THE EFFECT OF CORNCOB MIXTURES AND MULCHES ON THE GROWTH OF THE ROSE

By

WILLIAM JOHN CARPENTER, JR.

A THESIS

Submitted to the School of Graduate Studies of Michigan
State College of Agriculture and Applied Science
in partial fulfillment of the requirements
for the degree of

DOCTOR OF PHILOSOPHY

Department of Horticulture

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AN ABSTRACT

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Approved Donald P. Walton

Within the past five years the application of ground corncobs as a mulch for roses has been extensively adopted in commercial greenhouse production. The lack of adequate research and the conflicting reports concerning the value derived from ground corncobs were stimuli for the initiation of the present experiment.

The first experiment included 96 rose plants of the variety Peter's Briarcliff planted in 12-inch pots containing a media of 600 cubic inches. Three treatments received one to four inch depths of ground corncobs on the surface of the Miami clay loam soil. The media of the remaining five treatments varied from 100% soil to 100% corncobs with three intermediate mixtures.

The second experiment consisted of 360 rose plants of the variety Better Times planted in two greenhouse benches subjected to the following five treatments: 2 and 4 inch depths of ground corncobs as surface mulches, 10 and 20% ground corncobs mixed with the soil by volume, and a soil treatment.

The data collected included monthly records of the number of flowers produced, the number of centimeters of linear growth and the fresh weight of the vegetative growth in grams. The use of I.B.M. cards was employed to accelerate the collection and summarization of these data.

An evaluation of soil fertility, aggregation, moisture, aeration and temperature was made in an effort to explain plant growth differences between the various treatments.

Immediately following the application of freshly ground corncobs as either surface mulches or soil mixtures a large reduction in the nitrate level of the soil occurred. The data from the aeration study indicated that the oxygen content of the soil air was also very low at this time. Growth records showed that a reduction in the amount of linear growth was made by the plants of the mulch treatments after applying the fresh corncobs.

The aeration study indicated that although the percentage of aggregation, average diameter of the aggregates, total porosity and percentage of non-capillary pore space were increased in a soil beneath a surface mulch of ground corncobs, the percentage of the oxygen in the soil atmosphere was less than the oxygen content in the soil of the non-mulch treatments.

Fluctuations in the soil temperature were greater in the soil of the non-mulch treatment than in the soil of the mulch treatments.

Moisture retention was much greater in the soil of the mulch treatments than those of the non-mulch treatments.

The plants in the outside rows produced 39% more flowers during the summer period and 24% more flowers during the winter period than did the plants of the center rows. Similar results were found for linear growth.

The plants along the southern and northern edges of the benches produced 49.4 and 47.9% more flowers during the summer than the same plants produced during the winter. The center rows of plants produced 38.0 and 41.9% more flowers in the spring than in the winter.

In both the first and second experiments the largest production of flowers, linear growth and weight of vegetative growth were made by plants grown in the soil with mulch treatments. The growth and flower production of the 10 and 20% mixture treatments exceeded those of the soil treatment.

The thesis contains 17 tables and 9 figures.

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INTRODUCTION

Decaying plant material is the primary source of organic matter in the soil. The roots of plants are an important source of organic matter, but the residue of the above ground parts of the plant must be returned to the soil if an adequate organic content is to be maintained. Plant residues cannot be permitted to remain on the surface of greenhouse soils when their presence stimulates the development of infectious diseases and insects.

Animal excrement, usually cow manure, was the primary source of organic material applied to greenhouse soils before and during the early part of the twentieth century. The reduced number of animals on the farm and in the cities has increased the cost of animal manure and limited its use as a source of organic matter to greenhouse soils. There has been an increasing trend in recent years toward applying plant residues as organic matter. Ground corncobs have been one of the many materials recently tested.

Within the past five years the application of ground corncobs as a mulch for roses has been extensively adopted in commercial greenhouse production. The value of applying this material has been questioned within the past few years.

The lack of adequate research and the conflicting reports concerning the value derived from ground corncobs were stimuli for the initiation of the present experiment.

REVIEW OF LITERATURE

Preparation of greenhouse soils has been found to be especially important because deterioration of soil structure was accelerated by the intensive soil cultivation. Optimum environmental conditions for plant growth have favored the decomposition of organic matter. The degree of soil aggregation has been found to be closely associated with aeration and water retention of the soil (Baver, 1948).

The use of organic mulches on soil or mixtures of soil and organic matter in the production of greenhouse crops has been a common commercial practice for many years (Chadwick, 1948). While cow manure has been the most common material used, others such as peat moss (Laurie, 1930), straw and hay (Chadwick, 1948), leafmold and blue grass (Laurie, 1939) have been substituted frequently. Chadwick (1948) found that ground corncobs were an exceptionally fine mulching material for both greenhouse and garden roses.

The major effects of heavy applications of organic matter to greenhouse soils, as mulches and mixtures, have been: conservation of moisture (Brase, 1937), temperature regulation (Shanks and Laurie, 1949), increased quantity of available nutrients (Galle and Chadwick, 1948), and improvement in aeration (Boller and Stephenson, 1946).

Soil Fertility

Applications of fresh organic mulches of straw to orchard soils have been shown to greatly increase the quantity of several of the essential nutrient elements (Havis and Gourley, 1935). They found that readily available phosphorous was increased 7 to 8 times over that found in the surface 6 inches of cultivated soil and twice that found in the 6 to 12 inch level. Potassium was increased 3 to 4 times at all levels to depths of 24 inches. Exchangeable calcium was shown to have increased in the surface 6 inches, and magnesium in the surface 12 inches as a result of straw mulch. Mulches also prevented the fixation of potassium. The potassium which they applied to the surface of the cultivated soil was often fixed in the upper few inches because of the presence of free aluminum and the effect of alternate wetting and drying of the surface layers.

There has been little information dealing directly with the accumulation of nitrogen under mulches, but Proebsting, 1937, indicated considerable increase over a three year period. It was probable that an initial reduction in soil nitrogen occurred under some organic mulches because of bacterial action (Stephenson and Schuster, 1945). When materials high in carbon and low in nitrogen (such as straw, cornstalks, or corncobs) were applied to the soil or incorporated in it, soil bacteria were greatly increased in number due to the increase in carbohydrate (Chadwick, 1948). These bacteria utilize nitrogen which otherwise would be available to the crop. Although this effect was only temporary, Chadwick recommended that care should be exercised to avoid nitrogen starvation. Chadwick (1948) believed that it was not advisable to mix fresh corncobs with soil because this mass of raw organic matter was so great it would be difficult to add enough nitrogen to satisfy the requirement of the microorganisms without causing injury to the plants.

In contrast to Chadwick's conclusions, Eastwood and Gianfagna (1951) reported that no decrease in the nitrate level of the soil occurred immediately after applying a mulch of fresh corncobs. Their records showed no significant difference in the amount and kind of fertilizer required by a crop of greenhouse roses grown with or without a corncob mulch.

Bell (1936) found evidence that alfalfa, when applied as a mulch, had an inhibitory effect upon the growth of chrysanthemums. Lack of nitrogen was not given as the cause of reduced weight of plants grown with a mulch treatment but, instead, Bell postulated that the readily decomposable organic matter produced toxic substances which inhibited growth of chrysanthemums.

Over a period of 7 years, 1940-46, pine straw and oat straw as surface mulches had no effect on the acidity of orchard soil while cornstalks incorporated in the soil had a slightly alkaline effect (Johnson and Ware, 1950).

Waksman (1932) showed that organic acids formed from poly- and mono-saccharides, proteins, and their derivatives, when neutralized, were utilized by bacteria and fungi. The decomposition of these acids resulted in the formation of alkali carbonates which led to an alkaline reaction of the medium.

Appendix Table 1 (after Chadwick, 1948) gives the comparative mineral and dry weight content of several organic materials. On the basis of the analysis given, ground corncob mulch would be expected to be less effective than straw, hay and hops in building up the mineral content of the soil.

Soil Aggregation

Soil structure has been defined as the arrangement of particles of soil into certain definite patterns. The type of this arrangement varied with the amount and nature of the secondary particles or aggregates (Baver, 1948). Yet the degree of soil aggregation was closely associated with the organic matter content of the soil and microbial activity (Martin and Waksman, 1940).

Martin and Waksman (1940) observed that the growth of microorganisms led to a binding together of soil particles that increased soil aggregation. The extent of aggregation was found to be dependent upon the nature of the microorganisms and the nature of the substrate. The type of organic matter influenced the effectiveness of organisms in their ability to alter the aggregation of the soil. Organic matter containing a high sugar content was a better source of energy for growth of microorganisms than was one high in cellulose. The more readily the complex organic materials decomposed, the greater was the degree of aggregation of the soil particles.

McCalla (1942) observed that adding sucrose to the soil increased the development of mycelia which greatly increased the stability of aggregates. In addition to the direct mechanical effects of the mycelia, the suggestion was made that the organisms apparently produced gums or waxes. He suggested that these may have coated the soil particles and rendered the individual aggregates impermeable to water.

In 1944, it was shown by Ray that with roses grown in greenhouse benches, additions of sugar at the rate of two pounds to 100 square feet greatly increased granulation of the soil. This was more effective on old soils than those which were more recently placed in a greenhouse bench. He concluded, however, that such applications were too costly for practical use.

The effect of ground corncobs on soil aggregation and soil porosity was investigated by Chadwick (1948). He filled five-gallon glazed crocks with steam sterilized silt loam soil. Treatments were made contrasting two inch surface mulches of old and new corncobs. After 2½ months the soil was analyzed for aggregation and porosity. The results (Appendix Table 2) indicated that some substances were being leached from the fresh corncobs and either directly or indirectly brought about the increase in soil aggregation. The chemical composition of corncobs on a dry weight basis as reported by J. H. Salisbury (1948) was as follows: sugar 6.8%; resin 0.9%; fiber 63.8%; extract from fiber 22.7%; albumin 0.8%; casein 0.14%; dextrine 1.15%; glutinous material 3.7%, and starch, a trace.

