EFFECT OF USE OF MULCH PAPER ON GROWTH OF YOUNG PEACH TREES

THESIS FOR THE DEGREE OF M. S.

Carl S. Bittner

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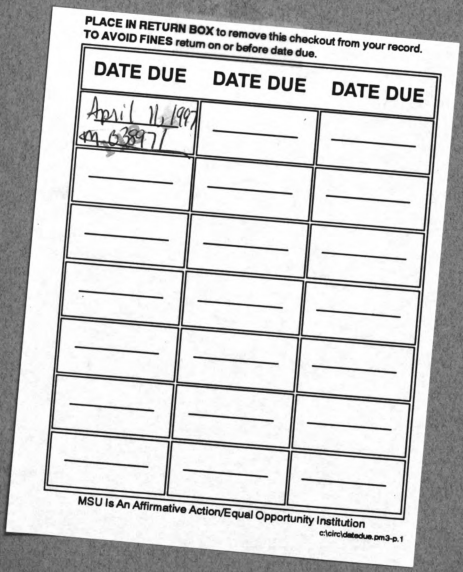
Peaches
Title: Mulch paper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EFFECT OF USE OF MULCH PAPER ON GROWTH OF YOUNG PEACH TREES

Submitted to the Faculty of the Michigan State College of Agriculture and Applied Science in partial fulfillment of the requirements for the degree of Master of Science

by
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THESIS

EFFECT OF USE OF MULCH PAPER ON GROWTH OF YOUNG PEACH TREES

The possible use of mulches as a means of controlling weeds, stimulating tree growth and cutting cultivation costs has been a question confronting orchardists for some years. Trials with paper mulches in the pineapple industry of Hawaii as well as reports of its extensive use in one of the forest nurseries of a Canadian province have called considerable attention to its various applications. The use of the paper in vegetable and flower gardens throughout the United States is generally confined, however, to small plots and but little definite information is available concerning the stimulation of growth of trees. Its use in the orchard has not been studied extensively.

Tests with paper mulches as a means of cutting production costs in the orchard have been reported from cherry growers in Door County, Wisconsin (11). The paper was used as a method of weed control around newly set cherry trees. A single instance of its use for moisture conservation and weed control has been reported from Vermont (16). In neither case were records of growth, moisture and temperature presented.

Review of Literature

The literature bearing directly upon the subject of mulch paper is not extensive. Its comparatively recent discovery, coupled with previous high costs of the paper have not encouraged wide spread use. In recent years demand for investigation has caused various experiment stations to run tests to determine its effectiveness.

Use in weed control was demonstrated by E. C. Eckart (17) in 1914 in pineapple plantings at Olaa, Hawaii, when he used asphalt coated paper for a satisfactory mulch instead of pineapple refuse that had been formerly used. Mrs. E. W. Berger (14) used newspapers for mulching roses in Florida and gave a report relative to their mulching properties before the Florida State Horticultural Association in 1915.

Favorable growth response characterized by its use in the Hawaii pineapple industry caused the United States Department of Agriculture to investigate its potentialities in 1924. Flint (10) was placed in charge and the work was carried out under his direction from 1924 to 1927 inclusive. The trials were made with tomatoes, corn, sweet potatoes, green peas, beets, carrots, peppers, egg plant, celery, sweet corn and cucumbers. He found that the use of mulch paper brought about definite increases in certain crop plants in the Eastern United States.

Increased yield of sugar cane resulted from the use of mulch paper in trials conducted in the Virgin Islands in 1923 as reported by M. S. Baker (1). The increased yield was not great enough to justify the use of the paper in commercial sugar cane plantings.

Stewart, Thomas and Horner (2) during the years 1921 to 1924 inclusive carried out investigations determining the effects of paper mulches on soils planted to pineapples. The results appeared to indicate higher soil temperature and higher moisture content as well as greater nitrate content.

The effect of paper mulch on soil temperature was shown by Smith (4). He found that during hot weather the soil one-half inch from the surface of a bare plot was 10 degrees warmer during the day and 5.6 degrees cooler at night than on a plot covered with perforated black paper. Papers of different colors gave varying results at other depths.

That the use of straw and hay mulches in apple orchards was effective in increasing soil nitrates was found by Beaumont, Sessions and Kelly (5) in 1925 and 1926.

Edmond (7), during the 1928 season, found that paper mulch is likely to be more beneficial on warm season vegetable crops than on cool season crops. Magruder, during the same season, worked on six

different kinds of paper. His findings indicate that paper mulch seems to have merit under Ohio conditions in the culture of early, quick maturing vegetable crops, for warm season crops and in periods of moisture shortage.

Starker (6), during 1929, found that the use of paper was less effective than a leaf mulch for mulching nursery transplants. The results were determined on a dry weight basis in comparison with other mulches. Robbins (9), however, found that paper mulching forest tree transplants increased the total growth on a dry weight basis.

Thompson and Platenius (12) worked with vegetable crops at Ithaca, New York, and found yields increased by the use of paper mulches.

Statement of Problem

This outline of available literature shows that little definite information drawn from orchards has been reported. The problem presented, therefore, is two fold; first, to ascertain whether young trees are benefitted by paper mulch and second, if benefits are secured, whether they arise from improvements in conditions of soil moisture, soil temperature or available nitrates. Information on the second aspect of the problem is essential to comparison of mulching with other possible means of securing similar improvements.

