# REJUVENATION OF AN OLD APPLE ORCHARD BY MEANS OF FERTILIZERS, MULCHES AND COVER CROPS

By

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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

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# REJUVENATION OF AN OLD APPLE ORCHARD BY MEANS OF FERTILIZERS, MULCHES AND COVER CROPS

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AN ABSTRACT

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Treatments which were designed to rejuvenate an old apple orchard included the use of three rates of fertilizer applications combined with straw and pea vine mulch plots and Ladino and bluegrass cover crop plots. Results were recorded in the field by means of shoot growth, trunk circumference and yield of the trees, and by weights of the cover crops. In the laboratory, dry weight, chlorophyll and nitrogen content, of the leaves were determined.

The higher fertilizer applications were effective in increasing trunk area, cover crop weights, leaf weight, nitrogen and chlorophyll content of the leaves, shoot growth and finally yield, in that relative order.

The effects on growth were in proportion to the amounts of fertilizer used.

The increase in leaf weight, leaf nitrogen and chlorophyll stimulated tree growth which in turn increased yield.

Among the mulch and cover crop treatments, pea vines were outstanding in their beneficial effect on tree performance. This effect was more apparent in the low than in the medium or high fertility plots.

A program of rejuvenation as conducted under the conditions of this experiment, would give temporary economic benefits. Over a long period of time, however, a tree removal and replanting program might be more profitable.

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# INTRODUCTION

In many large fruit growing sections of the country there are old apple orchards which fail to produce satisfactory yields, although the majority of them are situated in good locations and contain marketable varieties. Their low productive capacity may have been caused by low soil fertility, poor physical condition of the soil, or neglect of the trees themselves.

The owners of these orchards are faced with the problem of deciding whether to take out all of the old trees and replant the whole location or to give the old trees special treatments in order to restore their vigor and thus increase their fruit production. They must first decide whether the condition of the trees will respond to a rejuvenation program and, then, they must consider the cost of this procedure in relation to the cost of replanting and the loss of income until the trees come into bearing.

In any attempt to improve yields, it is first necessary to produce healthy vigorous trees. The trees must be pruned and there must be an adequate spray program to control insects and diseases. The physical condition and nutrient level of the soil must be suitable for optimum tree performance.

The present investigation was designed to rejuvenate an old apple orchard by improving the condition of the soil with the use of various mulches, cover crops and fertilizer treatments and at the same time to maintain the other needs of the trees. The first purpose was to find out to what extent cover crops and fertilizers would increase tree vigor and crop production. The second purpose was to determine if these treatments were financially sound or advisable.

## REVIEW OF LITERATURE

With the development of the fruit growing industry in the United States and in other countries, many older orchards of this early period began to decline in vigor and production. Thus many farmers and investigators were interested in rejuvenation programs. Ballou (3, 4, 5) described the poor conditions of orchards in Ohio in the early 1900's, and reported on the benefits that he obtained from using correct sprays and various combinations of fertilizers.

In reality, renovation and good orchard management practices do not differ greatly. According to Gould (16) these practices simply represent differences in the objects to be obtained and the manner in which the details are carried out; renovation is a more strenuous and more concentrated procedure, but it involves the same orchard management operations such as tillage or some substitute, fertilizing, pruning and insect and disease control.

Many "popular" or "semi-popular" articles and bulletins (1, 6, 7, 8, 10, 11, 12, 13, 14, 15, 18, 19, 20, 21, 22, 23, 24, 25) have been written on the subject of apple orchard rejuvenation. Some of these publications reported grower observations and gave detailed programs to improve the condition of the trees, others reported experimental projects, but none of the articles gave adequate evidence to substantiate the recommendations. The majority of the authors agreed, however, that the trees did not respond to treatment if they were very old or if their vitality had been reduced by neglect, pests or diseases. They also believed that no program was financially advisable unless the trees were located in a good situation as to air drainage, soil and climate and unless the variety was marketable.

# EXPERIMENTAL PROCEDURE

## Plot Layout and Application of Materials

The orchard selected for the current study was located on the Cumberland-Adams county line, just north of Idaville in south central Pennsylvania. The orchard was planted in 1908, and had not been cultivated for a number of years prior to 1946, the date when this experiment was started. The condition of the trees was very poor, although typical of many in the area. Numerous limbs were dead and needed cutting out. Terminal growth was in many cases negligible. Foliage was light and the leaves were small and poor in color. The trees shown in Figure 1 are characteristic of this condition.

The orchard site was excellent for air drainage. It was situated at an elevation of 1100 feet and overlooked most of the surrounding country. There was a gradual slope in the land from north to south and east to west.

The soil in this orchard was typical of that found in this section of the Blue Ridge Mountains.[1] It was an ashe silt loam derived from metamorphosed volcanic rock. The residual soil was from the metabasalt or greenstone and

1. Soil description made by R. C. Long, Soil Conservation Service, Gettysburg, Pa.

Figure 1. Typical tree when experiment was started. Note dieback of branches and sparse foliage.

epidote rock. This geological stratum of basic rock had been broken into small fragments which formed a moderately deep soil of good structure. The texture, that of a medium silt loam, was such that it eroded at only a moderate level. The available moisture holding capacity was high. It was well drained. The permeability of the subsoil and the substratum, or parent material, was moderate. The soil was slightly acid, pH between 5 and 6, and the inherent fertility was medium to low. Such a soil was considered to be particularly adapted to the culture of fruit trees.

Since there was a gradual slope in the orchard, the soil was not uniform. The more fertile soil was in the north, higher area, and the less fertile soil in the southwest, lower corner, where some erosion had occurred. The condition of the trees was related to the soil differences to a considerable extent which was taken into consideration when the plots were layed out.

Originally the orchard, which covered about 13 acres, contained 570 York Imperial apple trees. They were set 31 x 31 feet apart in 21 rows, the majority of the rows containing 28 trees. At the time this study was started, there were some trees missing and a few others had to be removed during the course of the study.

The plots for this experiment were laid out according to the diagram in Figure 2. Each plot contained from 9 to 12 trees, with the exception of one, which contained only 8.

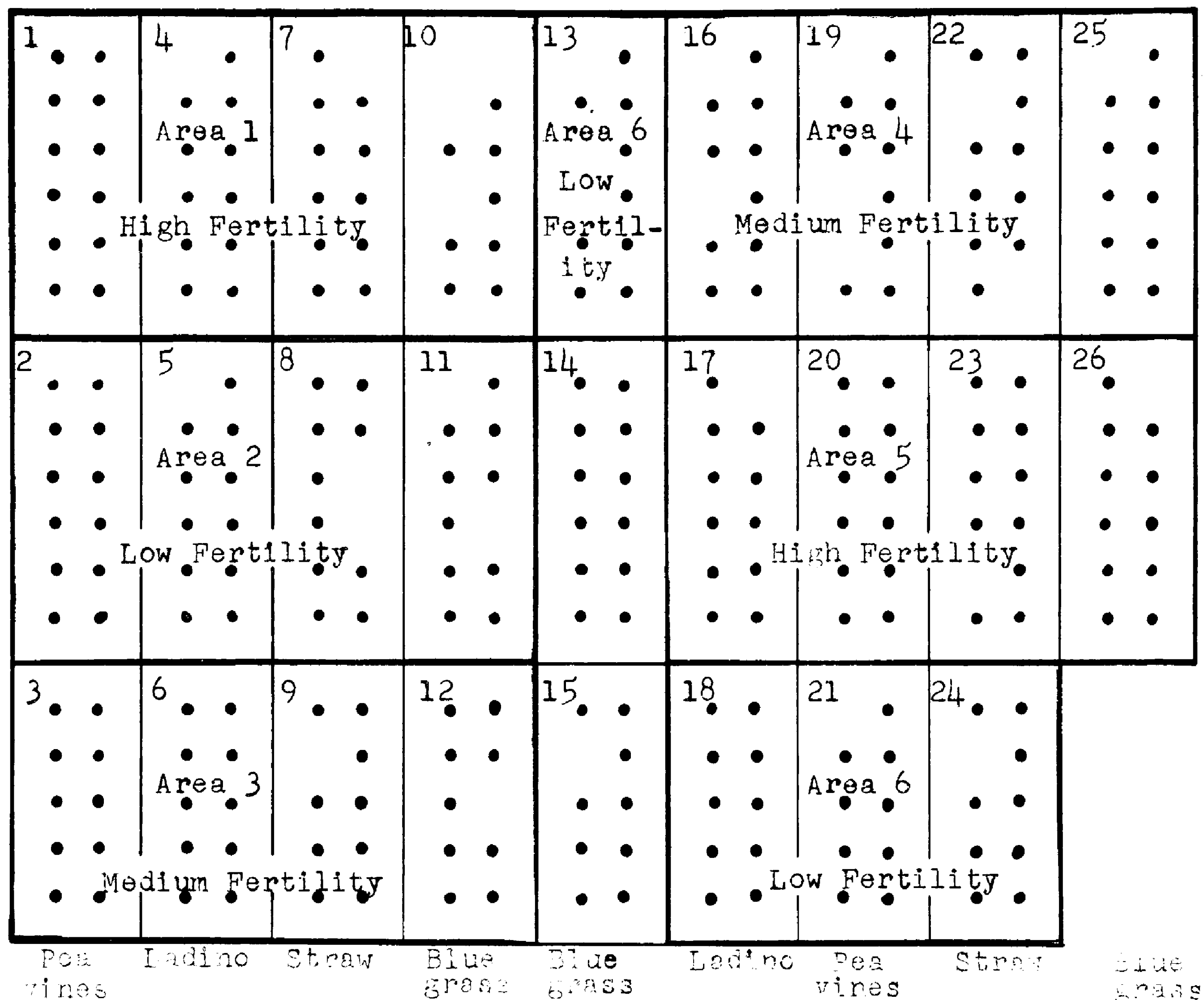


Figure 2. Diagram of tree planting and experimental plots used in the rejuvenation study.
(See pages 9 and 11 for details of the various treatments)

All plots were entirely surrounded by buffer trees. Pea vines and straw were used as mulching materials, while Ladino clover (Trifolium repens, L.) and bluegrass (Poa pratensis, L.) were used as cover crops. Within each of these treatments, there were three levels of fertility. Each sub-treatment was replicated once, making a total of 24 plots, which contained altogether 245 trees. There were from 19 to 24 trees for each of the treatments. Plots 14 and 15 were used for other purposes and were not included in this study.

The plot layout was based, as far as possible, on the size of the trees at the beginning of the experiments. Trunk circumference measurements were taken early in 1946, before any growth occurred. The average values for each plot, together with the probable error are shown in Table I. The data indicate that the smallest trees were located in the southwest corner, area 1, plots 1, 4, 7 and 10. Trees in the north half of the orchard were relatively uniform in size. On the basis of these measurements the orchard was divided from east to west, using the south portion as replicate 1 and the north as replicate 2.

This plan permitted replicating the treatments in such a way as to counteract soil variations as much as possible. Each half of the orchard was divided into three areas, one for each fertilizer treatment. Plot 13 was used instead of plot 15 to complete area 6 so as to keep plots 14 and 15 for

TABLE I

MEAN TRUNK CIRCUMFERENCE FOR PLOTS, AREAS AND FERTILITY TREATMENTS

| Plot | Number of trees | Average circumference (cm.) | Probable error |
|---|---|---|---|
| 1 | 12 | 89.6 | 3.17 |
| 4 | 11 | 95.7 | 2.17 |
| 7 | 11 | 86.6 | 3.08 |
| 10 | 8 | 101.9 | 1.77 |
| Area 1 | 42 | 92.8 | 1.46 |
| 2 | 12 | 111.6 | 2.68 |
| 5 | 11 | 106.1 | 2.18 |
| 8 | 10 | 99.5 | 2.25 |
| 11 | 10 | 105.0 | 2.04 |
| Area 2 | 43 | 105.9 | 1.20 |
| 3 | 10 | 114.6 | 1.54 |
| 6 | 10 | 111.9 | 2.43 |
| 9 | 9 | 116.1 | 2.43 |
| 12 | 9 | 109.2 | 2.49 |
| Area 3 | 38 | 113.0 | 1.11 |
| 16 | 10 | 97.1 | 2.88 |
| 19 | 9 | 101.9 | 1.92 |
| 22 | 10 | 103.6 | 2.24 |
| 25 | 11 | 100.1 | 2.43 |
| Area 4 | 40 | 100.6 | 1.20 |
| 17 | 11 | 98.6 | 1.99 |
| 20 | 12 | 99.2 | 2.62 |
| 23 | 11 | 102.5 | 1.45 |
| 26 | 11 | 100.6 | 1.62 |
| Area 5 | 45 | 100.2 | 0.98 |
| 13 | 9 | 102.7 | 1.72 |
| 18 | 10 | 109.0 | 1.87 |
| 21 | 9 | 97.7 | 3.96 |
| 24 | 9 | 108.1 | 1.68 |
| Area 6 | 37 | 104.4 | 1.62 |
| Fertility area | | | |
| High 1 and 5 | 87 | 96.6 | 0.90 |
| Medium 3 and 4 | 78 | 106.6 | 0.94 |
| Low 2 and 6 | 80 | 105.2 | 0.87 |

other studies. Table I also shows the circumference of the trees in each area. rea 1 had the smallest and area 3 the largest values. The figures for the other areas were relatively constant. The high fertility treatments were placed in areas 1 and 5, the average trunk circumference being 96.6 cm., the medium fertility treatments were placed in areas 3 and 4, the average trunk circumference of which was 106.6 cm., and the low fertility treatments were placed in areas 2 and 6, having an average trunk circumference of 105.2 cm. On this basis, the probable error was practically the same for each fertility level. Nevertheless, the high fertility treatments were on the poorest plots, giving an advantage to the lower fertility treatments. The mulch and cover crop treatments crossed the various fertilizer applications at right angles, Figure 2.