Gourley and Havis (1935) found that an organic matter mulch gradually increased the organic content of the soil directly beneath the mulch. By applying a mulch of wheat straw in an orchard and comparing the amount of organic matter in the soil beneath the mulch with that in a similar cultivated soil, Gourley and Havis showed a range of 4.3% of organic matter in the upper two inches of soil compared to only 1.9% in the upper two inches of a cultivated soil.

The increased quantity of organic matter under a mulch of ground corncobs was indicated for garden roses by Chadwick (1948). A comparison of the amount of organic matter present after three years showed 20% under ground corncobs, 7.25% under a sod of Chewing's fescue, 11% under a peat moss mulch, and 8.5% where cultivation was practiced.

Soil Moisture

The conservation of soil moisture has resulted from additions to the soil surface of innumerable organic materials. A reduction in the amount of moisture lost from the soil has been shown as a result of the use of surface mulches of straw, walnut leaves and sawdust (Boller and Stephenson, 1946); various grass sods and straws (Langford, 1937); paper (Thompson and Platenius, 1931); peat moss (Turk and Partridge, 1941); sawdust, seaweed, and meadow hay (Latimer and Percival, 1944); Lespedeza sericea hay and farmyard manure (Mooers, Washko and Young, 1946); and corncobs (Chadwick, 1948).

Stephenson and Schuster (1945) found that a straw mulch retained a moisture equivalent to 2 or 3 inches of rainfall during a dry growing season, a moisture saving that was principally in the upper 2 feet of soil. Eser (1884) reported that 8 times more water was lost from a bare soil than from the soil under a 2 inch surface mulch of chopped straw, beech leaves, pine needles, or fir needles. He concluded that a mulch protecting the surface from the direct rays of the sun and from wind currents, reduced the soil temperature.

Peat moss had such a great absorptive capacity for water that percolation of water through the soil and loss from surface drainage were reduced (Turk and Partridge, 1941). They also found after light rains or very long intervals between rains that evaporation from a mulch was enormous and this limited the amount of water which reached the soil.

Under garden conditions, Chadwick (1948) found ground corncobs to be more effective than peat moss in conserving soil moisture. The cobs ground into 3/8 to 3/4 inch irregular shaped pieces did not have the tendency to compact as much as some other types of organic mulches but provided a more uniform distribution of water applied to the surface.

The effects of the organic matter content of the soil upon water absorption and availability by plants was found in the data of Feustel and Byers (1936). They reported that mixtures containing equal parts of soil and peat moss were capable of absorbing from 40 to 50 percent more moisture than the soil alone, but the increased evaporation rate and the greater moisture content at the wilting point largely counteracted the initially higher moisture-holding capacity. They have recommended that, except on sandy soils, peat should not be used for the sole purpose of conserving a supply of available soil moisture.

Smith, Brown and Russell (1937) found that soils high in organic matter have more than double the rate of water penetration of soils with a low organic matter content. It was found by Dudley and Russell (1941) that crop residues left on the soil surface were much more effective in increasing the infiltration of water and decreasing evaporation than was the same amount of organic matter plowed into the soil.

Soil Aeration

Gillespie (1920) devised an electrical method for measuring the amount of redox in the soil. His apparatus consisted of gray platinum wire sealed into glass tubing which was pressed into the soil. A liquid contact was made between the soil and a calomel cell by laying a capillary tube filled with potassium chloride solution on the soil in order to measure the potential against the calomel electrode. Since an intimate relation has been found to exist between pH and Eh, it was agreed to adapt a value of 0.060 volts per unit of pH change. Gillespie found that when small quantities of dextrose ranging from 0.25 to 2.0 grams had been mixed with 200 grams of a loam soil, and when this soil had been kept moist for four days, that even the smallest quantity of dextrose produced a very large reducing effect upon the soil. This indicated a substantial decrease in the oxygen content of the soil.

Burrows and Gordon (1936), adapting Gillespie's apparatus, showed that additions of carbohydrate materials reduced the value of the electrical potential whereas casein had the opposite effect.

Andreasen (1951) employed an apparatus similar to that of Raney (1949). It consisted of a diffusion chamber that could be inserted to a desired depth in the soil and the chamber flushed and filled with nitrogen at atmospheric pressure. By means of a suitable valve arrangement the lower end of the chamber was opened to the soil atmosphere and the gases were allowed to diffuse into and out of the chamber for 10 minutes. The chamber was again closed, and the oxygen content of the gas determined by use of a Beckman Oxygen Analyzer.

Andreasen (1951) found that applications of organic fertilizers and mulches could cause serious oxygen deficiencies immediately after soils had been heavily watered because the organic materials furnished a substrate for the soil microflora. Andreasen concluded that roots of the higher plants used in his experiment may have been impaired from oxygen deficiency as a result of active competition for oxygen on the part of soil fungi and bacteria.

Seeley (1949) found that the growth of rose plants was not affected initially when the roots were exposed to gases containing 5, 10, and 21 percent oxygen in the soil but at the end of 37 days there was a very significant reduction in shoot growth with the lowest concentration of oxygen in the aerating gas. After almost 3 months plants with their roots exposed to a gas containing 5% oxygen were considerably smaller than those plants at the 10 and 21% oxygen concentrations. No significant difference was found in the amount of growth produced at the 10 and 21% oxygen levels.

The data of Boicourt and Allen (1941) revealed that by forcing air through the tile in the bottom of the bench for one hour per day the linear growth of greenhouse roses was nearly double that obtained in the same soil without soil aeration. This great difference in growth resulted from only slight differences in soil oxygen content.

Soil Temperature

The effect of soil temperature upon growth and flower production has been determined for numerous floricultural crops. Laurie (1939) reported that poinsettias, roses, gardenias, gerbera, African violet and other plants benefited from additions of water heated to 70°F. Increased number of flowers per plant and longer stem lengths of calendula and snapdragon were obtained as a result of increasing soil temperatures to 72°F. (Allen, 1934). Allen found that the number of flowers per plant of columnar stocks was not influenced by soil temperature, but flowering was delayed at the 72°F. temperature.

A soil temperature of 74°F. was found by Davidson (1941) to result in the highest flower production and the least bud drop of gardenias. Soil temperatures of 58°, 66° and 82°F. decreased the number of flowers per plant and increased the bud drop.

He concluded that a warm air temperature tended to offset the inhibiting effects of a low root temperature and that a cool air temperature reduced the harmful effects of high root temperatures.

Kohl, Fosler and Weinard (1949) reported that a high soil temperature range of 75° to 85°F. significantly reduced the number of roses per plant. Water at 80°F., when applied to the soil in which the roses were growing increased the soil temperature from 66° to 73°F. and resulted in a slight reduction in the average number of flowers produced per plant (Pfahl, Orr and Laurie, 1949). A bench of roses grown in gravel culture with grade B "Haydite" (expanded mica) as a medium showed inhibiting effects upon growth within 17 days after the solution was heated to 90°F. (Pfahl, Orr and Laurie, 1949).

Shanks and Laurie in 1949 conducted an experiment on greenhouse roses in which the root temperatures were varied at 4 degree intervals from 56° to 72°F. The optimum root temperature for vegetative growth of the top was found to be 64°F. and there was a decrease in the amount of roots produced for each plant as the soil temperature increased from 56° to 72°F.

Injury to the leaves and the fruit of cucumber was shown to be caused by soil temperatures of 55°F. or lower, (Schroeder, 1937). He concluded that the cucumber plant was unable to obtain sufficient water at these temperatures to replace that lost through transpiration.

Jenny (1928) working with prairie soils reported that the total nitrogen content of soils throughout the United States decreased from north to south; the average nitrogen content decreased by 50 percent with every 18°F. fall in the mean annual temperature. King and Whitson (1902) compared the rate of nitrification at constant temperatures of 35°, 48°, 68° and 90°F. and found that the rate of nitrification at 90°F. was 6.3 times more rapid than 35° and 68°F. and was about twice as rapid as at 48°F. At high soil temperatures, Eid, Black and Kempthorne (1951) reported that organic phosphorus was rapidly "mineralized" and readily served as a source of supply for the crop, while at low soil temperatures mineralization was limited.

Mulches have been found to exert a pronounced effect upon soil temperature. Wollny (1883) made comparisons between the daily temperatures of bare soil and soil that was covered with grass. He found that the major fluctuation in temperature of the subsurface of the grass-covered soil was about 3.5°C.; that of the bare soil was about 11°C. Chadwick (1948) reported that temperatures are more uniform under mulches and during the hot summer months may be as much as 10-15 degrees cooler. He indicated that under outdoor conditions a mulch of ground corncobs was not as effective in reducing temperatures as peat moss or a live cover of Chewing's fescue or bluegrass. Mooers, Washko and Young (1946) concluded that the effectiveness of some mulches was reduced more than other mulches the second and third year after application. Turk and Partridge (1947) found that the effectiveness of an artificial mulch varied greatly with the kind of mulch, type of soil, and climatic conditions.

EXPERIMENTAL PROCEDURE

Experiment One

Ninety-six rose plants of the variety Peter's Briarcliff were removed from five-inch pots, the soil washed from the roots, and placed in storage at $40^{\circ}F.$ for three weeks. The plants were then pruned and weighed so that they could be placed into groups consisting of eight plants of approximately equal weight. The inside of the twelve-inch clay pots was painted with an asphalt emulsion paint and a glass jar five inches in height fitted against the opening in the bottom to collect the leachate. Each pot contained a media of six-hundred cubic inches. The roses were planted in the pots August 23, 1950.

Treatments consisting of 1, 2½, and 4 inch depths of ground corncobs applied as surface mulches, as well as 16, 33, and 66 percent corncobs by volume were prepared. Treatments consisting of soil with no additions of ground corncobs and corncobs with no additions of soil were added for comparative purposes. All treatments were replicated twelve times and randomized throughout the bench.

A special wooden shelf was constructed on the greenhouse bench to support the pots (Fig. I) which were contiguous in rows four inches apart resulting in plant spacing of twelve by sixteen inches. Fig. II shows the ratio of corncobs to soil in the mixture treatments. The prescribed proportions of corncobs and soil were mixed before planting the roses, the mulch applications were applied immediately after planting. The mulches were in excess of the six-hundred cubic inches of soil, therefore requiring the height of the pot be increased to contain the organic material.