Location and Soil of the Plot

The orchard in which this experiment was conducted is located about one-half mile south of Sodus, Berrien County, Michigan. Considerable acreage of the farm in question and other farms nearby is set to peach trees. A gentle slop to the north is characteristic of the plot set aside for the experiment.

The soil of the plot is considered uniform. Though a Plainfield (15) loamy sand is not considered as an especially fertile type, the soil in this orchard has received good care for the past 30 years. Heavy applications of barnyard manure at about five year intervals and the use of commercial fertilizer have maintained the soil in a relatively high state of fertility as compared with Plainfield soils in general. Occasional field crops of grain and potatoes have been grown when the land has not been set to fruit. When set to peaches or raspberries it has been intercropped with tomatoes, cucumbers, beans or strawberries. As soon as the intercrops have interfered seriously with the growth of the raspberry plants or trees, they have been removed.

The brown loamy sand of the surface soil is underlain by a yellow, loose, penetrable sand to a depth of 40 inches or more. Organic content is fairly high as well as nitrogen, potassium and phosphorus. The soil

is strongly acid to a depth of at least 36 inches. Probably the chief limiting factor in plant growth is moisture. The subsoil does not retain moisture as well as that of a heavier soil. Consequently shallow rooted plants begin to suffer during the early summer months when the weather is warm and rainfall does not occur at regular intervals. There is little apparent damage to trees, however, even in years of severe drought. As a rule the soil is easy to cultivate at any time during the growing season. After a heavy rain, the soil can be worked within a few hours' time due to the rapid absorption of the water and its easy penetration to the lower depths of the soil.

History and Description of the Orchard

The peach trees in this orchard, all Elbertas, were planted in the spring of 1929. These trees were purchased from a Michigan nursery and were relatively uniform one-year-old whips when planted. All were set in early April at a distance of 18 feet by 18 feet. A row of black raspberries was set between each two rows of peach trees during the same spring. On each side of the raspberry row, a row of strawberry plants was set, thus making a double intercrop for the peach trees.

This system of intercropping is common in southwestern Michigan and apparently does no harm to the peach trees if the strawberries are removed at the end of the first picking season and the raspberries at the close of the third or fourth picking season. By following this system of intercropping, cash returns are available each year from the time the trees are set. If, however, the removal of the raspberries is delayed after the third or fourth picking season, both trees and bushes suffer.

In view of the fact that the strawberry row was four and one-half feet from the peach trees during the 1929 and early 1930 seasons, it is doubtful whether the roots of either peach trees or strawberries interfered with each other. After the removal of the strawberries on July 5th, 1930, the nearest plants were the one-year-old raspberry plants nine feet away.

Arrangement of Mulch Paper Plots

In consideration of the fact that the orchard site sloped gently to the north, the separate plots were arranged on an east to west basis. This minimized any cross transfer of plant nutrients which might occur.

The mulch paper treatment for each plot was as follows: Mulch paper was placed around the trees in the first row on the surface of the ground. The second

row received the same treatment except that an inch of soil was placed upon the mulch paper, completely covering it. The third row was the check row.

Each row consisted of 14 trees. Each plot was duplicated four times. One hundred and sixty-eight trees were included in the entire experiment (See Fig. 1). Heavy weight "Gator Hide" mulch paper was used.

Duration of Treatment

A two year plan of work was outlined for the experiment. The first work dealing with the experiment was done in early July, 1929. The orchard had received clean cultivation until this time and no fertilizer of any kind was applied before the trees were set or at any time during the experiment.

On July 3rd, 1929, the entire planting of the trees in the block was treated in the manner outlined. At that time the mulch paper was cut into three-foot squares. This allowed a root spread of one and one-half feet in each direction, which appeared to be adequate to cover the roots of the trees the first season. A small hole was cut in the center of the paper, just large enough to encircle the tree trunk at its base. A slit was made from the hole in the center to the edge of the paper so that the paper fitted around the tree like a