The pea vine and straw mulches were spread evenly over the entire tree square, except that they were kept about three feet away from the trunks. Pea vines were obtained from a vinery and were used at the rate of 10 tons per acre. Baled straw was used at the rate of five tons per acre. These rates provided approximately the same amount of dry material per acre. These two mulching materials were applied in 1946, 1947 and 1949. Pea vines were not obtainable in 1948, so neither mulch was added in that year.

The Ladino clover plots were given preliminary treatments prior to planting, in order to insure satisfactory growth of this cover. In 1946, these plots received manure at the rate of five tons per acre and were subsequently seeded to sweet clover. In 1947, the sweet clover was disked down and the plots seeded to Ladino clover at the rate of 1.5 pounds per acre. Oats, at the rate of 32 pounds per acre, were seeded along with the Ladino to act as a nurse crop.

The entire orchard was in bluegrass when the experiment was started. Therefore, this cover was already established.

The fertilizer treatments, which crossed over the mulch and cover crop treatments, contained nitrogen on a low, medium and high level. The grower made an overall application of five pounds of Cyanamid per tree in the late fall of 1945. The low fertility plots had no other fertilizer the first year. In addition to the Cyanamid, the medium and high fertility plots received 18.75 and 37.5 pounds, respectively, of a special fertilizer mixture, applied in the spring of 1946. In 1947 and subsequent years, Cyanamid was replaced by an overall application of five pounds of nitrate of soda and the special fertilizer was increased to 25 and 50 pounds per tree for the medium and high fertility plots, respectively. Lime at the rate of 1.5 tons per acre was applied to the entire orchard in March 1946.

The special fertilizer mixture is shown in Table II. It was formulated to give approximately a 10-10-10 fertilizer for the high fertility plots, considering the additional nitrogen fertilizer applied by the grower. It was

TABLE II

COMPOSITION OF THE SPECIAL MIXTURE FERTILIZER AND THE AMOUNTS OF THE VARIOUS INGREDIENTS USED PER TREE FOR THE DIFFERENT FERTILITY LEVELS

| Material | 1946 | | | | 1947-49 | | | |
|---|---|---|---|---|---|---|---|---|
| | Total (lbs) | N (lbs) | $P_2O_5$ (lbs) | $K_2O$ (lbs) | Total (lbs) | N (lbs) | $P_2O_5$ (lbs) | $K_2O$ (lbs) |
| **Special Mixture** | | | | | | | | |
| Uramon | 3.0 | 1.26 | | | 6.3 | 2.64 | | |
| $NaNO_3$ | 4.0 | 0.64 | | | 5.7 | 0.90 | | |
| $(NH_4)_2SO_4$ | 3.0 | 0.60 | | | 3.8 | 0.79 | | |
| Ammoniated super-phosphate (2.6-20-0) | 20.0 | 0.52 | 4.00 | | | | | |
| Super-phosphate | | | | | 25.7 | | 5.13 | |
| KCl | 6.5 | | | 3.90 | 8.5 | | | 5.13 |
| Borax | 1.0 | | | | | | | |
| Total | 37.5 | 3.02 | 4.00 | 3.90 | 50.0 | 4.33 | 5.13 | 5.13 |
| **Overall Material** | | | | | | | | |
| Cyanamid | 5.0 | 0.98 | | | | | | |
| $NaNO_3$ | | | | | 5.0 | 0.8 | | |
| **Total per Tree** | | | | | | | | |
| High fertility | 42.[illegible] | 4.00 | 4.00 | 3.90 | 55.0 | 5.13 | 5.13 | 5.13 |
| Medium fertility | 23.75 | 2.49 | 2.00 | 1.95 | 30.0 | 2.96 | 2.56 | 2.56 |
| Low fertility | [illegible] | .98 | | | 5.0 | 0.80 | | |
| **Percentage** | | | | | | | | |
| In special fertilizer | | 8.06 | 10.7 | 10.4 | | 8.67 | 10.27 | 10.27 |
| In special plus overall | | | | | | | | |
| High fertility | | 9.41 | 9.41 | 9.18 | | 9.33 | 9.33 | [illegible] |
| Medium fertility | | 10.48 | 9.42 | 8.21 | | 9.88 | [illegible] | [illegible] |

also designed to give a continuous supply of nitrogen throughout the growing season by the use of different forms of nitrogen. The first year, it contained four kinds of nitrogen: sodium nitrate, which readily releases its nitrogen; ammonium sulfate, which releases its nitrogen at a somewhat slower rate; Uramon; and ammoniated super phosphate, which release their nitrogen at an even slower rate. In the second and subsequent years, the ammoniated super phosphate was discontinued and regular 20 percent super phosphate used, the amount of the other nitrogenous chemicals being changed so that the formula would contain approximately the same total percentage of nitrogen. Borax was added the first year, but was discontinued in the following years. In the first year, the high fertility plots received 4.00 pounds each of nitrogen and $P_2O_5$ and 3.90 pounds of $K_2O$, and in the later years they received 5.13 pounds of each ingredient. The medium fertility plots received 2.49, 2.00 and 1.95 pounds of nitrogen, $P_2O_5$ and $K_2O$, respectively, the first year, and 2.96, 2.56 and 2.56 pounds of the same ingredients in the following years. The low fertility plots received only nitrogen at the rate of 0.98 pounds the first year and 0.80 pounds the subsequent years.

## Methods of Obtaining Data

The effects of the various fertilizer applications, mulches and cover crop treatments were recorded by measuring the yield of the cover crops and the performance of the trees. Tree performance was measured in terms of linear shoot growth, trunk circumference, yield and leaf response. The latter included leaf weight, nitrogen and chlorophyll determinations. As far as possible all data were subjected to statistical analyses.

The growth of bluegrass and Ladino clover crops was determined twice in each of the years 1947, 1948 and 1949. In the first two years, a one-yard square was marked off by means of a three sided "fork". All grass inside this square was cut off at ground level with a sickle and weighed in pounds. In 1949, the procedure was modified. A 31-foot strip one yard wide was cut with a sickle bar attached to a Gravely garden tractor. The cut cover was weighed and the results adjusted so as to be comparable to those in previous years. The results were expressed as fresh weight in tons per acre.

Shoot growth measurements were taken in the late summer after all terminal growth had been completed. In 1946, it was possible to measure this growth for the two preceding years. Thus the treatment responses could be compared to the previous performance of the trees. Shoots were selected on the basis of their position on the tree, which was divided into four quarters according to the four points of the compass. Within each quarter, terminals were used that were growing at an angle of 45° from the horizontal and which had made three years of non-branching growth. This procedure eliminated suckers and side shoots and has been shown by Wilcox (27) to be the most reliable procedure for measuring this type of growth. Twenty-five measurements were taken on each tree, distributed as evenly as possible in the four quarters of the tree. The average of these measurements represented the vigor of the tree and gave the annual shoot growth.

Trunk circumference measurements were taken at the end of the growing season after the leaves had fallen and the trees had completed trunk growth for the year. They were made at a mark one foot above ground level by means of a steel tape. Trunk area was calculated from trunk circumference measurements. A comparison of the actual growth increases per year did not give valid results because of initial variation in tree size. In order to compensate for this original difference in size, the annual increase each year was expressed as the percentage of the 1945 value.

During 1949, an intensive study was made on the leaves during the entire growing season. Total leaf weight, chlorophyll and nitrogen measurements were made four times during the season, on June 7, August 1, September 15 and October 13.

The samples for chemical analyses were collected from two representative trees in each plot. Seventy-five leaves per tree were selected from the mid-section of the current season's terminal growth. They were collected in the morning, placed out of the light in brown paper bags and brought into the laboratory.

Leaf weight measurements were determined on a dry weight basis. The 50 leaves used for chlorophyll determination, plus an additional 25 leaves were dried in paper bags in a constant temperature oven at 65° C. The samples were cooled in a dessicator, and weighed, as rapidly as possible, on a Tripp balance. Speed was necessary in order to eliminate water absorption by the leaves. The dry weight of the 200 disks, taken for chlorophyll samples was 0.433 mg. This correction was added to the total weight before determining the average leaf weight. The values were expressed as mg. per leaf.

Chlorophyll was determined according to the method described by Compton and Boynton (9). Two disks, $\frac{1}{4}$ inch in diameter, were taken from one side of 50 leaves and transferred to an amber glass bottle containing 30 ml. of 95 percent ethyl alcohol. A duplicate sample was taken from the other side of the same 50 leaves. The following morning the amount of chlorophyll was determined in a Klett-Summerson photoelectric colorimeter, using a red filter having an approximate spectral range of 640 - 700 millimicrons. Any color in the original alcohol was compensated by placing alcohol in the solution cell and adjusting the colorimeter to the zero position before each reading of the unknown. The colorimeter was calibrated with a standard solution containing a known amount of chlorophyll. This solution was obtained by determining the total chlorophyll content in a Coleman Universal Spectrophotometer, using the A.O.A.C. method (2).[1] The values were expressed as milligrams of total chlorophyll per 100 square centimeters of leaf area.

Total nitrogen was determined on the dried leaves. The samples were ground in a Wiley cutting mill using a 40-mesh sieve and stored in amber glass bottles. Nitrogen was determined by the official Kjeldahl-Gunning method (2) and the values were expressed as percentage of nitrogen in the dry leaf weight and as milligrams of nitrogen per leaf.

Yield records were taken each year, and were expressed as total bushels per tree, which included the drops as well as the picked fruit. The dropped fruit was picked up and measured after the picked fruit had been removed from the orchard.

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1. The standard solution was analyzed in the Plant Nutrition Laboratory at the Pennsylvania State College, by Joseph Wetzler.

# RESULTS

## Cover Crop Weights

The weights of the Ladino and bluegrass cover crops expressed as fresh weight in tons per acre are shown in Table III.

There was a definite relationship between the amount of fertilizer applied and the weight of the cover crop produced in both covers and in all three years. It will be noted that there was a much larger difference between the low and the medium fertility plot values than between those for the medium and high fertility plots, Figure 3. This may be explained by the fact that the low fertility plots received no phosphorus and potassium in their fertilizer treatments. Since cover crops need these nutrients for the best utilization of available nitrogen, the covers in the low fertility plots were hindered in their development. The addition of phosphorus and potassium with adequate amounts of nitrogen in the medium fertility plots, greatly stimulated the growth of both the Ladino and the bluegrass plots. Doubling the amount of fertilizer application as in the high fertility plots had only a slight effect in increasing the production of the cover crops. The Ladino produced considerably more vegetation as measured by weight

TABLE III

WEIGHT OF COVER CROP CLIPPINGS AS RELATED TO FERTILIZER APPLICATIONS EXPRESSED AS FRESH WEIGHT IN TONS PER ACRE

| Cover crop | Fertility level | 1947 | 1948 | 1949 | Total | Average |
|---|---|---|---|---|---|---|
| Ladino | High | 18.79 | 28.07 | 11.46 | 59.32 | 19.77 |
| | Medium | 18.19 | 23.78 | 11.20 | 53.17 | 17.72 |
| | Low | 12.57 | 10.89 | 3.29 | 26.75 | 8.92 |
| Bluegrass | High | 14.28 | 12.32 | 9.42 | 36.02 | 12.00 |
| | Medium | 11.52 | 11.92 | 8.33 | 31.77 | 10.59 |
| | Low | 5.03 | 9.37 | 2.99 | 17.39 | 5.79 |

