STUDIES ON THE EFFECT OF CERTAIN ORGANIC AND INORGANIC ELEMENTS ON PLANT GROWTH IN SOIL CULTURES

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INTRODUCTION

Much work has been done along the lines of essential plant elements and their effects upon plant growth, but little has been attempted on those supposedly non-essential elements which may have their part to play in plant stimulation or toxication.

With this purpose in view, experiments were conducted to determine the effects of certain inorganic and organic plant elements on plant growth.

The organic elements used were oils; namely, olive, castor, mazola, wesson, nujol, and a Squibb's petroleum oil.

The following organic sugars were used; saccharose, lactose, and glucose.

The inorganic compounds used were potassium permanganate and copper sulphate.

R E S U M E   O F   L I T E R A T U R E

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There is a dearth of work on the use of oils as plant foods. The only material that seems to be available on oil work is that on spray work and that material which pertains to toxicity in eradication work.

Thompson (37) found that the use of kerosene at the rate of one gallon of material to a 12 inch root diameter of barberry would entirely kill the root system of the plant. This was a very heavy application of oil but it had a killing effect and destroyed the barberry roots.

Thompson and Robbins (38) found the following conditions existent with barberries treated with oils.

Creosote oil (light) with an application of 42 cubic centimeters to the soil in eight inch pots in which barberries were growing, was applied. An entire killing of plant roots was made in a period of eighteen days.

Petroleum fuel oil, a very heavy oil, had a slow action. Some roots of barberry were readily killed when the oil was able to penetrate the soil freely enough and get into contact with the roots. The soil was black and caked with the oil two years after treatment.

Petroleum gas oil gave a 99 percent kill on barberry bushes with field treatment. This oil was very toxic and had a wonderful killing effect.

Gasoline with 21 cubic centimeters applied to the surface of soil in pots gave an entire kill in two weeks. The action of the gasoline was slow but death was the final result.

Kerosene produced a very effective killing action in field experiments. Barberries were not quickly injured by applications of 42 c.c. of material in greenhouse cultures. Field results on kerosene were also very slow.

Gasoline, gas oil, kerosene and fuel oil all were very slow in acting on the barberry roots. Gasoline was more rapid than the other three oils, yet was slightly less effective in its action than kerosene or gas oil.

The lighter more penetrating oils gave the greatest killing power. But considering this we can not explain the action of gasoline in these experiments. Gasoline was the lighter oil of the four, yet did not prove quite as effective.

Thompson and Robbins (38) found that heavy oils and tarry substances fail to produce a general killing, either because of failure to penetrate the soil or the failure of plant roots to absorb them. They found that lighter oils were much more satisfactory and produced good killing effects.

Very little is known as to the chemical reactions which cause a killing effect, this being especially true with oils.

General on Toxic Action.

True and Oglevee (39) have shown that the poisonous action of dissolved substances is more harmful to roots of plants immersed in solutions, than is the case when the same plants are grown in sand cultures, even tho the concentrations of the solutions is greater in the last growth media. They also found that the presence of other insoluble substances in the soil lessened the toxic action of a toxic substance. If sand particles were increased the toxic action of plant poisons was lessened to such an extent that growth was practically normal.

Heald (9) in his work came to the conclusion that the toxic action on plant tissue has much to do with the turgescence factor in the cell. If there is a sudden and decided decrease in turgor pressure, the growth in such a case will be retarded or inhibited. Such a retardation or inhibition in rate of growth must thus be considered a sign of poisoning. Retardation is thought to be connected with the factors of both turgescence and the irritability of the protoplasm. The irritability of plants varies with the plants, and thus different compounds must have a widely varying effect with different plants.

Copper Sulphate Action.

Brenchly (1) found that badly poisoned plants made very weak or no growth at all. When plant growth is not so badly injured, root growth may have a flacid state of development.

Whenever plants must fight against very adverse conditions often curious malformations occur in their root systems.

Brenchly (1) states, "It is not clear whether certain nutrients stimulate the protoplasm or in some way hasten the metabolic processes in the plant, whether they help the roots in their absorbent work or whether they are simple nutrients needed only in infintesimal quantities. Thru the use of inorganic food salts in conjunction with a poison toxicity is reduced. Plants under these conditions will grow and stand a greater amount of poison than they would in the absence of nutrient solutions.

Brenchly (1) states, "The Rothamsted experiments go to uphold Kanda's statements as to the failure of copper sulphate to stimulate plants grown in water cultures." Brenchly (1) says, "Altogether, after looking at the question from many points of view, one is forced to the conclusion that under most typical circumstances copper compounds act as poisons to the higher plants and that it is only under particular and peculiar conditions and in very great dilutions that any stimulative action on their part can be clearly demonstrated."

Kahlenberg and True (12) state, "It will be noted in concentrations not fatal, that in general the amount of growth increases as the concentration decreases. The copper ion itself is far more poisonous than the complex ion which contains copper. If the addition of certain substances to a solution containing a physiologically active ion forms a complex ion of much less powerful action, it follows that these additional ingredients afford a means of reducing, so to speak, the physiological action of the simple ion."

Collier (3) did work with a two percent and five percent soil mix, which contained copper compounds. These experiments showed the foliage to be a darker green than the check plots in both the two and five percent soil mixes. The five percent mixture showed a greener foliage coloration than the two percent. In maturity it was found that the two percent plants matured first, but they were dwarfed in appearance. The yield was lower than the check plot. Five percent plot did not ripen any earlier than the check plots and there was a markedly poor yield of vine and peas. Plants treated with copper sulphate had very meager root systems. In fact in some cases only short stubs with a very loose hold on the soil developed when plants were treated with a copper sulphate solution.

Dr. Emil Hasselhoff, as abstracted from New York bulletin under Collier's work states the following:

1. "Soluble copper salts are injurious to plants. The injurious action begins when the solution (water culture) contains ten milligrams of copper oxide per liter, while at the same time, when the amount of copper oxide is not more than five milligrams per liter, there is no marked retarding action.

2. "By spraying soil with copper sulphate the

nourishing elements of the soil, especially lime and potash, are dissolved and leached out, while the copper oxide is precipitated and retained in the soil. Both of these actions reduce the productiveness of the soil.

3. "The injurious action of copper sulphate and copper nitrate solutions is more marked with barley and oats than with grass. Copper sulphate is more harmful to corn than to the growth of beans.

4. "Upon the addition of lime ($CaCO_3$) to the soil this action is counteracted as long as any of the lime remains not acted upon. As soon as the excess of the lime is acted upon the destructive action of the copper begins as well as the leaching away of the potash from the soil."

True and Oglevee (40) in their work found that in greater concentrations copper sulphate was quite toxic, growth being suppressed, but they also found that as the solutions were decreased growth was increased. Their work further showed that the action of insoluble bodies (such as sand and so forth) were great factors in lessening toxicity of a toxic solution.

A LeRenard (16) in his work states, "The groups of salts K., Mg., NH_4, or organic acids which contain in their structure the groups CH_3, CH_2, or CH, singly joined to a functional group possess an anti-toxic value against copper salts."

Osterhout (25) found that water twice distilled from glass and the rejection of at least the first third of the distillate, gave a good distilled water for experimental purposes. But even at this, new apparatus will give a poisonous effect in the distilled water. This toxicity ceases after long use of the distilling apparatus.

Stockberger (35) shows that with copper sulphate treatment in every case less elongation of cells occurred. In higher concentrations there was practically a complete inhibition of growth after a period of twenty-four hours. Mitosis was arrested in sixteen hours with a solution of $\frac{N}{20,000}$; in twenty hours, with $\frac{N}{30,000}$; and in forty hours with $\frac{N}{40,000}$. In $\frac{N}{12}$ or about a one percent copper sulphate solution the outer cells are killed. Its action slowly penetrates to inner cell tissue. (1) The stronger copper sulphate solutions inhibited mitosis, disorganized and interrupted spindle formation, and arrested the development of the cells. This fact was further demonstrated by the loss of function and a subsequent degeneration of the achromatic figure. (2) The next condition found to occur was the enlargement of the vacuoles in the cytoplasm thus deforming the achromatic figure and the nucleus. (3) Later on in the treatment the cytoplasm was entirely disorganized. (4) The development of the chromatic figure was also inhibited thru the treatment of cell tissue with copper sulphate.

Lipman and Wilson (17) in their work found a direct injury to plants, due to the absorption of copper. This absorptive process was manifest thru analysis made. With wheat plants treated with copper sulphate solutions no stimulation was observed, and plants were a lighter green than the check plots. Toxic effect of copper sulphate did not manifest itself until a concentration of 1000 ppm. was reached, with wheat. In vetch plants the use of copper sulphate gave stimulation in growth.

Harter (7) claims that to many plants one of the most toxic of substances known is copper. He also believes that it has been present in many cases in water used for experimental purposes and that some other substance was blamed as the toxic agent. Harter (7) states that Coupin has found one part of copper to 700,000,000 parts of water is sufficient to retard the root growth of wheat seedlings. A mere trace of copper has been found to be sufficient to retard growth in many cases.

Pammel (26) in his work, used three different strengths of copper salts. They all retarded germination. Roots were injured with the first treatment in all except the check. With Bordeaux and copper sulphate solutions, good root systems and healthy plants developed. But later on injury occurred to the root systems with the above treatments. Germination with the three salts was quite irregular.

Moore and Kellerman (23) found in their work with protozoa and algae that one part of copper to 10,000 and to 10,000,000 are destructive to such life. In higher concentrations bacteria are killed by the action of copper sulphate solutions.

Haywood (8) found with concentrations of soluble copper of two and one-tenth to three and one-half parts per million the growth of wheat and rye was markedly interferred with. Haywood (8) states, "Irrigation waters containing the copper sulphate salts make land unfit for cropping, when such water is used for irrigation purposes."

Forbes (6) found in his work that the fine roots of plants absorbed a greater amount of copper salts than did the larger coarser roots. This is readily explained by the greater amount of absorbing surface to weight in the smaller roots. It was found that a more toxic condition existed, with a greater copper content, of the plant roots.

Forbes (6) states, "Copper in sufficient amounts presumably kills the protoplasm." In his work he found a varying sensitiveness to toxicity with different plants. Corn was more sensitive than squash or beans. He also found that stimulation occurred with .01 to .1 parts per million of copper. Accelerations in root growth are only observed with one part of copper to 10,000,000 to 100,000,000 parts of water. In distilled water stimulation was only observed with the dilution of one to 100,000,000.

In the presence of other soluble salts the effects of copper are materially lessened. Forbes (6) says, (1) "Toxic effects of copper in soil are due (1) to the converting of insoluble into soluble compounds, (2) reconverting these again into insoluble combinations, (3) modifying the toxic effects of copper salts in solution. Copper sulphate reacts in the soil to form various insoluble compounds with consequent lessening of toxic soil action."

Varying soil agencies react with the copper salts when they are mixed with soil, and these substances withdraw a great amount of the copper from solution. Thus this helps check the toxic action of copper. Lumpiness within a soil mass was found by Forbes (6) to cause a lessening of the toxic action caused by copper compounds.

Forbes (6) found with his work on roots that old roots are more resistent to the action of copper compounds than are the younger more tender roots. His work showed (1) that copper is fixed in plant roots by the action of the protoplasm, (2) the presence of nutrient solutions along with copper compounds lessens the effects of the copper solutions upon young sensitive growing plant roots, (3) also that old quiescent plant roots developed in nutrient solutions are distinctly less sensitive to copper salts than still actively growing young roots.

Forbes' (6) report on the physiological work shows; (1) that there is a probable variation in degree of resistance to penetration of plant cells by copper salts, (2) that young roots are less resistant to such salts than old roots, (3) that the resistance of the roots of certain plants (namely, corn) is less than the roots of other species, and (4) that to some extent toxic effects may be related or correlated with the structure and distribution of root systems.

Forbes' (6) diagnosis of copper injury shows (1) that roots, in the presence of sufficient amounts of copper to be toxic, become very harsh, crinkly, have almost a total loss of root hairs, root systems are checked in growth extent, and also in feeding capacity. The individual roots are very coarse, covered with thick epidermis and also are abruptly angular due to what may be considered the results of chemotropic contortions. The root tips are much shortened, thickened, and in some cases strongly proliferated.

Forbes (6) gives the anatomical effects of copper salts as follows: (1) An attack by these salts on the plant proteids at the most delicate, vital and vulnerable points in the plant system, (2) that a small enough portion of copper required for complete reaction is enough to kill the protoplasm at these weak points, and (3) in seedling stages of plants the number of growing points are necessarily small and minute, and an extremely small portion of copper solution is all that would be necessary to arrest the spread of the plant root system and the nutrition of the plant.

Forbes (6) found a stimulative effect to be produced with a poison such as copper sulphate, or other poisons to have a stimulative effect providing small enough quantities of the solutions are used and also that other conditions are quite favorable. He believes that the sulphate ions effect on the soil is the liberation and release of plant food, which in turn produces a stimulative effect.

Forbes (6) conclusions are: That copper is found in root systems in combination with the plant proteids, especially near the growing points of plant root systems. The place and nature of the attack of copper salts makes them more toxic to plants. The varying effects of copper toxicity and the difference in sensitiveness of different plants may be possibly explained by the number and position of plant growing points. Copper dioxide and certain soluble salts are conditions which both effect the toxicity of copper compounds.

According to Forbes (6) there are numerous conditions existing which oppose the toxicity of copper compounds; namely, the presence of copper compounds in the form of chrysocolla and chalcocite, also there is a process of absorption thru contact with finely divided soil particles, reactions of silicates, carbonates, and organic matter all tending to precipitate copper from its solutions; the presence of certain soluble salts in the soil that overcome toxic actions and the tendency of increased resistance in older plant roots.

The stimulation of vegetative growth has been noted in both pot and water cultures by Forbes (6), with the use of copper as a nutrient. He also feels that stimulated growth of crops under field conditions is a possibility.

Forbes' (6) further conclusions are: (1) That pot cultures may be used successfully for determinations of toxicity, providing rigidly uniform conditions are used in the experiments.

The physiological conditions and the copper content of such material under such a type of culture, will be much greater than plants grown under plot or field conditions.

Forbes (6) in field conditions finds that a toxic condition exists only where the roots of young growing crops are exposed to what are classed as surface soils, in which maximum amounts of copper may be found.

Vageler (41) found that .042 grams of a $CuSO_4$ solution per liter would give very toxic action if used in water cultures. He found no stimulating effects in any water cultures. The addition of calcium and sodium chlorides failed to diminish poisonous effects. Beans were found to be less sensitive to copper treatment than oats.

Fred (5) found that copper sulphate gave a stimulating effect on plant growth, and growth in a biological way also. He states that it helps a great deal in the growth of nitrifying bacteria or in other words Azotobacter growth.

Wilson (23) in his studies on wheat and vetch found that the tolerance of plants for certain of the inorganic salts which are commonly thought to be very toxic is much greater than many investigators have been led to believe. Some plants have been found, which are stimulated to a considerable extent by fairly large proportions of such salts.

Zehl (43) found that when inorganic compounds were used singly and the temperature was raised, poisonous action and toxicity was increased. With the use of two poisons in combination the toxicity or poisonous effect was less than when either one of the compounds were used singly.

Steglich (34) found in his work that the application of $CuSO_4$ to soil plots for a two-year period, at the rate of 40, 80 and 160 grams per square meter of surface did not produce injurious effects on fruit trees and strawberries. When a like treatment of $CuSO_4$ was applied to potatoes and beans, in the field, injury to such crops was very apparent.

Kanda (13) states that $CuSO_4$ in very dilute solutions when applied to pea seedlings were injurious, that is in water cultures. In humus soils it proved not only non-injurious, but exerted a stimulative effect on growth.

Sachser (33) in pot experiments and field tests with potatoes, oats and clover sprayed a solution of $CuSO_4$ on healthy plants, with very beneficial results.

Sugars.

Knudson (14) says, (1) "Corn grown in nutrient solutions containing certain sugars is able to absorb these sugars by means of their roots and the sugars are assimilated effecting increased growth of plant; (2) beneficial effects of sugars in light; first, glucose; second, saccharose; and third, maltose, with glucose also leading, when used in the dark; (3) increased growth with radish, with glucose, saccharose, maltose and lactose."

Knudson (14) found that the Canada field pea responded with a markedly increased growth in the presence of sugar nutrients. These nutrients affected the plants beneficially in the following order; saccharose, glucose, maltose and lactose.

Knudson under the discussion of Curtis' (4) work found that the nutrient action of sugar increases root growth very much in seedlings when grown under sterile conditions. Nutrient solutions of sugar are also beneficial to top growth, but the roots respond more readily to an increased carbohydrate supply. Privet cuttings were used for sugar tests.

Curtis (4) found that sugar treatment on cuttings for fourteen days were beneficial but that continuous treatment with either mature or immature cuttings would have a tendency to retard root formation. Immature cuttings, if placed in a sugar solution continuously, gave a suppression in the root development. This might be explained as due to detrimental conditions produced thru bacterial and fungial action, or to a lessening of the oxygen content accompanied with an increase in carbon dioxide content.

According to Curtis (4) mature twigs were but slightly benefited with cane sugar as a nutrient treatment, Any injury which accompanies the treatment of plants with nutrient sugar solutions, must be attributed more to the products which may be formed by bacterial or fungial action. Curtis (4) states that as a rule nutrient solutions are injurious to root cuttings.

Russel (32) shows in the work of Koch that the application of small doses of dextrose, when used experimentally in soil cultures, would give nitrogen fixation quickly. Koch found the maximum amount of nitrogen fixation was reached after about 18 weeks, and that losses would set in after that period of time had elapsed.

Russel (32) found that 8 milligrams of nitrogen were fixed for each gram of dextrose, where applications of dextrose were used in small doses. This amount of nitrogen fixation occurred during an 8 weeks' period. After this 8 weeks' period only 4 to 5 milligrams per gram of dextrose were fixed in the form of nitrogen. In larger doses but 5 to 6 milligrams of nitrogen per gram of sugar was fixed, during the earlier period. Later during the tests this dropped to 3 milligrams per gram, that is, toward the last of the experiment.

Pot experiments showed a ready availability of this nitrogen as a plant nutritive.

Dextrose and sucrose at first suppressed the growth of a crop, then at a later period left a soil richer in nitrogen.

Russel (32) says, "An increase in crop following the application of sugar or starch to the soil is not evidence of nitrogen fixation, but might equally well be adduced to show that sugar and its decomposition products are direct plant nutrients."

Patterson and Scott (27) say that neither starch nor sugar are helpful in nitrification, but that they aided the destruction of nitrates already present. Their action was one of denitrification.