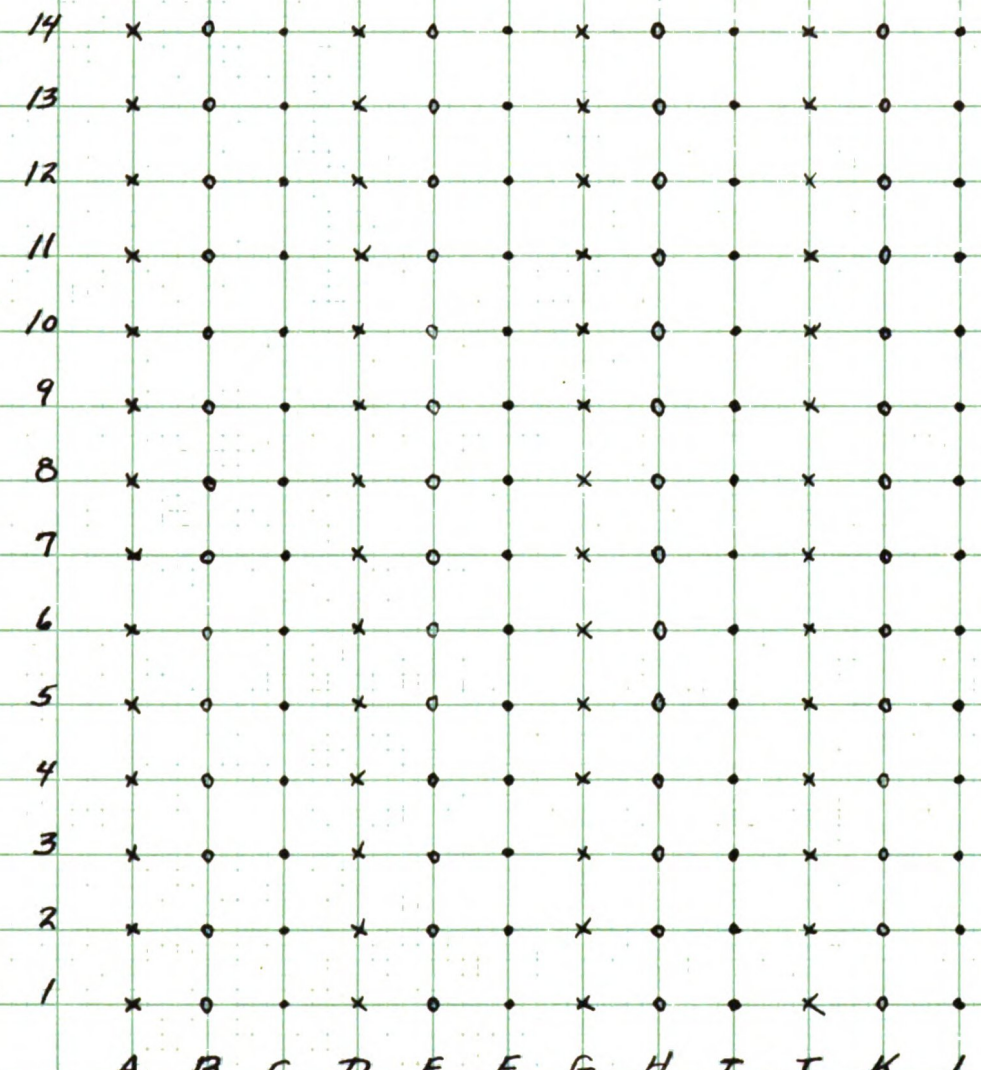


Fig. I. Arrangement of Mulch Paper Plots

x = Mulch Paper

o = Mulch Paper and Soil

• = Check

collar. In some cases it was found necessary to smooth the surface of the soil somewhat and also to raise the level a little near the base of the tree so that any rainfall would run off the paper and be absorbed by the soil rather than collecting on the paper and being lost by evaporation.

An attempt was made the first year to gather enough sticks from a nearby wood to hold the mulch paper firmly to the fround. It was found, however, that from eight to twelve sticks per tree were necessary to keep the paper in place. Even with that number the results were indifferent. On a windy day there was a tendency for the wind to get under one corner of the paper, thereby loosening the paper from the sticks or tearing it entirely away. The task of gathering the sticks proved to be much greater than was apparent at first. This system of holding the paper in place is, therefore, scarcely to be recommended. It was found, however, that 10 or 12 stones about three inches in diameter or larger held the paper securely in position. The field in question had very few stones and it was not considered feasible to haul stones for that purpose.

After a number of trials with various types of slats with nails driven through them and with wire wickets, it was found that a piece of wire, about 30 to 40 inches long with six or eight inch prongs turned down on each

end and thrust into the ground, held the paper firmly in place. During the second year of the experiment these wire fasteners were used with satisfactory results.

The mulch paper covered with soil did not present any of the difficulties experienced with the mulch paper on top of the ground. Few, if any, weeds came through the paper even though the paper appeared to be penetrable after the first rain or two.

All the check rows were kept under clean cultivation. No especial efforts were made to keep the weeds under control except by regular cultivation with cultivator or harrow. Cultivations, both seasons, started early in May and ended during the latter part of July.

Growth Results of the 1929 Season

Owing to the late application of the mulch paper in 1929, only trunk circumference and total branch growth records were taken (13). The entire block of 168 trees was measured at the beginning of the treatment and again at the close of the season. Measurement of the total branch growth was taken in inches. This presented little difficulty, since the trees were one year whips with no laterals, and all growth made was of the current season.

It was thought that circumference measurements of the trunk would be more accurate than diameter measurements

because of the tendency of young peach trees to develop in a flat-sided fashion. Circumference measurements were taken to the nearest one-sixteenth inch. To permit taking succeeding circumference measurements at the same point on each tree, a smooth barked area on the tree, about 18 inches from the ground, was selected. A small notch was cut an inch or so below the place where the measurement was taken. These notches were all made on the west side of the tree in order to make them quickly discernible for subsequent measurement. Locating the place of measurement by means of a thumb tack thrust into the tree at some point immediately below the point of measurement was abondoned in favor of the notch method.

At the close of the first year all the paper used that season was discarded because the paper squares would be inadequate the next season to cover the enlarged root systems of the trees. Furthermore, heavy weight paper used on the surface of the ground tends to stiffen after months of exposure and is very difficult to handle.

Table I
Linear Growth of Branches in Inches During 1929 treatment

	Mulch	Mulch and Soil	Check
Plot I	714	859	688
Plot II	847	1278	677
Plot III	629	1191	664
Plot IV	474	1266	904
Totals	2664	4594	2933
Average per tree	47.57	82.03	52.03

Circumference Growth of Tree Trunks in inches During 1929 treatment

	Mulch	Mulch and Soil	Check
Plot I	7.75	8.13	7.00
Plot II	7.38	10.70	9.70
Plot III	8.31	13.70	10.03
Plot IV	6.44	12.70	11.30
Totals	29.88	44.93	38.03
Average per tree	.53	.80	.68

A correlation seems to exist in this case between the linear growth and trunk circumference (See Table I). In both types of growth the mulch paper and soil averaged the most growth, with the check plots averaging next highest and the mulch treatment third.