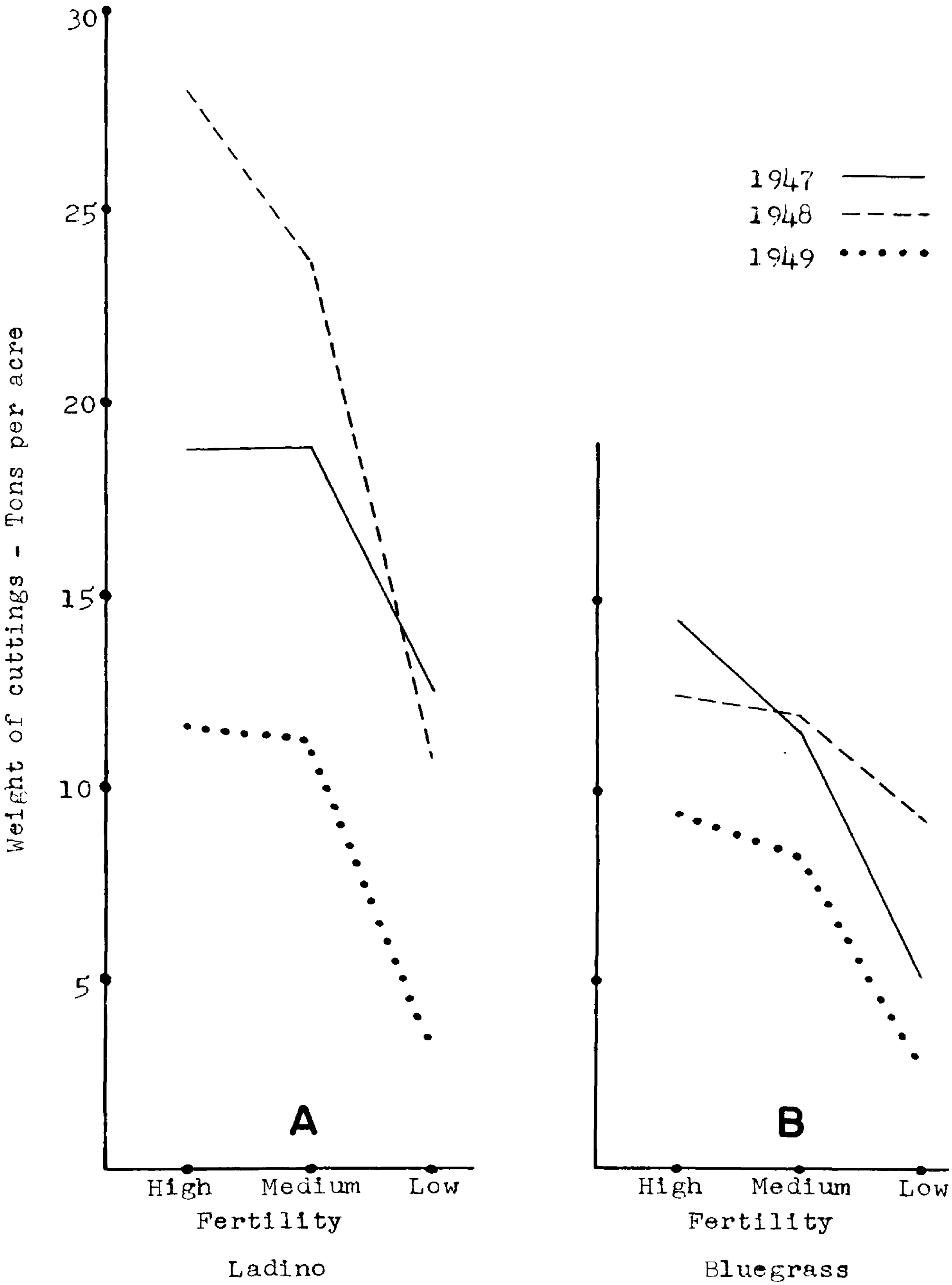


Figure 3. Weight of two cuttings of cover crops in each year in relation to fertility levels and years of sampling.

of clippings than the bluegrass under similar conditions. However, this may have been due to the fact that the high fertility had stimulated the growth of grasses more than the medium level of fertility. This additional growth of grasses, in a large measure, accounted for the greater production of clippings from the Ladino plots receiving the high level of fertilizers.

These data bring out the fact that an early effect of the fertilizer application may be noted in the cover crop response, which will eventually improve the condition of the soil. In turn, this should provide better growing conditions for the trees.

## Tree Growth

### Shoot Growth

Table IV shows shoot growth linear measurements from 1944 to 1949, expressed as average values per tree, and tabulated according to fertilizer, mulch and cover crop applications each year. It also gives the average values for the various treatments and the least significant differences.

The average shoot growth data for all trees show that, before the study started, the trees were rapidly declining in vigor and that the experimental treatments checked the decline, finally producing an increase in the fourth year. The average growth for all treatments in 1944 was 7.35 cm.

TABLE IV

ANNUAL LINEAR SHOOT GROWTH IN RELATION TO FERTILITY LEVELS AND GROUND COVERS, EXPRESSED AS CENTIMETERS PER TREE

| Fertility level | Ground cover | 1944 | 1945 | 1946 | 1947 | 1948 | 1949 | Average |
|---|---|---|---|---|---|---|---|---|
| High | Pea vine | 7.12 | 5.21 | 3.41 | 3.47 | 3.29 | 4.80 | 3.74 |
| | Straw | 7.21 | 6.00 | 3.52 | 3.70 | 2.66 | 4.99 | 3.72 |
| | Ladino | 7.52 | 5.76 | 3.87 | 3.22 | 3.25 | 4.77 | 3.78 |
| | Bluegrass | 9.96 | 7.86 | 5.08 | 5.00 | 3.84 | 5.74 | 4.91 |
| | Average | 7.87 | 6.13 | 3.92 | 3.80 | 3.24 | 5.05 | 4.00 |
| Medium | Pea vine | 5.32 | 4.43 | 2.77 | 2.29 | 2.23 | 2.88 | 2.54 |
| | Straw | 6.31 | 5.13 | 3.47 | 3.71 | 2.25 | 3.27 | 3.17 |
| | Ladino | 6.58 | 5.00 | 3.24 | 2.92 | 2.55 | 2.95 | 2.91 |
| | Bluegrass | 8.10 | 6.12 | 4.18 | 3.54 | 2.61 | 3.70 | 3.51 |
| | Average | 6.60 | 5.18 | 3.42 | 3.12 | 2.41 | 3.20 | 3.04 |
| Low | Pea vine | 7.88 | 6.33 | 4.75 | 4.18 | 2.76 | 3.32 | 3.75 |
| | Straw | 8.07 | 6.07 | 3.84 | 3.24 | 2.09 | 2.32 | 2.87 |
| | Ladino | 7.54 | 6.37 | 4.08 | 3.09 | 2.72 | 2.36 | 3.06 |
| | Bluegrass | 6.58 | 6.21 | 3.72 | 2.32 | 1.56 | 1.63 | 2.31 |
| | Average | 7.53 | 6.25 | 4.11 | 3.23 | 2.30 | 2.43 | 3.02 |
| Total | Pea vine | 6.84 | 5.35 | 3.66 | 3.36 | 2.80 | 3.74 | 3.39 |
| | Straw | 7.20 | 5.75 | 3.61 | 3.56 | 2.35 | 3.60 | 3.28 |
| | Ladino | 7.23 | 5.72 | 3.74 | 3.08 | 2.85 | 3.39 | 3.26 |
| | Bluegrass | 8.21 | 6.72 | 4.32 | 3.52 | 2.57 | 3.69 | 3.57 |
| All | Average | 7.35 | 5.87 | 3.83 | 3.40 | 2.67 | 3.60 | 3.37 |

| | Fertility | Year | Cover |
|---|---|---|---|
| L.S.D. 5% | 0.487 | 0.562 | 0.562 |
| 1% | 0.644 | 0.744 | 0.744 |

and by 1948 had declined to 2.67 cm. The greatest reduction in shoot growth occurred before the experimental treatments had had time to influence the results, the values being 5.87 in 1945 and 3.83 in 1946. Analysis of variance on the data from 1946 to 1949 showed that there was no significant difference between the 1946 and 1947 values, but that the reduction in 1948 and the increase in 1949 were both significant at the one percent level. The average figures, however, show only the general trends and mask the effects of the various fertilizers, mulch and cover crop treatments.

Shoot growth response after 1946, varied in relation to the amount of fertilizer applied. The average values for the 1946-1949 period were 4.00, 3.04 and 3.02 cm. for the high, medium and low fertility levels, respectively. The value for the high fertility was significantly greater than those on the medium and low fertility levels even at the one percent level. There was, however, no significant difference between the figures for the medium and low levels.

Mulch and cover crop treatments produced some slight differences in shoot growth, but they were less pronounced than those caused by the fertilizer applications. The average values for the four cover treatments were practically the same, 3.39, 3.28, 3.26 and 3.57 for the pea vine and straw mulch and for the Ladino and bluegrass cover crops, respectively. These differences were not significant.

In order to minimize original differences in tree size, shoot growth was expressed in percentage of the 1944 values, see Table V and Figure 4. Although the percentages showed the same trends as the figures for actual growth, they made several facts more evident. In the first place, they showed clearly that the trees in the three fertility plots were losing vigor at the same rate when the study started. The 1946 shoot growth measurements were quite similar, representing 49.8, 51.9 and 54.7 percent of the 1944 values for the high, medium and low fertility, respectively (Figure 4A).

In the second place, the percentage figures showed more clearly the effect of the three fertility levels. By 1947, the high fertility treatment had checked the percentage reduction in shoot growth, the medium fertility had reduced it to some extent, but the low fertility had not altered the downward trend. Although shoot growth was smaller on all trees in 1948, the percentage values showed the definite relationship between the three fertility levels. Finally in 1949, shoot growth in the high fertility plots represented 64.1 percent of the 1944 values, those on the medium fertility plots represented 48.6 percent, while those in the low fertility plots represented only 32.3 percent of the 1944 shoot growth.

Although there were no significant differences between the centimeters of actual growth for the ground cover treatments

TABLE V

ANNUAL LINEAR SHOOT GROWTH IN RELATION TO FERTILITY LEVELS
AND GROUND COVERS, EXPRESSED AS PERCENTAGE OF THE 1944 VALUES

| Fertility level | Ground cover | 1945 | 1946 | 1947 | 1948 | 1949 | Average |
|---|---|---|---|---|---|---|---|
| High | Pea vine | 73.2 | 47.9 | 48.[illegible] | [illegible] | 67.4 | [illegible] |
| | Straw | 82.2 | 48.2 | 51.3 | 31.2 | [illegible] | [illegible] |
| | Ladino | 76.6 | 53.4 | 42.8 | 43.1 | 65.4 | 50.2 |
| | Bluegrass | 78.9 | 51.0 | 50.2 | 38.6 | 57.[illegible] | 45.3 |
| | Average | 77.9 | 49.8 | 48.3 | 41.2 | 64.1 | 50.9 |
| Medium | Pea vine | 83.3 | 52.1 | 43.0 | 41.9 | 54.1 | 47.8 |
| | Straw | 81.3 | 55.0 | 58.7 | 35.7 | 51.5 | 50.[illegible] |
| | Ladino | 76.0 | 49.3 | 44.4 | 38.7 | 44.8 | 44.3 |
| | Bluegrass | 75.6 | 51.6 | 43.6 | 32.2 | 45.7 | 43.3 |
| | Average | 78.5 | 51.9 | 47.2 | 36.6 | 48.6 | 46.1 |
| Low | Pea vine | 86.3 | 60.3 | 53.1 | 35.0 | 42.1 | [illegible] |
| | Straw | 71.2 | 47.6 | 40.2 | 25.9 | 28.7 | 35.6 |
| | Ladino | 84.5 | 54.1 | 40.9 | 33.0 | 31.3 | [illegible] |
| | Bluegrass | 94.5 | 56.5 | 35.2 | 23.7 | 24.8 | 35.1 |
| | Average | 83.0 | 54.7 | 42.9 | 30.6 | 32.3 | 40.1 |
| Total | Pea vine | 78.2 | 53.6 | 49.2 | 40.9 | 54.8 | [illegible] |
| | Straw | 79.8 | 50.1 | 40.4 | 32.6 | 50.0 | 45.5 |
| | Ladino | 79.2 | 51.7 | 42.6 | 39.4 | 46.9 | 45.2 |
| | Bluegrass | 81.9 | 52.6 | 44.0 | 32.5 | 44.9 | [illegible] |
| All | Average | 79.8 | 52.0 | 46.2 | 36.3 | 49.0 | 48.9 |

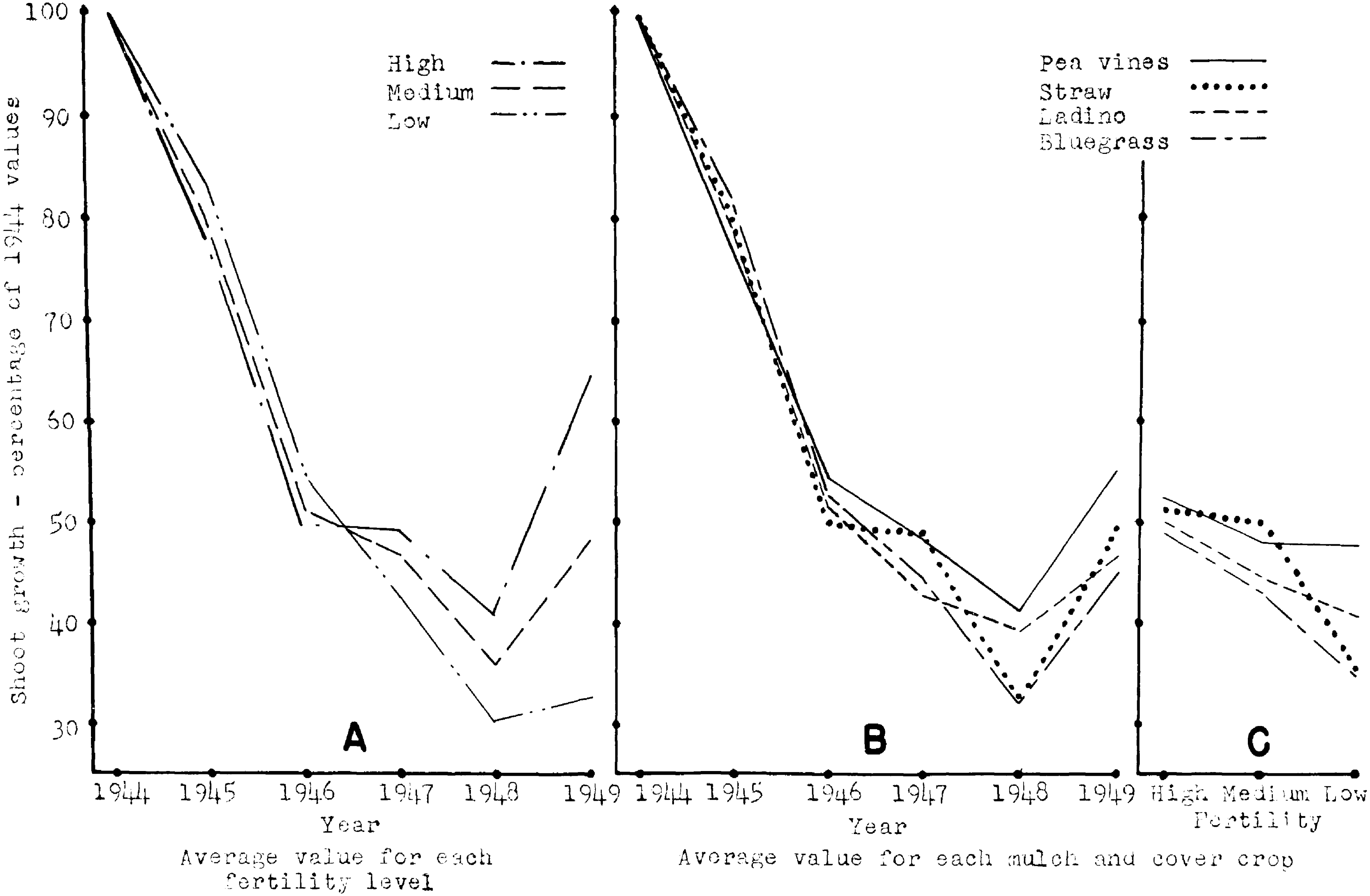


Figure 4. Relative shoot growth as influenced by fertility levels and ground covers.