Robson (31) found with the addition of organic matter, especially sugar, there was a reduction in the amount of soluble nitrogen compounds in the soil. In all the soils with the addition of sugar, there was an increase in the fixation of ammonium sulphate nitrogen but there was no affect on nitrate nitrogen content. This fixation of ammonium sulphate nitrogen, due to sugar, was found to be as follows: From 18.18 to 26.18 percent in sandy soils, from 22.32 to 43.2 percent in loam soils, and from 29.08 to 38.38 percent in clay soils.

Hoffman (11) found that the application of sugar markedly increased the fixation of atmospheric nitrogen thru Azotobacter action, even in the absence of a legume. This increased activity of nitrogen fixing bacteria produced an actual increase of nearly 1,000 pounds of nitrogen per acre foot in a three-year period.

Munter and Robson (24) in their work found that a liberal addition of sugar produced a decrease in soluble nitrogen compounds such that it caused a deficiency in nitrogen for crop growth, and an increase in nitrate assimilation in all of the soils and a loss of gaseous nitrogen from sand and loam soils. When sugar was added to a soil ammonium sulphate decomposed more rapidly, but there was not a corresponding increase in nitrate formation.

Pfeiffer and Blanck (28) in their work confirmed the work of other investigators and showed that the addition of sugars to a soil did not promote the action of nitrogen collecting bacteria to a sufficient extent to produce a very appreciable increase in crop yield.

Pfeiffer and Blanck (28) found that the use of one kilogram of sugar to 100 grams of Thomas meal per square meter, gave a slightly injurious effect on the yield of an oat crop. This same treatment was but slightly beneficial to a turnip crop. They concluded from these experiments that the beneficial effects of sugar as a fertilizer or organic substances has been very much overrated.

Petit (30) worked with Coleuses, Calceolarias and Abutilons. He grew these plants in pots, with a diameter of 15 cm., filled with earth. Doses of 4 and 8 grams of glucose were added in 2 doses at 15-day intervals. A reduction was then made in the amount of glucose used. Glucose was found too unfavorable and positively detrimental to plant growth. .5 of a gram of glucose, at 8-day intervals, gave a reduction in plant growth. The author concluded that no notable growth could be obtained thru the use of glucose in the earlier forcing of horticultural plants.

Maze and Perrier (20) in their experiments with the germination of maize found a retardation for several days, yet it did not wholly prevent the development of the plants. If sugars are added to plants which are already growing the sugars may be absorbed in darkness, but they will not supply the action of the sun in photo-synthesis. Their work further showed that soluble organic substances in the soils or solutions may aid in the growth of chlorophyll bearing plants.

Heinze (10) in his work with organic substances such as straw, sugar, starch, as well as other compounds, found that there was a material increase in the number of beneficial bacterial organisms altho the inorganic nitrogenous compounds under the same conditions did not exert an appreciable influence in this respect.

Marr (19) with a 2 to 8 percent solution of sugar found that results were variable, some vessels showing a gain in nitrogen while others showed a loss. Usually a loss occurred, then a gain or a condition of increased nitrogen fixation.

Pfeiffer (29) reported experiments which show no advantage gained in nitrogen fixation thru the addition of a 2 percent sugar solution to the soil.

Stoklasa (36) in his work found sugars to be very helpful to Azotobacter growth and action. Thus he found an increase in nitrification to occur.

Koch (15) found in pot experiments with pure sand cultures that the rate of nitrogen fixation was 7.2 mg. of nitrogen per 100 grams of sand. A 2 gram sample of cane sugar was added over a period extending from March 4 to June 1. Field fixation of nitrogen with sugar was found to be least the first year and much greater the second and third years. He found the sugars Mannite and dextrose to be the most valuable sugars.

Molliard (22) found an increased fleshy development of radish roots, onion bulbs and onion seedlings, with an available supply of sugars. The flowers of the radish and morning glory showed abnormal development under the influence of glucose. In the presence of large amounts of sugars the leaves of plants underwent very profound modifications. With radishes a marked destruction of nuclear tissue was found from excessive treatments of sugar.

Maize and Nicolas (18) experimented with bean seedlings. They found sugar solutions to have an osmotic and plasmolytic effect on plants causing a retardation in growth. Penetrating power of a sugar, thru a cell tissue varies with the sugar. Sacchrose is a more active sugar than maltose, and maltose is more active than lactose, glucose, or levulose.

Potassium permanganate literature is very meager. Little work has been done on this that is available in the American or English field.

Chirikov (2) found potassium permanganate and other solutions used gave a stimulating effect with wheat, while with other plants the results were variable. His work showed two stimulants were able to give the aggregate action of the two used separately or as separate chemicals.

McBride (21) reported that the growth of sweet peas was materially increased thru the sprinkling of the soil with a solution of potassium permanganate. The solution was made up at the rate of 2 ounces to 25 gallons of water.

M A T E R I A L S   A N D   M E T H O D

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Solutions of the oils, namely, olive, castor, mazola, wesson, nujol and petroleum, were used in the treatment of the soil, in soil cultures. These oils were as thoroly incorporated within the soil culture as was possible. This mixing was done by sprinkling the solution thru the soil and then mixing the soil material thoroly.

The plants in which soil treatment with oils were tried were: Potted geraniums from 2½ inch pots; nasturtuims started from the seed stage within the oil-treated soil; corn and wheat under similar conditions to those of the nasturtiums; and 2 plots of tomatoes which were transplanted from 3 and 4 inch pots respectively.

The geraniums were run in series of eights. Two pots were treated with 20 c.c. of oil, two pots with 10 c.c. of oil, two pots in which greenhouse soil was used, but in which all earth was removed from the roots of the plants, and two plants which were repotted in the regular greenhouse soil mixture. Five series of pots with 8 pots to the series were used, or a total of 40 plants. The treatment was applied but once. The plots were run for a period of 5 months. The geranium plots and the first series of tomato plants had a ½ inch layer of sand placed on top of the soil to check evaporation of soil moisture, as much as was possible.

Nasturtiums were planted and allowed to germinate in a soil culture in which varying amounts of oil were well incorporated within the soil. A series of pots were used in which two were treated with 50 c.c. of oil, two with 40 c.c., two with 30 c.c., two with 20 c.c., two with 10 c.c., and 8 in which the seed were allowed to germinate in the ordinary greenhouse soil culture. The commercial vegetable oil, mazola, was the only oil used in carrying thru these experiments with nasturtiums.

Wheat was run thru a series of experiments with 4 types of oil. A series composed of 2 plants treated with 10 c.c. of mazola, 2 with 10 c.c. of castor, 2 with 10 c.c. of nujol, 2 with 20 c.c. of nujol, and the use of 10 pots as checks.

Corn was grown and run in a series very similar to that of wheat. The series was run in such a way as to have 2 pots of each, treated with the following: 10 c.c. and 20 c.c. of petroleum oil, 10 c.c. and 20 c.c. of mazola, 10 c.c. of wesson oil, and 10 pots with no treatment were used as checks.

Two series of tomatoes were run. The first series was treated as follows: 2 pots with each of the following amounts of oil, 50 c.c. of oil, 40 c.c., 30 c.c., 20 c.c., 10 c.c.; 3 pots with the earth removed from the roots of the plants and then repotted, and 7 check plants potted in greenhouse soil. Commercial Wesson oil was used in this experiment.

The plants were repotted from 3 inch into 5 inch pots.

The second series of tomato plants were treated as follows: 1 pot each with 10 c.c., 20 c.c., 30 c.c., 40 c.c. of olive oil, 1 pot each with 10 c.c., 20 c.c., 30 c.c., 40 c.c., of mazola oil, and 2 pots without treatment were used as checks. These tomatoes were given the same treatments later, but with an additional increase of 10 c.c. of oil per plant over their first treatment amounts. This last feeding was done during the period at which the fruit was maturing.

Measurements on geraniums treated with oil were made as to height of plant, diameter of crown of stem, and the number of leaves developing under the various treatments. All blossoms were pinched back for a specified period of time and later on each plant was allowed to flower.

Measurement of height was taken on wheat, corn and nasturitiums.

On the tomatoes measurements were taken as to height, and weight of ripened fruit.

The wheat seed used was registered Marquis which was as near a pure line as could be obtained. Seven wheat seeds were planted per pot. Four inch red clay florists' pots were used.

The nasturtium seed was a seed which tested 95 percent germination. Three seeds were planted per pot. Five inch red clay florists' pots were used.

The corn used was golden bantam which tested 95 percent germination. Four seeds were planted per pot. Four inch red clay florists' pots were used.

The greenhouse soil used was made up of a 3/4 portion of fine field loam to a 1/4 portion of well-rotted manure. This soil mass was the type used in potting work for all the plants on which experimental work was done.

Each pot in which oil and checks were used in the series with geraniums had a shallow white glazed porcelain sauce dish about 14 cm. in depth placed under it.

The solutions were made up so as to form 2, 3, and 5 percent sugars. Saccharose, lactose and glucose were used in the work.

Geraniums were treated with the sugars, saccharose and lactose. The first treatment was the use of saccharose in the strengths of 2, 3, and 5 percent solutions on each of a 6 plant series. A group of 6 plants were used as checks. Lactose was used in a similar series in the same strength solutions. Then both sugar solutions were cut down to 1, 1.5, 2.5, percent solutions and feeding of plants was continued.

The amount of saccharose fed per plant in the first series was 20 c.c. Plants fed lactose were fed a similar amount. This 20 c.c. feeding was used with the solutions of a concentration of 2, 3, and 5 percent. When these sugars were reduced in percentage they were fed in 40 c.c. amounts per plant.

Measurements were taken of these geranium plots in an exactly similar manner to those of the geraniums treated with oil.

A series of 24 aster plants were treated with glucose as the food element. The first feeding was applied in strengths of 2, 3, and 5 percent solutions of the sugar. Twenty c.c. amounts per plant were used. The next and subsequent feedings were made in 40 c.c. amounts per plant with solution strengths of 1, 1.5, and 2.5 percent. Six plants were used for each concentration. A 6-plant group was used as a check, Potassium permanganate was made up as a 1/10 of 1 percent solution and then was reduced to a 1/100 percent solution. This solution was applied to each of 8 plants in amounts of 40 c.c. per plant.

A copper sulphate solution of 1/100 percent solution was made up in a similar way to that of the potassium permanganate solution. This solution was applied to a group of 6 plants at the rate of 40 c.c. per plant.

A check plot with a group of 6 aster plants potted in greenhouse soil was run in conjunction with these 14 plants treated with the potassium permanganate and copper sulphate solutions.

Leaf numbers were kept as a record with these asters in the case of the sugar treatments and also with those plants treated with copper sulphate and potassium permanganate.

Green weight and dry weight of both the roots and tops of all asters used in the experiments were taken.

Leaf growth, that is numbers of leaves per plant, is not a very accurate way in which to check growth, because leaves vary greatly in size and weight. This leaf number, especially in asters, is a very poor index of total plant growth.

Distilled water was used for making up all the solutions used in these experiments.

Distilled water was applied every day to the plots to which sugars, potassium permanganate, and $CuSO_4$ were applied. The use of distilled water was to check any conditions which might exist in tap water that would be either beneficial or detrimental to plant growth.

Ordinary tap water was used in the irrigation of all oil plots.

E X P E R I M E N T A L   D A T A

- - -

Plot I.

Olive Oil. During the period of the experiment olive oil showed the following growth results: With 20 c.c. treatment, 1 inch increase in height, 1 cm. in diameter, and the final leaf growth number to be the same as that which pertained when measurements were first taken; 10 c.c solution, gave 1 inch increase in height, 1 cm. in diameter, and 4.5 in leaf growth number; the plot with earth removed entirely from roots was found to have increased 5.25 inches in height, 3 cm. in diameter, and 19 in leaf growth number; and the checks showed 4 inches increase in height, 3.15 cm. in diameter and 26.5 in leaf growth number.

Thus the oil plots show a marked toxic action and a retardation in growth, in the 3 growth measurements.

The heavier application of oil was more detrimental to leaf development than the lighter application of oil.

Root development was greatly hindered in the oil plots. The roots of oil treated plots developed but little root system from that of the original rooted cuttings. The check plots on the otherhand had well developed fibrous, well massed root systems. This type of root development was found to be the identical condition which occurred thruout all experiments with geraniums, in which oil was used.

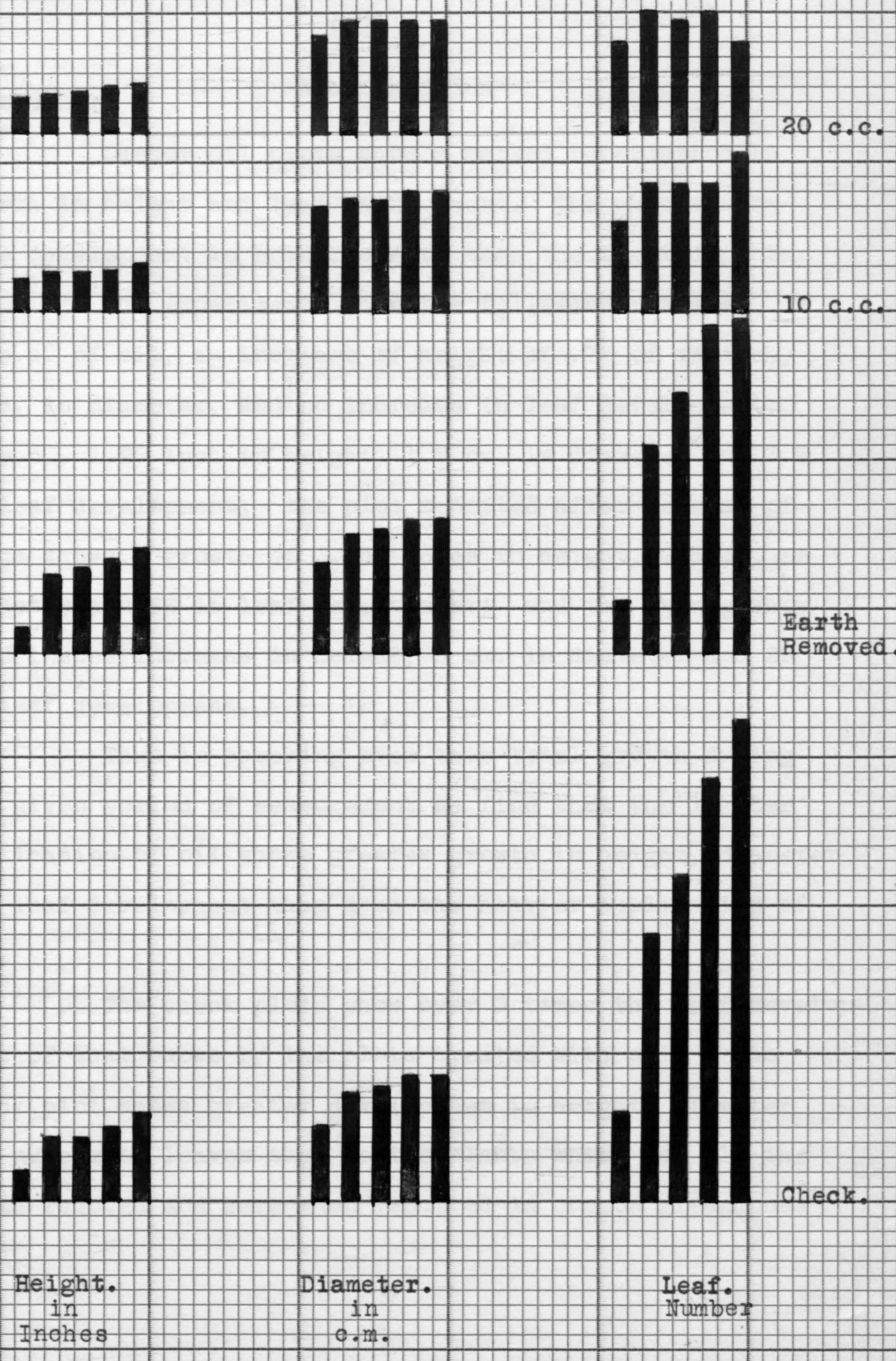
Leaves of oil plots were small, poorly colored and very unhealthy in appearance.

Geraniums. Average Growth Record under Treatment with Olive Oil.

Treatment	Feb. 26	May 1	May 9	May 25	June 9
20 c.c. Height	2.125	2.5	2.875	3.00	3.125
Stem Diameter	6.5	7.5	7.5	7.5	7.5
No. of Leaves	6.	8.	7.5	8.	6.
10 c.c. Height	2.25	2.75	2.75	2.875	3.25
Stem Diameter	7.	7.5	7.5	8.	8.
No. of Leaves	6.	8.5	8.5	8.5	10.5
Without Earth Height	1.75	5.25	5.75	6.25	7.0
Stem Diameter	6.	8.	8.25	9.	9.0
No. of Leaves	3.5	14.	17.5	22.	22.5
Check Height	2.	4.125	4.125	5.0	6.0
Stem Diameter	5.	7.5	7.75	8.5	8.5
No. of Leaves	6.	18.	22.	28.5	32.5

Height growth in inches.
Stem diameter in millimeters.

OLIVE OIL TREATMENT.



Castor Oil.

Castor oil plots show a marked retardation in growth in height and leaf development. The checks show more development in both respects than the treated plots.

The experiments show the following results: 20 c.c. of oil, an increase of height of .75 of an inch, 1 cm. in diameter, and no increase in leaf development; 10 c.c., 1.25 inch in height, 1.5 cm. in diameter and 3.5 in leaf development; the plot repotted after removal of earth shows a growth of 3.75 inches in height, 2.5 cm. in diameter and 26 in leaf development; and the checks show 5.75 inches increase in height, 3 cm. in diameter and 29 in leaf development.

Thus in checking over this total growth during the given period of measurement we find that the lighter application of oil shows greater growth in height, diameter and leaf development than does the heavier application of oil.