Methods Employed During the 1930 Season

For the 1930 season a more comprehensive study of the mulch paper treatment was outlined. This plan included studies of nitrate nitrogen as well as temperature

and soil moisture determinations. The same trees were used as during the previous year. It was necessary, therefore, to increase the area covered by the paper at the base of the tree. The paper used was 36 inches wide. Two six-foot lengths were cut for each tree. Small notches were cut in the edge of each sheet of paper so that each sheet fitted snugly to the tree when laid along side. This made a six by six-foot collar. Wire brackets held the paper in place, as previously explained. Soil was again placed on the paper for the mulch and soil treatment. Clean cultivation was used for the check rows.

In early April the mulch paper was placed around the trees. At this time the buds had started to swell but no other external growth was evident. Since the trees had received no pruning up to this point, sufficient pruning was done to develop suitable frameworks. Measurements of both trunk circumference and length of branches after pruning were taken at this time as well.

System Used in Soil Sampling

The first soil samples for nitrate and moisture determinations were taken on April 23, when the paper had been placed about two weeks. This allowed sufficient time for the various treatments to become effective.

In taking the soil samples, a one and one-half inch

soil auger was used so that the soil would not be disturbed to interfere with later sampling (8, 5). The dryness of the 1930 season made this task somewhat more difficult than usual because of the tendency of the dry, sandy surface soil to trickle into the hole made by the auger. This was particularly true when the deeper samples were taken. The soil samples were taken from the second plot at approximately two week intervals from April 19th to September 15th, inclusive.

Samples were taken from one to six inch depths, six to 12 inch depths, and 12 to 18 inch depths from each treatment. Moisture and nitrate determinations were made from these samples. The six inch, 12 inch and 18 inch samples were taken at the same spot. That is, a small sample was taken at each depth and of each treatment from trees listed as D_2, E_2 and F_2. Another similar sample was taken at D_4, E_4 and F_4, again at D_6, E_6 and F_6 and so on until finally each sample consisted of six parts taken at regular intervals throughout one plot. No samples were taken from border rows or border trees at any time during the season. This decreased the error which might creep in because of proximity of the orchard to a pasture on the north and farm road on the south.

Whenever the nitrate determinations could not be made immediately, the soil samples were treated with toluene and their determinations were made as soon as

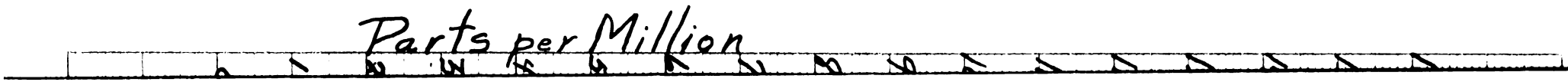
possible. The phenoldisulphonic method of determining nitrate nitrogen was used. In this procedure moisture content of the soil sample was also found. All samples were run in duplicate.

Though figures on nitrate nitrogen content of soil are an index as to the amount of accumulation, small differences are not significant. This would be particularly true where trees are growing and the nitrate content would vary greatly within short periods of time.

Flint (10) in his investigations found less nitrate in the mulched soil than in the unmulched. Magruder (8) did not consider the differences in nitrate nitrogen content of the soil consistent enough or large enough to warrant definite conclusions. Stewart, Thomas and Horner (2) found a consistently higher nitrate content in mulched soil in both fertilized and unfertilized plots. Thompson and Platenius (12) found moisture content higher in mulched soils than in unmulched.

Average nitrate content under straw mulched apple and pear trees was higher throughout the season than under cultivated plots of the same trees, according to Beaumont, Sessions and Kelly (5). Differences existed even during the season of greatest growth, or when the draft on nitrates is greatest.

As indicated by Figs. 2, 3 and 4 of this experiment no significant differences in nitrate content were


Parts per Million


Parts per Million

Parts per Million

apparent at the beginning of the season at a six inch depth. This applies to all treatments. At the 12 inch depth, the mulch paper and the check treatments showed no appreciable difference. The mulch paper and soil, however, showed an increase of 7.8 p.p.m. over the check plot and 7.0 p.p.m. over the mulch paper plot.

A still more striking difference was noted at the 18 inch depth. Here the check and mulch paper treatments showed small differences throughout the entire season. The mulch paper and soil treatment ranged from 11 p.p.m. higher on April 23rd to 79.45 p.p.m. higher on June 24th. At no time during these two periods did the results show a lower nitrate content than the check or mulch plots.

On June 24th at a six inch depth nitrates with the mulch paper treatment were 18.81 p.p.m. higher than those in the check plot (3.10 p.p.m.) and the mulch paper and soil 156.26 p.p.m. higher than the check.

The reason for the lack of considerable differences in nitrates on June 24th at the 12 inch depth when such differences existed at six and 18 inches is a matter of conjecture. The mulch paper and soil did, however, show an increase of 10.52 p.p.m. over the mulch paper which in turn was 3.40 p.p.m. higher than the check (2.90 p.p.m.).

July 8th was the only time at which the mulch paper showed a significantly higher content. At this time it showed 11.75 p.p.m. higher than the mulch paper and soil (10.94 p.p.m.) and 18.43 p.p.m. higher than the check (4.26 p.p.m.). These figures refer to the 12 inch depth.