by 1949, the percentage increase indicated somewhat superior growth in the plots having the pea vine mulch. Figure 4B shows that the shoot growth for all trees receiving pea vine mulch represented a slightly higher percentage of the 1944 values, each year, than did the average values for the other covers. Figure 4C shows that this superior shoot growth of trees in the pea vine plots was particularly evident in the low fertility level, the values representing 42.1 percent of the 1944 figures. On this same level, the trees in the Ladino plots represented 31.3 percent while those for straw and bluegrass represented only 28.7 and 24.8 percent, respectively. Thus the effect of the materials supplying nitrogen was more evident on the low than on the other fertility levels.

Trunk Cross Section Area

The annual average trunk cross section area per tree for each treatment is shown in Table VI. These data, while showing the actual values, do not consider the differences in tree size at the beginning of the experiment. For example, the trees in the high fertility plots had an average area of 755.4 sq. cm. at the beginning of the study, while those in the medium and low fertility plots had average areas of 917.1 and 891.7 sq. cm., respectively. Although the trees in the high fertility plots made good growth, they were still smaller than the others at the end of the study. Thus, it

TABLE VI

ANNUAL TRUNK CROSS SECTION AREA PER TREE, ACCORDING TO THE VARIOUS FERTILITY LEVELS AND GROUND COVERS

| Fertility level | Ground cover | 1945 | 1946 | 1947 | 1948 | 1949 |
|---|---|---|---|---|---|---|
| | | | | (sq. cm.) | | |
| High | Pea vine | 726.8 | 745.7 | 783.8 | 817.2 | 836.5 |
| | Straw | 727.4 | 743.8 | 775.9 | 809.8 | 826.9 |
| | Ladino | 759.3 | 777.0 | 806.6 | 844.6 | 861.1 |
| | Bluegrass | 819.4 | 843.4 | 866.3 | 917.5 | 938.6 |
| | Average | 75[illegible].4 | 774.5 | 808.3 | 844.2 | 862.6 |
| Medium | Pea vine | 946.0 | 962.8 | 994.2 | 1027.5 | 1044.8 |
| | Straw | 965.2 | 984.3 | 1022.9 | 1067.2 | 1085.0 |
| | Ladino | 881.8 | 903.4 | 940.7 | 968.7 | 986.6 |
| | Bluegrass | 875.5 | 898.0 | 932.5 | 972.2 | 992.4 |
| | Average | 917.1 | 936.2 | 970.6 | 1007.4 | 1026.3 |
| Low | Pea vine | 909.2 | 930.2 | 965.5 | 999.3 | 1015.0 |
| | Straw | 861.6 | 876.6 | 906.3 | 932.9 | 949.2 |
| | Ladino | 925.8 | 943.8 | 981.6 | 1019.5 | 1034.1 |
| | Bluegrass | 864.8 | 880.4 | 905.4 | 930.6 | 943.4 |
| | Average | 891.7 | 909.2 | 941.4 | 972.6 | 987.4 |

was necessary to express the effect of the various experimental treatments by some other measure. After testing several methods of expressing trunk size increase, it was found that the percentage increase in trunk area each year reduced the effect of the original trunk area and showed the most consistent relationships to the treatments.

Table VII gives the average percentage increase per tree in the trunk cross section area tabulated according to mulch, cover crop and fertilizer applications. It also gives the least significant differences between the values.

Although there were considerable differences in annual growth during the four years, the growth was related to the amount of fertilizer used. Even in the first growing season, the trees in the low fertility plots showed inferior growth and those in the high fertility plots grew at the most rapid rate. The average percentage increases over the four year period were 3.55 for the high, 2.98 for the medium and 2.68 for the low fertility plots. Statistical evaluation showed that there was a significant difference at the one percent level between the percentage increases for the high and medium fertility levels, but only at the five percent level between the medium and low fertility treatments.

The average percentage increase in trunk area for all trees showed that there was an annual variation in growth. During the first three years, when there was very little fruit production, the percentage increase was larger each

TABLE VII

TRUNK CROSS SECTION AREA EXPRESSED AS AVERAGE PERCENTAGE INCREASE PER TREE, ACCORDING TO THE VARIOUS FERTILITY LEVELS AND GROUND COVERS

| Fertility level | Ground cover | 1946 | 1947 | 1948 | 1949 | Average |
|---|---|---|---|---|---|---|
| High | Pea vine | 2.60 | 4.97 | 4.37 | 2.66 | 3.77 |
| | Straw | 2.26 | 4.54 | 4.52 | 2.35 | 3.42 |
| | Ladino | 2.34 | 3.89 | 5.01 | 2.18 | 3.40 |
| | Bluegrass | 2.94 | 4.49 | 4.55 | 2.57 | 3.64 |
| | Average | 2.53 | 4.48 | 4.74 | 2.44 | 3.55 |
| Medium | Pea vine | 1.77 | 3.32 | 3.31 | 2.04 | 2.61 |
| | Straw | 1.90 | 4.10 | 4.49 | 1.85 | 3.08 |
| | Ladino | 2.10 | 3.65 | 3.72 | 2.03 | 2.87 |
| | Bluegrass | 2.57 | 3.95 | 4.53 | 2.30 | 3.34 |
| | Average | 2.08 | 3.75 | 4.02 | 2.05 | 2.98 |
| Low | Pea vine | 2.31 | 3.83 | 3.71 | 1.73 | 2.91 |
| | Straw | 1.74 | 3.45 | 3.09 | 1.39 | 2.54 |
| | Ladino | 1.95 | 4.08 | 4.09 | 1.58 | 2.93 |
| | Bluegrass | 1.81 | 2.89 | 2.94 | 1.45 | 2.27 |
| | Average | 1.96 | 3.61 | 3.50 | 1.66 | 2.68 |
| Total | Pea vine | 2.23 | 4.06 | 3.96 | 2.14 | 3.10 |
| | Straw | 1.97 | 4.03 | 4.09 | 2.08 | 3.08 |
| | Ladino | 2.13 | 3.37 | 4.28 | 1.93 | 3.07 |
| | Bluegrass | 2.44 | 3.78 | 4.01 | 2.11 | 3.08 |
| All | Average | 2.21 | 3.93 | 4.09 | 2.04 | 3.07 |

| | Fertility | Years | Covers |
|---|---|---|---|
| L.S.D. 5% | 0.305 | 0.363 | 0.363 |
| 1% | 0.403 | 0.480 | 0.480 |

year, but in the fourth year the percentage growth decreased. The difference between the values for the first and second years was significantly higher at the one percent level and the decrease between the third and fourth years was significantly lower at the same level. The cumulative data in Figure 5A show how the differences between the three fertility levels increased as the fertilizer effect built up, the range between the high, medium and low becoming greater each year.

The mulch and cover crop treatments had little effect on the percentage of trunk area increase except in the low fertility plots, Figure 5B. Here, as also noted for shoot growth measurements, the two covers supplying nitrogen, Ladino and pea vines, produced percentage increases of 2.93 and 2.91, respectively. These values were higher than the 2.54 percent for the straw and the 2.27 percent for the bluegrass. Thus the data indicate that the two legume and the two non-legume materials were associated rather than the two mulch and the two cover crops. The average values for each of the ground cover treatments mask the variations and thus they were not significantly different.

## Leaf Growth and Composition

### Leaf Weight, Chlorophyll and Nitrogen Data in 1947

The data for leaf weight, chlorophyll and nitrogen are presented in Table VIII and Figure 6. The table gives the

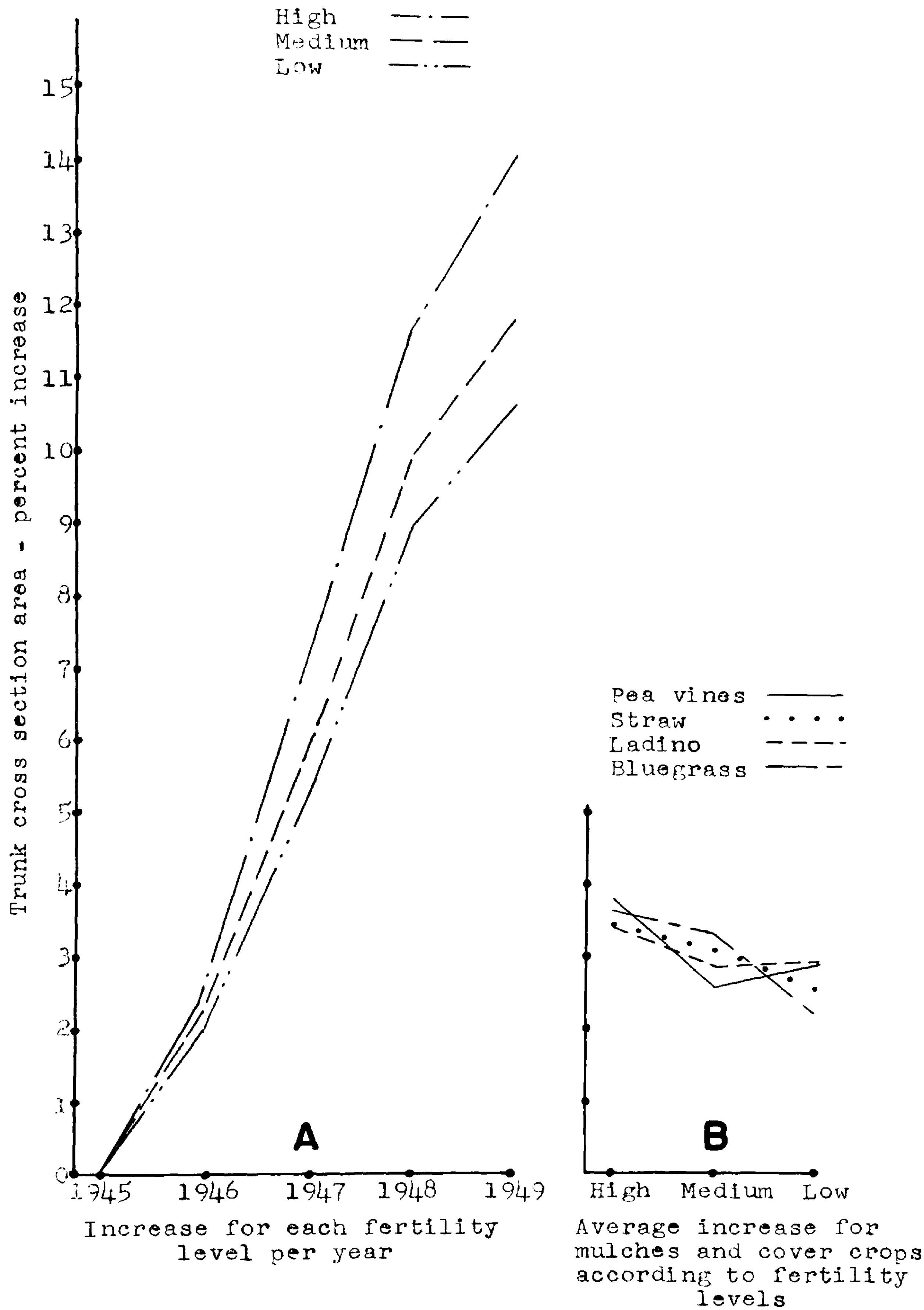


Figure 5. Percentage increase in trunk cross section area in relation to fertility levels and ground covers.