As a guide to the amount of soil nutrients required by each plant in each treatment, a preliminary trial was conducted using the same sterilized Miami clay loam soil in the following manner. Twenty-four 200 gram samples of a previously sterilized Miami soil were placed in 500ml beakers. Various amounts of chemically pure sodium nitrate, potassium sulfate, and monocalcium phosphate were applied in an effort to find the amounts of these fertilizers necessary to increase the fertility level of the soil to 50 ppm. nitrate, 10 ppm. phosphorous and 30 ppm. potassium. The beakers were covered after moistening the soil to field capacity and left one week. A soil sample was then taken from each beaker and the nitrate, phosphate and potassium levels determined by the modified Spurway Method (Spurway and Lawton, 1949).

Soil samples were taken before planting, at weekly intervals for ten weeks and bimonthly thereafter. The result of each analysis was used as a basis to maintain soil fertility within the desired range. Distilled water was applied during the first six months and tap water during the second half year. All leachates were re-added.

Fig. I

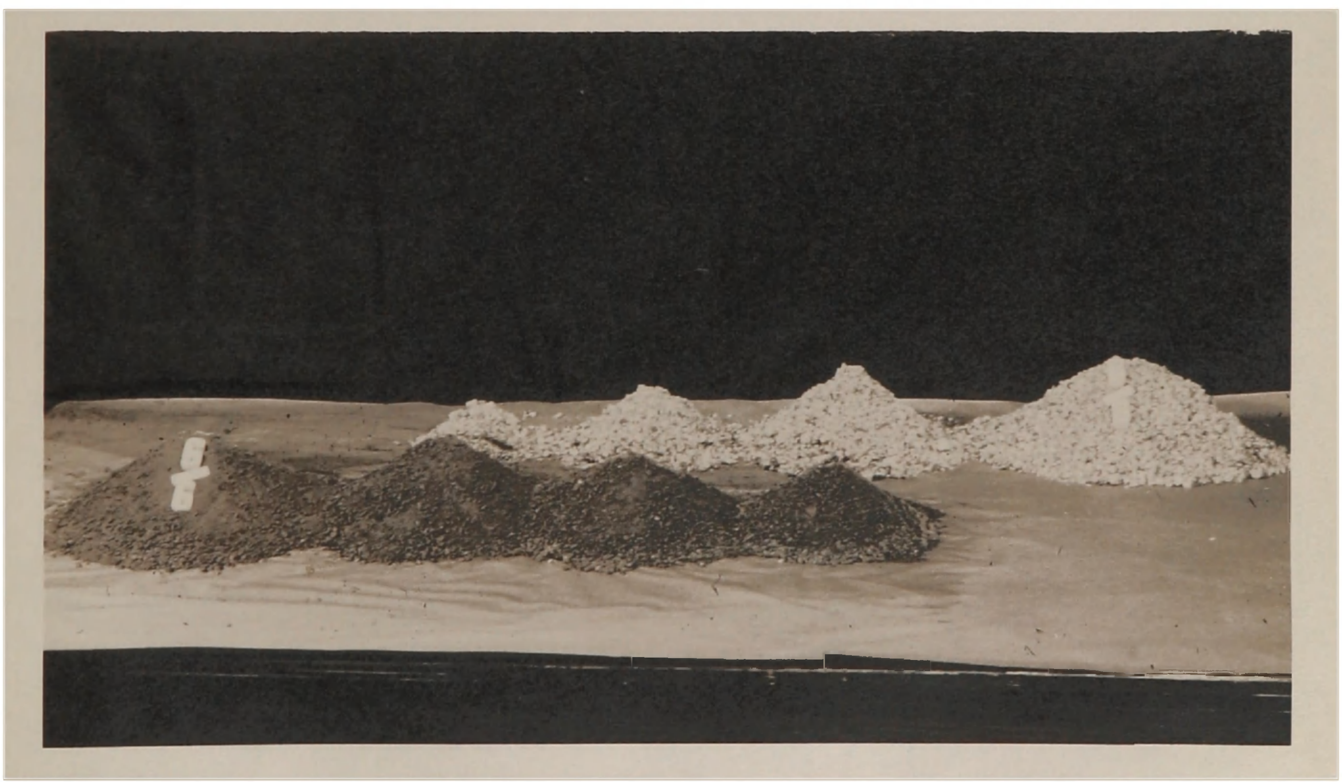
THE GREENHOUSE BENCH AND WOODEN

SHELF TO SUPPORT THE POTS

Fig. II

THE RATIO OF CORNCOBS TO SOIL

IN THE MIXTURE TREATMENTS



The weight and linear measurement of the individual plants were obtained at the time of planting and the measurement of linear growth was obtained at the end of each month. The number of flowers produced, the length of the peduncle and the weight of the flower were recorded.

Fifty days after planting, samples of soil were removed from the check and mulch treatments for an aggregate analysis of the soil. Determinations of the soil pH were made periodically by the use of the glass electrode.

Experiment Two

Treatments. As a result of the first experiment a more extensive, yet more refined procedure was adopted for the second experiment.

The following five treatments were included: 1) a two-inch depth of ground corncobs as a mulch, 2) a four-inch depth of ground corncobs as a mulch, 3) ten percent by volume of ground corncobs mixed with the soil, 4) twenty percent by volume of ground corncobs mixed with the soil and 5) one-hundred percent soil. The mixture and mulch treatments were replicated four times and the soil treatment was replicated only twice; each replication consisted of twenty plants (Fig. III).

Material. The 360 dormant rose plants of the variety Better Times used in these treatments were selected from 400 plants, each of which was weighed individually and grouped

Fig. III

BENCH PLANTING PLAN

Bench 1	G	2"	20%	4"	10%	20%	2"	10%	Soil	4"	G
Bench 2	G	10%	Soil	4"	20%	2"	10%	4"	2"	20%	G

into lots containing plants weighing from: 20.0 to 24.9 gms, 25.0 to 29.9 gms, 30.0 to 34.9 gms, 35.0 to 39.9 gms, 40.0 to 44.9 gms, 45.0 to 49.9 gms, 50.0 to 54.9 gms. Plants for each treatment were selected so that there was the same number of plants from each weight group and the total weight of plants per plot was approximately equal.

Method. The planting was in a Conover loam soil on April 4, 1951 according to the plan shown in Fig. III. The plants were syringed twice daily with water until growth was renewed. Greenhouse temperature regulation, ventilation and other cultural practices were followed as required for best plant development. During the first two months all buds were removed including a part of the stem and the uppermost five-foliolate leaf. Corncob applications were made at six month intervals to maintain the desired depths of mulch; no corncobs, other than the original applications, were added to the mixture treatments.

Immediately after the applications of ground corncobs either as mixtures or mulches, biweekly soil testing (modified Spurway Method, 1949) was made to study the modifying effect upon the fertility level of the soil.

The first flowers were cut on July 1, 1951 and cutting continued until the termination of the experiment on October 1, 1952.

Growth measurements. The collection of data was accelerated by the use of individual record cards, one for each plant, to facilitate the use of International Business Machines (IBM). Cards were clamped to each flower before cutting it from the plant so that the weight of the flower and length could be recorded on the card as well as the monthly linear growth measurement of the plant. At the termination of each month the information was transferred to standard I.B.M. cards for rapid summarization. Weight and length of non-flowering growth removed in a gradual cutback, final measurement of length and weight of each plant as well as weight of roots at the end of the project were recorded in a similar manner.

Soil temperature. Soil temperature studies were conducted in January and August to determine the effect of the various treatments upon the temperature of the soil under extreme greenhouse and water temperatures. Thermometers were placed in each plot; the bulbs were inserted 2 inches below the soil surface and after saturation of the soil, temperature readings were taken at regular time intervals for the following 24 hour period.

Soil moisture. Bouyoucos nylon moisture blocks buried in each plot, (Bouyoucos, 1942), provided moisture retention comparisons between treatments. The percentages of available moisture were obtained by use of the Bouyoucos electrical resistance bridge at 12 hour intervals after saturation of the soil. Water retention studies were also conducted in conjunction with soil aeration.

Soil aeration. An apparatus for soil aeration study was patterned after the one used by Erickson and Lemon (1952). Platinum microelectrodes of Pyrex glass tubing, 4 mm in diameter, were drawn to a taper with a short 25-gauge platinum wire sealed into the glass to allow 4 mm of exposed wire to protrude from the sealed end. A mercury-copper wire contact was made in the usual way with the platinum wire inside the glass tubing. This electrode was then forced into the soil to a depth of 2 inches. The large calomel cell with a ground glass joint attached was slightly but firmly pressed into the surface of the soil to make good contact with the moisture films of the soil. The leads from the calomel and platinum electrodes were connected to a voltage of 0.8 volts across the two electrodes to measure the current flow when the circuit was closed.

In the soil aeration study two readings were made from each electrode. The original reading, which was recorded immediately following insertion of the electrodes into the soil, reduced the oxygen in the soil solution at the platinum wire surface. This reading lacked the accuracy of the second reading because if the 4 mm of exposed wire protruding from the sealed end of the electrode was lodged in a large non-capillary pore a higher reading would be obtained than if this did not occur. The second reading (after 5 minutes) measured the reduction of the quantity of oxygen which had diffused into the area of the exposed platinum wire during a 5 minute interval following the initial reading.

RESULTS

Although similar results were obtained from experiment one and experiment two, the results are presented separately to emphasize definite phases of the results.

Experiment One

<u>Fertility level</u>. Equivalent quantities of chemically pure nitrate, phosphate, and potassium compounds were applied to the soil in each of the 96 pots. Soil samples were removed and tested August 23, 1950, the day before the applications of corncobs and the planting of the roses. The extent of the nitrate reduction was revealed upon testing the soil samples taken one week later, (Table 1).

Table 1

SOIL NITROGEN IN VARIOUS COMBINATIONS

OF SOIL AND CORNCOBS

(Average of Twelve Soil Samples)

Treatment	Day before planting	After one week	After five weeks
	ppm	ppm	ppm
Soil	52	36	46
1" mulch	54	19	38
2½" mulch	52	15	35
4" mulch	55	13	30

Table 1 - continued

Treatment	Day before planting	After one week	After five weeks
	ppm	ppm	ppm
Soil	52	36	46
16% mixture	59	11	37
33% mixture	56	7	32
66% mixture	56	8	25

Chemically pure sodium nitrate at the rate of 2.75 and 3.20 grams respectively was added, to each plant containing a surface mulch and each plant of the mixture treatments. Five weeks after planting the bi-weekly sodium nitrate applications had increased the nitrate level of the soil.