The sole case of the check plot showing a materially higher nitrate content occurred on August 1 at an 18 inch depth, when it rose to 24.2 p.p.m., or 8.3 p.p.m. above the mulch and soil treatment and 8.6 p.p.m. higher than the mulch (15.6 p.p.m.).

At the three depths studied only a slight difference existed on August 20 and September 15. All treatments revealed 10 p.p.m. or less of nitrate nitrogen.

Slight increases of nitrate content followed periods of higher moisture content as would be expected, but these increases were not great, nor were they consistent.

A seasonal average for the paper mulch and soil treatment for all depths down to 18 inches was 18.0 p.p.m. of nitrate nitrogen. Mulch paper treatments averaged 7.9 p.p.m. while check plots averaged only 5.52 p.p.m.

Effects of Mulch paper on Soil Moisture

One of the advantages claimed for mulch paper has been the conservation of moisture. Stewart,

Thomas and Horner (2) found this to be true under conditions in Hawaii in paper mulched soils planted to pineapples. Thompson and Platenius (12) found virtually the same thing in New York working with vegetable crops, as did Magruder (8) in Ohio.

In this experiment little difference in moisture existed between the mulch paper, mulch paper and soil and the check plots during April, May, August and September (See Figs. 5, 6, 7). During June and July, however, a slight increase was noted under the paper mulched soil. The average moisture content was highest under the mulch paper with 6.34 grams per 100 grams of soil. Mulch paper and soil followed with 6.21 grams while the check plot averaged 5.94 grams.

In view of the fact that the nitrate content did not follow the same trend, and that the seasons growth records did not indicate any marked increase, the moisture increase is not considered significant.

Soil Temperatures Under Mulch Treatments

Two series of temperature readings were made, the first on July 4, 5 and 6, the second on September 29 and 30. In both cases readings were taken at 6:00 A.M., 12:00 M, 4:00 P.M. and 9:00 P.M. The thermometers were placed on the south sides of the trees to avoid shading

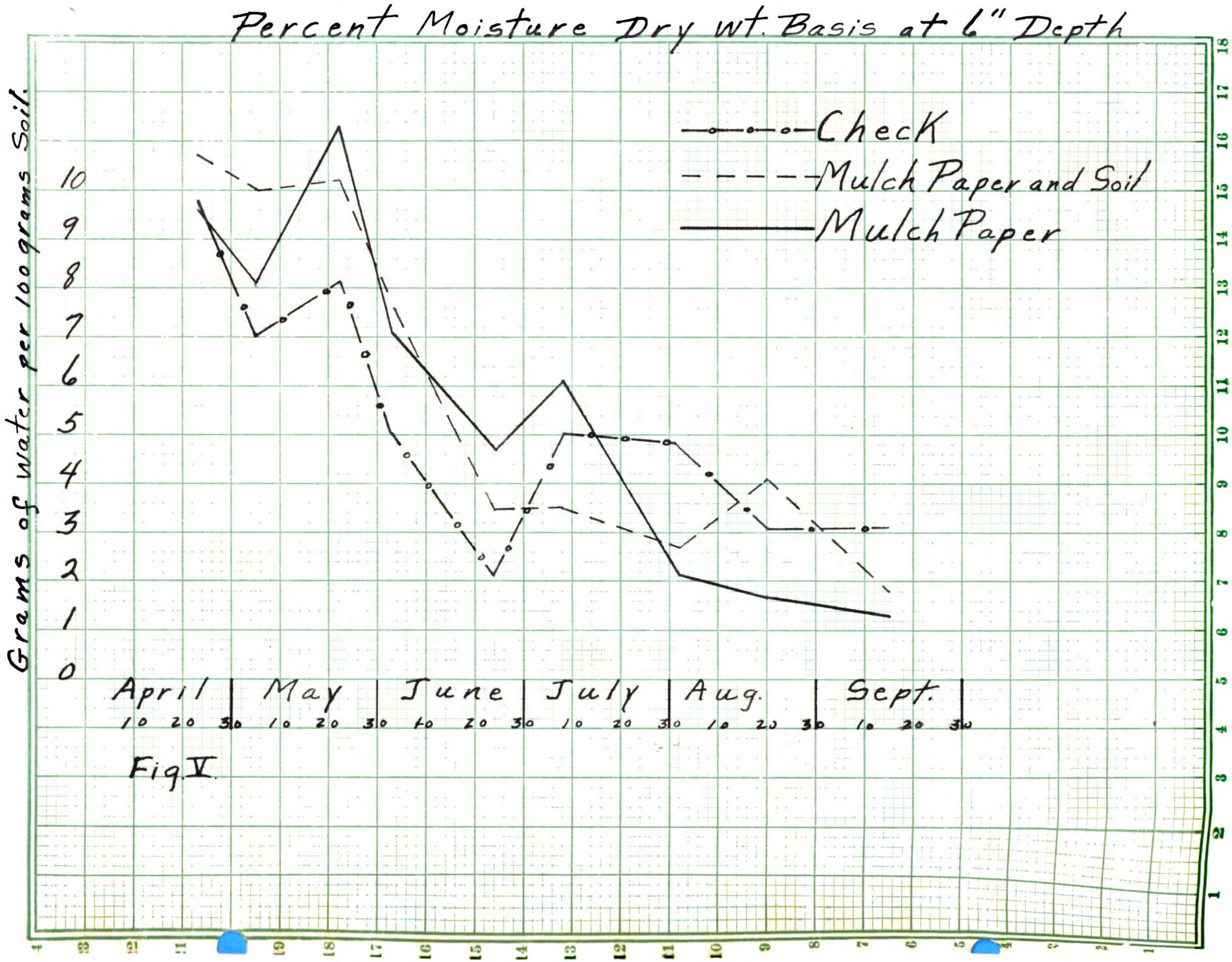

Percent Moisture Dry wt. Basis at 6" Depth
Grams of water per 100 grams Soil.
Check
Mulch Paper and Soil
Mulch Paper
0
1
2
3
4
5
6
7
8
9
10
April
May
June
July
Aug.
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Fig. V