TABLE VIII

LEAF WEIGHT, CHLOROPHYLL AND NITROGEN VALUES FOR 1947
ACCORDING TO FERTILITY LEVELS AND GROUND COVERS

| Fertility level | Ground cover | Weight per leaf (mg.) | Chlorophyll (mg./100 sq. cm.) | Total nitrogen (percent) |
|---|---|---|---|---|
| High | Pea vine | 125.0 | 1.36 | 1.54 |
| | Straw | 153.7 | 1.43 | 1.65 |
| | Ladino | 151.4 | 1.32 | 1.61 |
| | Bluegrass | 127.2 | 1.10 | 1.52 |
| | Average | 139.3 | 1.30 | 1.58 |
| Medium | Pea vine | 125.9 | 1.18 | 1.43 |
| | Straw | 135.8 | 1.12 | 1.64 |
| | Ladino | 129.9 | 0.96 | 1.49 |
| | Bluegrass | 142.0 | 0.99 | 1.57 |
| | Average | 133.4 | 1.06 | 1.54 |
| Low | Pea vine | 113.9 | 1.07 | 1.47 |
| | Straw | 113.3 | 0.95 | 1.38 |
| | Ladino | 136.5 | 0.87 | 1.47 |
| | Bluegrass | 95.9 | 0.78 | 1.29 |
| | Average | 114.9 | 0.92 | 1.41 |

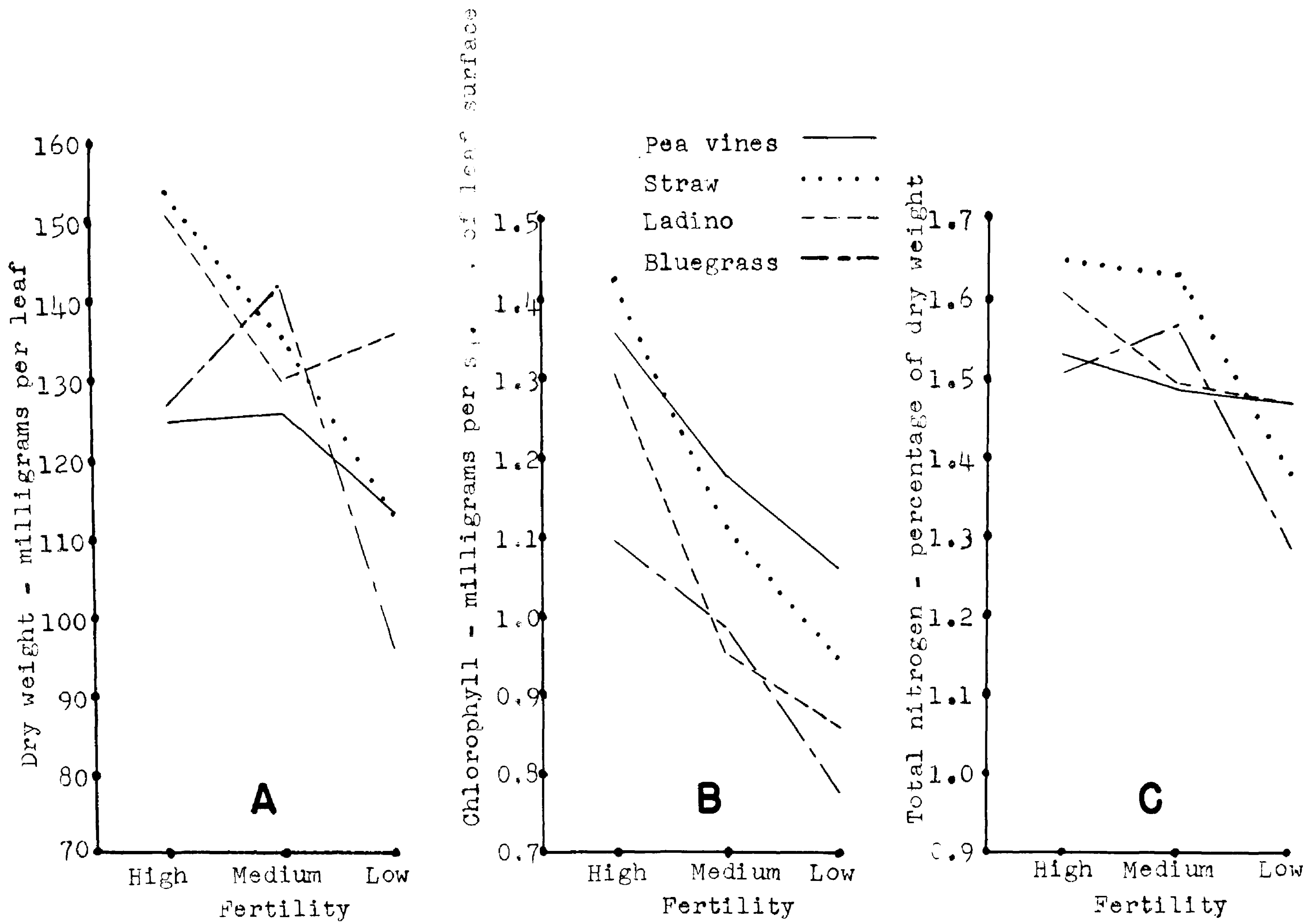


Figure 6. Leaf analyses in 1947 as measured by dry weight, chlorophyll and total nitrogen with respect to fertility levels and ground covers.

figures tabulated according to mulch, cover crop and fertilizer treatments and the figure shows the average values for each ground cover treatment on the three fertility levels.

Even as early as 1947, the various treatments influenced the values for leaf weight. The average figure for each fertility level varied directly with the amount of fertilizer applied, the values being 139.3, 133.4 and 114.9 mg. per leaf for the high, medium and low fertility plots, respectively. These figures indicate that there was little difference between the trees in the medium and high fertility plots, but that the trees in the low fertility plots were in much poorer condition. There was a considerable variation in leaf weight between the various mulch and cover crops which was not altogether consistent with the different fertility levels. Straw and Ladino in the high, bluegrass in the medium and Ladino in the low fertility plots seemed to produce somewhat larger leaves than did the other treatments.

Average chlorophyll values also varied in relation to fertilizer applications, being 1.30, 1.06 and 0.92 mg. per 100 sq. cm. from the high, medium and low fertility plots, respectively. The data for the mulch and cover crop treatments showed some slight differences, but the values for each treatment were proportional to the fertilizer applications. The leaves from the pea vine and straw plots had slightly higher chlorophyll figures than those from the bluegrass and Ladino plots.

At each fertility level, the average values for nitrogen were again proportional to the amount of fertilizer applied. The figures, expressed in percentage of dry weight, were 1.58 for the high, 1.54 for the medium and 1.41 for the low. The drop in the low level, as shown in Figure 6, was almost entirely due to the low straw and bluegrass values. The percent nitrogen in leaves from the Ladino and pea vine plots remained practically the same on the medium and low fertility levels, which indicated that these two materials must have supplied some additional nitrogen to the soil.

These three determinations on leaves all indicated that the different amounts of fertilizer applied had started to take effect, although the variations were small. At this time, the mulch and cover crops had had little influence upon the results.

Since the values for leaf weight, chlorophyll and nitrogen all fluctuated in relation to fertilizer applications and since chlorophyll contains nitrogen in its molecule, correlations were made between these three sets of data. There was no relationship between the figures for chlorophyll and either leaf weight or total nitrogen, the coefficient of correlations being + 0.17 and + 0.34, respectively. There was, however, some relationship between the weight of the leaves and the total nitrogen content, since the correlation was + 0.71. From this it could be assumed that the total amount of nitrogen in the larger leaves was greater than the percentage figures indicated.

## Leaf Weight, Chlorophyll and Nitrogen Data in 1949

Two years later, in 1949, the study of leaf weight, chlorophyll and nitrogen content of the leaves was made on a more extensive scale. Samples were taken four times during the growing season, on June 7, August 1, September 15 and October 15. These data not only show the effect of the various mulches, cover crops and fertilizer applications, but also show the leaf weight, chlorophyll and nitrogen fluctuations during the growing season. At this time the trees had received the treatments for four years, so the original variations in tree size were less obvious and the relationships between these measurements were more accurately portrayed than in 1947. There was also sufficient data to permit analyses of variance, which further substantiated the results obtained.

Leaf weight. The dry weight of the leaves, calculated as milligrams per leaf, are recorded in Table IX. The data are tabulated according to the cover crop, mulch and fertilizer applications.

Leaf weight and thus the original size of the leaf showed a definite relation to fertilizer application. Considering all data together, the values were 241.7, 221.6

TABLE IX

LEAF WEIGHTS IN 1949 AS INFLUENCED BY FERTILITY LEVELS, GROUND COVER AND TIME OF SAMPLING

| Fertility level | Ground cover | Date: June 7 (mg.) | Aug. 1 (mg.) | Sept. 15 (mg.) | Oct. 15 (mg.) | Average (mg.) |
|---|---|---|---|---|---|---|
| High | Pea vine | 229.0 | 261.4 | 266.0 | 231.7 | 247.5 |
| | Straw | 224.2 | 254.3 | 255.[illegible] | 209.[illegible] | 235.1 |
| | Ladino | 227.7 | 265.0 | 266.5 | 215.0 | [illegible] |
| | Bluegrass | 218.8 | 255.3 | 261.2 | [illegible] | 241.[illegible] |
| | Average | 224.9 | 259.0 | 262.2 | 220.6 | 241.7 |
| Medium | Pea vine | 209.3 | 256.7 | 259.8 | 226.9 | 238.2 |
| | Straw | 213.5 | 256.8 | 234.8 | 214.5 | 230.4 |
| | Ladino | 193.5 | 212.2 | 213.7 | 181.2 | 200.1 |
| | Bluegrass | 194.7 | 241.2 | 243.7 | 191.5 | 217.5 |
| | Average | 202.8 | 242.2 | 237.8 | 203.4 | 221.6 |
| Low | Pea vine | 221.3 | 253.7 | 261.5 | 199.5 | 23[illegible].9 |
| | Straw | 175.5 | 196.2 | 18[illegible].5 | 188.0 | 18[illegible] |
| | Ladino | 191.0 | 223.0 | 204.8 | 187.4 | 201.5 |
| | Bluegrass | 153.7 | 215.2 | 184.2 | 170.5 | 180.9 |
| | Average | 185.4 | 220.0 | 207.8 | 186.4 | 200.4 |
| Total | Pea vine | 219.9 | 257.3 | 263.1 | 219.4 | 239.9 |
| | Straw | 204.4 | 236.4 | 222.8 | 203.9 | 214.9 |
| | Ladino | 204.1 | 233.4 | 228.3 | 193.9 | 217.2 |
| | Bluegrass | 189.1 | 237.2 | 22[illegible].4 | 196.9 | 213.1 |
| All | Average | 204.4 | 241.1 | 236.2 | 203.5 | 221.3 |

| | Fertility | Date | Cover |
|---|---|---|---|
| L.S.D. 5% | 8.76 | 10.11 | 10.11 |
| 1% | 11.59 | 13.39 | 13.39 |

and 200.4 mg. per leaf for the high, medium and low fertility levels, respectively. A statistical analysis of variance showed that these averages were significantly different even at the one percent level.

The general averages, however, did not show the differences in the development of the leaves during the growing season. The average values for each collection period showed that the leaves maintained their maximum weight longer in the higher fertility level. On July 7, when the first samples were taken, the weight of the leaves was definitely related to the fertilizer application, those from the high fertility plots being the heavier, Figure 7A. On all three fertility levels, the leaves grew until the first of August at approximately the same rate, keeping a proportional difference in total weight. At the time of the third sampling in September, the leaves in the high fertility plots had increased and those in the medium and low plots had decreased in weight, the reduction being lowest in the low fertility plots. By October 15, all leaves had lost weight and had reached the approximate weight of the immature leaves collected in June. These differences in leaf weight indicate that with higher levels of fertility, the leaf maintains its ability to produce plant nutrients longer and thus best fulfills its function in the growth of the tree. The average increase in weight from June to August and the decrease from September to

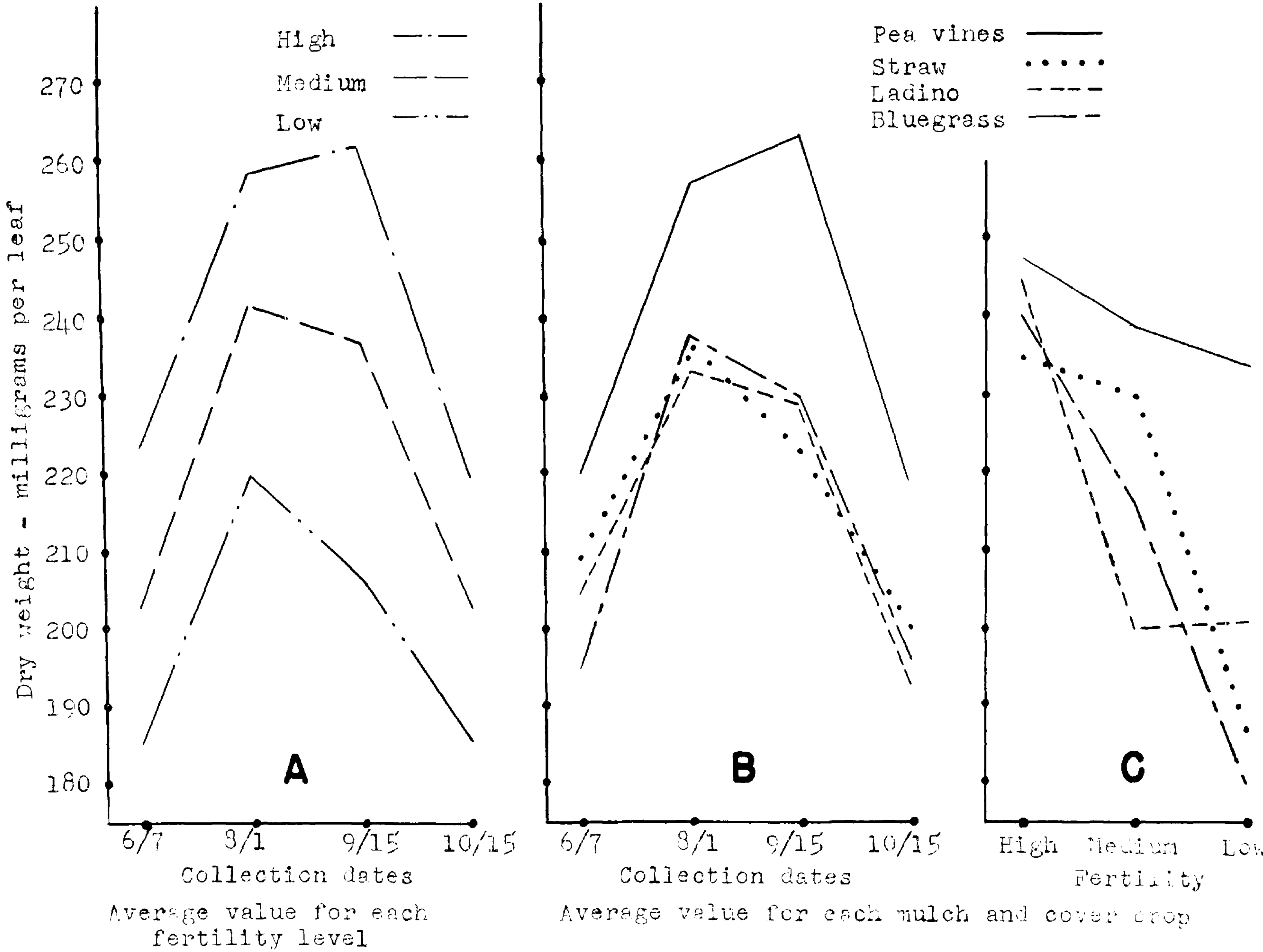


Figure 7. Leaf weights during 1949 season in relation to fertility levels and ground covers.