The original pH of the soil was 6.5. Two and one-half weeks after planting the soil pH had increased as shown in Table 2.

Additions of ammonium and iron sulfates had partially reduced the alkalinity to produce the pH readings listed in Table 2 "after five weeks."

Table 2

SOIL pH IN VARIOUS COMBINATIONS

OF SOIL AND CORNCOBS

(Average of Three Soil Samples)

Treatment	After two and one-half weeks	After five weeks
Soil	6.7	6.3
1" mulch	7.2	6.7
$2\frac{1}{2}$" mulch	7.1	6.6
4" mulch	7.1	6.9
16% mixture	7.6	7.0
33% mixture	8.1	7.2
66% mixture	8.3	8.0
Corncobs	8.2	8.3

Aggregation. An aggregate analysis of soil samples fifty days after planting the roses revealed an increase in soil aggregation resulting from the presence of surface mulches of ground corncobs (Table 3).

Table 3

SOIL AGGREGATION AS INFLUENCED BY VARIOUS

DEPTHS OF CORNCOB MULCHES

(Average of Three 25 Gram
Samples of Air Dry Soil)

Sieve	Soil	1" mulch	2½" mulch	4" mulch
mm	gm	gm	gm	gm
4.00	0.00	0.03	0.04	0.54
2.00	0.05	0.39	0.41	3.47
1.00	0.63	0.94	1.07	2.85
0.50	1.06	1.91	1.67	2.53
0.25	4.54	6.95	6.42	4.62
0.11	1.11	2.04	1.84	4.12
Total	7.38	12.26	11.45	18.13

Water penetration. Water penetration of the soil was more rapid in the mulch and mixture treatments than the control treatment. The number of minutes required for one-half gallon of water to penetrate the soil of the various treatments is shown in Table 4.

Table 4

WATER PENETRATION AS EFFECTED BY VARIOUS
COMBINATIONS OF SOIL AND CORNCOBS
(Average of 12 plants)

Treatment	Sept. 24, 1950	July 30, 1951
	Minutes	Minutes
Soil	108	420
1" mulch	49	45
2½" mulch	38	30
4" mulch	32	27
16% mixture	14	31
33% mixture	6	12
66% mixture	2	3
Corncobs	0	0

Quantity of flowers. The total number of flowers produced during a nine month period from December 15, 1950 through August 14, 1951 as well as the total linear growth and weight increase from August 24, 1950 through August 14, 1951 are shown in Table 5.

Table 5

TOTAL NUMBER OF FLOWERS, AMOUNT OF LINEAR GROWTH AND FRESH WEIGHT, AS INFLUENCED BY MULCHES AND MIXTURES OF GROUND CORNCOBS

Treatment	Flowers	Linear Growth	Fresh Weight
		(m)	(Kg)
Soil	286	127	4.91
1" mulch	338	170	7.10
2½" mulch	315	151	6.14
4" mulch	364	180	7.38
16% mixture	283	132	5.29
33% mixture	193	91	3.72
66% mixture	77	39	1.54
Corncobs	32	10	.36

Experiment Two

Nitrogen level. A reduction in the nitrate level resulted immediately after incorporating ground corncobs with the soil, but tests of the mixture treatments revealed that nitrate applications had eliminated this deficiency within 10 days. A slight increase in the soil pH developed one week after mixing corncobs with the soil. The pH of the control treatment was 6.8, the 10% mixture treatment 7.3 and the 20% mixture treatment 7.7; within one week a reduction in pH value occurred where no additions of acidifying materials were made. Yet no reduction in the amount of linear growth of the plants resulted during this period.

In the ground corncob mulch treatments, applied six weeks after planting when the plants were actively growing, the nitrate level of the soil decreased from 40-48 to 9-14 ppm. nitrate over a two week period. This increase occurred although a total of four grams of ammonium nitrate containing 33% nitrogen had been added to each plant during the same period. Three weeks after applying the mulches, the nitrate level had increased to at least 25 ppm. for all mulch plots. The reduction in the amount of linear growth shown in Table 6 was related to the reduction in nitrogen content of the soil.

Table 6

THE DELAYED EFFECT OF CORNCOBS

ON LINEAR GROWTH

(Control Treatment 40 Plants,

Others 80 Plants)

	Time in Relation to Application of Corncobs			
Treatment	One Week Before	Three Weeks After	Seven Weeks After	One Year After
	cm	cm	cm	cm
Soil	2,535	6,192	15,631	81,560
2" mulch	5,010	12,079	29,478	181,028
4" mulch	5,171	10,964	29,229	190,647
10% mix.	6,284	14,394	35,068	179,022
20% mix.	5,483	14,693	35,644	184,354

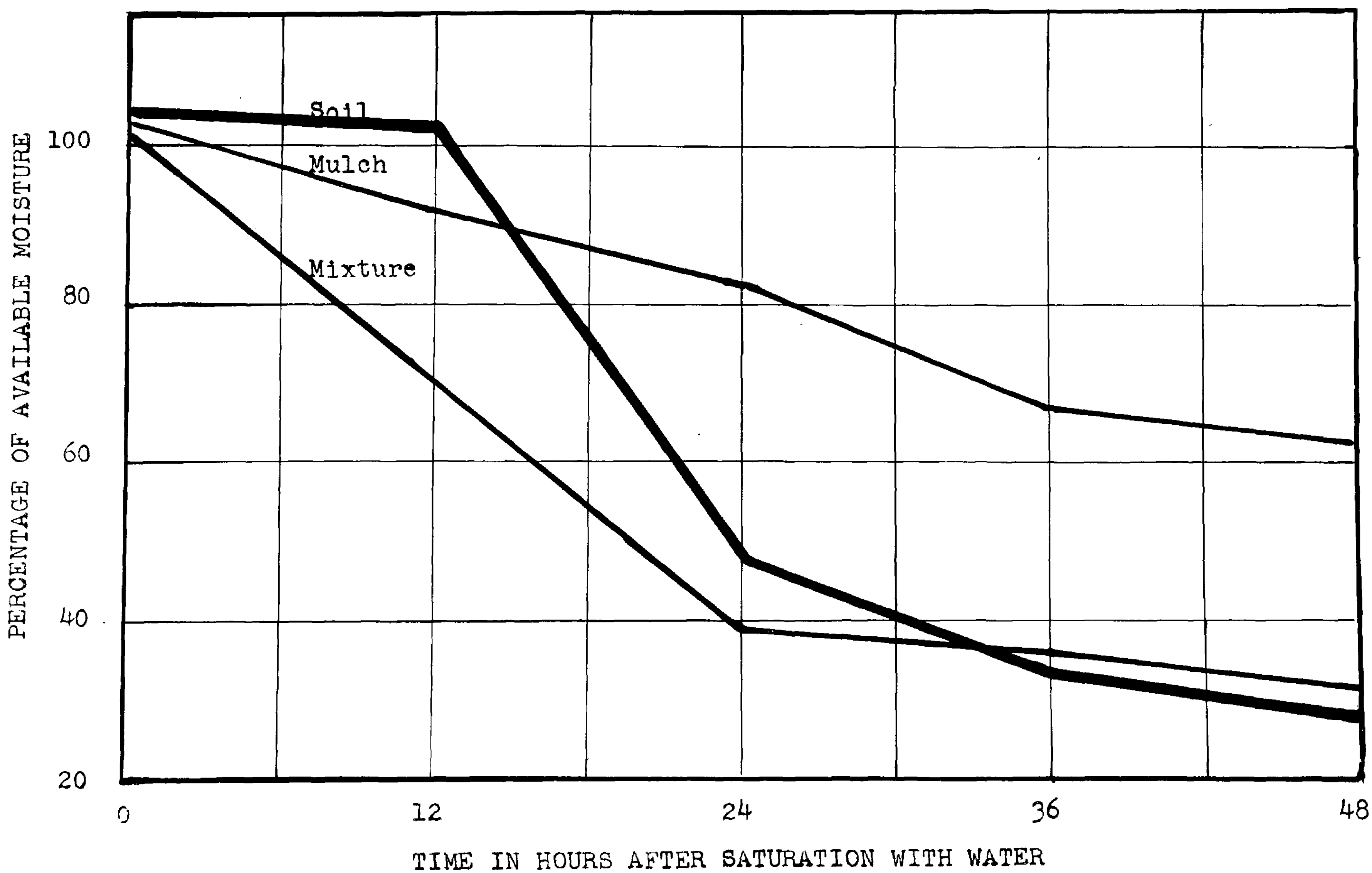
Moisture. Moisture retention was greatest beneath the surface mulches. The soil treatment maintained the least moisture retention, the poorest drainage, and the shortest time interval in the high moisture range (Fig. IV). Only slightly more moisture was retained by incorporating the corncobs into the soil.

The soil moisture readings corresponding to the time intervals at which the aeration determinations were made have been included in the averages of the moisture retention data (Fig. IV).

Figure IV

MOISTURE RETENTION AFTER SATURATION WITH WATER

(Averages 2 and 4" mulch, 10 and 20% mixtures; six replications)



Aeration. The soil atmosphere of the mixture and control treatments contained more oxygen than those of the mulch treatments. Cracking of the soil in the non-mulch treatments resulted when the soil moisture was reduced below 45% moisture. The oxygen content of the soil during a 48 hour period after soil saturation is shown in Table 7.

The soil aeration study was repeated one month later, but, additional corncobs were applied a week earlier to the mulch treatments to maintain the prescribed depths. Approximately a half inch layer of freshly ground corncobs was applied to the plots of the two inch mulch treatment and ½ to 3/4 of an inch of mulch was added to the plots of the 4 inch mulch treatment. Soil aeration readings revealed that the oxygen content of the soil atmosphere beneath the mulches had been reduced below that of the previous month. The aeration of the mixture and the soil treatments was similar to that found earlier, Table 8.