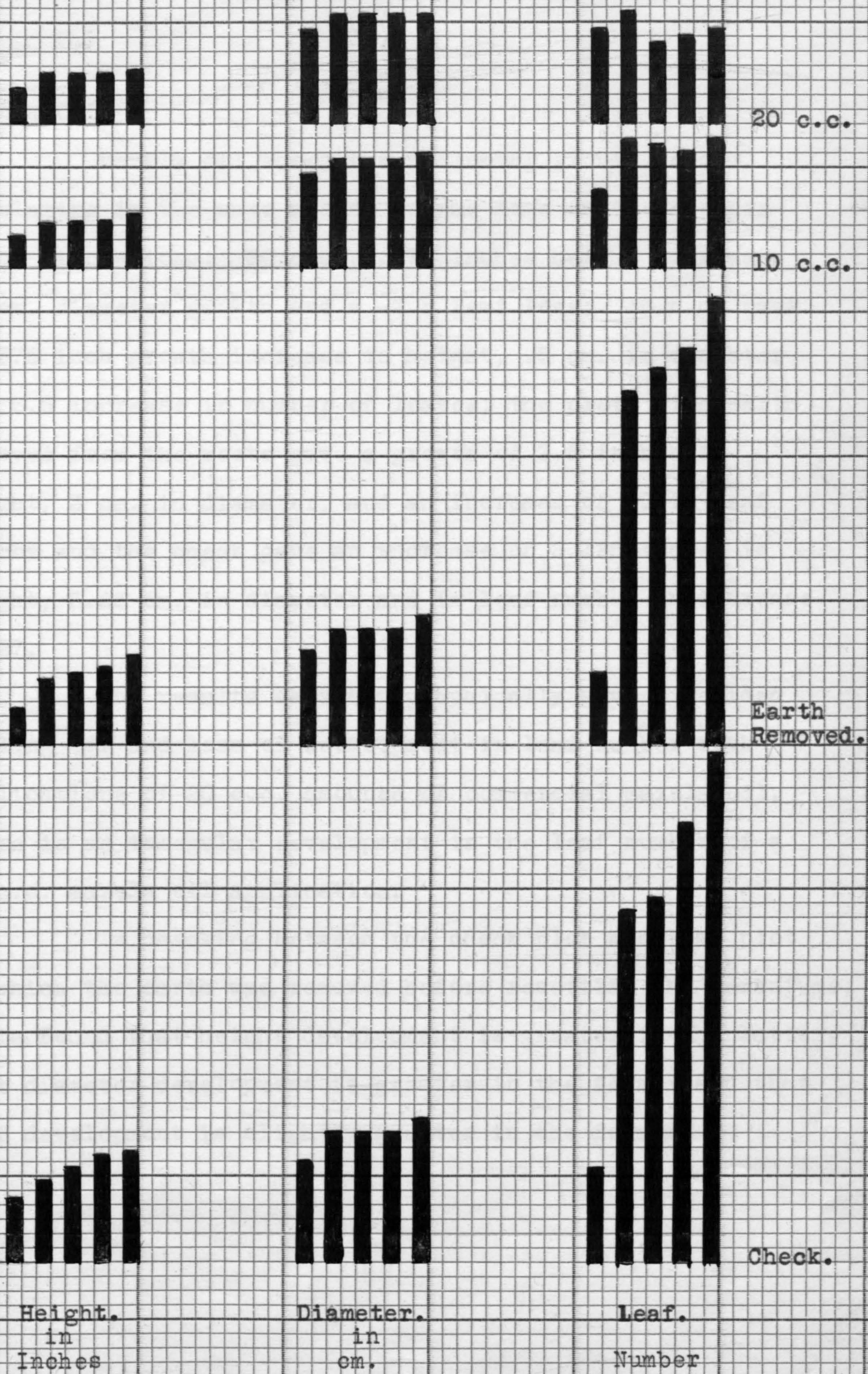
The check plots show over 3 times the leaf development of that shown by the plots treated with oil. The check plot shows greater development in height, diameter and number of leaves than do the plants which had all the earth removed and were then repotted in common greenhouse soil.

Geraniums. Average Growth Record under Treatment with Castor Oil.

Treatment	Feb. 26	May 1	May 9	May 25	June 9
20 c.c. Height	2.625	3.125	3.125	3.25	3.375
Stem Diameter	6.5	7.5	7.5	7.5	7.5
No. of Leaves	6.5	7.5	5.5	6.	6.5
10 c.c. Height	2.125	3.125	3.25	3.25	3.375
Stem Diameter	6.5	7.6	7.5	7.5	8.
No. of Leaves	5.5	9.0	8.5	8.	9.
Without Earth Height	2.375	4.5	5.	5.375	6.125
Stem Diameter	6.5	8.	8.	8.	9.
No. of Leaves	5.	24.5	26.	27.5	31.
Checks Height	2.125	5.875	6.5	7.375	7.875
Stem Diameter	7.	9.	9.	9.	10.
No. of Leaves	6.5	24.5	25.5	30.5	35.5

Height growth in inches.
Stem diameter in millimeters.

CASTOR OIL TREATMENT.



Mazola Oil.

Mazola oil shows the following growth record, tabulating in the same manner as was done in the two previous discussions: 20 c.c., .575 inches height increase, .5 cm. diameter growth and a -2.5 leaf loss; 10 c.c. gave a .375 inch growth increase in height, .5 cm. in diameter and 3.5 increase in number of leaves; the plots with earth removed from the roots gave a growth of 3.5 inches in height, 3 cm. in diameter, and an increase of 25 in leaf number and the check gave an increase of 3.125 inches in height, 3.25 cm. in diameter and in leaf number an increase of 27.

The results as shown graphically give a decided falling off and loss of development in leaf number with applications of 20 c.c. amounts of commercial mazola oil. There is an irregular development in the leaf number of a 10 c.c. mazola oil application.

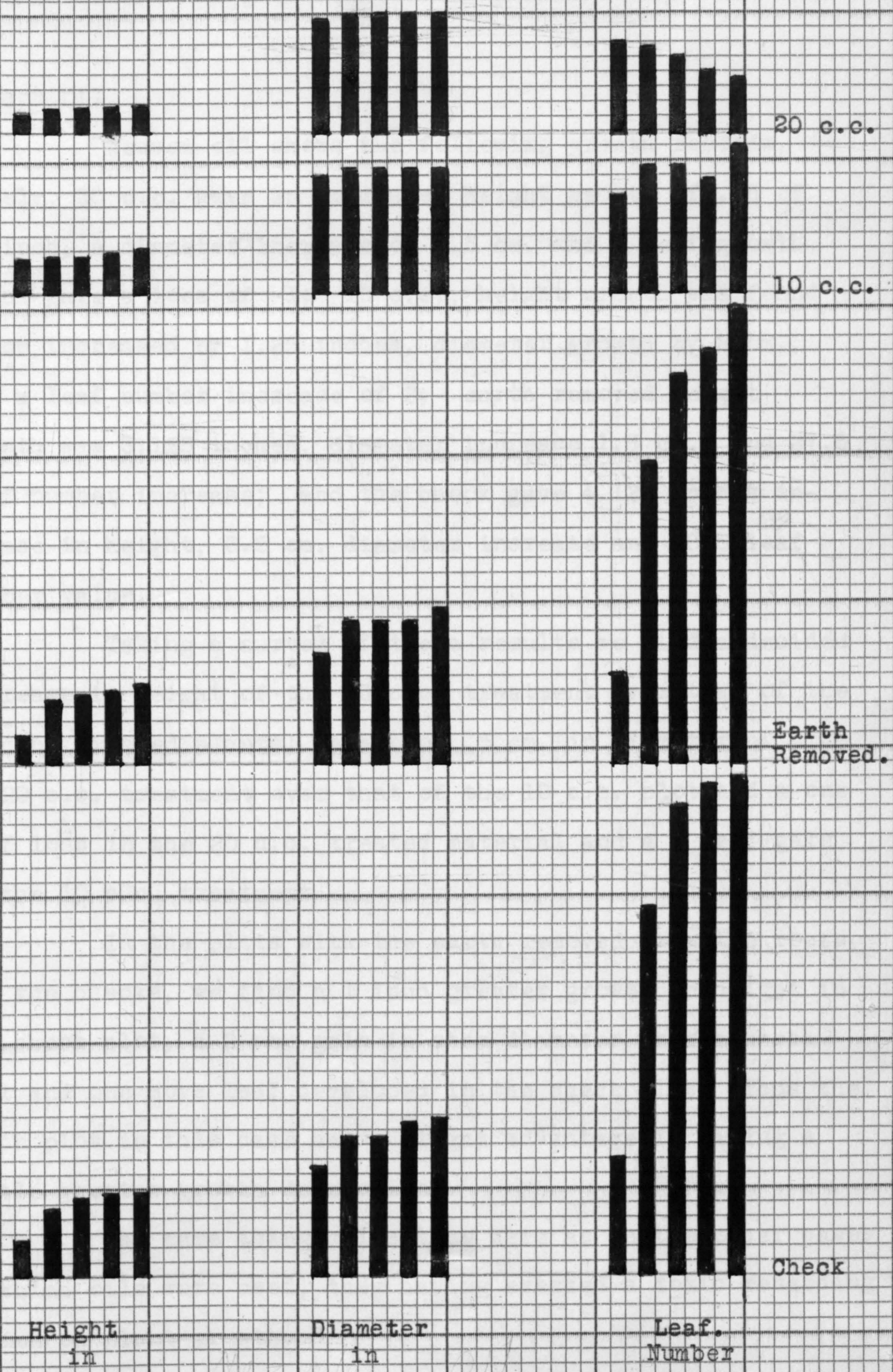
In checking between the check plot and that plot in which the earth was removed before resetting the geraniums, it is found that height development is greater in the latter, that diameter development is greater in the former and that leaf development is slightly greater in the former.

Geraniums. Average Growth Record under Treatment with Mazola Oil.

Treatment	Feb. 26	May 1	May 9	May 25	June 9
20 c.c. Height	1.25	1.75	1.75	1.825	1.825
Stem Diameter	7.5	8.	8.	8.	8.
No. of Leaves	6.	5.5	5.	4.	3.5
10 c.c. Height	2.5	2.5	2.5	2.625	2.875
Stem Diameter	8.	8.5	8.5	8.5	8.5
No. of Leaves	6.5	8.5	8.5	7.5	10.
Without Earth Height	2.	4.625	4.75	5.	5.5
Stem Diameter	7.5	9.5	9.5	9.5	10.5
No. of Leaves	6.	20.5	26.5	28.	31.
Checks Height	2.5	4.875	5.125	5.625	5.625
Stem Diameter	7.25	9.5	9.5	10.5	10.5
No. of Leaves	8.	25.	31.5	34.5	35.

Height growth in inches.
Stem diameter in millimeters.

Mazola Oil Treatment.



Wesson Oil.

Wesson oil shows the following growth records, namely, 20 c.c. gave an increased height growth of .45 of an inch, a diameter increase of 2.5 cm. and a leaf growth which gave a loss of -1; 10 c.c., height growth was found to be increased by 1.25 inches, diameter growth by 2 cm., and a leaf number increase of 2; earth removed height growth was 3.125 inches, diameter increase 1.5 cm., and 27.5 leaf number increase; and the check gave 4.125 inches increase in height, 3.5 cm. diameter increase and 28.5 leaf number value.

Taking a survey of these results we find a decided increase in height of the 10 c.c. treatment over that of the 20 c.c. treated plants; again of .5 cm. in diameter of stem in 20 c.c. treatment over that of the 10 c.c. plot and a one leaf loss in the 20 c.c. treated material and a 2 leaf gain in the 10 c.c. treatment.

In the plots with the earth removed from the roots, and the checks, we find a 1 inch greater growth in height in the check plot, a 2 cm. gain in stem diameter in the check plot and one more leaf developed in the check plot. Thus the check plot in this case has a slight advantage in having a little greater growth development.

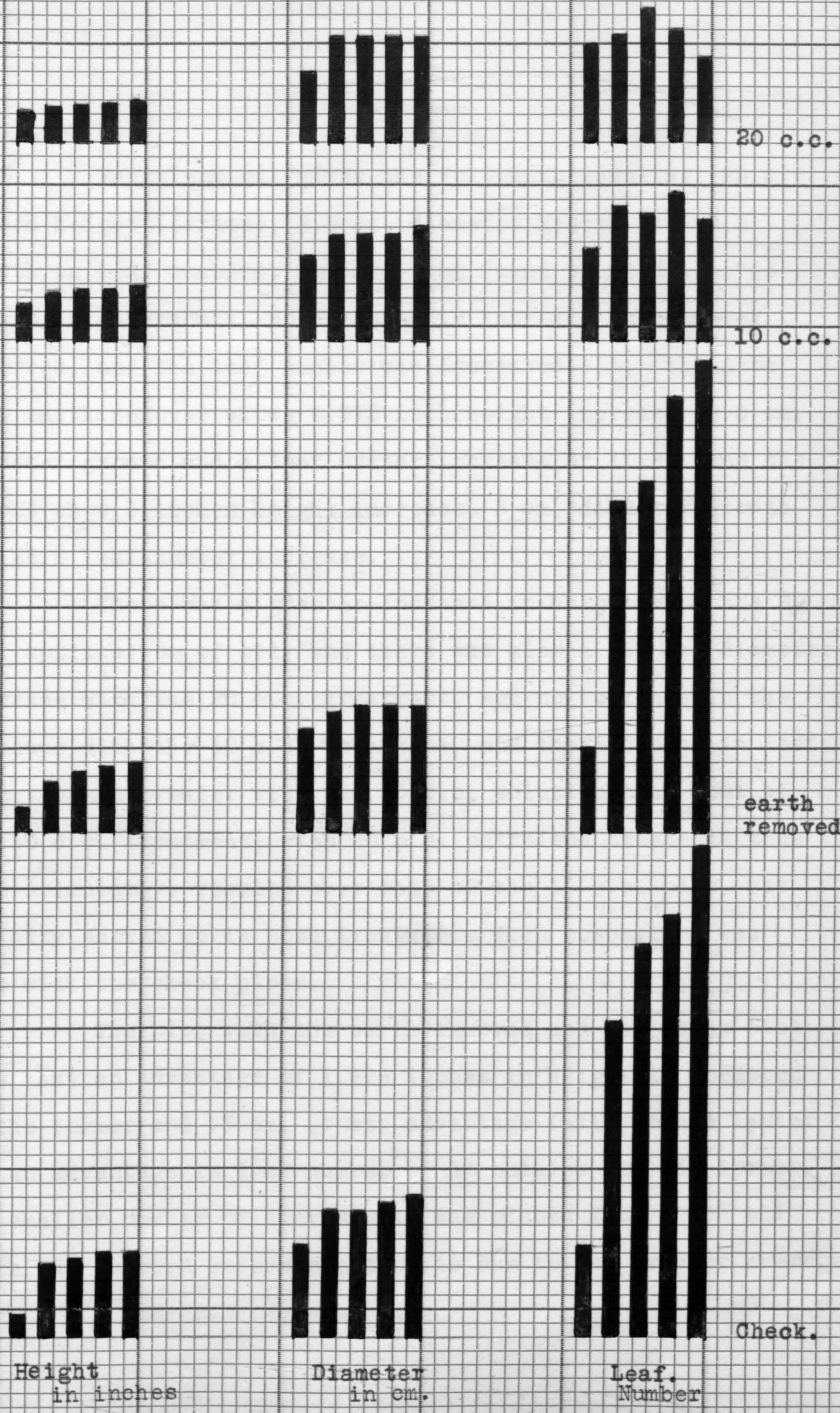
The same thing holds true here as in the other cases in which oils were used, they having exerted a toxic retarding action on plant growth.

Geraniums. Average Growth Record under Treatment with Wesson Oil.

Treatment	Feb. 26	May 1	May 9	May 25	June 9
20 c.c. Height	2.375	2.625	2.75	2.75	2.825
Stem Diameter	5.	7.5	7.5	7.5	7.5
No. of Leaves	7.	7.5	9.5	8.	6.
10 c.c. Height	2.5	3.25	3.45	3.45	3.75
Stem Diameter	7.	8.5	8.5	8.5	9.
No. of Leaves	6.5	9.5	9.	10.5	8.5
Without Earth Height	1.875	3.625	4.125	4.625	5.
Stem Diameter	7.5	8.5	9.	9.	9.
No. of Leaves	6.	23.5	25.	30.	33.5
Checks Height	1.875	5.	5.5	6.	6.
Stem Diameter	6.5	9.	9.	9.5	10.
No. of Leaves	6.5	22.5	28.	30.	35.

Heighth growth in inches.
Stem diameter in millimeters.

Wesson Oil Treatment.



Petroleum Oil.

Petroleum oil gives the following results: 20 c.c., 2 inch height increase, 2.5 cm. diameter growth, and 9,5 growth in leaf numbers; 10 c.c. was found to produce .725 inches height growth, no measureable increase in diameter occurred, and the leaf number was increased 4.5; the plot with earth removed shows 4.375 inch height increase, 2.5 cm. diameter growth and a leaf number increase of 11.5; and the checks show 3 inches height increase, 3 cm. diameter growth and 25.5 leaf number increase.

There was a greater increase in height with the 20 c.c. application of oil, and there was also a 2.5 cm. diameter increase with the 20 c.c. treatment, and no increase in the diameter with the 10 c.c. treatment, and the increase in leaf number was 5 greater with the 20 c.c. solution than that of the 10 c.c. treatment. The 20 c.c. petroleum treatment thus gave stimulative results over that of the 10 c.c. plot, yet toxicity showed up in both treatments when comparison was made with the check plots.

The plot with the earth removed and the check plot show that an advantage of 1.375 inches in height is credited to the former and .5 cm. growth advantage falls to the latter and an advantage in leaf number of 14 obtains for the former. The smaller number of leaves with the plants from which all earth was removed before planting is due to the greater average size of the leaves.

The petroleum oil was the only oil to give an increased growth with the 20 c.c. application. This oil was made up by Squibb's as a medicinal oil, and thus is a highly refined and purified oil.

Of all the oils tested the petroleum oil gave the greater increase in height and in leaf number.

Geraniums. Average Growth Record under Treatment with Petroleum Oil.

Treatment	Feb. 26	May 1	May 9	May 25	June 9
20 c.c. Height	2.375	3.375	3.625	4.25	4.375
Stem Diameter	6.	8.	8.	8.	8.5
No. of Leaves	4	9	12.5	14	13.5
10 c.c. Height	2.65	3.	3.	3.25	3.375
Stem Diameter	9.	9.	9.	9.	9.
No. of Leaves	4.5	9.5	10.5	9.5	9.
Without Earth Height	1.625	4.125	4.125	5.625	6.
Stem Diameter	7.5	9.5	10	10	10
No. of Leaves	4.5	10.5	12.5	16	16
Checks Height	2.625	3.5	3.875	4.75	5.625
Stem Diameter	7.5	10.	10.	10.	10.5
No. of Leaves	6.	24.	23.5	29.	31.5

Height growth in inches.
Stem diameter in millimeters.

Petroleum Oil Treatment.

