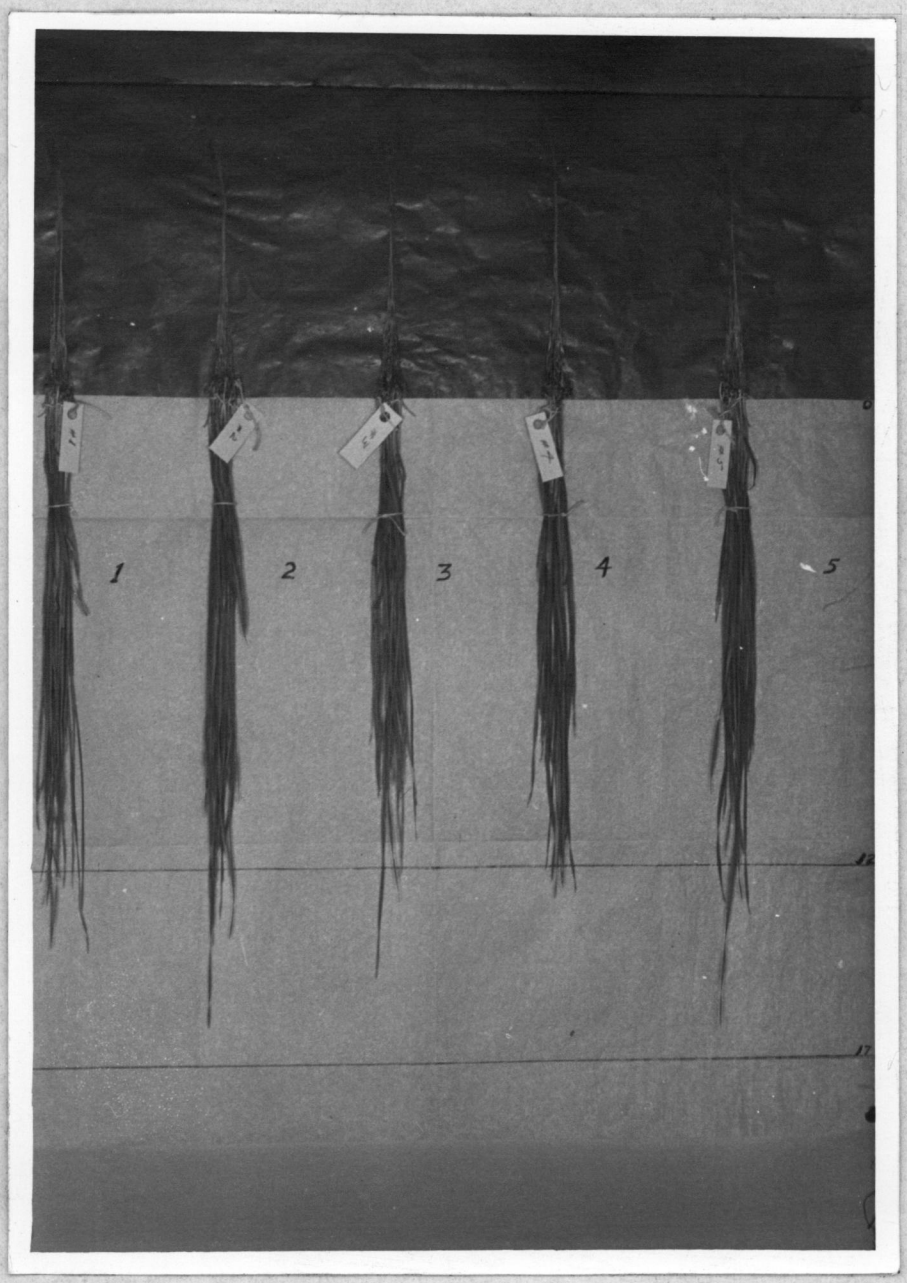

Fig. 3. PLANTS AT END OF FOURTH WEEK: From tap water (1), from water boiled over a wood fire (2), from water boiled over a coal fire (3), from water boiled over a gas fire (4), from water boiled over an electric fire (5).

three of the cultures were short one or two plants.

So much variation in the weights of the three cultures in some of the sets was not anticipated, but after this was discovered, it was impossible to separate and weigh each of the five samples in each culture separately due to their brittle condition.

CONCLUSIONS

Significance of the Results

A simple arithmetic application of the resulting total weights for the various sets of cultures, Table II, indicated the following differences in plant growth:

Wood fire	16.67%	more weight than coal fire
Wood fire	6.67%	more weight than gas fire
Wood fire	8.33%	more weight than electric fire

A statistical analysis of the variation between the weights obtained from the plants grown in water boiled over the wood fire and those grown in water boiled over the coal fire indicated that these variations were significant even though there was a wide dispersion in weights of the three samples from the coal fire.

Since I was unable to obtain weights for the individual plants from each culture, I did not feel that I had enough samples to justify any conclusions that these figures were significant, due to the many chance influences that might have had some effect on the variations of growth secured.

Some of these chance influences are: (1) Differences of vitality or nutrient supply of the seeds used, (2) The possibility of injury to the

tender seedlings while the cultures were being set up and during the washing process after the fungi attack, (3) The chance that all of the effects of the fungi attack might not have been removed during the washing process.