Table 7

PART I: OXYGEN CONTENT OF SOIL SOLUTION

(Averages of 10 Electrode Readings at 2" Depth, September 1-3, 1952)

Time	2" mulch	4" mulch	Treatments Control	10% mix.	20% mix.
After			Readings in Microamperes		
12 hrs.	48	38	30	34	52
24 hrs.	35	25	58	24	43
36 hrs.	14	17	62	36	28
48 hrs.	33	37	54	50	47

PART II: OXYGEN DIFFUSION RATE --

READINGS AFTER FIVE MINUTES

(Averages of 10 Electrode Readings at 2" Depth)

Time	2" mulch	4" mulch	Treatments Control	10% mix.	20% mix.
After			Readings in Microamperes		
12 hrs.	3.8	3.3	2.0	5.3	6.4
24 hrs.	2.5	2.8	6.1	3.1	5.8
36 hrs.	1.4	1.7	8.4	4.2	2.6
48 hrs.	3.8	4.2	8.9	6.2	4.9

Table 8

PART I: OXYGEN CONTENT OF SOIL SOLUTION

(Averages of 10 Electrode Readings at 2" Depth, October 3-5, 1952)

Time	2" mulch	4" mulch	Treatments Control	10% mix.	20% mix.
After		Readings in Microamperes			
0 hrs.	35	40	37	32	55
12 hrs.	15	12	45	77	54
24 hrs.	7	7	82	79	70
36 hrs.	11	8	79	82	75
48 hrs.	16	8	80	67	73
60 hrs.	44	31			

PART II: OXYGEN DIFFUSION RATE --

READINGS AFTER FIVE MINUTES

(Averages of 10 Electrode Readings at 2" Depth)

Time	2" mulch	4" mulch	Treatments Control	10% mix.	20% mix.
After		Readings in Microamperes			
0 hrs.	2.5	2.6	2.5	2.9	3.5
12 hrs.	1.3	1.1	2.9	7.1	4.6
24 hrs.	.7	.6	6.7	8.1	4.3
36 hrs.	.9	.4	9.5	9.5	11.7
48 hrs.	1.2	.6	10.1	9.1	10.2
60 hrs.	3.1	2.4			

<u>Soil temperature</u>. A lower daily maximum soil temperature as well as a more uniform soil temperature were maintained during the summer months beneath the mulches. The soil temperature readings for an 18 hour period obtained from thermometers inserted in the soil in a central location of each plot are listed in Table 9.

Table 9

DAILY SOIL TEMPERATURES IN VARIOUS COMBINATIONS OF SOIL AND CORNCOBS

(Average of 3 Thermometer Readings)

Time	Treatments 2" mulch	4" mulch	Soil	10% mix.	20% mix.
	deg. F.	deg. F.	deg. F.	deg. F.	deg. F.
10 A.M.	72	73	70	70	69
1 P.M.	76	74	85	84	82
4 P.M.	78	76	82	82	81
7 P.M.	81	79	79	79	79
10 P.M.	79	77	74	75	75
1 A.M.	75	76	73	73	73
4 A.M.	74	75	70	71	71

The soil temperatures in the southern one-fourth of the bench during an eighteen hour period are shown graphically in Figure V.

The presence of the mulches reduced temperature fluctuations in the soil along the southern edge of the bench. The daily soil temperature variations over an 18 hour period for the non-mulch treatments was $80^{\circ} \pm 10^{\circ}$F. compared with daily soil temperature fluctuations of $75^{\circ} \pm 5^{\circ}$F. for the mulch treatments. The soil temperatures of the various treatments were uniform after saturation of the soil with water. Soil temperature of the check treatment had increased 19°F. compared to a soil temperature rise of only 2°F. beneath a 4 inch mulch when temperatures were recorded three hours after the application of the water. The soil temperature of the control treatment remained higher than the soil temperature beneath the mulch until 8:30 P.M. in the evening (Fig. V).

Fewer flowers and less linear growth were produced by those treatments where soil temperatures became excessively high. This relationship is shown in Table 10.

Figure V

SOIL TEMPERATURE ALONG SOUTHERN ROW OF BENCH

(Average of 2 and 4" mulch, three replications)

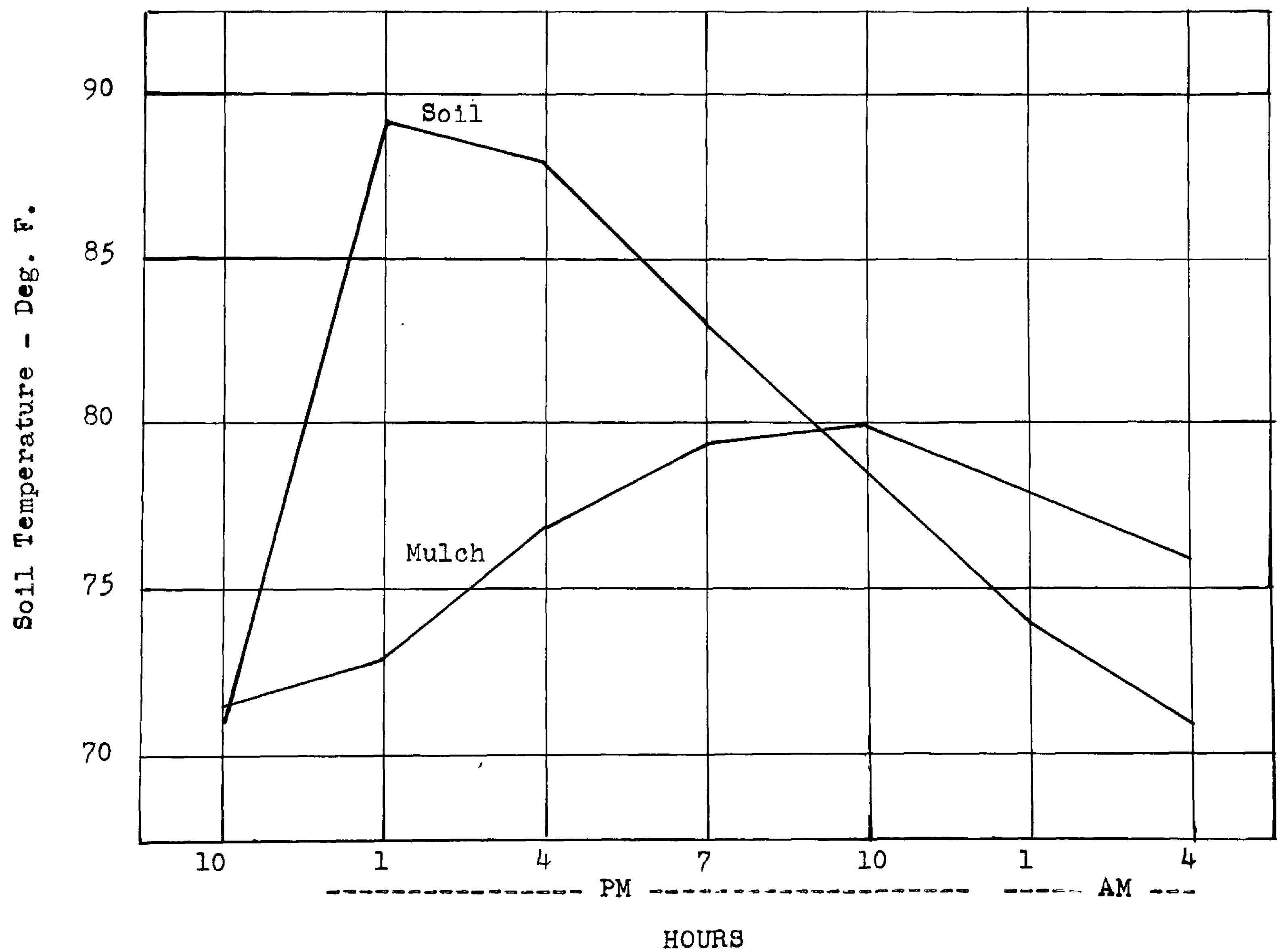


Table 10

YIELD OF FLOWERS AND LINEAR GROWTH

(Average of 20 Plants; July, August and September, 1952)

Treatment	Flowers	Linear Growth
		cm
Soil	13.5	631
10% corncobs 90% soil	12.4	618
20% corncobs 80% soil	13.6	551
2" mulch on soil	15.4	735
4" mulch on soil	16.2	709

During the winter months saturation of the soil with water having a temperature of 43°F. resulted in cooler soil temperatures beneath the mulches than in the other treatments.