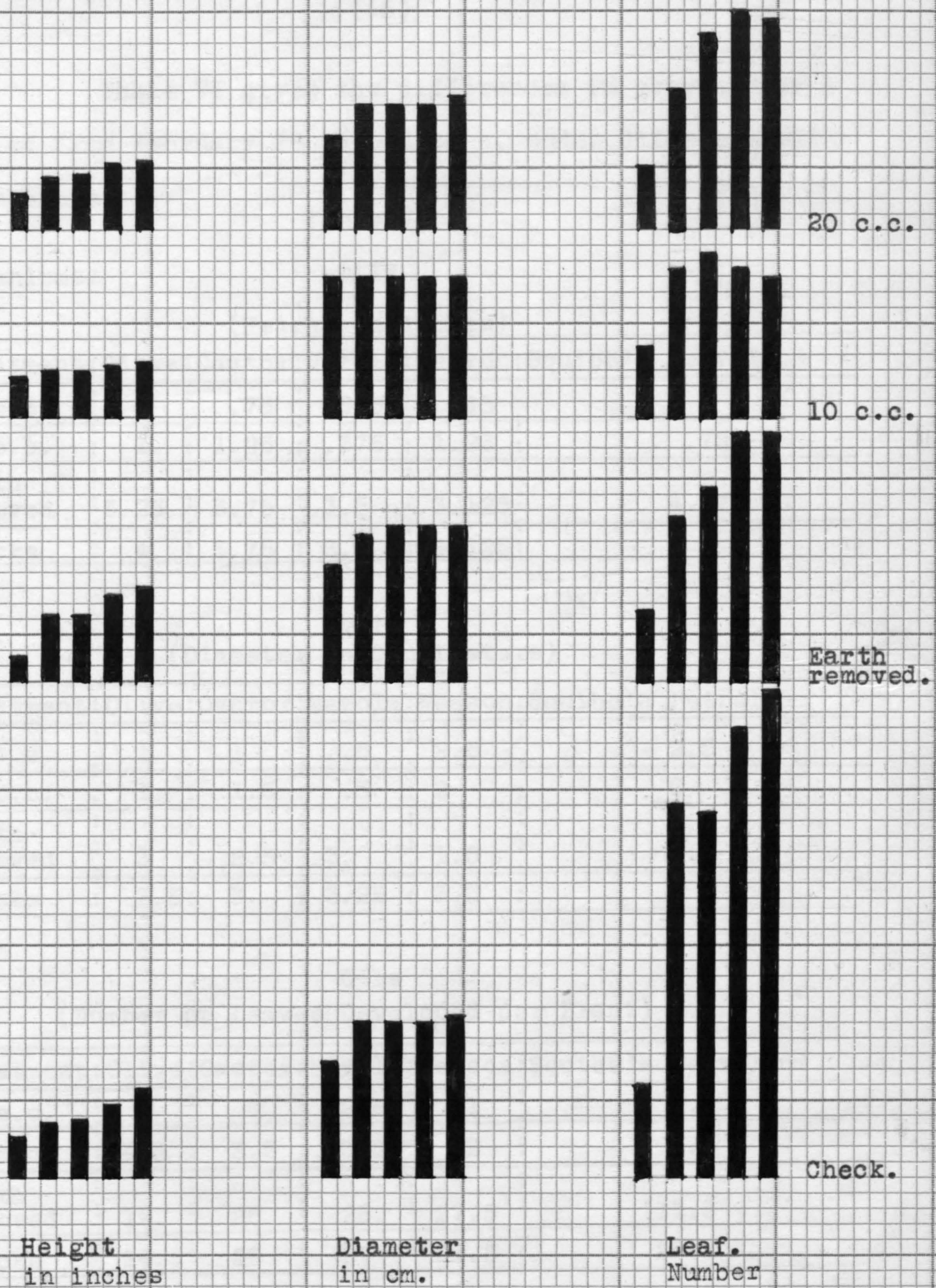


Table VI gives the differences in growth over a period from February 26 thru June 9, under different oil treatments.

Table VI.

Geraniums: Oils

(Height in inches)

Treatment	Olive	Castor	Mazola	Wesson	Squibb's Petroleum
20 c.c.	1	.75	.575	.45	2
10 c.c.	1	1.25	.375	1.25	.725
Earth Removed	5.25	3.75	3.5	3.125	4.375
Checks	4	5.75	3.125	4.125	3

Oils
(Diameter in Centimeters)

Treatment	Olive	Castor	Mazola	Wesson	Squibb's Petroleum
20 c.c.	1	1	.5	2.5	2.5
10 c.c.	1	1.5	.5	2	0
Earth Removed	3	2.5	3.	1.5	2.5
Checks	3.5	3.	3.25	3.5	3

Oils
(Number of Leaves Developed per Plant)

Treatment	Olive	Castor	Mazola	Wesson	Squibb's Petroleum
20 c.c.	0	0	-2.5	-1	9.5
10 c.c.	4.5	3.5	3.5	2	4.5
Earth Removed	19.	26.	25.	27.5	11.5
Checks	26.5	29	27	28.5	25.5

All oils from this table are shown to give a toxic action and there is a great retardation in height, leaf and root development in all of these plots.

Roots in all cases in the oil plots were very much retarded. Some of such roots had the root tissue practically destroyed. Such root tissue looked as if decay had injured it. The roots of the oil treated plants were very short and seemed to be stubby or broken off where ever they seemed to come in contact with the oil. The roots of all check plants were fibrous, well developed and entirely filled the pot. Those with the oil treatment seemed unable to penetrate from their original 2.5 inch of soil into the oil treated soil mass.

In Table VII the blossom record of June 5 to June 30 shows the amount of blossoming for each treatment. All plants were pinched back and kept from blossoming for a period of about 3½ months. Then records on blossom growth were taken.

The blossom record of olive oil and petroleum oil show 5 blossoms each for the total blossoming of the 20 c.c. and 10 c.c. applications. Castor, Mazola and wesson oils show with the same treatment, 4, 1 and 2 blossoms respectively. Out of 4 plants but 1 blossom was obtained thru the use of mazola oil and but 2 blossoms with wesson oil.

All checks gave a greater amount of blossoms than did the oil plots. Thus oil does not help to increase blossoming.

Table VII.

Geranium Blossoming under Oil Treatments. Record taken from June 5 thru June 30.

Treatment	No. of Blossoms	No. of Plants
Olive Oil- 20 c.c.	2	2
10 c.c.	3	2
Without Earth	3	2
Check	6	2
Castor Oil- 20 c.c.	2	2
10 c.c.	2	2
Without Earth	6	2
Check	5	2
Mazola Oil- 20 c.c.	0	2
10 c.c.	1	2
Without Earth	0	2
Check	6	2
Wesson Oil- 20 c.c.	1	2
10 c.c.	1	2
Without Earth	5	2
Check	3	2
Petroleum- 20 c.c.	3	2
10 c.c.	2	2
Without Earth	2	2
Check	4	2

Nasturtiums run from the seed thru to maturity showed quite well the detrimental effects of oil. The experiment shows the least height growth with the heavier applications of an oil solution.

The differences in height growth between May 8 and June 21 show a marked variation and give a very definite gradation of growth. The increase in height is as follows: 50 c.c., 1 inch; 40 c.c., 2.25 inches; 30 c.c., 2 inches; 20 c.c., 4 inches; 10 c.c., 9 inches; and the check 12.94 inches.

Thus we may infer that there must be less toxic action with a decrease in the amount of oil added to the soil media in which the nasturtiums were grown.

The tables and the graph show the differences in development between the different oil plots.

Nasturtium Height under Oil Treatment, given in inches.

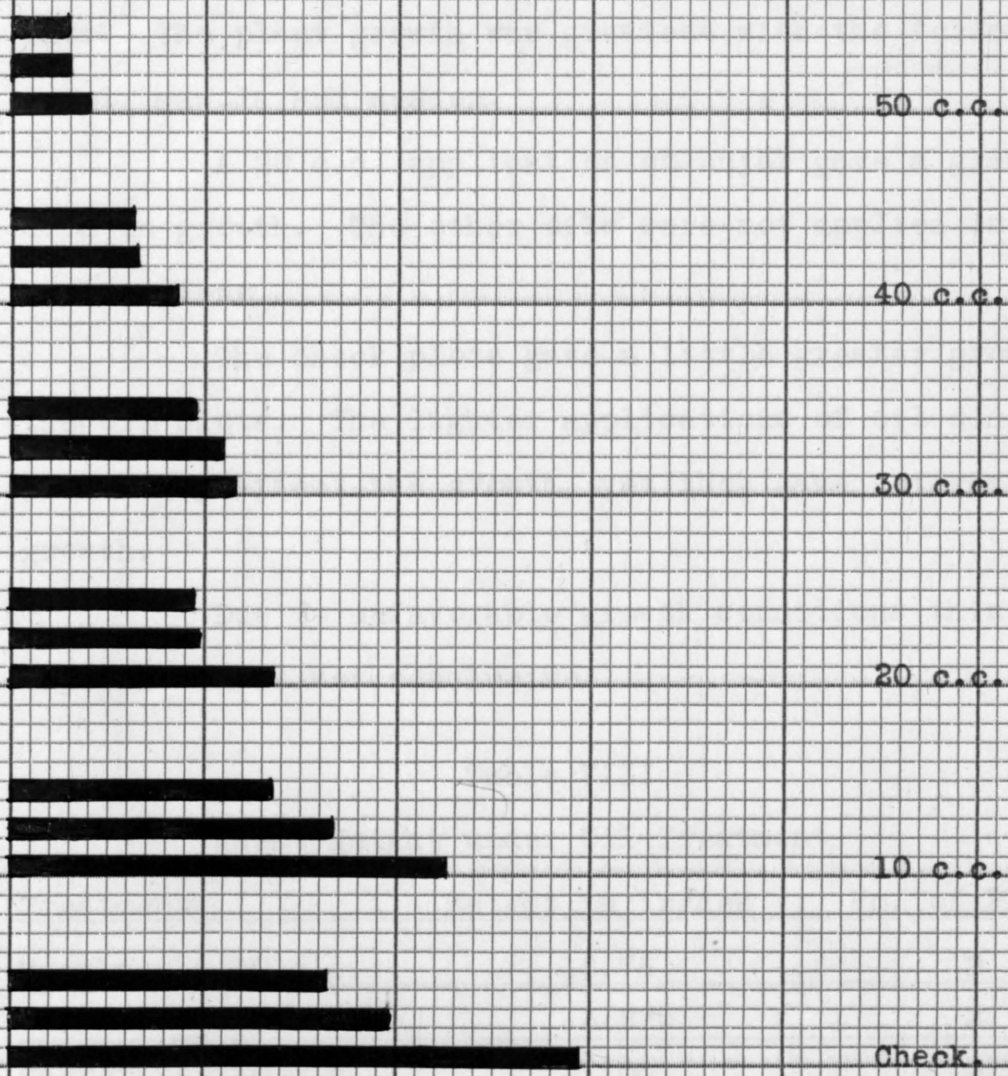
Treatment	May 8	May 26	June 21	No. of Plants	Increase in Height
Mazola					
50 c.c.	3	3	4	1	1
40 c.c.	6.25	6.5	8.5	2	2.25
30 c.c.	9.5	11.	11.5	2	2
20 c.c.	9.5	9.75	13.5	2	4
10 c.c.	13.5	15.75	22.5	2	9
Checks	16.43	19.62	29.37	8	12.94

Final vegetativeness and blossoming of the plants show the checks to be far superior in both respects. Those with less oil show more growth and blossoming than those with the heavier applications of oil.

The nasturtiums show less root development with the greater amounts of oil applications and as the oil application was lightened a greater root development occurred.

Nasturtium Growth under Oil Treatment.

Height in inches.



Plot II.

Table VIII shows the height growth in inches with wheat. Castor oil gave an abnormal growth of the castor oil plot. The plant growth was greatest with the following oil; nujol, mazola and wesson.

A 20 c.c. application of nujol gave a great retardation in growth. The other oils were not applied in 20 c.c. applications.

The check plots gave a little greater growth than the oil plots. The lighter applications of oil did not so materially affect the growth, yet they gave retardation in growth.

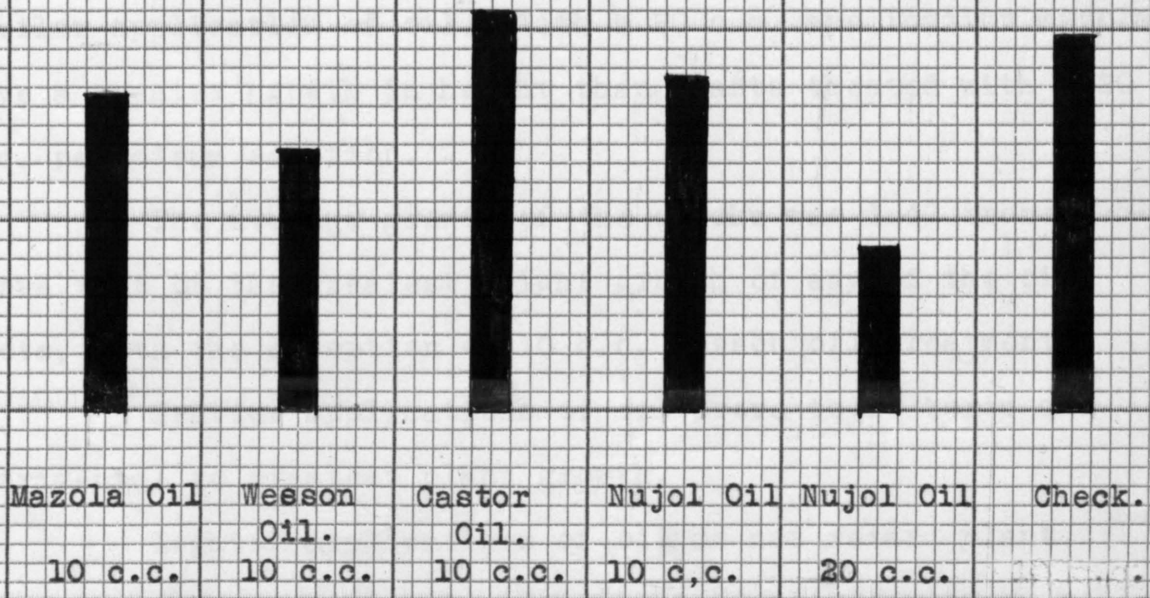
Due to unfavorable growth conditions this set of experiments is not conclusive.

Table VIII.

Wheat Height under Oil Treatment

Treatment		Height in inches	No. of Plants
Mazola,	10 c.c.	16.75	2
Wesson,	10 c.c.	13.875	2
Castor,	10 c.c.	21.00	2
Nujol,	10 c.c.	17.5	2
Nujol,	20 c.c.	8.5	2
Checks		19.40	10

Height Increase with Wheat
under Oil Treatment.
Height in inches.



Plot III.

Corn with the 20 c.c. solutions shows a marked retardation in growth.

Ten c.c. oil applications give a greater growth than pertains with the heavier oil applications. Ten c.c. of Wesson Oil had one plant with a normal growth and one with an abnormal growth. Thus this increased oil growth must be thrown out of our calculations.

Petroleum oil gave the greatest growth with a 10 c.c. application. Mazola oil gave the next greatest growth with a similar application of oil. With a 20 c.c. application mazola gave a greater growth in height than plants treated with a 20 c.c. petroleum solution.

The average growth of the checks was 1.47 inches above that of the greatest height growth of any of the oil plots, with the exception of 10 c.c. wesson oil treatment.

Heavier applications of oil prove to be toxic and detrimental to greatest plant growth.

Lighter applications of oil do not retard plant growth to such a great extent, yet retardation occurs as well with the higher applications.

The experiments with the corn were rather fragmentary and not as comparable as if growth conditions had been better.

Table IX

Corn Studies under Oil Treatment

Oil Treatment	Height in inches	No. of plants
Petroleum- 20 c.c.	8.5	2
Petroleum- 10 c.c.	19	2
Mazola- 20 c.c.	10.5	2
Mazola- 10 c.c.	17.75	2
Wesson- 10 c.c.	26.	2
Checks	21.47	10

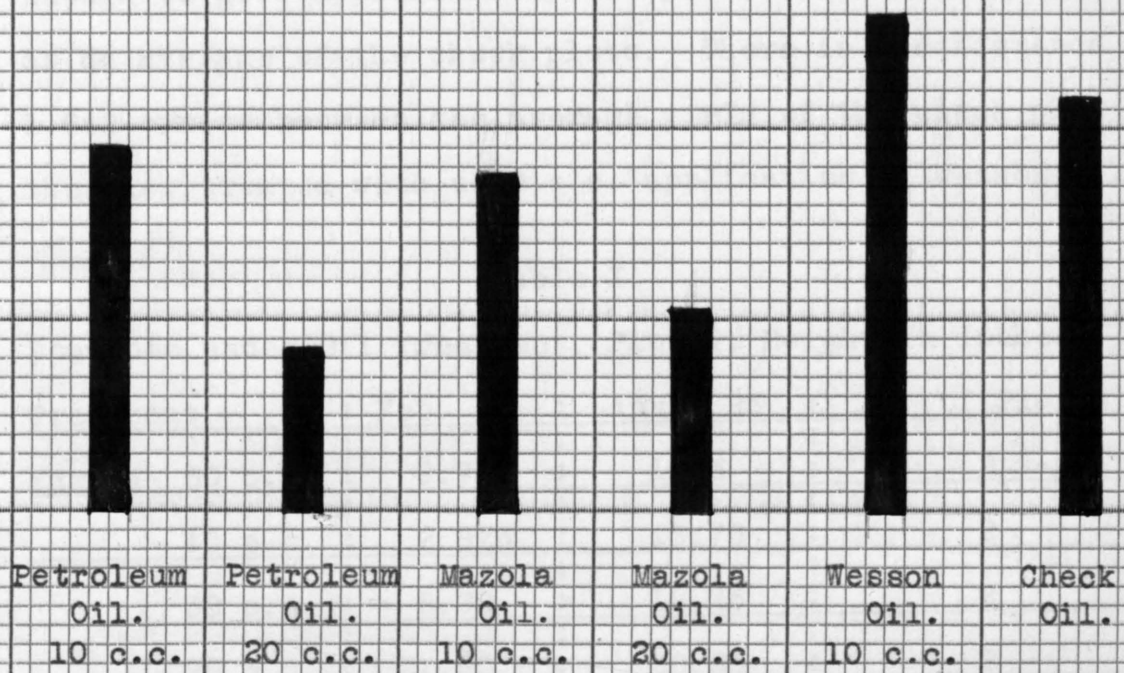
Tomatoes under the different applications show the toxic action of the oils.

Fifty c.c. mazola shows a little more growth than the lighter applications of oils. This may be accounted for by the fact that one of the plants of the 50 c.c. plot produced no blossoms or set no fruit. A vegetative growth thus was the only production of this plant. A gradual increase in growth was found with a lessening of oil content.

The checks and those tomatoes with the earth entirely removed from the roots produced the greatest growth in height. There was only .48 of an inch difference in final growth with this advantage of growth to the credit of the check plot. The pots with the earth removed gave the greater difference in amount of growth increase.