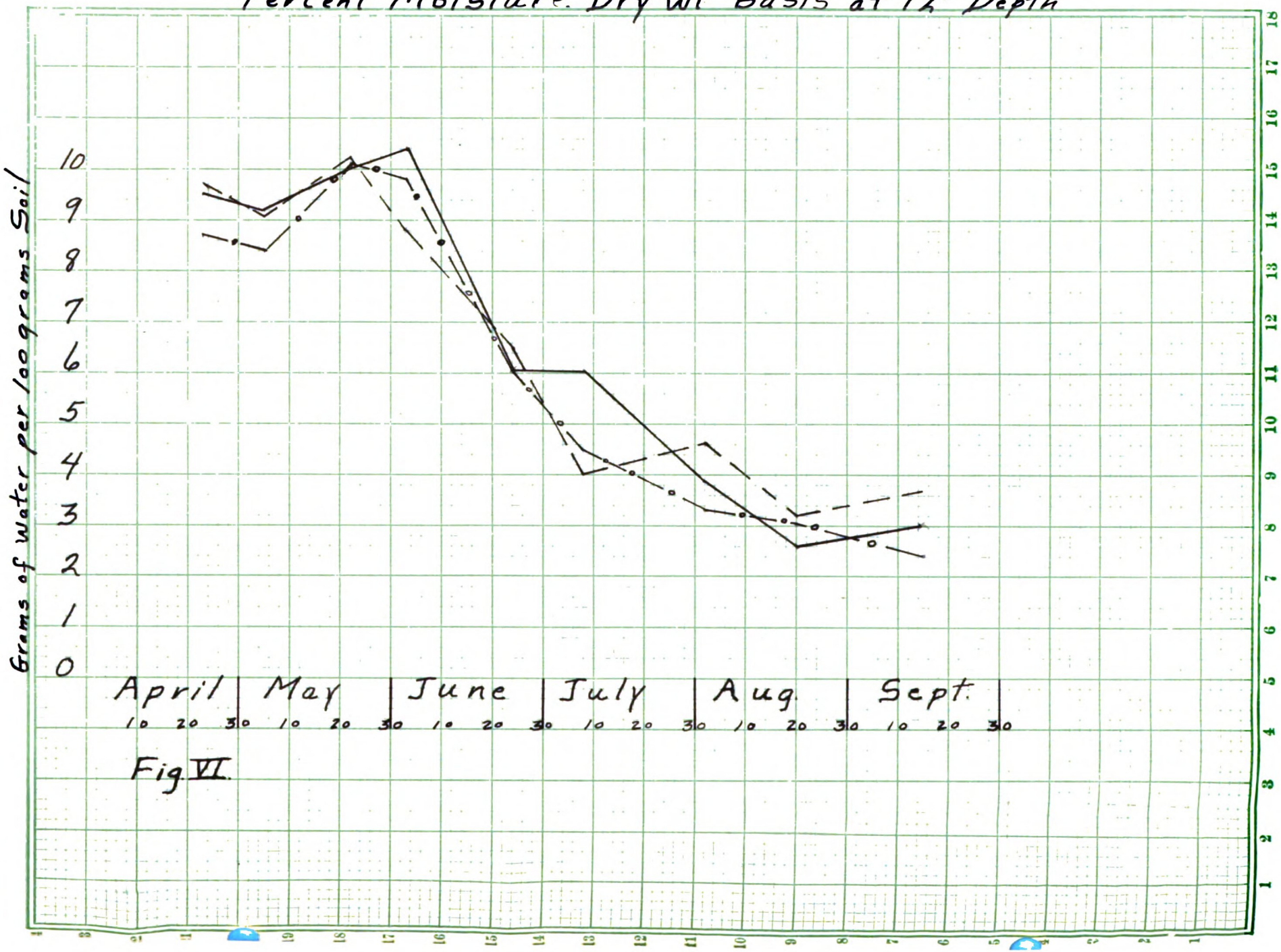
Percent Moisture. Dry wt Basis at 12" Depth
Grams of water per 100 grams Soil
0
1
2
3
4
5
6
7
8
9
10
April
May
June
July
Aug.
Sept.
10 20 30 10 20 30 10 20 30 10 20 30 10 20 30 10 20 30

Fig VI.

Percent Moisture Dry wt. Basis at 18" Depth.