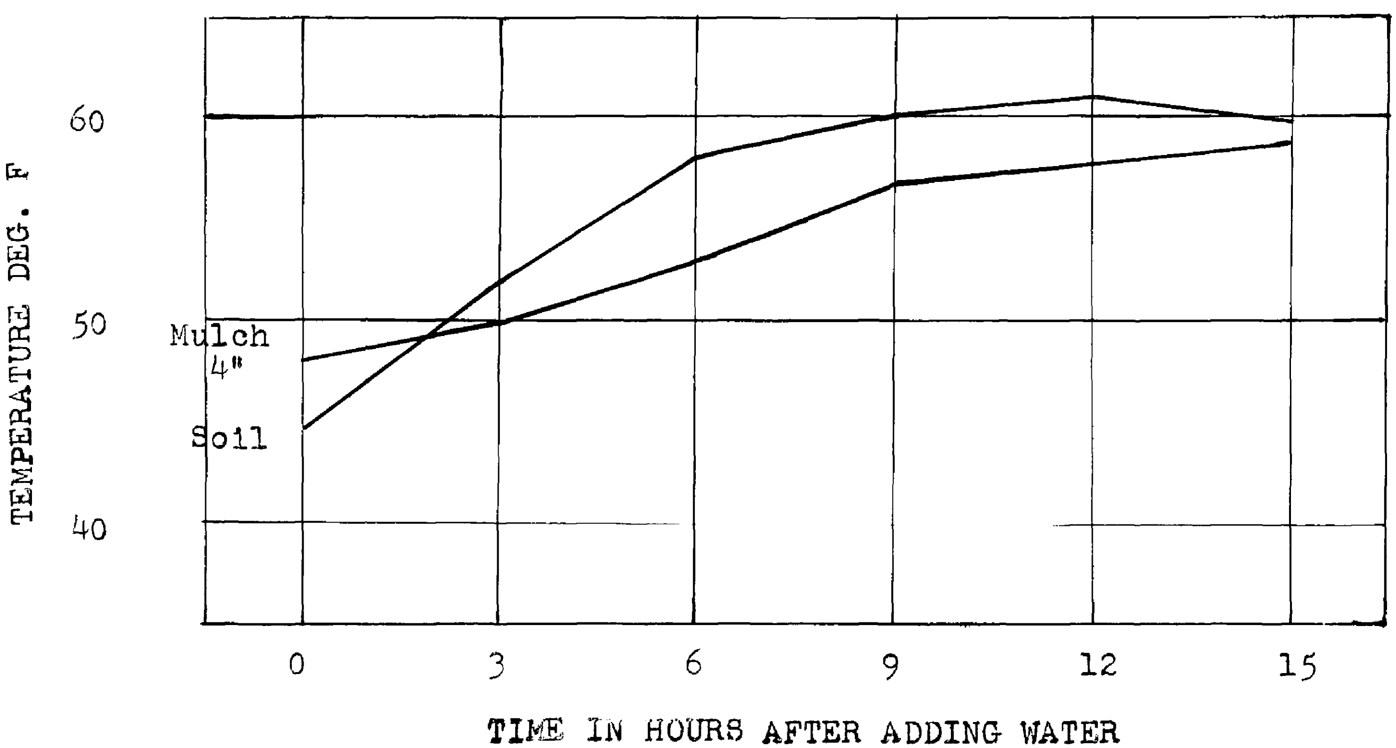
The data in Table 11 indicated that there was no apparent difference in either flower production or in the amount of linear growth made by plants in any treatment during the fall and winter periods.

Figure VI

SOIL TEMPERATURE BENEATH MULCHES

IN THE WINTER AFTER SATURATION WITH WATER

(AVERAGE OF TWO REPLICATIONS)



Plant variability. A considerable variation in production of flowers and growth in length existed between the individual plants. The greatest variability was found when comparisons were made between the rows, while differences within rows and between treatments were less significant. This has been shown in Tables 11 and 12, where the total flower production and growth in length of the treatments have been divided into seasonal subtotals and averages in relation to the position within the plot.

The variability between the rows appears to be modified by the season of the year; variability during the winter period was less than during the summer period.

Table 11

FLOWER PRODUCTION

VARIABILITY BETWEEN SEASONS AND TREATMENTS

(Averages of 20 Plants Over 3 Month Periods)

			Treatments		
Bench Row	Soil	2" mulch	4" mulch	10% mix.	20% mix.
			Fall		
1	7.20	8.86	9.65	9.25	9.30
2	5.60	6.00	5.65	5.55	5.70
3	4.30	5.70	5.70	5.95	5.40
4	7.20	10.15	9.55	9.15	8.65
			Winter		
1	5.85	7.25	7.50	7.30	7.40
2	4.40	4.70	5.80	5.80	5.25
3	5.10	5.40	6.35	6.05	6.40
4	7.50	7.20	6.80	7.20	7.95
			Spring		
1	12.20	14.15	13.55	12.95	13.55
2	8.40	10.20	9.95	9.35	9.60
3	7.30	9.35	8.90	9.70	9.70
4	13.10	13.30	14.90	12.25	13.00
			Summer		
1	12.80	13.90	15.30	13.60	13.95
2	7.60	8.70	9.00	8.20	8.85
3	5.75	9.45	9.00	9.70	9.15
4	13.50	15.40	16.15	12.35	13.60

Table 12

LINEAR GROWTH

VARIABILITY BETWEEN SEASONS AND TREATMENTS

(Averages of 20 Plants Over 3 Month Periods)

Bench Row	Soil	2" mulch	Treatments 4" mulch	10% mix.	20% mix.
			Fall		
	cm	cm	cm	cm	cm
1	346	453	513	463	481
2	229	299	308	290	308
3	268	236	255	291	311
4	429	445	435	456	471
			Winter		
1	332	340	406	366	329
2	260	252	219	271	219
3	275	222	239	223	278
4	326	378	376	306	423
			Spring		
1	584	642	661	594	645
2	355	542	592	418	490
3	392	490	500	507	438
4	684	691	804	599	643
			Summer		
1	628	754	659	605	633
2	307	476	445	420	352
3	347	446	354	444	411
4	631	735	709	618	551

Linear growth. The number of centimeters of linear growth produced by the various treatments from April 1, 1951 through October 1, 1952 is shown in Table 13. The growth measurements have been summarized at three month intervals, each interval including the increase within that period.

An initial reduction in the amount of linear growth occurred in the mulch treatments, but at the termination of the project the mulch treatments had made the largest amount of linear growth.

Fresh weight. The fresh weight of the flowers produced, the non-flowering wood and the roots of all plants has been summarized in Table 14.

Table 13

LINEAR GROWTH AS INFLUENCED BY SOIL MULCHES OR MIXTURES OF GROUND CORNCOBS

(Soil Treatment 40 Plants, Others 80 Plants)

Period	Soil	Soil with 2" mulch	Soil with 4" mulch	Soil with 10% mix.	Soil with 20% mix.
	cm	cm	cm	cm	cm
Apr.-June 1951	15,630	29,478	29,229	35,068	35,644
July-Sept. 1951	21,972	50,880	54,019	48,108	50,037
Oct.-Dec. 1951	11,755	28,312	29,115	30,828	31,206
Jan.-Mar. 1951	11,917	24,645	26,414	22,745	22,595
Apr.-June 1952	20,276	47,713	51,865	42,273	45,272
July-Sept. 1952	19,633	48,476	46,025	41,642	39,366
Total	101,183	229,504	236,662	220,664	224,120

Table 14

WEIGHT OF VEGETATIVE GROWTH AS INFLUENCED BY SOIL MULCHES OR MIXTURES OF GROUND CORNCOBS

(Soil Treatment 40 Plants, Others 80 Plants)

Period	Soil	Soil with 2" mulch	Soil with 4" mulch	Soil with 10% mix.	Soil with 20% mix.
Weight of Flowers	gm	gm	gm	gm	gm
July-Sept. 1951	7,814	16,233	17,323	17,333	17,950
Oct.-Dec. 1951	4,774	12,002	11,956	11,324	11,477
Jan.-Mar. 1952	4,698	10,697	13,999	11,343	13,409
Apr.-June 1952	7,077	17,006	17,481	15,497	15,886
July-Sept. 1952	5,006	12,986	13,279	11,218	11,581
Wgt.-Non-Flowering Wood 7/51-10/52	9,686	21,082	21,350	18,562	19,391
Total Wgt. of Roots 10/52	4,001	7,705	8,424	8,002	8,278
Total Wgt. of Plants 3/51-10/52	43,056	97,711	103,812	93,279	97,972

<u>Quantity and quality of flowers</u>. The first flowers were severed from the plant on July 1, 1951 and cutting continued until October 1, 1952. The number and quality of the flowers from the various treatments have been shown in Table 15.

The flower production of the mixture treatments was larger than that of the mulch and soil treatments during the first three months, however, the flower production of the mulch treatments exceeded those of the other treatments after this initial period. At the termination of the 15 month flowering period the mulch treatments had produced the largest number of flowers and the soil treatment the least number of flowers, while the production of the mixture treatments was intermediate.

The number of flowers in excess of the check treatment has been summarized graphically in Figures VII, VIII, IX.

Table 15

QUALITY AND YIELD OF FLOWERS INFLUENCED BY SOIL MULCHES OF GROUND CORNCOBS AND MIXTURES OF SOIL AND GROUND CORNCOBS

(Soil Treatments 40 Plants, Others 80 Plants)

Periods	Soil	Soil with 2" mulch	Soil with 4" mulch	Soil with 10% mix.	Soil with 20% mix.
	Total Number of Flowers Per Treatment				
July-Sept.1951	452	886	946	972	1,020
Oct.-Dec. 1951	253	611	611	590	581
Jan.-Mar. 1952	232	491	529	536	541
Apr.-June 1952	410	934	946	912	918
July-Sept.1952	405	968	1,000	877	911
	Average Number of Flowers Per Plant				
July-Sept.1951	11.30	11.07	11.82	12.15	12.75
Oct.-Dec. 1951	6.35	7.64	7.64	7.37	7.26
Jan.-Mar. 1952	5.77	6.14	6.61	6.70	6.76
Apr.-June 1952	10.18	11.67	11.83	11.38	11.25
July-Sept.1952	10.12	12.10	12.50	10.96	11.38
	Average Number of Grams Per Flower				
July-Sept.1951	17.34	18.28	18.24	17.82	17.60
Oct.-Dec. 1951	18.82	19.63	19.62	19.21	19.82
Jan.-Mar. 1952	20.34	21.58	22.37	21.43	21.10
Apr.-June 1952	18.80	18.72	18.48	17.00	17.31
July-Sept.1952	12.36	13.41	13.28	12.78	12.71
	Average Number of Cms Per Stem				
July-Sept.1951	44.90	46.51	46.22	45.92	45.58
Oct.-Dec. 1951	44.80	47.98	47.67	47.13	48.93
Jan.-Mar. 1952	42.19	44.16	44.35	44.28	43.60
Apr.-June 1952	36.94	39.91	40.24	36.70	36.72
July-Sept.1952	30.84	33.10	31.90	31.39	30.97