Corn Height under Oil Treatment.

Height in inches.



The tables and graphs show the toxicity of the oils, in the different amounts, in which applications of oil were made.

Yield results with Wesson oil show a marked decline in yield with the heavier applications of oil. As the applications of oil become lighter, the yield of tomatoes becomes greater.

A 10 c. c. application of oil is just about light enough to give approximately the yield of tomatoes obtained as an average of the check plots. There is a difference of 1.642 ounces between the average yield of the check plot and the plot treated with a 10 c.c. application of Wesson oil.

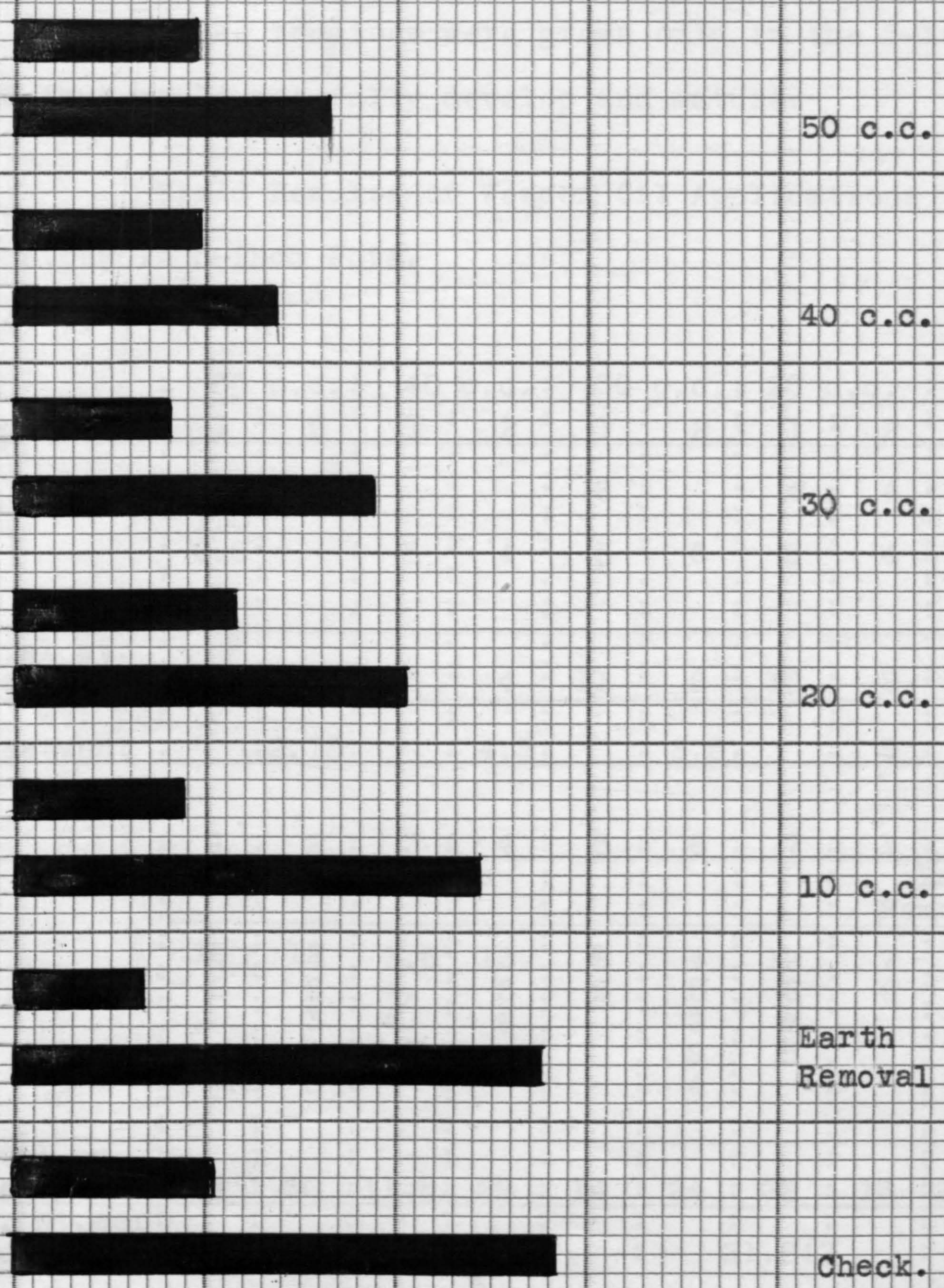
Table X.

Tomatoes under Oil Treatment, Plot I, Height in Inches.

Treatment	Feb. 18	April 25	No. of Plants
Mazola- 50 c.c.	9.75	16.5	2
40 c.c.	9.875	15.75	2
30 c.c.	8.00	18.75	2
20 c.c.	11.50	20.25	2
10 c.c.	8.625	24.25	2
Earth Removal	6.83	27.66	3
Checks	10.28	28.14	7

The plot with the earth removed gave a greater average yield than the check plot. One plant gave a very great yield of tomatoes under this treatment.

Tomato Record Height Increase with Oil.
Height in inches



Heavy applications of oil were detrimental to yield of tomatoes.

These tomatoes were grown only in the 5-inch pots and thus could not fully develop and mature.

Yield Results of Wesson Oil Applications to Tomatoes in 5-inch Pots.

Plot I.

	50 c.c.		40 c.c.		30 c.c.		20 c.c.		10 c.c.	
	1	2	1	2	1	2	1	2	1	2
	2.5 1.0 2.0		5	4	6 5	6	4 6	4 4	4 6 4 8	10 18
Total wt. ozs.	5.5	0	5	4	11	6	10	8	22	28
Av. wt. per treatment		2.75		4.5		8.5		9		25

	1	2	3	4	5	6	7	1	2	3
			Checks						Earth Removed	
	10 8	12 6 3 4 5	3.5 4. 4.	13 3 6	9 5	4 5 3 8 4	12 8 7 5	7 6	4.5 4. 7 4 3	4 4 11 12 5 4
Total wt. ozs.	18	30	11.5	22	14	24	32	13	22.5	40
Av. wt. per treatment							21.642			25.16

Plot II.

Tomato Height under Different Oil Treatments
(Height in inches)

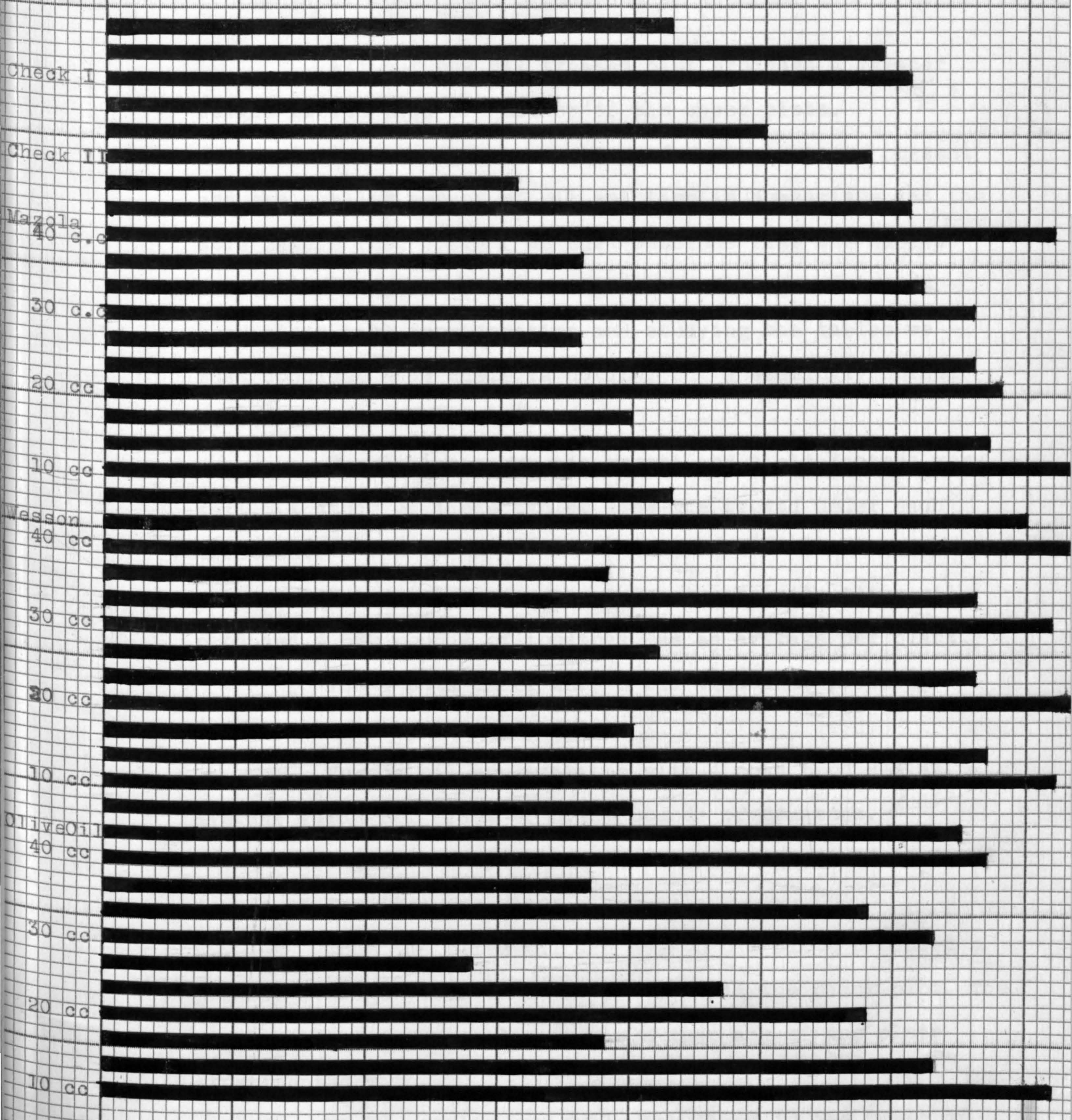
Treatment		May 1	May 30	June 25
Check I.		43	58.5	61
Check II.		34	50	58
Mazola-	40 c.c	31	61	72
	30 c.c	36	62	66
	20 c.c	35.5	66	68
	10 c.c	39.5	67	77
Wesson-	40 c.c	43	70	75
	30 c.c	38	66	72
	20 c.c	41.5	66	74
	10 c.c	39.75	67	72
Olive-	40 c.c	40.	65	66.5
	30 c.c	36	58	62.5
	20 c.c	27.5	46.5	57.5
	10 c.c	37.5	62.5	72.

Tomatoes under the various oil treatments varied very much in their growth in height.

Mazola, wesson and olive oils were applied to a group of older, more mature tomato plants. These tomatoes were moved about the greenhouse to a considerable extent.

The amounts of oil applied were quite insignificant in comparison with the soil content of 10-inch pots.

TOMATO HEIGHT UNDER DIFFERENT OIL TREATMENTS
PLOT II



All but one oil treated plot produced a greater height growth than did either of the check plots.

With the greater amount of soil nutrients present and the smaller amount of oil solution in comparison and the more mature root system, we must conclude that the tables show no detrimental effect on growth. Taking these same conditions into consideration and studying the tables we must conclude that there is nothing but a seemingly normal growth and variation existent.

The tables cover the growth and yield factors very well. A study of these tables show the growth under each treatment.

The 4 pots under the 4 treatments with olive oil produced 4.562 pounds of tomatoes, as an average per plant.

The 4 pots under Wesson oil treatment produced 5.406 pounds per plant.

Mazola oil applications with 4 pots produced an average yield per plant of 3.484 pounds of tomatoes.

The 2 check pots produced an average yield of 4.531 pounds of tomatoes per plant.

Thus the olive oil and wesson oil plots produced a greater average yield of tomatoes than did the check plot. The mazola oil plot gave a lesser yield than any of the plots experimented with.

Yield results are fully tabulated in the table of yield results.

From these tables we find yield results were slightly higher in 2 cases and lower in 1 case than were the results obtained with the check.

Yield Results of Oil Applications to Tomatoes.

Plot II.

	Olive Oil			
	40	30	20	10
	16	16	8	8
	16	20	2	24
	13	5	12	3
	12	6	6	19
	8	8	12	9
	6		5	12
			4	16
			10	16
Total ozs.	71	55	59	107
Total pounds	4.437	3.437	3.687	6.687
Total pounds per treatment				18.248
Av. yield per plant				4.562

	Wesson Oil			
	40	30	20	10
	8	12	16	8
	8	12	6	5
	16	16	16	4
	6	10	8	24
	20	9	6	12
	14	8	14	12
	14	16	16	
		10	8	
		12		
Total ozs.	86	105	90	65
Total pounds	5.375	6.562	5.625	4.062
Total pounds per treatment				21.624
Av. yield per plant				5.406

	Mazola Oil				Checks	
	40	30	20	10	1	2
	2	12	16	20	8	12
	12	12	12	7	8	8
	10	15	8	8	12	8
	9	5	4	4	4	8
	24	12	3	12	11	4
		8	8		8	12
					6	
					4	
					16	
					16	
Total ozs.	57.	64	51	51	93	52
Total pounds	3.562	4.00	3.187	3.187	5.812	3.05
Total pounds per treatment				13.936		9.062
Av. yield per plant				3.484		4.531

Saccharose.

Saccharose in a 1 percent solution gave an increase in height growth of 1.04 inches, a diameter growth increase of .33 cm. and a leaf number increase of 4.34.

With a 1.5 percent solution of the same sugar height increase was 1.167 inches, diameter increase .5 cm. and leaf number increase 6.

It was found that a 2.5 percent solution of the same sugar produced .87 of an inch increase in height, .34 cm. increase in diameter and a leaf increase number of 4.66.

The height increases of these sugar plots were all found to be greater than those of the checks.

The increase in diameter was greater under the three treatments than was that of the check plot.

The number of the leaf increase was greater in every case, but that of the 1 percent treatment than was that of the check. The 1 percent solution gave a leaf increase of 4.34 as also was found to be the case with the check.

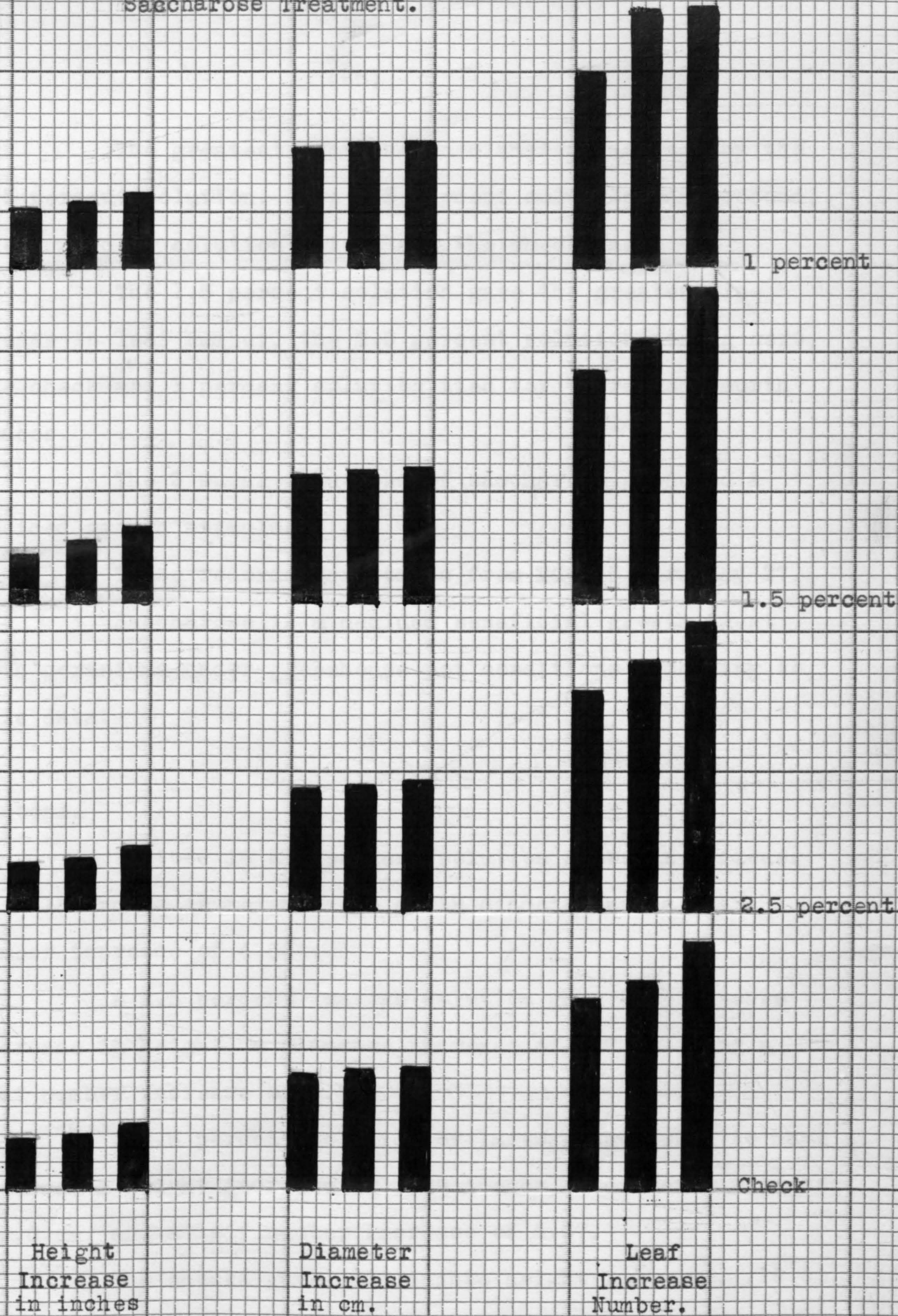
Geraniums. Average Growth Records under Treatment with Saccharose.

Treatment	May 15	May 23	May 27	No. Plants	Diff. in Growth
1 percent ht.	4	4.416	5.04		1.04
Stem Diameter	8.5	8.83	8.83		.33
No. of Leaves	13.82	18.16	18.16	6	4.34
1.5 percent ht.	3.875	4.416	5.042		1.167
Stem Diameter	9.	9.33	9.5		.5
No. of Leaves	16.33	18.835	22.33	6	6.
2.5 percent ht.	3.29	3.54	4.16		.87
Stem Diameter	8.66	8.83	9		.34
No. of Leaves	15.5	17.66	20.16	6	4.66
Checks, Height	3.66	3.83	4.291		.631
Stem Diameter	8	8.166	8.18		.18
No. of Leaves	13.16	14.66	17.5	6	4.34

Height in inches
Stem diameter in millimeters

The greatest average height increase was made with the 1.5 percent solution. The 1 percent solution came second in this respect, the 2.5 percent solution third, and the check last.