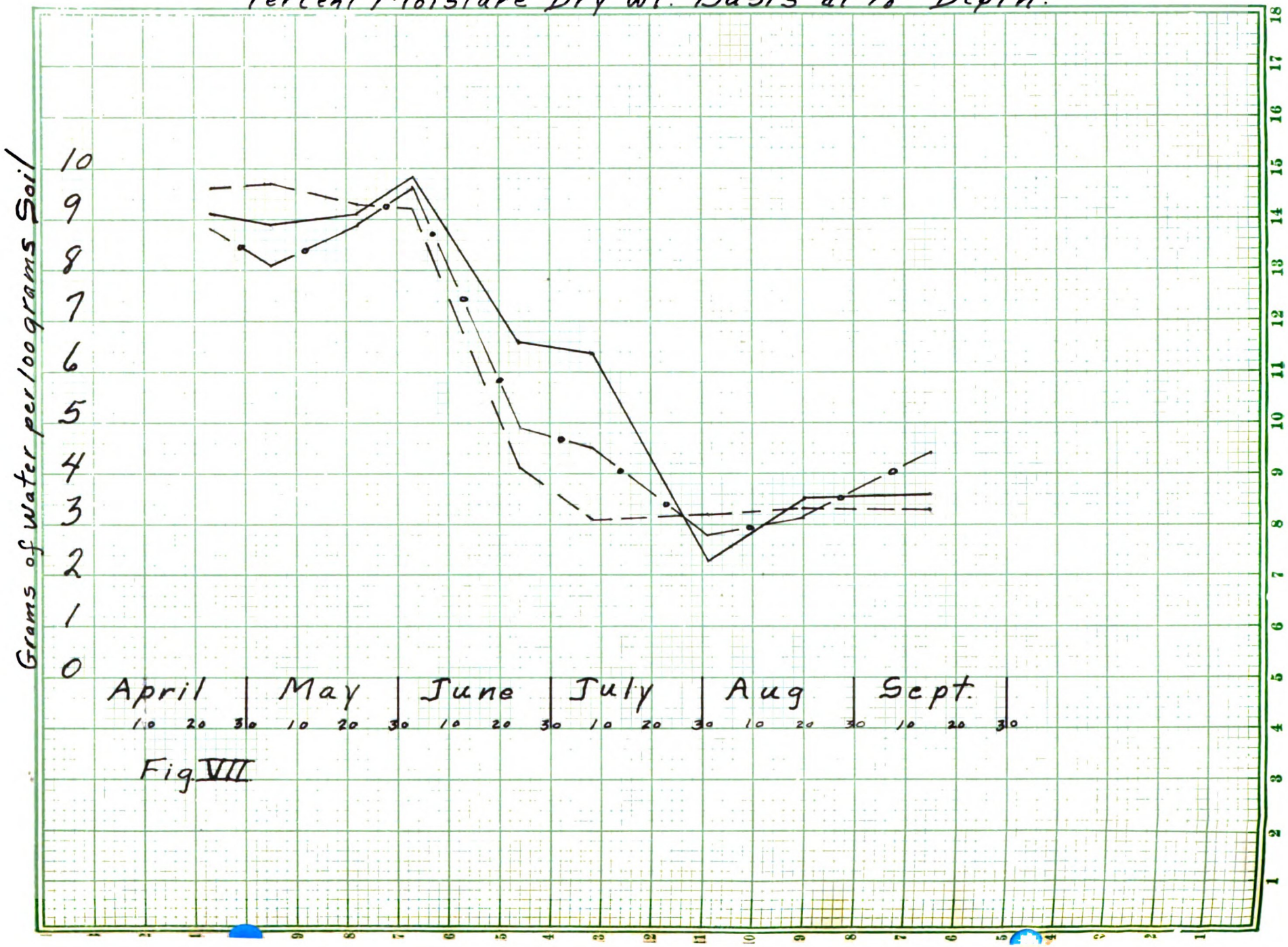

Fig VII

by the trees. They were placed at one inch, three inch, and six inch depths under each of the treatments and were corrected for accuracy.

Smith (3, 4) found that a bare plot under California conditions showed the highest temperature of any plot at one-half inch depth and that the bare plot at one-half inch depth averaged 10°F. warmer during the day and 5.6°F. cooler at night than a plot covered with perforated black paper. Stewart, Thomas and Horner (2) found higher soil temperatures under mulch paper.

The highest temperature in this experiment, 35°C., was found at a one inch depth under the mulch paper and soil treatment. This was on July 6, 1930 at 4:00 P.M. In most cases, however, at one inch depths at 4:00 P.M. the check plot temperatures were found to be slightly higher than the mulch paper and soil readings, which in turn were higher than the mulch paper. Maximum temperatures occurred consistently at 4:00 P.M. readings (see Table II).

At a three inch depth the mulch paper and soil temperature was highest for practically all readings. There were two exceptions, the first on September 29, 1930, at 4:00 P.M. in a check plot. A difference of 0.9°C. was found. The following morning at 6:00 A.M. the check plot reading was 0.3°C. higher and the mulch paper reading was 1.5°C. higher.

Table II
Soil Temperatures (°C) under Various Treatments at Different Times of the Day

Date	Treatment	Depth	6:00 A.M.	12:00 M	4:00 P.M.	9:00 P.M.	Average
July 4	Mulch	1 to 6in.	17.4	23.1	25.2	24.4	22.5
	Mulch and Soil	"	19.2	24.6	28.4	24.2	24.1
	Check	"	18.2	20.9	25.8	23.2	22.0
July 5	Mulch	"	18.1	20.9	24.8	22.8	21.6
	Mulch and Soil	"	22.9	22.9	27.9	23.6	24.3
	Check	"	18.4	20.9	25.7	22.8	21.9
July 6	Mulch	"	21.4	24.8	29.9	27.1	25.8
	Mulch and Soil	"	21.7	25.9	31.4	28.3	26.8
	Check	"	21.4	24.0	28.8	26.2	25.1
Sept. 29	Mulch	"	12.1	15.2	17.3	16.2	15.2
	Mulch and Soil	"	12.2	17.7	20.7	17.3	16.9
	Check	"	10.9	17.1	21.6	17.3	16.7
Sept. 30	Mulch	"	11.2	15.9	17.7	14.0	14.7
	Mulch and Soil	"	10.1	19.0	23.1	15.8	17.0
	Check	"	10.0	17.2	21.8	14.7	15.9

Average for five days Mulch 19.9°C.
" " " " Mulch and Soil 21.8°C.
" " " " Check 20.3°C.