Fig. VII

WEIGHT OF VEGETATIVE GROWTH OF THE MULCH AND MIXTURE TREATMENTS IN EXCESS OF THE SOIL TREATMENT

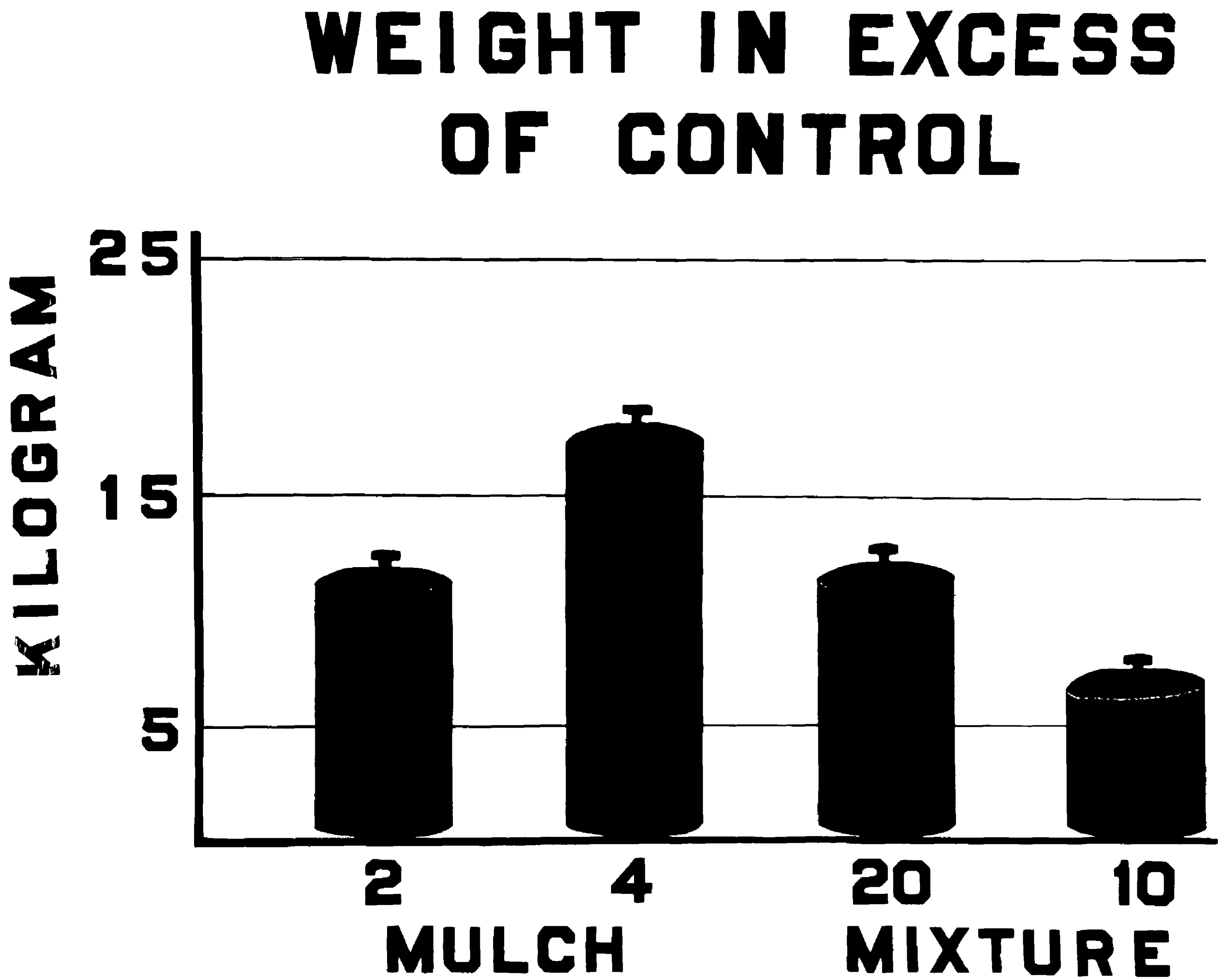

WEIGHT IN EXCESS
OF CONTROL
KILOGRAM
25
15
5
2
4
20
10
MULCH
MIXTURE

Fig. VIII

LENGTH OF VEGETATIVE GROWTH OF MULCH
AND MIXTURE TREATMENTS IN EXCESS
OF THE SOIL TREATMENT

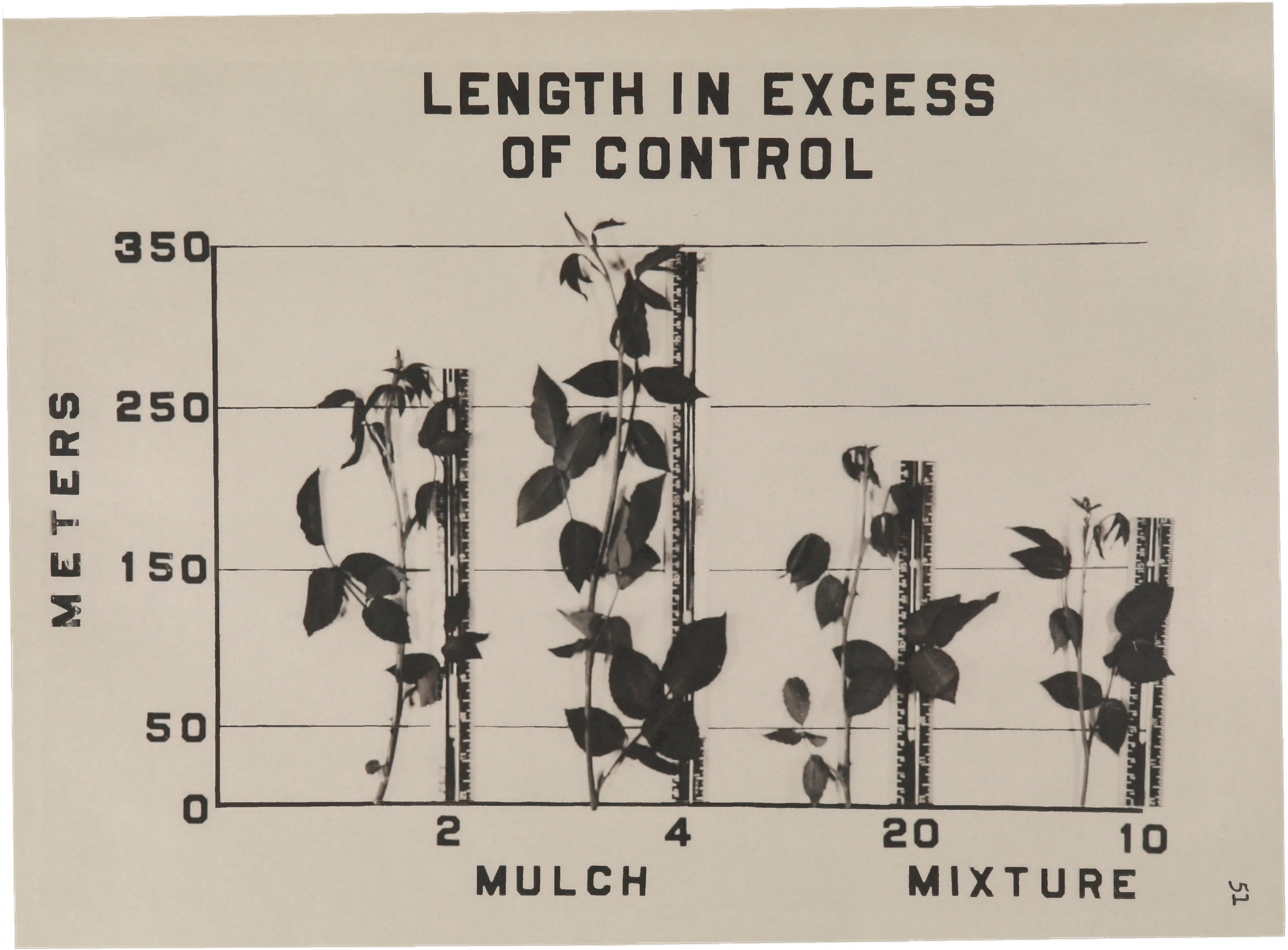
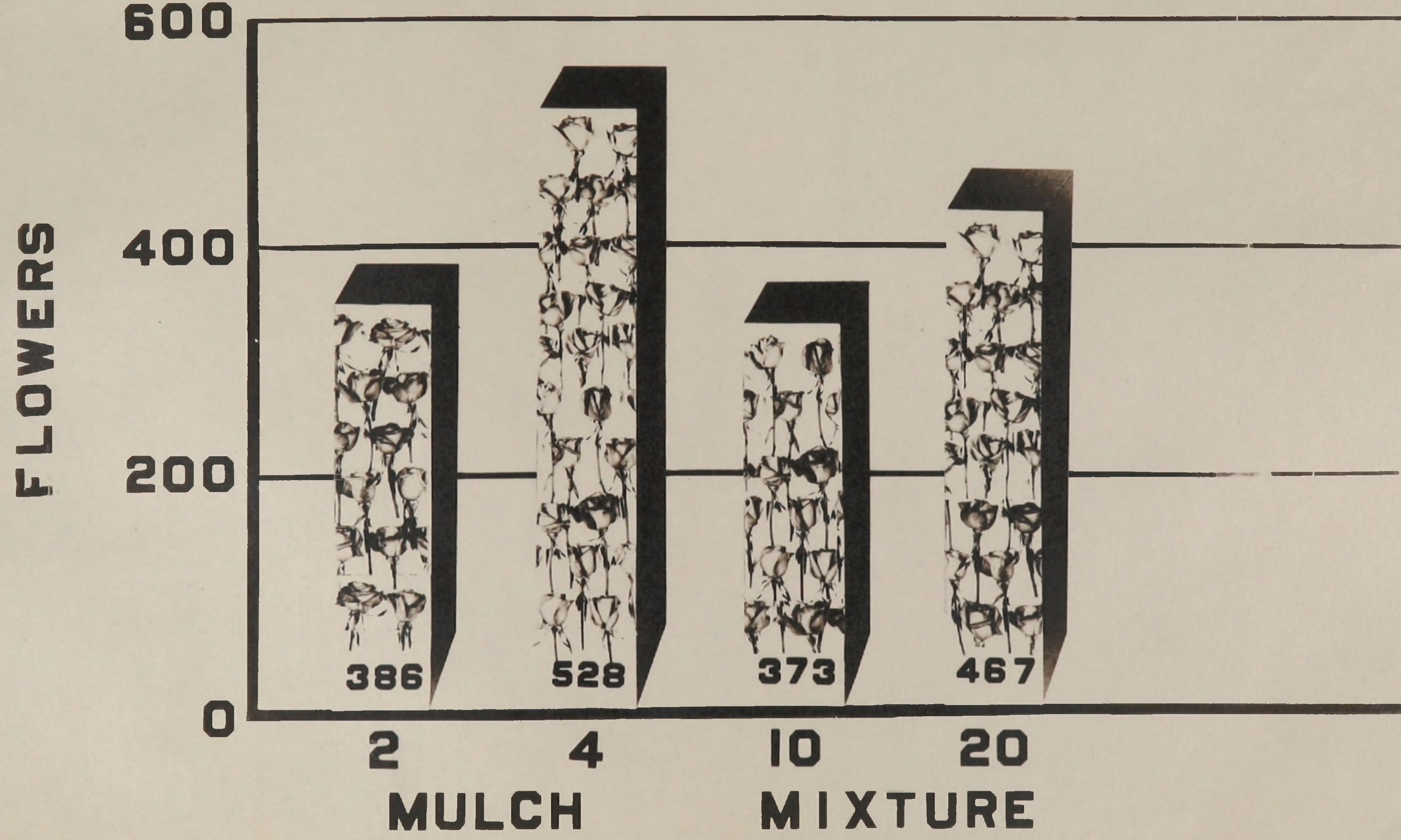