Saccharose Treatment.



The greatest increase in diameter was made by the 1.5 percent solution. The 2.5 percent solution came second, the 1 percent solution third, and the check last.

The 1.5 percent solution gave the greatest increase in leaf number, the 2.5 percent solution coming next, the check and 1 percent solution tied for third and fourth places.

The 3 sugar solutions of saccharose produced a decided growth stimulus.

These records were taken from May 15 thru May 27.

Saccharose is a decided beneficial growth agent with geraniums under greenhouse pot conditions according to this data.

Lactose.

Lactose in a 1 percent solution shows an increase of .918 inches in height, .20 cm in diameter and a leaf number increase of 4.664.

A 1.5 percent lactose solution gave 1.042 inches increase in height, a diameter increase of .67 cm., and a leaf number increase of 5.33.

A 2.5 percent solution of lactose was found to have produced a height increase of .628 inches, a diameter increase of .6 cm. and a leaf number increase of 4.67.

The checks gave .631 inches height increase, .18 cm. diameter growth and a 4.34 leaf number increase.

Geraniums. Average Growth Records under Treatment with Lactose.

Treatment	May 15	May 23	May 27	No. of Plants	Diff. in Growth
1 percent height	3.54	3.725	4.458		.918
Stem diameter	9.13	9.16	9.33		.20
No. of Leaves	14.166	17.	18.83	6	4.664
1.5 percent ht.	3.708	3.875	4.75		1.042
Stem Diameter	8.16	8.33	8.83		.67
No. of Leaves	15.5	17.66	20.83	6	5.33
2.5 percent ht.	3.33	3.583	3.958		.628
Stem Diameter	8.23	8.33	8.83		.60
No. of Leaves	13.66	14.83	18.33	6	4.67
Checks, Height	3.66	3.83	4.291		.631
Stem Diameter	8.	8.166	8.18		.18
No. of Leaves	13.16	14.66	17.5	6	4.34

Height in inches.
Stem Diameter in Millimeters.

The height increase was greatest in the 1.5 percent solution, the 1 percent solution coming second, the check third, and the 2.5 percent solution fourth.

The diameter increase was greatest with the 1.5 percent solution, the 2.5 percent solution coming second, the 1 percent solution third, and the check last.

The leaf number increase- the 1.5 percent solution comes first, the 2.5 percent solution second, the 1 percent solution third, and the check last.

The check was found to be lowest in everything but height and this was true in only 1 case. The 2.5 percent solution did not develop to within .003 of an inch of the average height increase of the check plot.

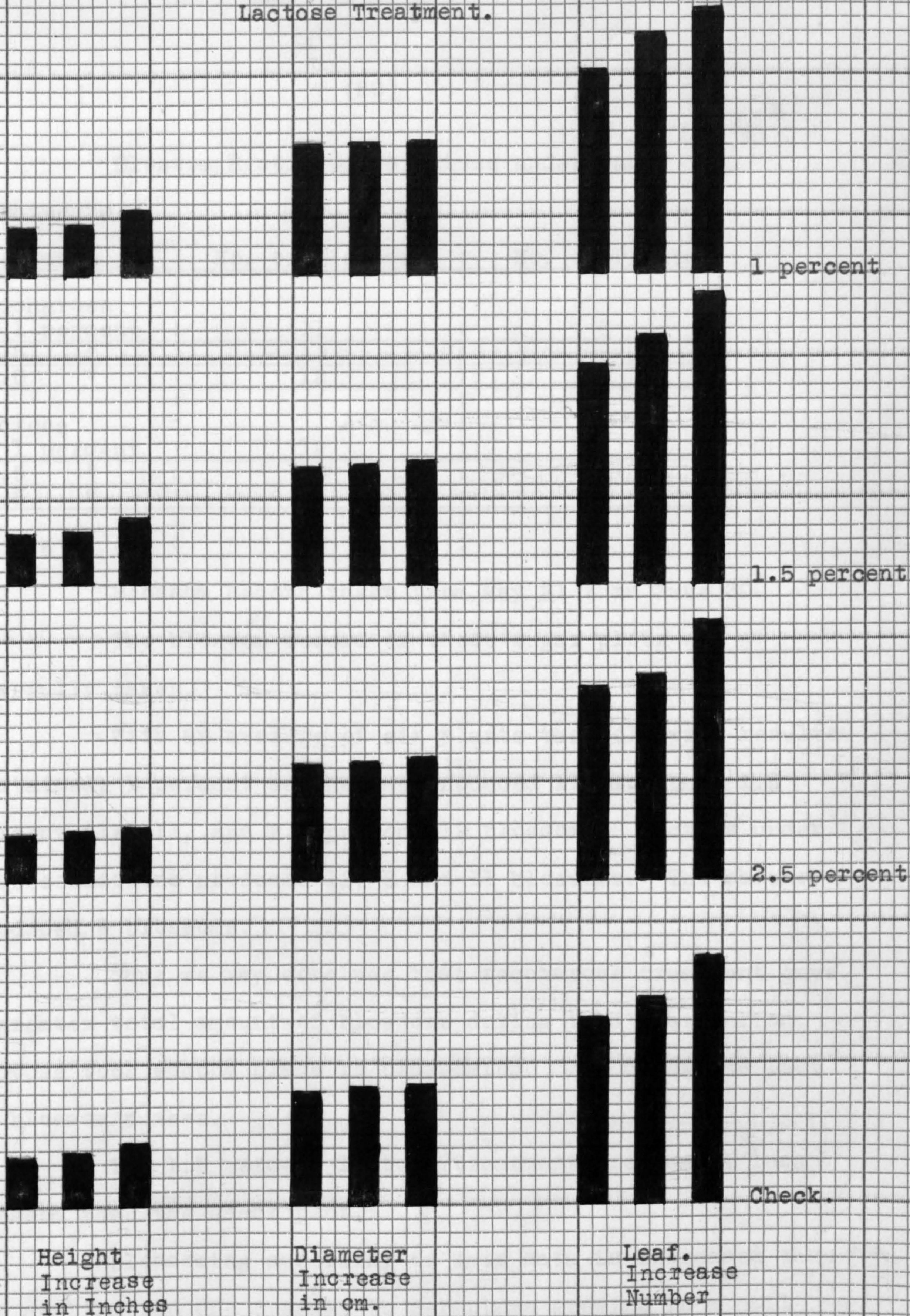
We may thus state that lactose produced a stimulation of growth in these experiments.

Comparing saccharose with lactose we find a greater height growth with the former using the 3 percentage solutions.

Diameter growth is greater in the 1 percent saccharose solution added to soil, less in the 1.5 percent and in the 2.5 percent solutions.

Leaf number increase in growth is greater in the lactose plot with a 1 percent solution, less in a 1.5 percent solution, and greater in the 2.5 percent solution.

Lactose Treatment.



Blossom Record of Geraniums under Sugar Treatments.

Treatment	No. of Blossoms	No. of Plants
Saccharose		
1 percent	11	6
1.5 "	11	6
2.5 "	12	6
Lactose		
1 percent	12	6
1.5 "	8	6
2.5 "	11	6
Checks	9	6

Blossom Record taken from May 21 thru June 30.

The blossom record of these sugar plots was carefully taken.

With an average of six plants the following results pertained; 1 percent saccharose produced 11 blossoms, 1.5 percent also 11, and 2.5 percent 12 blossoms. Lactose under like conditions produced 12, 8 and 11 blossoms. The checks produced 9 blossoms.

Thus we may conclude that saccharose treatment gave a greater total amount of blossoms during this test period. Lactose took second place in blossoming. The check was last in blossom number.

The 1.5 percent lactose treatment produced 1 less blossom than the check plot.

Blossoming according to this data is increased thru the application of sugar to geraniums growing in a soil culture.

Glucose.

Asters. Average Height under Glucose Treatment.

Treatment	Height in Inches	No. of Plants
Glucose 1 percent	10.687	6
1.5 "	11.5	6
2.5 "	12.00	6
Checks	11.66	6

The average height of each of the 6 plant tests will be found in the table on height.

One percent glucose gave 10.687 inches growth; 1.5 percent, 11.5 inches growth; 2.5 percent, 12 inches; and the checks produced a growth of 11.66 inches.

The 2.5 percent solution was the only one to produce a greater height growth than the check.

Asters. Average Number of Leaves under Glucose Treatment.

Treatment	May 15	May 25	June 5	No. Plants	Difference in Growth
1 percent	16.5	21.33	24.66	6	8.16
1.5 "	18.33	23.	25.	6	6.67
2.5 "	16.5	23.33	25.5	6	9.00
Check	11.83	16.33	23.5	6	11.67

The leaf growth number increase is given in the table and in graphical form.

The difference in increased growth favors the check plot. Eleven and sixty-seven hundreds percent is the leaf increase to be noted with the check plot, 9 is the leaf increase with a 2.5 percent solution, 8.16 is the increase with 1 percent treatment and 6.67 with a 1.5 percent solution.

The greatest total number of leaves was obtained with a 2.5 percent solution; second, a 1.5 percent solution; third, a 1 percent and last the check.

Thus on total number of leaves the glucose treated plots show to advantage.

Asters. Green Weight under Glucose Treatment.

Treatment	Wt. of 3 Roots	Mean Wt. of Roots	Wt. of 3 Tops	Mean Wt. of Tops
1 percent	12.4	4.133	48.5	16.166
1.5 "	23.8	7.933	49.6	16.533
2.5 "	23.3	7.766	48.7	16.233
Checks	11.6	3.866	40.6	13.533

Green Weight taken in grams

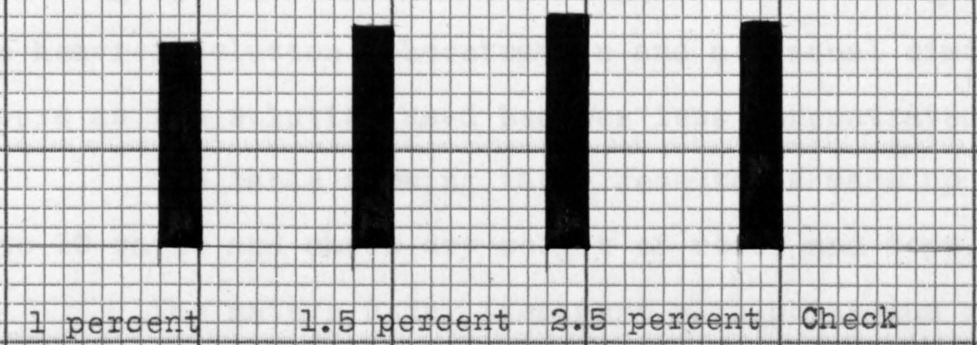
The average green weight of the aster roots is as follows: 1 percent, 4.133 grams; 1.5 percent, 7.933 grams; 2.5 percent, 7.766 grams; and the check 3.866 grams. The 1.5 percent solution thus produced the greater green weight in roots.

The average green weight in tops gives the advantage to the 1.5 percent solution, with the 2.5 percent solution second, the 1 percent solution third, and the check last.

Asters. Dry Weight under Glucose Treatment.

Treatment	Wt. of 3 Tops	Avg. Wt. of Tops	Wt. of 3 Roots	Avg. Wt. of Roots
1 percent	10.6	3.533	3.4	1.133
1.5 "	10.3	3.433	4.0	1.33
2.5 "	10.4	3.466	4.2	1.4
Checks	9.2	3.066	3.3	1.1

Height of Asters with the Glucose Treatment



On dry weight tests the top weight is as follows: 1 percent, 3.533 grams; 1.5 percent, 3.433 grams; 2.5 percent, 3.466 grams, and the check with 3.06 grams weight.

With this total dry weight, as per table, we can see the stimulative effect produced on an aster crop thru the use of a glucose solution.

The average dry weight per plant in root development was as follows: 1 percent, 1.133 grams; 1.5 percent, 1.33 grams; 2.5 percent, 1.4 grams; and the check 1.1 grams.

Root development was increased with the three different percentage solutions. The dry weight of roots is greater with the heavier solution concentration and a gradual diminution occurs as the solution used becomes less concentrated.

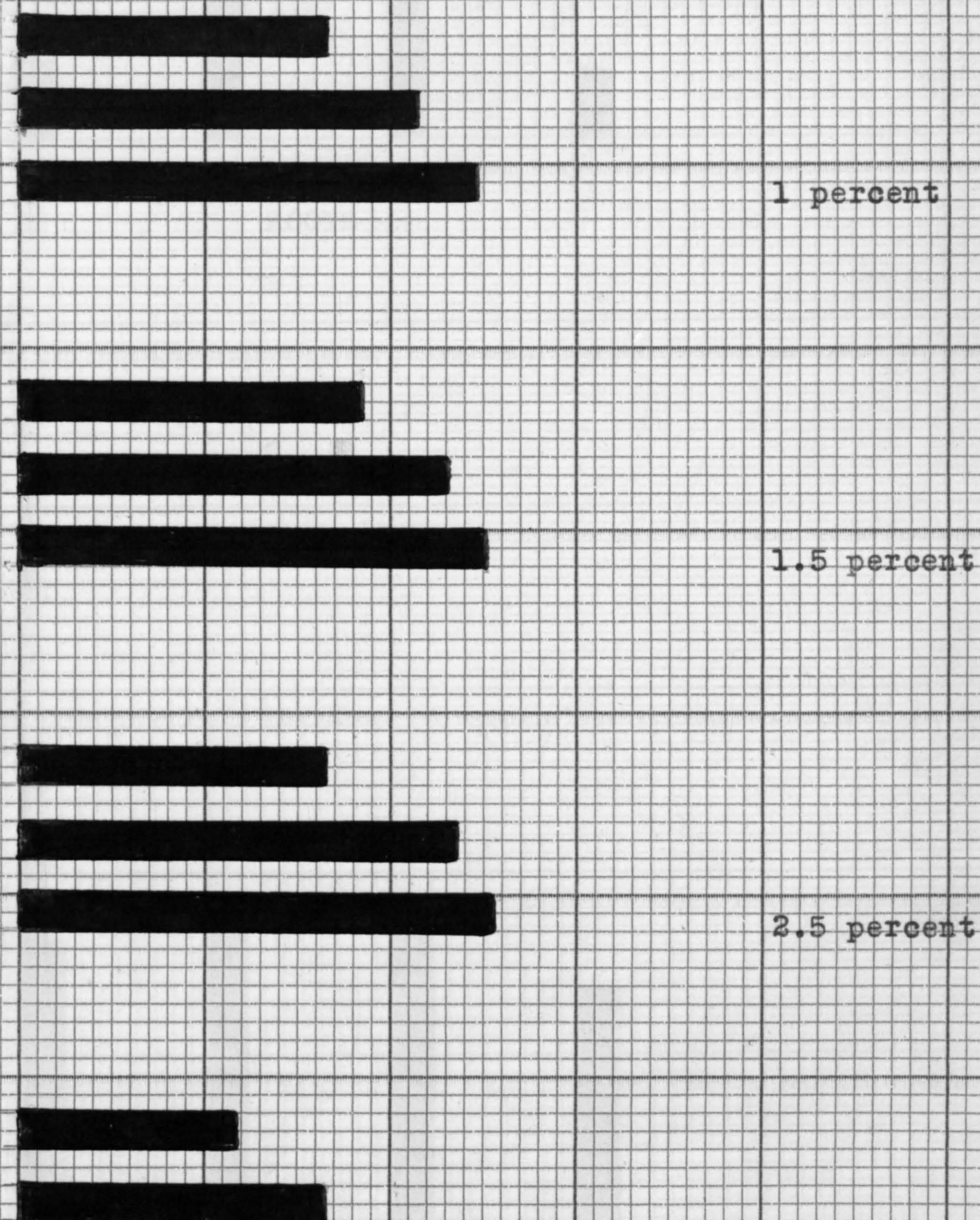
The table showing these results is made up with a 1 to 10 ratio and shows dry weight of roots and tops.

The asters under treatment with potassium permanganate and copper sulphate, were run thru tests very similar to those used with glucose.

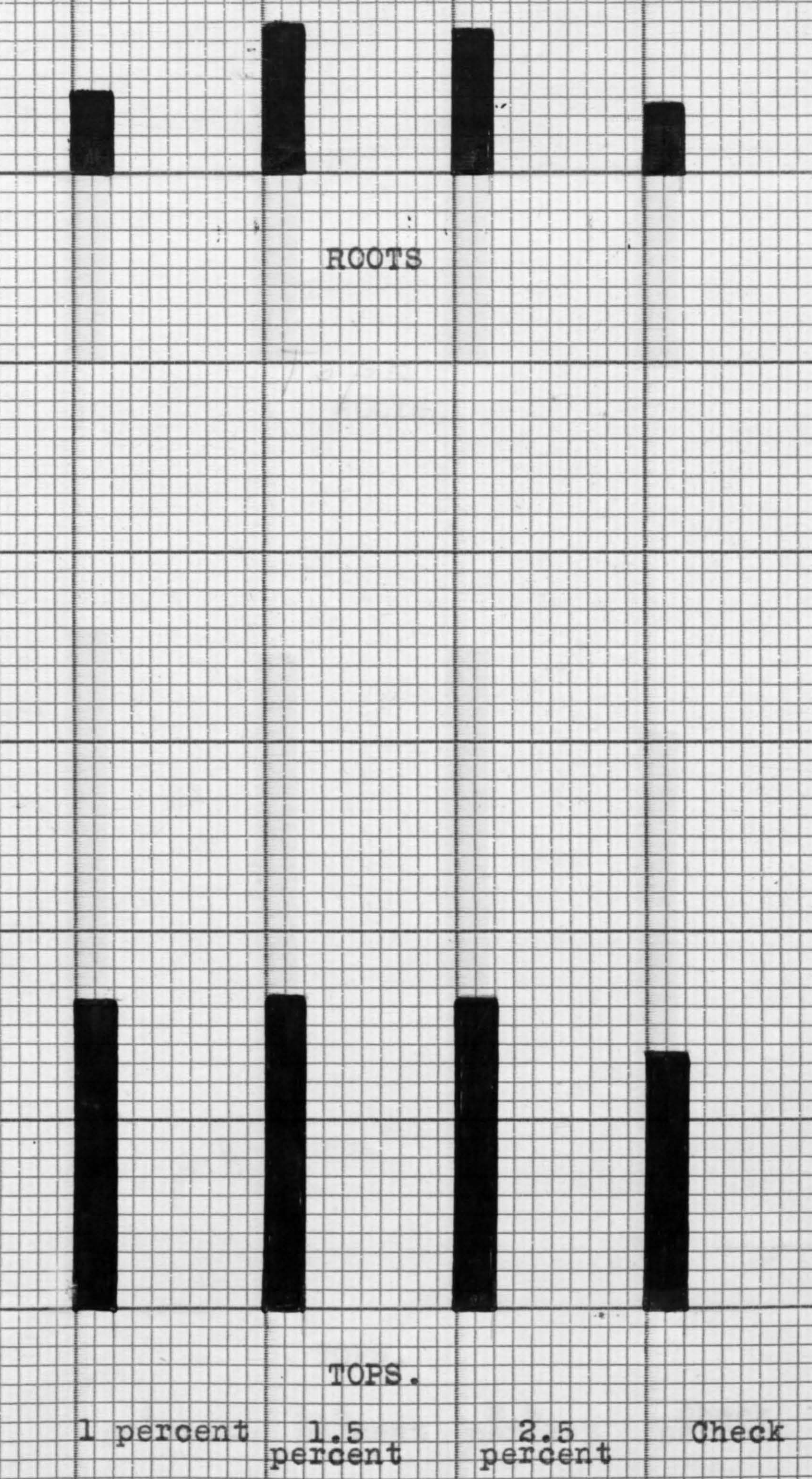
Asters. Average Height under Treatment.