October were significant at the one percent level, at all levels of fertility. There was no significant difference between the August and September values in the high and medium fertility levels, but the difference between these collection dates in the low fertility level was significant at the five percent level.

During the entire growing season, average values showed that the pea vine mulch produced heavier leaves than did any of the other covers, Figure 7B. In addition the leaves from the pea vine plots increased in weight at the third sampling period on September 15, while the values for all of the others decreased. This superiority of the pea vines was substantiated by the analysis of variance, which showed that there was no difference between the values for Ladino, straw or bluegrass, but that the figures for pea vine were significantly higher at the one percent level, than those for any of the other covers.

The effect of pea vine mulch on leaf weight became more pronounced as the fertility level decreased, Figure 7C. In the high fertility plots the pea vine had little effect on the size of the leaves which were slightly higher only in the last two sampling periods. The effect was more pronounced in the medium fertility plots, but, in the low fertility plots, the values were highest during the entire growing season. It is probable that the pea vines supplied additional nitrogen which produced the most striking effect when the fertility was low.

Chlorophyll. Average chlorophyll values, expressed as mg. per 100 sq. cm., showed variations similar to those for leaf weight. Table X gives the chlorophyll values tabulated according to fertilizer, mulch and cover crop treatments and date of collection, together with the least significant differences.

The chlorophyll data varied according to fertilizer applications, the average values being 1.36 mg. for the high, 1.22 mg. for the medium and 0.97 mg. for the low fertility levels. The statistical analysis showed that these figures were significantly different at the one percent level.

On each collection date, as shown in Figure 8A, the average values for each fertility level were high at the beginning of the season and decreased gradually until the leaves were almost ready to fall from the trees. The values on the high fertility level were almost the same in August and September but fell rapidly in October. Those on the medium fertility plots had a more gradual decline, but at all times were lower than those on the high fertility plots. The average chlorophyll content of the leaves in the low fertility plots was lower at their highest level in the early summer than were the values for the high fertility plots at their lowest level at the end of the growing season. The decline was exceedingly fast so that by the end of the

TABLE X

CHLOROPHYLL VALUES DURING THE 1949 SEASON AS RELATED TO FERTILITY LEVELS AND GROUND COVERS

| Fertility level | Ground cover | Date: June 7 | Aug. 1 | Sept. 15 | Oct. 15 | Average |
|---|---|---|---|---|---|---|
| | | (mg./100 sq. cm.) | | | | |
| High | Pea vine | 1.59 | 1.40 | 1.32 | 1.10 | 1.34 |
| | Straw | 1.35 | 1.40 | 1.38 | 1.14 | 1.32 |
| | Ladino | 1.48 | 1.44 | 1.39 | 1.16 | 1.37 |
| | Bluegrass | 1.51 | 1.37 | 1.47 | 1.20 | 1.39 |
| | Average | 1.48 | 1.40 | 1.39 | 1.15 | 1.36 |
| Medium | Pea vine | 1.38 | 1.29 | 1.26 | 1.05 | 1.24 |
| | Straw | 1.37 | 1.35 | 1.20 | 1.06 | 1.24 |
| | Ladino | 1.28 | 1.22 | 1.18 | 0.95 | 1.16 |
| | Bluegrass | 1.34 | 1.29 | 1.33 | 1.05 | 1.25 |
| | Average | 1.34 | 1.29 | 1.23 | 1.03 | 1.22 |
| Low | Pea vine | 1.25 | 1.19 | 1.12 | 0.87 | 1.11 |
| | Straw | 1.12 | 1.10 | 0.88 | 0.77 | 0.97 |
| | Ladino | 1.10 | 1.02 | 0.87 | 0.65 | 0.91 |
| | Bluegrass | 1.05 | 0.97 | 0.83 | 0.73 | 0.90 |
| | Average | 1.13 | 1.07 | 0.93 | 0.76 | 0.97 |
| Total | Pea vine | 1.40 | 1.29 | 1.23 | 1.01 | 1.23 |
| | Straw | 1.28 | 1.28 | 1.15 | 0.99 | 1.18 |
| | Ladino | 1.29 | 1.23 | 1.13 | 0.92 | 1.15 |
| | Bluegrass | 1.30 | 1.21 | 1.22 | 0.99 | 1.18 |
| All | Average | 1.32 | 1.25 | 1.19 | 0.98 | 1.18 |

| | Fertility | Date | Cover |
|---|---|---|---|
| L.S.D. 5% | 0.034 | 0.041 | 0.041 |
| 1% | 0.046 | 0.054 | 0.054 |

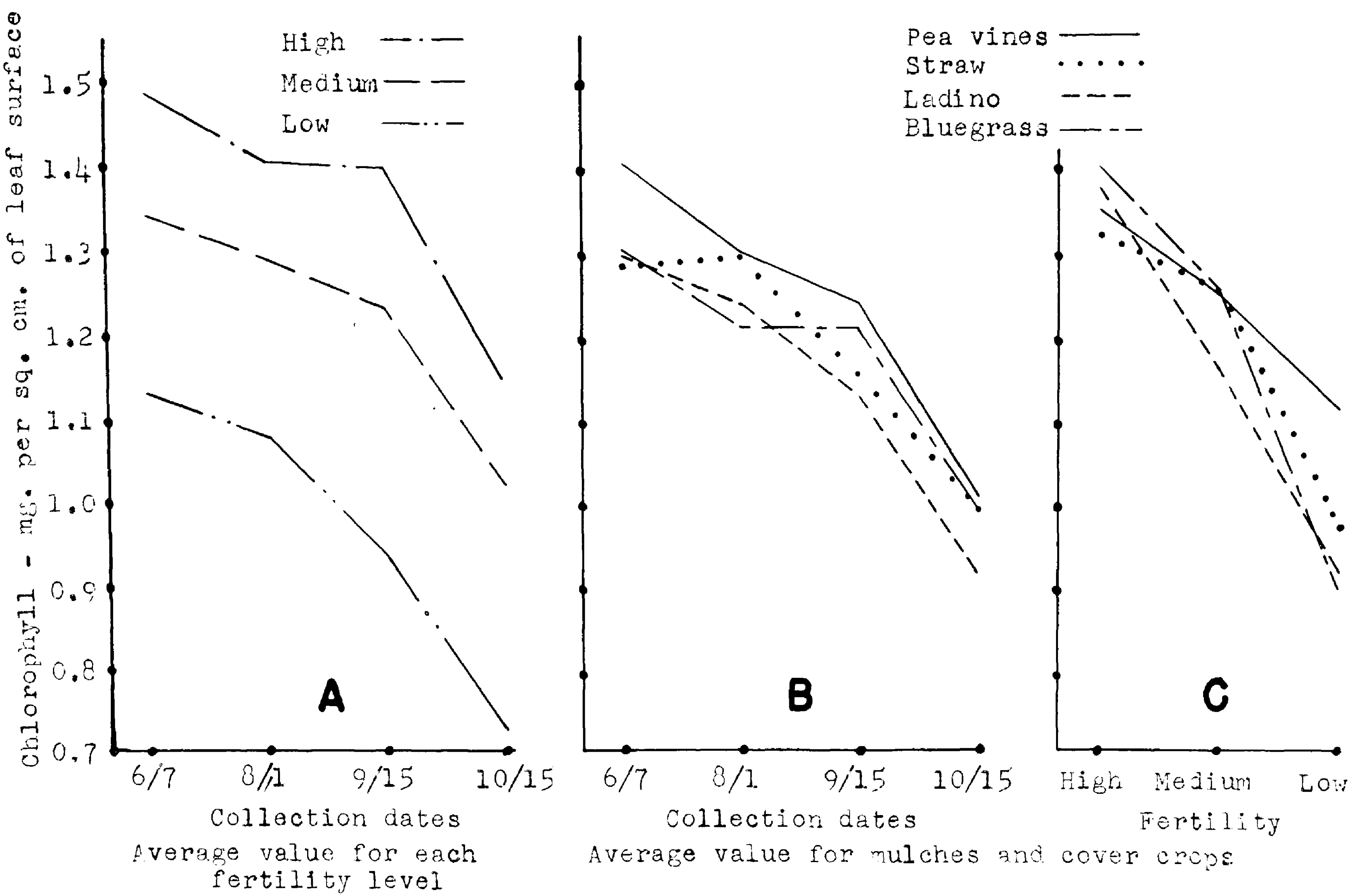


Figure 8. Leaf chlorophyll values during the 1949 season in relation to fertility levels and ground covers.

summer there was only 0.76 mg. of chlorophyll per 100 sq. cm. of leaf surface in the low fertility plots as compared to 1.15 mg. for the high. Because the leaves in the low fertility plots weighed less than those in the other plots, the actual amount of chlorophyll was undoubtedly lowest. Therefore, the leaves could not produce as much food material for growth of the tree or for the production of fruit in the low fertility plots as did those in the high and medium fertility plots. On the same basis, the trees in the medium had less chlorophyll than those in the high fertility plots.

Chlorophyll values arranged according to mulches and cover crops, Figure 8B, showed that leaves on trees receiving pea vine mulch had the highest amount of chlorophyll during the entire growing season. On the other hand, trees growing in the Ladino plots, except for the one collection period in August, had the lowest leaf chlorophyll values throughout the season. Chlorophyll values for straw and bluegrass were between these two extremes.

The relationship between fertility levels and mulch and cover crop treatments as measured by leaf chlorophyll is illustrated in Figure 8C. In the high fertility plots, the bluegrass plots produced significantly higher chlorophyll values than the straw plots, but there was no significant difference in the other mulch and cover treatments. At the medium fertility level, the Ladino plots had somewhat lower levels than those for the other three cover treatments, which were practically the same. At the low fertility level, the chlorophyll values with pea vines were much higher than the other cover treatments. This effect of pea vines on chlorophyll values at the lower fertility level accentuated the value of this legume mulch which in itself supplied considerable nitrogen to the tree.

Nitrogen. Table XI presents the total nitrogen content of the leaves, in percentage of dry weight, at the four sampling periods in 1949. The data are tabulated according to mulch, cover crop and fertilizer applications.

The nitrogen content of the leaves was again closely associated with fertilizer applications. The average figures were 1.95 for the high, 1.88 for the medium and 1.63 for the low fertility levels. The difference between these values was significant at the one percent level.