Considerable variations in temperatures of the mulch paper and the check plots at this depth will allow no conclusions.

The six inch depth readings showed a higher average temperature under the mulch paper and soil treatment. The check treatment was second high with the mulch coming last.

The conclusions of Stewart, Thomas and Horner (2) indicated that the highest increase in soil temperature occurred under mulching paper in clear, bright weather. In this experiment the average highest temperature occurred under the mulch paper and soil treatment, with the check row next and the mulch treatment lowest.

There was a tendency for the soil temperature to subside rather slowly in the evening under the mulch paper and soil treatment. This was due, in all likelihood to the retention of the day's heat by the mulch paper and soil which acted as an insulator.

Growth Measurements of the Trees in the Mulch Paper Plots

Owing to the increased number and length of the branches of the trees at the close of the second year, only 60 of the original 168 trees were measured for linear branch growth. These measurements were taken from rows running crosswise to the treated rows so that the measurements would be representative for each plot.

Circumference measurements were taken on the entire group of 168 trees. Readings were taken to the nearest one-sixteenth of an inch. Table III indicates the growth results.

Table III

Linear growth in inches of Branches during 1930 Treatment

	Mulch	Mulch and Soil	Check
Plot I	4562	4951	2890
Plot II	3439	5040	4064
Plot III	3901	4440	3658
Plot IV	3642	4190	4729
Total	15544	18621	15341
Average growth per tree	277	332	274

Circumference Growth of Trees in inches During 1930 Treatment.

	Mulch	Mulch and Soil	Check
Plot I	17.56	21.94	17.44
Plot II	18.63	19.06	15.31
Plot III	14.31	13.88	16.50
Plot IV	17.81	17.12	18.50
Total	68.31	72.00	67.75
Average growth per tree	1.22	1.28	1.21

Upon the removal of the paper in October numerous mouse nests were found under the mulch paper treatment. None were found under the mulch paper and soil. The presence of these rodents would constitute a threat not to be taken lightly. During severe winter weather many trees would very likely be girdled unless the paper were removed in the fall.

Discussion

The question arises whether nitrate, moisture or temperature was responsible for the increased growth made by the trees undergoing the mulch paper and soil treatment. Apparently nitrate was the significant factor.

Despite greater growth and the consequent greater drain on nitrates, the accumulation under the mulch paper and soil more than offset the depletion by the trees. Very likely there was little, if any, leaching under either mulch treatment. During the 1930 season, which was admittedly dry, little or no leaching occurred in the check plot due to scanty rainfall. Nitrification was also probably retarded in the check plot due to lack of water. Soil temperature was presumably a more important factor than soil moisture.

It is questionable whether moisture was a limiting factor because the greatest moisture percentage was found under the mulch paper and the greatest nitrate content under the mulch paper and soil. The tree response seemed to indicate a higher correlation with nitrates than moisture.

Lack of difference between the mulch paper and soil and the check may indicate greater depletion under the mulch paper and soil due to increased growth, or that moisture was not the limiting factor in any of these cases,

or that higher nitrates in the mulch and soil lowered the water requirements of the tree. Therefore the experiment as presented here is not entirely conclusive as to the relative importance of nitrates and moisture. However, in view of the fact that these data were gathered in an abnormally dry season, when the check plots were drier, and the mulched plots were about as high in moisture as in a normal season, it would appear that moisture is secondary to nitrates in importance.

If this view of the importance of nitrates is correct, the question is resolved into a decision as to the cheaper method of securing high nitrates in the soil. The cost of paper mulching per tree was around 17 cents. It seems probable that adequate fertilization and cultivation would be somewhat cheaper.

Conclusions

1. No appreciable differences were found in the water content of the soils underlying the mulch paper, mulch paper and soil and the check plots.

2. Nitrate nitrogen present under various treatments indicated the highest percentage under the mulch paper and soil. The mulch paper was second and the check plot third.

3. Tree circumference increases averaged highest for the mulch paper and soil treatment during the 1929 and 1930

seasons. In 1929 the check row showed greater increase than the mulch paper. In 1930, however, the mulch was slightly higher than the check.

4. Linear branch growth of the trees showed greatest growth increases for the mulch paper and soil treatment for both seasons. The check plot was second in 1929 and third in 1930. The mulch paper treatment was, therefore, third in 1929 and second in 1930.

5. Temperature, down to a six inch depth averaged 21.8°C. for the five day period in 1930 in the mulch paper and soil treated soil. The check averaged 20.3°C. and the mulch paper 19.9°C.

6. Correlation between increased growth of the tree and nitrate content appeared to be greater in this experiment than correlation between increased growth and the moisture content or the temperature.

7. This study indicates that benefits arising from the use of mulch paper can be secured in other ways at lower costs.

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