However, I do believe, after observing the growth of these seedlings during the four weeks period in which the experiment was being carried on, that the heat from the various types of fuels used does exert different influences on the growth of plants and that there is a good probability that further experimentation of this and similar types may yield some great possibilities for timber production as fuel wood.

Recommendations for Further Experimentation

Having had to begin this experiment without any information regarding the procedure to follow, I realize the advantage of any details, precautions, don'ts, etc. pertaining to the subject and will try to offer any knowledge or experience I have gained as suggestions for future experimentation along this same line.

The major consideration should be a thorough study of the problem before attempting any phase of it. A careful method of procedure should be written, carefully analyzed, rewritten, and reanalyzed until it is very complete in every detail.

In any experiment of this type where variation in growth of plants is to be measured there are always a number of variable influences to be encountered even after elimination of as many as possible. Therefore, the more samples you can obtain to measure, up to a certain number, the more significant will be your results and even though I believe that the 75 samples I had to start with would have given me a good indication of what I was after, had I taken precautions to get accurate measurements of each one, I would recommend a greater number for an experiment of this kind.

I also wish to again emphasize the need for careful consideration of every detail so that accurate measurements will be obtained of those samples which are present.

I believe that each sample should be oven-dried and weighed to the finest accuracy obtainable.

It might be possible to eliminate some of the chance variables by weighing the seeds for uniformity before using them.

I was informed by Dr. Atwood that the chances of fungi attack are never entirely eliminated and even though I apparently prevented further attack by replacing the seedlings in the stoppers with the kernels far enough above the stopper to to prevent contact with absorbed water, I believe it advisable to boil sufficient water and to prepare sufficient nutrient solution to allow washing the plants and replacing the solution in the cultures, should an attack occur.

Professor T. J. Starker suggested that the wheat kernels be sprouted either directly in the stoppers or in sterilized cotton to prevent injury that might occur to the roots and shoots when the cultures were being set up and I believe this a very feasible and practicable suggestion.

It was noticed that the plants grown in the water boiled over the electric fire put on the least growth for the first two and one half weeks, at which time an acceleration began and continued until the end of the experiment. This might suggest an experiment in which the solution in the cultures would be replaced once every week or two weeks with freshly boiled water.

Suggestions for other experiments might be: (1) Different types of water as rain water etc., (2) Different lengths of time for boiling the water as 20 minutes, 30 minutes, 45 minutes, etc., (3) Different types of containers for boiling water as aluminum, tin, porcelain, etc.

During my preliminary research, I learned that experiments testing different influences on plant growth are also made by using chemically pure sand instead of water cultures. This would allow the use of more samples with less care in setting up the experiment and during the length of the experiment although it would require a great deal more water plus the application of the water at regular intervals.

These are all of the suggestions I can think of at the present time but I will be glad to give any suggestions or information that I can to any one wishing to carry on experiments along this line in case they care to contact me.

APPENDIX

MATERIALS AND EQUIPMENT

4 1000 cc pyrex flasks for boiling water.

1 Milk bottle for storing tap water.

15 Culture containers (ordinary water tumblers used).

15 Water tumblers for inverting over cultures.

15 Black paper wrappers.

15 Wire frames for supporting plants.

½ Pound of spring wheat.

1 Jar with cork, two glass tubes, and rubber hose for washing wheat.

4 Shallow pottery dishes and covers for sprouting wheat.

4 Shallow pans to set pottery dishes in.

1 100 cc graduate cylinder.

1 Set of gram weight scales.

1 1000 cc flask to mix nutrient solution in.

Calcium Nitrate	4.0 Grams
Potassium Nitrate	1.0 Gram
Magnesium Sulfate	1.0 Gram
Potassium Dihydrogen Phosphate.	1.0 Gram
Potassium Chloride.	0.5 Gram
Ferric Chloride	Trace

Wood heat

Coal heat

Gas heat

Electric heat

RECORD OF THE NUMBER OF PLANTS AND THE AMOUNT OF SOLUTION REMAINING IN EACH CULTURE AT THE END OF THE EXPERIMENT

No. of Culture	No. of Plants	CCs of Sol.	Ave. CCs of Sol.
1a	5	177	
1b	5	151	
1c	5	170	166
2a	5	163	
2b	5	159	
2c	5	172	158
3a	5	167	
3b	5	177	
3c	5	179	174.3
4a	5	163	
4b	5	164	
4c	3	170	165.8
5a	4	171	
5b	4	174	
5c	5	143	162.8

TABLE I

WEIGHT OF PLANTS

after

Air Drying for Thirteen Days

Cultures Number One (Check)	Weight		
1a	0.19 Grams		
1b	0.22 "		
1c	0.19 "	0.60	Grams
Cultures Number Two (Wood Fire)			
2a	0.20 "		
2b	0.20 "		
2c	0.20 "	0.60	Grams
Cultures Number Three (Coal Fire)			
3a	0.18 "		
3b	0.17 "		
3c	0.15 "	0.50	Grams
Cultures Number Four (Gas Fire)			
4a	0.18 "		
4b	0.20 "		
4c	0.18 "	0.56	Grams
Cultures Number Five (Electric Fire)			
5a	0.19 "		
5b	0.16 "		
5c	0.20 "	0.55	Grams

TABLE II