The percentage of nitrogen in the leaves was highest in June and fell continuously until October. The differences between the average values in June and August and between those in September and October were significant at the one percent level but the difference between the August and September values was barely significant at the five percent level. Throughout the growing season, the average values for the high and medium fertility plots followed the same general trend, Figure 9A. They were high in the early summer, dropped rapidly to the August and September levels, which were practically the same, and again went down in the

TABLE XI

PERCENTAGE OF TOTAL NITROGEN IN THE DRIED LEAVES DURING 1949 WITH RESPECT TO FERTILITY LEVELS AND GROUND COVERS

| Fertility level | Ground cover | Date | | | | Average |
|---|---|---|---|---|---|---|
| | | June 7 | Aug. 1 | Sept. 15 | Oct. 15 | |
| High | Pea vine | 2.26 | 1.95 | 1.90 | 1.79 | 1.97 |
| | Straw | 2.07 | 1.87 | 1.88 | 1.80 | 1.91 |
| | Ladino | 2.22 | 1.92 | 1.89 | 1.82 | 1.96 |
| | Bluegrass | 2.22 | 1.89 | 1.91 | 1.80 | 1.95 |
| | Average | 2.19 | 1.91 | 1.89 | 1.82 | 1.95 |
| Medium | Pea vine | 2.12 | 1.84 | 1.84 | 1.72 | 1.88 |
| | Straw | 2.10 | 1.89 | 1.88 | 1.76 | 1.91 |
| | Ladino | 2.00 | 1.79 | 1.78 | 1.70 | 1.82 |
| | Bluegrass | 2.04 | 1.90 | 1.87 | 1.78 | 1.90 |
| | Average | 2.07 | 1.85 | 1.84 | 1.74 | 1.88 |
| Low | Pea vine | 1.92 | 1.70 | 1.62 | 1.56 | 1.70 |
| | Straw | 1.79 | 1.67 | 1.59 | 1.49 | 1.64 |
| | Ladino | 1.83 | 1.61 | 1.46 | 1.51 | 1.60 |
| | Bluegrass | 1.68 | 1.57 | 1.52 | 1.46 | 1.56 |
| | Average | 1.81 | 1.66 | 1.55 | 1.51 | 1.63 |
| Total | Pea vine | 2.10 | 1.83 | 1.79 | 1.69 | 1.85 |
| | Straw | 1.99 | 1.81 | 1.78 | 1.69 | 1.82 |
| | Ladino | 2.02 | 1.77 | 1.71 | 1.68 | 1.79 |
| | Bluegrass | 1.98 | 1.79 | 1.77 | 1.68 | 1.80 |
| All | Average | 2.02 | 1.80 | 1.76 | 1.68 | 1.82 |

| | Fertility | Date | Cover |
|---|---|---|---|
| L.S.D. 5% | 0.036 | 0.041 | 0.041 |
| 1% | 0.047 | 0.054 | 0.054 |

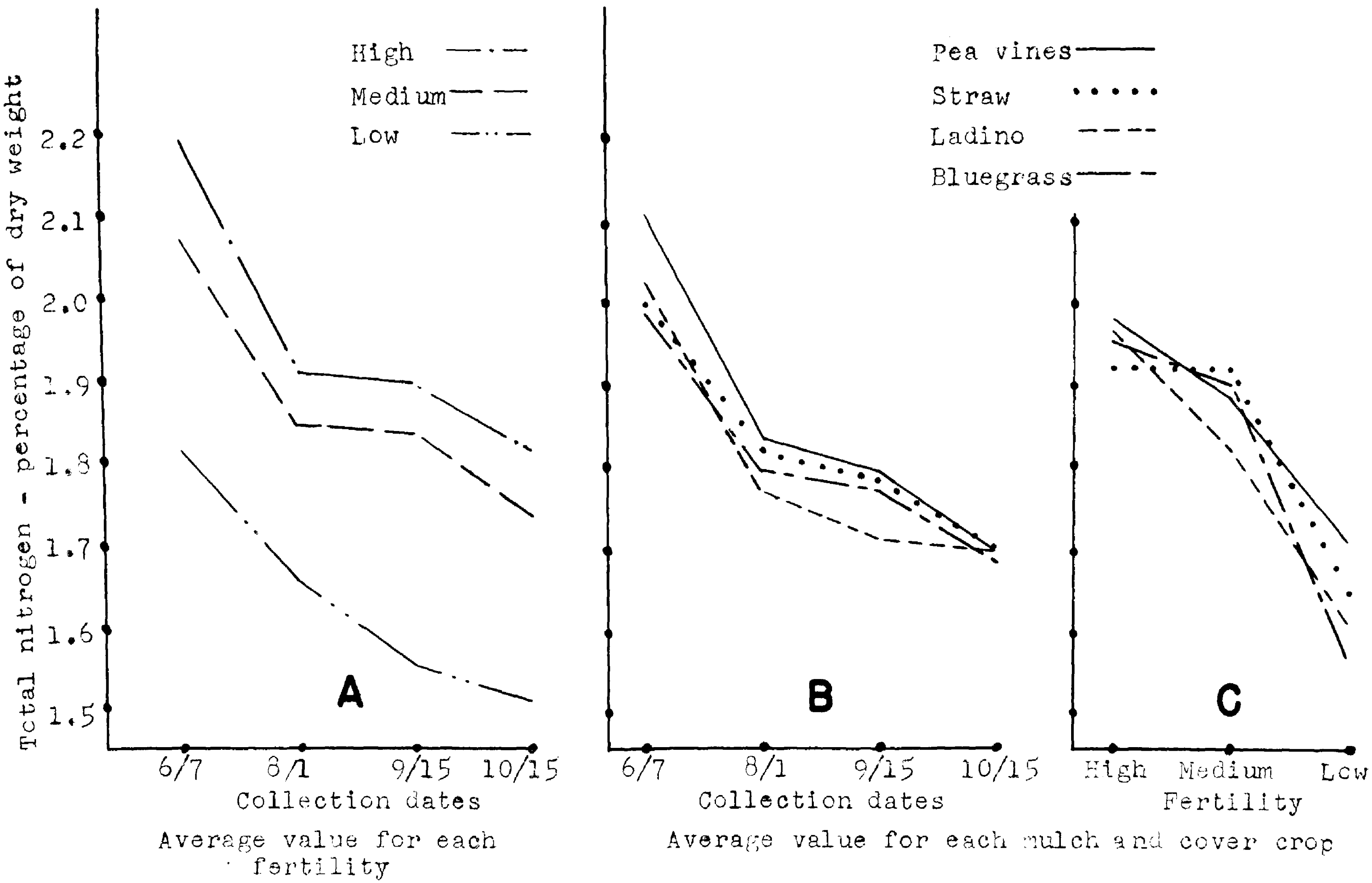


Figure 9. Total percentage nitrogen in dried leaves during the 1949 season as influenced by fertility levels and ground covers.

October analyses. The values for the low fertility plots were considerably lower than those for the other plots and they dropped continuously at each sampling period.

The average values for each of the covers are shown in Figure 9B. The percentage of nitrogen in the leaves from the pea vine plots was higher than that for the Ladino at the one percent level, higher than that for the bluegrass at the five percent level, but not significantly higher than that for the straw. The high values from the pea vine plots, Figure 9C, were more pronounced in the low than in the other fertility levels, the percentages in that level being highest at all times during the growing season.

In order to obtain a better understanding of the tree performance, the nitrogen data was also expressed as milligrams per leaf, Table XII. On this basis, the values gave a more accurate estimate of the total quantity of nitrogen available to the trees on the various dates and at the different fertility levels.

The results were similar to those for percentage of nitrogen in the leaf, but the differences were accentuated. The fall from the high to the medium to the low fertility was almost a straight line, the values being 4.70, 4.12 and 3.35 mg. of nitrogen per leaf. The average values for each collection date maintained the same relationships between the three fertility levels as did the percentage figures, but produced quite a different type of curve, Figure 10A.

TABLE XII

MILLIGRAMS OF NITROGEN PER LEAF DURING THE 1949 SEASON IN RELATION TO FERTILITY LEVELS AND GROUND COVERS

| Fertility level | Ground cover | Date | | | | Average |
|---|---|---|---|---|---|---|
| | | June 7 | Aug. 1 | Sept. 15 | Oct. 15 | |
| High | Pea vine | 5.16 | 5.07 | 5.07 | 4.14 | 4.86 |
| | Straw | 4.65 | 4.74 | 4.75 | 3.76 | 4.48 |
| | Ladino | 5.07 | 5.10 | 5.04 | 3.87 | 4.76 |
| | Bluegrass | 4.86 | 4.82 | 4.98 | 4.11 | 4.69 |
| | Average | 4.94 | 4.93 | 4.96 | 3.97 | 4.70 |
| Medium | Pea vine | 4.44 | 4.72 | 4.77 | 3.90 | 4.46 |
| | Straw | 4.47 | 4.87 | 4.42 | 3.76 | 4.38 |
| | Ladino | 3.89 | 3.81 | 3.82 | 3.09 | 3.65 |
| | Bluegrass | 3.97 | 4.55 | 4.53 | 2.92 | 3.99 |
| | Average | 4.19 | 4.49 | 4.38 | 3.42 | 4.12 |
| Low | Pea vine | 4.26 | 4.33 | 4.26 | 3.11 | 3.99 |
| | Straw | 3.15 | 3.27 | 2.86 | 2.82 | 3.03 |
| | Ladino | 3.47 | 3.57 | 3.01 | 2.64 | 3.22 |
| | Bluegrass | 2.43 | 3.38 | 2.81 | 2.48 | 2.77 |
| | Average | 3.33 | 3.64 | 3.24 | 2.82 | 3.25 |
| Total | Pea vine | 4.62 | 4.71 | 4.70 | 3.72 | 4.44 |
| | Straw | 4.09 | 4.19 | 4.01 | 3.45 | 3.96 |
| | Ladino | 4.14 | 4.16 | 3.96 | 3.27 | 3.88 |
| | Bluegrass | 3.75 | 4.25 | 4.11 | 3.17 | 3.82 |
| All | Average | 4.15 | 4.35 | 4.19 | 3.40 | 4.03 |

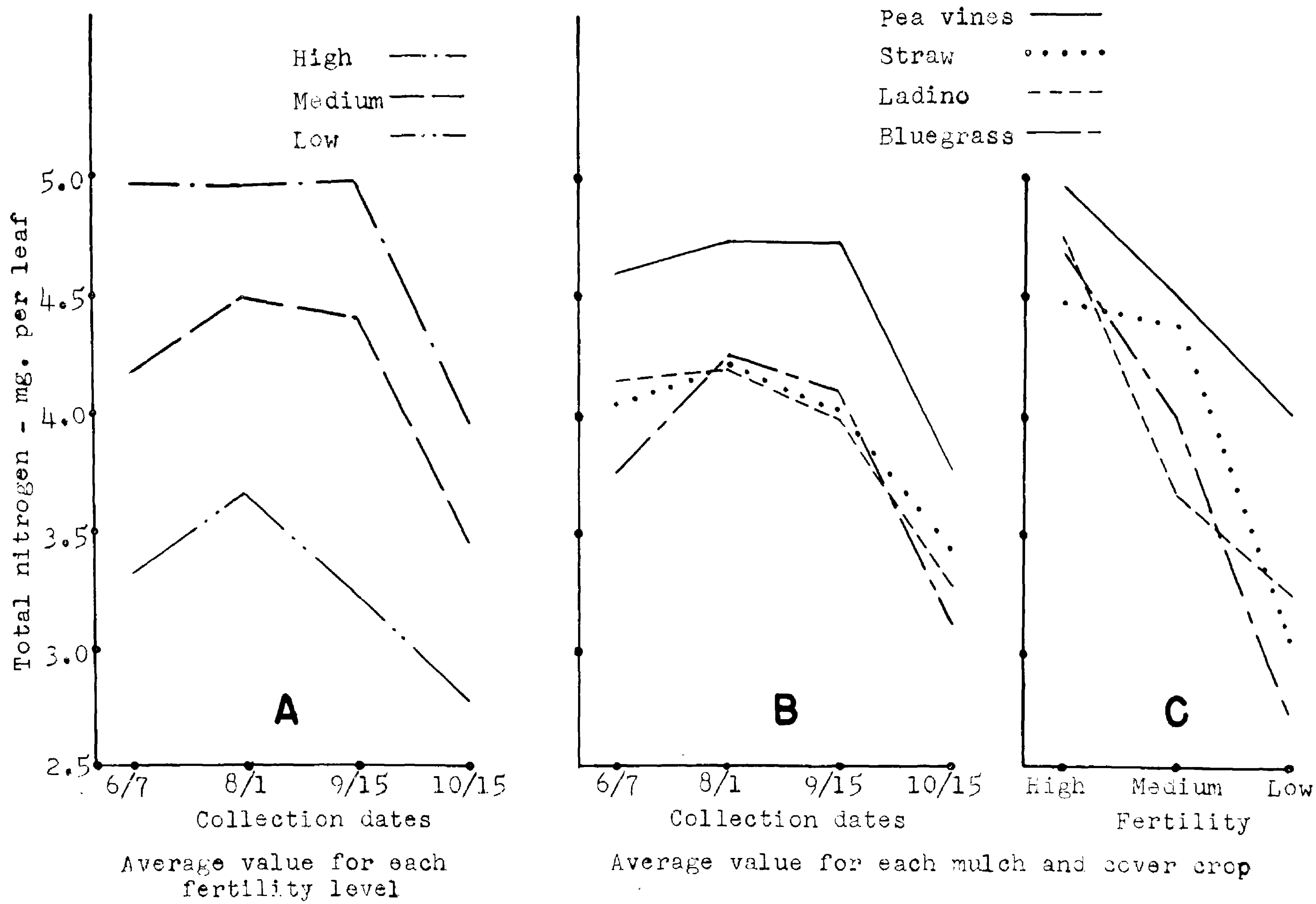


Figure 10. Total nitrogen per leaf during the 1949 season as influenced by fertility levels and ground covers.

The values in the high fertility level were practically the same through the September 15 analyses but then dropped rapidly in October. In both the medium and low fertility plots, the values rose rapidly from June to August and then declined, those for the medium fertility slightly, but those for the low quite rapidly. This maintenance of the total nitrogen per leaf during the summer as compared to the continuous decline of the percentage nitrogen was explained by the fact that the leaf weight increased from June to August, stayed at about the same figure until September and then declined rapidly.

Since the leaves in the pea vine plots were much heavier than those from the other ground cover treatments, the superiority of the pea vine mulch was accentuated. All values with this ground cover were highest both in relation to date of collection and to fertility level, Figures 10B and 10C. The average value for the pea vine plots was 4.44 mg. as compared to 3.96, 3.88 and 3.82 mg. for the straw, Ladino and bluegrass plots, respectively. The greatest difference occurred in the low fertility plots, Figure 10C. Although the difference was less striking, the weight of nitrogen per leaf in the Ladino plots in the low fertility level was greater than that for the straw or bluegrass plots. Again, the legumes seemed to give additional nitrogen to the tree in the low fertility plots.