LENGTH IN EXCESS
OF CONTROL
METERS
350
250
150
50
0
2
4
20
10
MULCH
MIXTURE

Fig. IX

NUMBER OF FLOWERS OF MULCH AND MIXTURE
TREATMENTS IN EXCESS OF
THE SOIL TREATMENT

FLOWERS IN EXCESS OF CONTROL



DISCUSSION

Aggregate analysis of soil samples from beneath varying depths of ground corncob mulches sampled six weeks following the application of the mulch showed that the total number and size of aggregates increased as the depth of the mulch increased. The mulch treatments had a larger quantity of aggregates in each of the six sieves than the soil treatment (Table 3). Chadwick (1948) in a more extensive investigation procured similar results. He reported that the percentage of aggregation, average diameter of the aggregates, total porosity and percentage of non-capillary pore space were increased in a soil beneath a surface mulch of ground corncobs (Appendix Table 2).

The rapid reduction in the nitrate level of the soil immediately after the application of ground corncobs may be a result of sugars (7% by weight, Salisbury, 1948) being leached into the soil. The presence of sugar in the soil has been thought to have stimulated a rapid increase in the microorganism population; possibly the reduction of the soil nitrates was caused by utilization of nitrogen in the protein of protoplasm.

Mulches were shown to decrease the moisture content more than did the same quantity of corncobs incorporated into the soil. Mixtures of corncobs and soil did not improve moisture retention, but the rate of water penetration was accelerated and the time interval within the 40 to 80% moisture range was increased (Fig. IV).

The oxygen content of the soil beneath surface mulches during a 48 hour period following saturation with water was less than the oxygen content of soil of the other treatments during the same period. The oxygen content of the soil beneath the mulches became extremely low following an application of a one-half inch layer of fresh corncobs when it was applied in order to renew the prescribed depths (Table 8).

Andreasen (1951) also found serious oxygen deficiencies followed heavy waterings after organic fertilizers or mulches had been applied. He concluded that the roots of higher plants may be impaired from oxygen deficiency as a result of the active competition for oxygen on the part of soil fungi and bacteria.

Immediately after the original application of the mulches a reduction occurred in the amount of linear growth being made by the plants to which the mulches had been added (Table 6). Although aeration determinations were not made at this time, it might be assumed from the data in Table 8 that a very low oxygen content existed in the soil beneath the mulches. A large reduction in the amount of nitrogen coincided with the application of mulches. The reduction in plant growth therefore may have been caused by either one or both of these conditions. Monthly summaries of the flower production and linear growth measurements indicated that no reduction resulted when the mulches were renewed to their original depths.

In agreement with results of Wollny (1883) and Chadwick (1948), more uniform daily soil temperatures were found to exist beneath the mulches. In the center of the plots a temperature difference of between 10 and 12 degrees existed between the mulched and non-mulched soils during the periods of highest temperature. In the southern edge of the benches this difference was from 15 to 20 degrees. The data indicated that, in the summer, fewer flowers and less linear growth were found on non-mulched plants in the outside row of the bench than on comparable plants growing in a soil beneath a surface mulch. Less moisture retention along the southern edge of the bench of the non-mulch treatments was a second factor in the reduction of growth and flower production. The non-mulch treatments were watered more frequently during the summer months and additional water was applied to the edges of the bench. Soil moisture however should not be eliminated as a factor in the above mentioned reduction in growth.

In the first experiment, significant increases in flower production, linear growth and plant weight were obtained by applying ground corncobs as surface mulches (Table 5). The amount of growth and flower production of the mixture treatments progressively decreased as the percentage of corncobs increased from 16 to 100%. The Miami clay loam soil, which was used, possessed a low organic content. In the mulch and mixture treatments increased water penetration and retention were readily apparent. Adequate spacing of the plants (Fig. I) resulted in more uniform light intensities throughout the bench and this reduced plant variability within the treatments.

In the second experiment, differences in the number of flowers and in the amount of linear growth made by plants within the same plot were caused by variations in light intensity. Shadows cast by the outside rows of plants undoubtedly reduced the light intensity of the inside rows of plants and this was a factor that may have governed the amount of growth made by the shaded plants. The flower production of the outer rows of plants was 39% higher during the summer period and 24% higher during the winter period than the flower production of the center rows (Table 11). Similar results were found for linear growth (Table 12).

Seasonal differences in light intensity caused additional fluctuations in growth and flower production. The rows of plants along the edge of the bench produced almost twice as many flowers during the summer period as the same plants produced during the winter period. The exact percentages of reduction were 49.4% for the southern row and 47.9% for the northern row (Table 11). The center rows in the winter produced 38.0 and 41.9% fewer flowers than in the spring period.

The application of ground corncobs as either surface mulches or soil mixtures resulted in more flowers being produced than in the soil treatment (Table 15). The total flower production of the mixture and mulch treatments was approximately equal, with a slight increase in the flower production of the mulch treatments during the spring and summer.

An average flower removed from plants in the soil treatment had a slightly shorter stem and less weight than an average flower cut from plants in other treatments. The stem length and weight of an average flower of the mulch and mixture treatments were similar, but the stems of flowers from the mulch treatments were slightly longer and the flowers and stems were heavier during the spring and summer (Table 15).

The flowers of highest quality, as measured by stem length, were produced during the seasons of lowest light intensity. The average flower stem length during the fall and winter periods was 20.3% longer and the average weight was 39.4% greater than for comparable flowers produced in the summer.

The plants of the mulch treatment made 15% more linear growth than the soil treatment and 3.5% more linear growth than the mixture treatment during the eighteen month period.

The growth and production records indicated that the beneficial effect of the mulch occurred during the spring and summer (Table 11). A great retention of soil moisture was possibly the most important benefit the plant received from this mulching material, however, the reduced soil temperature beneath the mulch was of probable significance.

SUMMARY

The first experiment included 96 rose plants of the variety Peter's Briarcliff planted in 12-inch pots containing a media of 600 cubic inches. Three treatments received one to four inch depths of ground corncobs on the surface of the Miami clay loam soil. The media of the remaining five treatments varied from 100% soil to 100% corncobs with three intermediate mixtures.

The second experiment consisted of 360 rose plants of the variety Better Times planted in two greenhouse benches subjected to the following five treatments: 2 and 4 inch depths of ground corncobs as surface mulches, 10 and 20% ground corncobs mixed with the soil by volume, and a soil treatment.

The data collected included monthly records of the number of flowers produced, the number of centimeters of linear growth and the fresh weight of the vegetative growth in grams. The use of I.B.M. cards was employed to accelerate the collection and summarization of these data.

An evaluation of soil fertility, aggregation, moisture, aeration and temperature was made in an effort to explain plant growth differences between the various treatments.

Immediately following the application of freshly ground corncobs as either surface mulches or soil mixtures a large reduction in the nitrate level of the soil occurred. The data from the aeration study indicated that the oxygen content of the soil air was also very low at this time. Growth records showed that a reduction in the amount of linear growth was made by the plants of the mulch treatments after applying the fresh corncobs.

The aeration study indicated that although the percentage of aggregation, average diameter of the aggregates, total porosity and percentage of non-capillary pore space were increased in a soil beneath a surface mulch of ground corncobs, the percentage of the oxygen in the soil atmosphere was less than the oxygen content in the soil of the non-mulch treatments.

Fluctuations in the soil temperature were greater in the soil of the non-mulch treatment than in the soil of the mulch treatments.

Moisture retention was much greater in the soil of the mulch treatments than those of the non-mulch treatments.

The plants in the outside rows produced 39% more flowers during the summer period and 24% more flowers during the winter period than did the plants of the center rows. Similar results were found for linear growth.

The plants along the southern and northern edges of the benches produced 49.4 and 47.9% more flowers during the summer than the same plants produced during the winter. The center rows of the plants produced 38.0 and 41.9% more flowers in the spring than in the winter.

In both the first and second experiments the largest production of flowers, linear growth and weight of vegetative growth were made by plants grown in the soil with mulch treatments. The growth and flower production of the 10 and 20% mixture treatments exceeded those of the soil treatment.

APPENDIX TABLES

Appendix Table 1

MINERAL AND DRY WEIGHT CONTENT

OF SEVERAL ORGANIC MULCHES

Material	Percentage				Total Mineral Matter	Total Dry Matter
	N	P	K	Ca		
					%	%
Corn cobs, ground	0.40	0.08	0.44	0.02	1.60	90.4
Oat straw	0.64	0.20	1.25	0.30	6.00	89.6
Wheat straw	0.50	0.15	0.60	0.21	8.20	90.1
Alfalfa hay	2.35	0.21	2.02	1.43	8.30	90.4
Hops, dried spent	3.68	0.00	0.00	0.00	5.30	93.8

After Chadwick Roses Incorporated
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Appendix Table 2

EFFECT OF CORNCOBS ON AGGREGATION AND POROSITY

Treatment	% Aggregation	Avg. dia. of aggreg. (mm)	Total Porosity	% Non-Cap. pore space
No mulch	27.5	.90	59.1	25.3
Old corncobs	28.8	.97	59.7	24.4
New corncobs	37.5	2.26	63.6	30.5

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