Treatment	Height	No. of Plants
$KMnO_4$	10.416	6
$CuSO_4$	8.5	6
Checks	12.625	6

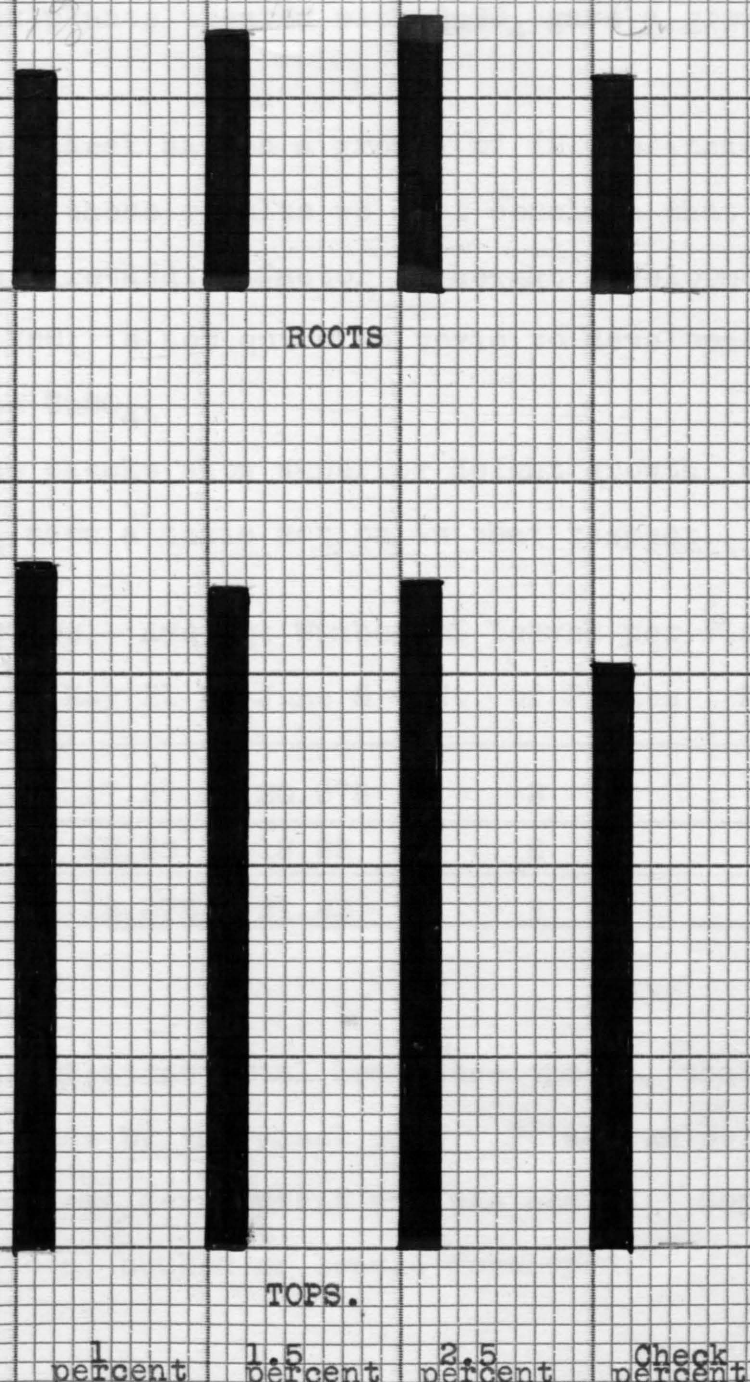
Asters Leaf Measurement under Glucose Treatment.



Asters Green Weight under Glucose Treatments.



Dry Weight of Asters under Glucose Treatment.
Scale 1 to 10.



Height Studies.

$K\ Mn\ O_4$ gave a height growth in inches of 10.416. Six plants were run to get this average.

Six plants treated with $CuSO_4$ gave a growth of 8.5 inches.

The check showed a growth of 12.625 inches.

From these results we must conclude that a $CuSO_4$ treatment is a retarding factor in height development.

$K\ MnO_4$ is not quite so toxic to development of height as the $CuSO_4$.

The checks show superior height growth, while $K\ Mn\ O_4$ and $CuSO_4$ show a toxic action in that respect.

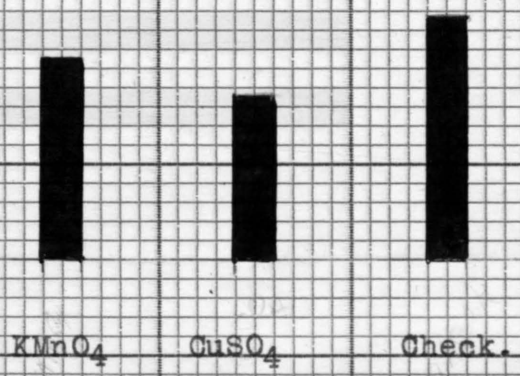
Asters. Average Number of Leaves per Plant.

Treatment	May 21	June 5	No. of Plants	Difference in Growth
$KMnO_4$	17.87	20.375	8	2.505
$CuSO_4$	18.66	18.83	6	.17
Checks	18.375	21.83	8	3.455

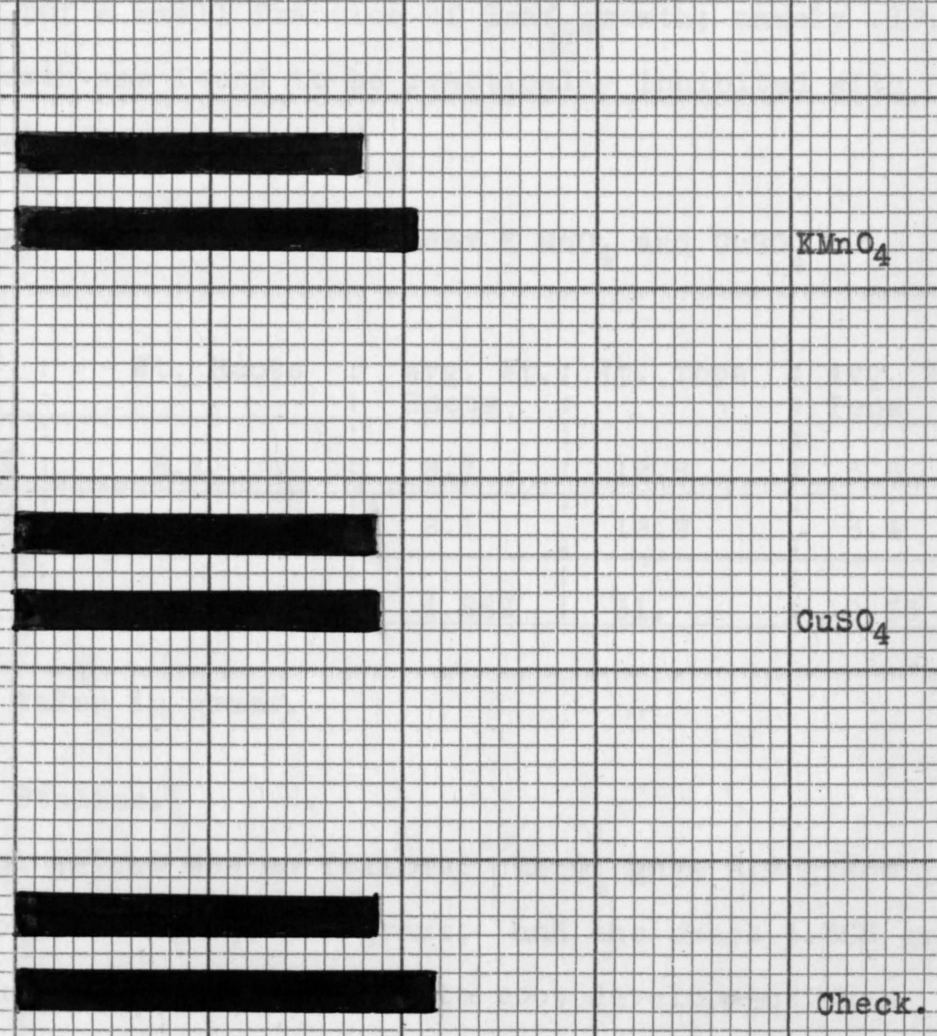
Leaf Studies.

The greatest total leaf development, that is in numbers, was made by the check plot. Potassium permanganate showed a good leaf development and was second. Copper sulphate was last in total number of leaves developed.

Height of Asters.



Number of Leaves Developed with Asters.



The greatest total increase in leaf development was made by the check plot, with an increase of 3.455 leaves. Potassium permanganate was second with an increase of 2.505. $CuSO_4$ showed but a small fraction of leaf growth; namely .17. Thus leaf growth was found to be practically inhibited with a 1/100 percent $CuSO_4$ solution.

Asters. Green Weight of Plants under K MnO_4 and $CuSO_4$ Treatment.

Treatment	Wt. Roots	Avg. Wt. Roots	Wt. Tops	Avg. Wt. Tops
$KMnO_4$ 1/100 %	8.1	2.7	19.8	6.6
$CuSO_4$ 1/100 %	6.3	2.1	19.2	6.4
Checks	14.6	4.866	31.	10.33

Green weight taken in grams.

Green Weight Studies.

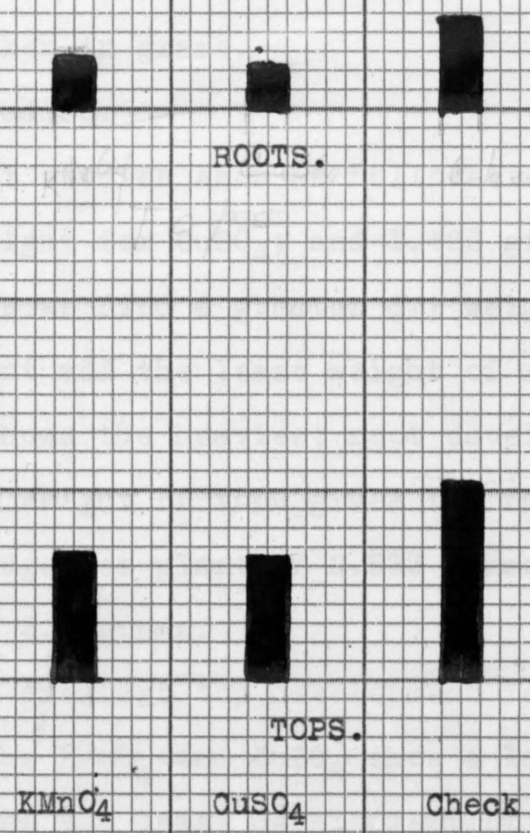
Root weight was as follows: $KMnO_4$ gave 2.7 grams average per plant; $CuSO_4$, 2.1 grams; and the check 4.866 grams.

Thus $CuSO_4$ is more toxic to root development than $KMnO_4$. But both solutions are toxic to root development in comparison with the check.

Top development was found to be as follows: $KMnO_4$ 6.6 grams average per plant; $CuSO_4$ 6.4 grams; and the check gave a total weight per plant of 10.33 grams.

$CuSO_4$ is found to be more toxic than $KMnO_4$ and $KMnO_4$ than the check, to top development.

Green Weight of Asters,



Dry Weight of Asters.

Treatment	Wt. of 3 Tops	Avg. Wt. of Tops	Wt. of 3 Roots	Avg. Wt. of Roots
$KMnO_4$	7.6	2.533	1.9	.633
$CuSO_4$	6.5	2.166	2.8	.933
Checks	10.5	3.5	4.4	1.466

Dry Weight taken in grams.

Dry Weight Studies.

Root studies show as follows: .633 grams for $KMnO_4$; .933 grams weight for $CuSO_4$; and 1.466 grams for the check plot.

Thus we find a greater dry weight of roots with the $CuSO_4$ treatment and the least weight of roots with $KMnO_4$. The check group shows the heaviest root development.

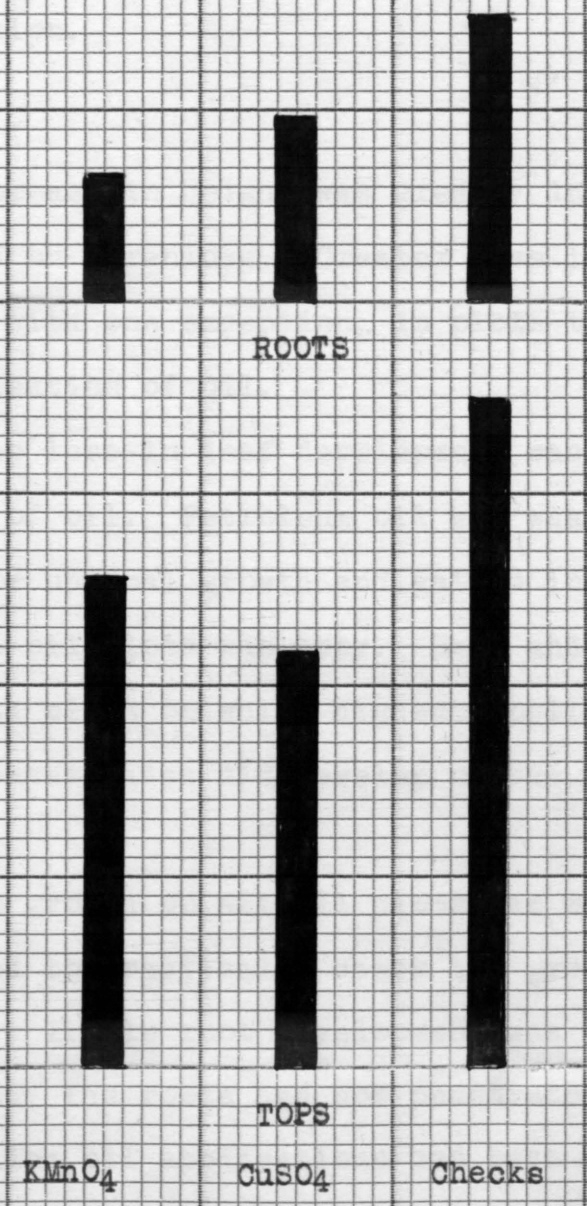
Dry weight of tops gives the following results: $KMnO_4$ an average per plant of 2.533 grams; $CuSO_4$ 2.166 grams; and the check 3.5 grams.

The greatest top development is shown with the check plot. Both the $KMnO_4$ and $CuSO_4$ show a lack of top development. The $CuSO_4$ shows the least development of top weight.

$CuSO_4$ exerts the greater amount of toxic action on top growth, with $KMnO_4$ coming second.

$CuSO_4$ and $KMnO_4$, even in 1/100 percent solutions can not be said to be stimulative to root or top development with asters.

Dry Weights of Asters.
Scale 1 to 10.



G E N E R A L   D I S C U S S I O N

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The above data as presented shows some of these nutrients exert a toxic influence on plant growth and others show stimulation.

Oils.

Increase in height was greatly inhibited with all the oils used on geraniums. Greater loss in height growth was evident, with one exception, in plots treated with a 20 c.c. application of oil.

The loss in leaf development was greater with 20 c.c. applications of oil. Petroleum oil had what might be termed an abnormal or unusual growth and gained in leaf number. Leaf growth on all oil plots was poor. Reds and sickly looking greens developed with plots on which highest applications of oil were used. The leaves which did develop on the 20 c.c. plots were quite small.

Top growth on all oil plots was materially hindered. the oil seemed to practically check top growth.

Very little root development was observed with oil treated plots. The roots had not penetrated the soil to any extent, in which oil applications had been made. Some of the roots showed a decay of tissue. The root hairs were coarse and stubby, instead of being fine branched. The roots were small and did not penetrate the potting soil. The roots had developed but little from the original callus formed when the cutting was made. Thus oil inhibits normal root development.

Diameter increase in general was decreased with the addition of oils. In only two treatments was diameter increase found to be equal to that of the check plots.

All in all we must conclude oil to be detrimental to height, diameter and leaf growth with geraniums.

Blossoming was hindered with oil treated plots. Blossoms would form first on oil plots. This is a condition which exists in nature. Those plants most retarded try to reproduce their kind first.

Nasturtiums treated with mazola oil show retarding in growth.

The heavier applications of oil show greater retarding of growth. Lesser applications of oil produce a more nearly normal growth.

Root growth was hindered a great deal more with the heavier oil applications. The roots of all oil plots were smaller, less fibrous, and not so well branched as was found to be the case with the check plots.

Nasturtiums germinating from seed, and growing in this oil solution to maturity, did not germinate so well with the heavier applications of oil. On one pot with a 50 c.c. application, no plants germinated. Germination tests of seed showed a 95 percent germination.

Top growth was much less with heavier applications of oil and as the applications became lighter more top growth was evident.

Blossom growth was heavier with the check plots and less blossoming occurred as oil applications became heavier.

In all conditions of growth studied under this experiment, gradual proportionate gradations in all growth factors was found to occur.

Wheat experiments may not be quoted as being as comparable as should have been expected.

The wheat under 10 c.c. oil treatment showed less growth in height, with the exception of castor oil, than did the check. In the one case in which nujol was used in a 20 c.c. portion, growth was greatly retarded.

With the exception of the abnormal growth which occurred with castor oil, we may conclude that the oils are unbeneficial to growth in height with wheat. The lighter applications of oil are not so detrimental as heavier applications.

Corn experiments were carried out under conditions such that results are not entirely conclusive.

With the exception of the 10 c.c. treatment of wesson oil, retarding of growth occurs with the 10 c.c. applications of mazola and petroleum oils.

The 20 c.c. applications of mazola and petroleum oils gave a very great retarding effect in growth.

We may conclude oil to be unbeneficial in the heavier and lighter applications but less toxic in the lighter applications. This applies to the plants used in these experiments.

Tomatoes run in plot I show retarding growth, with one exception, with all oils used. One plant of the 50 c.c. series gave an excessive vegetative growth and no fruit set. This made a higher growth record. Disregarding this we find growth in height to be less as the applications of oil applied becomes heavier and greater as the applications of oil become lighter.

The lighter applications of oil very nearly approach the height growth of the checks. This is truer of the 10 c.c. oil applications. Yet in a number of cases they far from approach the normal growth of the checks.

Root development was less with the heavier applications of oil and was found to be greater as oil applications became lighter. The heavier applications of oil gave small, poorly developed roots and the lighter applications produced larger more fibrous roots. But the roots of those plots with lighter applications of oil were far from the fibrous, well developed root systems of the checks.

In fruit yield the same conditions prevail. Heavier applications produced a lower yield and as applications of oil became lighter a greater yield was evident. The oil plots did not produce the yield of tomatoes that were produced by the check plot.

As far as growth and yield are concerned oil treatment is unbeneficial.

These experiments were carried out in 5 inch pots. Tomatoes can not grow to full maturity under such conditions. These plants were also small when transplanted.

Tomatoes in Plot II.

Tomatoes were larger when transplanted in this plot. These tomatoes were also set in a greater amount of soil. They were transplanted to 10 inch pots. Less oil was added in comparison with the amount of soil used as a growth medium.

The results in height and in fruit set were quite variable.

The soil condition and nutrient availability did not seem to be changed to any marked degree.

The plants produced differences, just as might be expected to occur under normal growth conditions.

Whatever variations occurred no attributable cause may be given.

The mazola oil plot was the only plot to give a smaller yield of tomatoes than the check plot, yet the other 2 plots with oil gave a greater yield than the check.

A great amount of blossom end rot was found in the later part of this experiment with oil treated plots and none occurred in the checks. This blossom end rot condition might be attributed to any number of other factors, besides that of the oil applications.

Geraniums under saccharose and lactose treatments show a stimulation in growth.

Saccharose gave the greatest increase in height, with lactose second and the checks last.

The 1.5 and 2.5 percent lactose solutions showed the greatest diameter growth. The 1 percent saccharose solution produced a greater diameter growth than the 1 percent lactose treatment.

Leaf growth number was greater in lactose 1 percent solution, less in a 1.5 percent solution, and greater in a 2.5 percent solution. These comparisons are between saccharose and lactose.

Saccharose produced the greatest amount of blossoming, with lactose second, and the check last.

From this discussion it is plainly to be seen that both sugars exert a stimulating effect on all conditions of growth on geraniums.

Glucose on asters did not increase height until a 2,5 percent solution was used. The 2.5 percent solution gave a stimulation in growth over the check plot.

Total number of leaves produced was found to be greater with all percentage solutions used. The greatest difference in leaves produced from thē time measurements were made was found to occur in the check plot. The check plot had a smaller average number of leaves to start with when measurements were first taken.

There was stimulation of roots and tops with the application of glucose. This is well shown by the table on green weights of root and tops.

There is a stimulative effect shown in dry weight with glucose treatment. Roots and tops show the beneficial and stimulating effects produced thru the applications of glucose.

The height growth and leaf growth are not as good a means of comparison of growth as green and dry weights of the aster plant. This was found to be true in this experiment.

Asters treated with $KMnO_4$ and $CuSO_4$ gave less height development that the check. Thus these solutions must retard growth, even in the small percentage used.

Leaf development was less with these 2 solutions than with the check.

In green weight studies the check produced the greatest weight of roots and tops. $KMnO_4$ came second in this respect, and $CuSO_4$ last.

The check produced the greater dry weight of roots, with $CuSO_4$ second, and $KMnO_4$ third.

Top weight shows the check to have first, $KMnO_4$ second, and $CuSO_4$ last.

Thus both solutions prove detrimental to top and root growth, with $CuSO_4$ producing the least total growth. $CuSO_4$ was found to be more detrimental to growth than the $KMnO_4$ treatment.

Taking oils into consideration there seems to be an exclusion of oxygen. Oils seem to produce a soil condition which in itself must be physical. Oils must not enter into any reaction with the soil because they break dpwn very slowly. Oils, if they exclude oxygen, must also destroy one of the conditions most necessary for ideal bacterial growth and action.

Sugars at first cause a retarding of growth. Bacteria multiply rapidly at first and use a considerable amount of nitrate for their development.

After this increase in bacterial growth and consequent decrease in nitrate conditions, ideal conditions exist for Azotobacter action. With a lowering of nitrate content, an ideal condition exists for rapid nitrogen fixation, thru the rapidly increased Azotobacter action. Thus there is a retarding of nitrogen which is available to a plant at first and then later on a greater amount of nitrogen is made available.

Thus plants are retarded for a short time and later on a stimulating effect is observed.

The sugars used in these experiments produced stimulative effects, with geraniums and asters.

Potassium permanganate and copper sulphate have an effect which causes sterility in the soil. Much beneficial action of soil bacteria is destroyed.

S U M M A R Y   O F   R E S U L T S

- - -

Oil produced a retarding of growth with geranium plants. This retarding of growth was equally evident in both top and root development.

Oil applications decreased blossoming.

Oil in heavier applications was more detrimental than in the lighter concentrations.

Oil produced a poorer physical condition within the soil.

Oil produced a very small leaf with geranium plants. Toxic effects were produced and showed up in these leaves. The leaves became very dark sickly looking greens. Red leaves also predominated in the oil treated plots.

Sugar exerted a very stimulating effect on root and top development. Even in 1 percent solutions a stimulating effect was well shown.

Geraniums and asters showed a marked stimulation in growth with all sugar solutions.

Copper sulphate in a 1/100 percent solution produced a marked retarding of growth on asters. This retarding effect was produced in a greenhouse soil medium.

Copper sulphate produced a marked retarding effect on top and root development.

Potassium permanganate in a 1/100 percent solution, in a soil medium retarded both top and root growth.

Copper sulphate and potassium permanganate did not give poorly colored, unhealthy looking plants, yet the growth and development of the plants were greatly retarded in comparison with the check plots.

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A C K N O W L E D G E M E N T S

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PLATE I.

Effect on Growth Produced by Olive Oil.

Reading from left to right:

1 and 2 20 c.c. of olive oil.

3 and 4 10 c.c. of olive oil.

5 and 6 Checks. of olive oil.

PLATE II.

Effect on Growth Produced by Castor Oil

Reading from left to right:

1 and 2 20 c.c. of castor oil.

3 and 4 10 c.c. of castor oil.

5, check.

PLATE III.

Effect on Growth Produced by Mazola Oil.

Reading from left to right:

1, 20 c.c. of mazola oil.

2, 10 c.c. of mazola oil.

3, check.

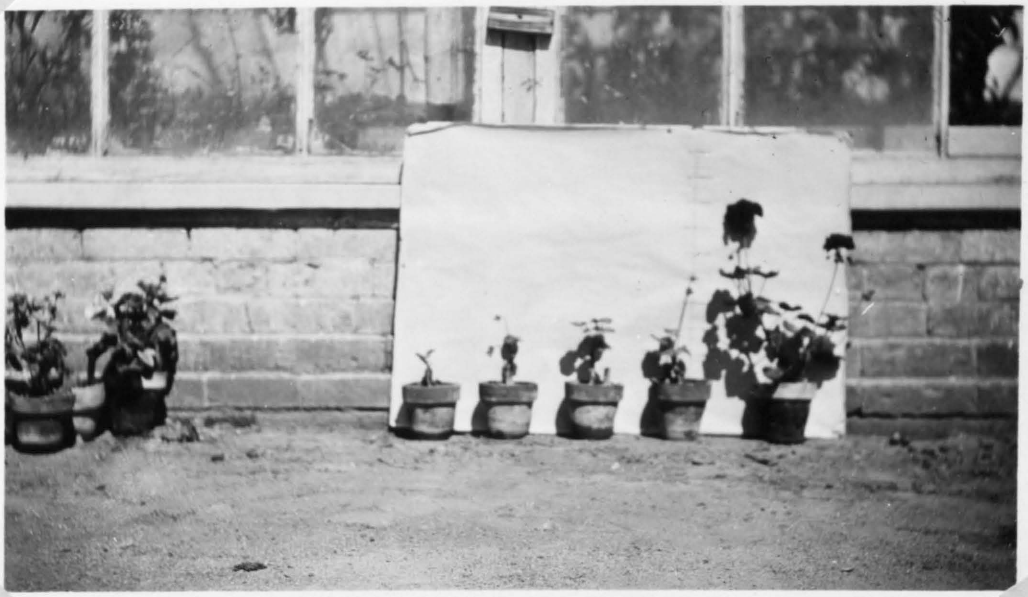

PLATE IV.

Effect on Growth Produced by Wesson Oil.

Reading from left to right:

1 and 2 20 c.c. of Wesson oil.

3 and 4 10 c. c. of Wesson oil.

5, check.

PLATE V.

Effect on Growth Produced by Petroleum Oil.

Reading from left to right:

1 20 c. c. of petroleum oil.

2 and 3 10 c. c. of petroleum oil.

4, check.

PLATE VI.

Effect on Root and Top Growth.

Reading from left to right:

1 and 2 20 and 10 c.c. olive oil.

3 and 4 20 and 10 c.c. castor oil.

5 and 6 20 and 10 c.c. mazola oil.

7 and 8 20 and 10 c.c. Wesson oil.

9 and 10 20 amd 10 c.c. petroleum oil.

11 check.

PLATE VII.

Effect on Growth with Mazola Oil.

Reading from left to right:

1, check

2, 10 c.c. of mazola oil.

3, 20 c.c. of mazola oil.

4, 30 c.c. of mazola oil.

5, 40 c.c. of mazola oil.

6, 50 c.c. of mazola oil.

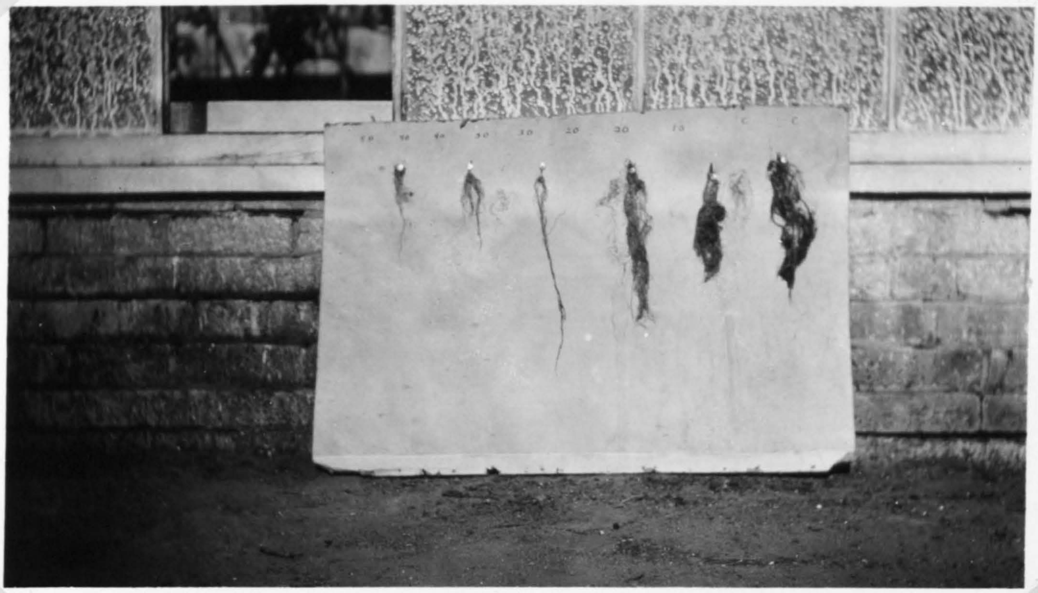

PLATE VIII.

Effect of Mazola Oil on Root Development of Nasturtiums.

Reading from left to right:

1, 50 c.c. of mazola oil.

2, 40 c.c. of mazola oil.

3, 30 c.c. of mazola oil.

4, 20 c.c. of mazola oil.

5, 10 c.c. of mazola oil.

6, check.

PLATE IX.

Effect of Oils on Wheat Development.

Reading from left to right:

1, check.

2, 10 c.c. of nujol oil.

3, 10 c.c. of Wesson oil.

4, 10 c.c. of mazola oil.

PLATE X.

Effect of Oils on Growth of Corn.

Reading from left to right:

1, check.

2 and 3, 10 and 20 c.c. of petroleum oil.

4 and 5, 10 and 20 c.c. of mazola oil.

6 and 7, 10 and 20 c.c. of Wesson oil.

PLATE XI.

Effect of Wesson Oil on Tomato Growth.

Reading from left to right:

1, check.

2, 50 c.c. of Wesson oil.

3, 40 c.c. of Wesson oil.

4, 30 c.c. of Wesson oil.

5, 20 c.c. of Wesson oil.

6, 10 c.c. of Wesson oil.

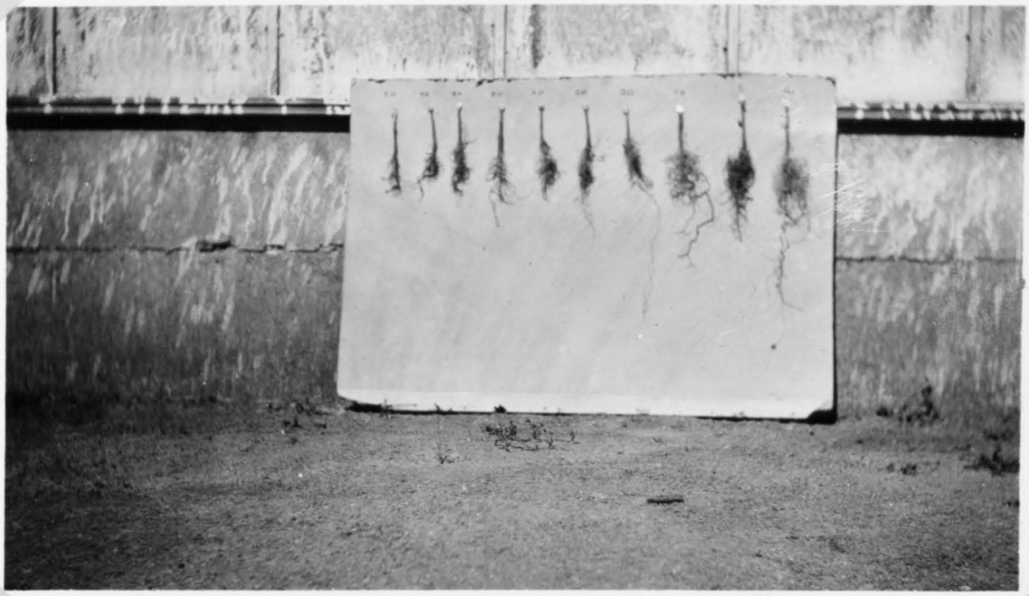

PLATE XII.

Effect of Wesson Oil on Tomato Roots.

Reading from left to right:

1, 50 c.c. of Wesson oil.

2 and 3, 40 c.c. of Wesson oil.

4 and 5, 30 c.c. of Wesson oil.

6 and 7, 20 c.c. of Wesson oil.

8 , 10 c.c. of Wesson oil.

9 and 10, checks.

PLATE XIII.

Effect of Glucose on Aster Development.

Reading from left to right:

1, 1 percent solution of glucose.

2, 1.5 percent solution of glucose.

3, 2.5 percent solution of glucose.

4, checks.

PLATE XIV.

Effect of Glucose on Aster Development.

Reading from left to right:

1, 1 percent solution of glucose.

2, 1.5 percent solution of glucose.

3, 2.5 percent solution of glucose.

4, check.

PLATE XV.

Effect of Glucose on Root Development of Asters.

Reading from left to right:

1, 1 percent glucose treatment.

2, 1.5 percent glucose treatment.

3, 2.5 percent glucose treatment.

4, check.

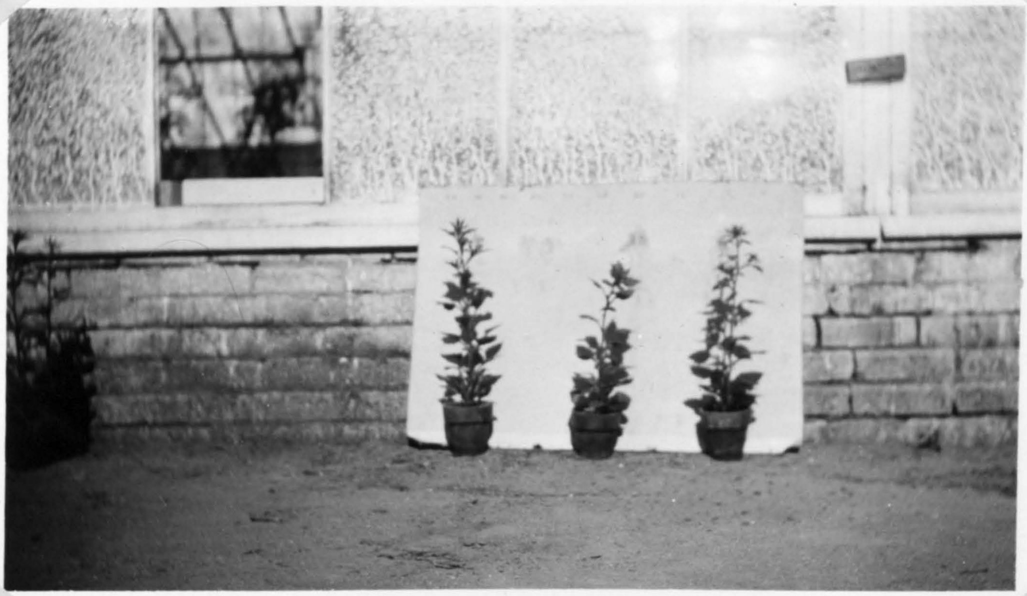

PLATE XVI.

Effect of $KMnO_4$ and $CuSO_4$ on Aster Growth.

Reading from left to right:

1, $KMnO_4$, 1/100 percent solution.

2, $CuSO_4$, 1/100 percent solution.

3, check.

PLATE XVII.

Effect of $KMnO_4$ and $CuSO_4$ on Aster Growth.

Later Picture than Previous One.

Reading from left to right:

1, $KMnO_4$, 1/100 percent solution.

2, $CuSO_4$, 1/100 percent solution.

3, check.

PLATE XVIII.

Effect of $KMnO_4$ and $CuSO_4$ on Root Development.

Reading from left to right:

1, $KMnO_4$, 1/100 percent solution.

2, $CuSO_4$, 1/100 percent solution.

3, check.