<u>Correlations between leaf weight, chlorophyll and nitrogen.</u> The percentage of nitrogen in the leaves was closely associated with the chlorophyll values. The correlation between these two sets of data was very high for each collection period, Table XIII, ranging from + 0.95 at the beginning of the season to + 0.92 at the end. When all of the data were considered together, the correlation was + 0.90. This relationship was higher than that found in 1947, which may be explained by the fact that the study had continued for two additional years and the differences in tree vigor had been somewhat stabilized.

There was some correlation between leaf weight and nitrogen when the data were considered for each collection period, the values varying from + 0.47 to + 0.66. The small leaves which contained a large amount of nitrogen at the beginning of the summer, however, reduced the correlations to + 0.31 when all of the data were considered together.

There was higher correlation between leaf weight and chlorophyll than between leaf weight and nitrogen. The values for each collection period ranged from + 0.53 to + 0.79, and when all the data were considered together the value was + 0.59.

In the light of these correlations the chlorophyll content of the leaf, which can be a relatively simple determination, would appear to be a fairly accurate indication of the nitrogen content of the leaf. The use of chlorophyll

TABLE XIII

CORRELATION BETWEEN LEAF WEIGHT, CHLOROPHYLL AND NITROGEN IN 1949

| Date | Nitrogen and chlorophyll | Nitrogen and leaf weight | Chlorophyll and leaf weight |
|---|---|---|---|
| June 7 | 0.95 | 0.64 | 0.59 |
| August 1 | 0.94 | 0.47 | 0.58 |
| September 15 | 0.92 | 0.66 | 0.79 |
| October 15 | 0.92 | 0.60 | 0.66 |
| All data | 0.90 | 0.31 | 0.59 |

determinations for estimating leaf nitrogen would be particularly accurate for data collected at any one time. Leaf weight would give some indication of the condition of the tree, but could not be considered as a substitute for the nitrogen or chlorophyll determinations.

## Yield

Yields, in bushels, from individual trees were recorded throughout the duration of the experiment. Table XIV gives the annual, average and total four year yield per tree, tabulated according to fertilizer, mulch and cover crop treatments, together with a statistical evaluation of the data.

Since the trees were in very poor condition at the beginning of the experiment, the yields were exceedingly low, many trees having little or no fruit on them at all. This condition existed for three years, the total values becoming slightly lower each year. In the fourth year the trees had recovered sufficiently to produce a fair crop, which was significantly higher than those for the other years.

Except for the first year, the yields for all plots were in relation to the fertility levels, Figure 11A. The average accumulated yields were 17.46, 15.29 and 11.15 bushels per tree for the high, medium and low fertility plots, respectively. A statistical analysis of the data showed that there was a significant difference, at the one

TABLE XIV

ANNUAL YIELD PER TREE ACCORDING TO THE FERTILITY LEVELS AND GROUND COVERS

| Fertility level | Ground cover | 1946 (bu.) | 1947 (bu.) | 1948 (bu.) | 1949 (bu.) | Total (bu.) | Average 1946-49 (bu.) |
|---|---|---|---|---|---|---|---|
| High | Pea vine | 1.61 | 1.96 | 1.62 | 13.56 | 18.66 | 4.66 |
| | Straw | 1.32 | 2.01 | 1.01 | 12.50 | 16.84 | 4.21 |
| | Ladino | 1.67 | 1.14 | 1.04 | 10.96 | 14.82 | 3.70 |
| | Bluegrass | 1.77 | 1.93 | 2.25 | 13.76 | 19.71 | 4.93 |
| | Average | 1.59 | 1.73 | 1.46 | 12.68 | 17.46 | 4.36 |
| Medium | Pea vine | 0.73 | 0.53 | 1.32 | 9.12 | 11.69 | 2.92 |
| | Straw | 1.61 | 2.46 | 1.24 | 13.43 | 18.74 | 4.68 |
| | Ladino | 1.15 | 0.70 | 0.94 | 8.32 | 11.60 | 2.90 |
| | Bluegrass | 2.16 | 2.29 | 0.60 | 14.08 | 19.12 | 4.78 |
| | Average | 1.42 | 1.49 | 1.02 | 11.36 | 15.29 | 3.82 |
| Low | Pea vine | 1.74 | 0.93 | 0.93 | 10.32 | 13.92 | 3.48 |
| | Straw | 2.18 | 0.51 | 0.48 | 7.09 | 10.26 | 2.56 |
| | Ladino | 3.34 | 0.73 | 0.81 | 9.67 | 14.55 | 3.64 |
| | Bluegrass | 1.32 | 0.29 | 0.33 | 3.28 | 5.22 | 1.30 |
| | Average | 2.17 | 0.62 | 0.65 | 7.71 | 11.15 | 2.79 |
| Total | Pea vine | 1.39 | 1.16 | 1.30 | 11.18 | 15.04 | 3.76 |
| | Straw | 1.68 | 1.67 | 0.92 | 11.08 | 15.36 | 3.84 |
| | Ladino | 2.06 | 0.86 | 0.93 | 9.85 | 13.70 | 3.42 |
| | Bluegrass | 1.76 | 1.52 | 1.05 | 10.44 | 14.76 | 3.69 |
| All | Average | 1.72 | 1.29 | 1.05 | 10.64 | 14.71 | 3.68 |

| | | Fertility | Date | Cover |
|---|---|---|---|---|
| L.S.D. | 5% | 0.883 | 1.012 | 1.012 |
| | 1% | 1.168 | 1.349 | 1.349 |

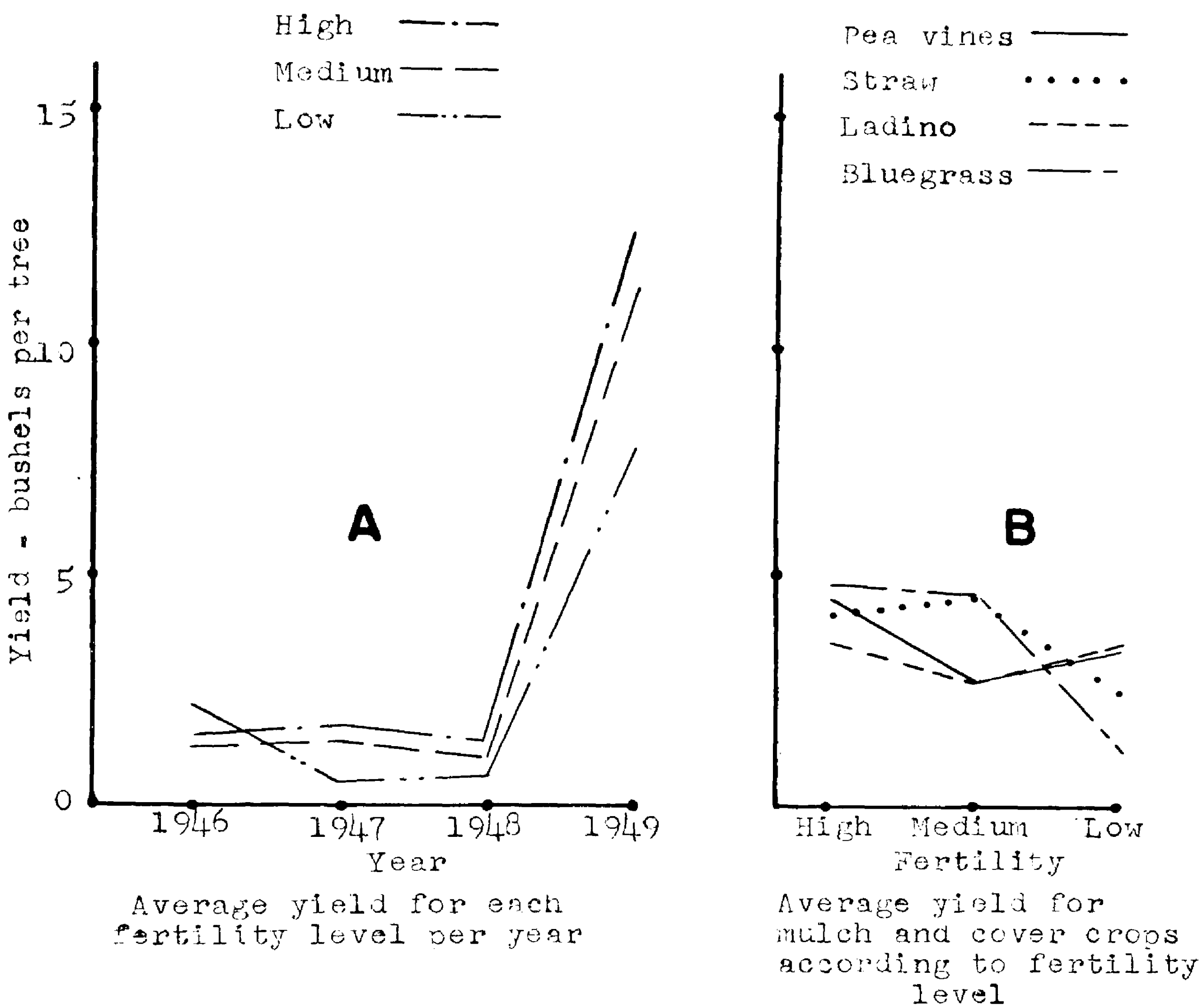


Figure 11. Annual yield per tree from 1946 to 1949 according to fertility levels and ground covers.

percent level, in the four year average yields between the high and low fertility plots. There was, however, no significant difference between the yields on the high and medium levels, and a significant difference at only the five percent level between the yields on the medium and low fertility plots.

During the first three years the yields were so small that there were no differences between the values for the cover and mulch treatments. In the fourth year, the higher yields made some differences evident. The trees in the pea vine plots had the highest yield, averaging 11.18 bushels per tree and the Ladino, the lowest, 9.85 bushels. Considering all data together, the relatively high yields in the straw plots for the first two years, made the values higher than those for pea vine. There was, however, no statistical difference between the values for pea vine, straw or bluegrass. The yields from the Ladino plots were lower than that from straw at the one percent level and from the pea vine at the five percent level.

The relationship between the fertility rates and yields, found when all covers were considered together, did not hold for the individual covers and mulches, Figure 11B. Total yields for the bluegrass plots were the only ones which varied directly with the fertility levels. Those for straw were higher in the medium than in the high fertility plots and both pea vine and Ladino plots yielded more fruit in the low than in the medium fertility level. Straw and especially bluegrass, which added no nitrogen to the soil, produced very small yields in the low fertility level.

## ECONOMIC APPLICATION

The evaluation of a rejuvenation program would not be complete without a study of the costs involved and the financial benefits from increased returns. Such a study should be compared to the cost of replanting the orchard plus the loss of income during the years when the trees were growing to maturity.

The operating costs during the four years of this study varied according to the fertilizer applications. The approximate overall cost per tree for material and application of the sprays was $11.00 (17); for pruning, cultivating, etc., $1.50, making a total of $12.50 per tree. This would be the total cost in the low fertility plots. In the high fertility plots, the cost of the extra fertilizer was $5.00. Thus the total cost for the four-year period would be $17.50. The trees in the medium fertility plots had half the additional fertilizer, so the cost in those plots would be about $15.00.

The return also varied with the fertility plots. Table XV shows the prices paid during the time of the study for the various grades of apples and the average amount received per bushel each year. The grower thus received an average of $1.16 per bushel and paid $0.15 for picking, leaving a net of approximately $1.00 per bushel.

TABLE XV

ANNUAL PRICES AND CROP VALUE FOR YORK IMPERIAL APPLES

| Year | Prices per grade, per 100 pounds* | | | | Value** | |
|---|---|---|---|---|---|---|
| | US1 Canners $2\frac{1}{2}$" & up ($) | US1 Canners $2\frac{1}{4}$"-$2\frac{1}{2}$" ($) | US2 Canners ($) | Ciders ($) | Per 100 lbs. ($) | Per bushel ($) |
| 1946 | 4.35 | 3.25 | 2.00 | 1.00 | 3.56 | 1.60 |
| 1947 | 3.75 | 2.75 | 1.50 | 0.75 | 3.02 | 1.35 |
| 1948 | 2.50 | 1.85 | 0.85 | 0.50 | 2.00 | 0.90 |
| 1949 | 2.25 | 1.65 | 0.70 | 0.50 | 1.60 | 0.81 |
| Average | | | | | | 1.16 |

*Courtesy C. H. Musselman Co., Biglerville, Pa.
**Based on average orchard grade of 60% #1, $2\frac{1}{2}$ & up; 20% #1, $2\frac{1}{4}$-$2\frac{1}{2}$; 10% #2 and 10% cider.

Considering the total four-year yield, the low fertility trees produced 11.15 bushels during the four-year period, which would cause a loss to the grower of $1.35 per tree ($12.50 - $11.15). The high fertility trees produced 17.46 bushels over the same period, giving the grower $17.46 per tree, which would just about pay the cost of production.

Presuming that the trees would continue to produce at least as much as in 1949 and that the cost of production would be the same (one-fourth of the above figures), the trees in the low fertility plots would net the grower approximately $4.58 per tree per year (7.71 bu. or $7.71 - $3.13 the cost of production) after the loss of $1.35 had been absorbed. On the same basis the trees in the high fertility plots would net the grower approximately $8.30 per tree per year ($12.68 - $4.38). Therefore, after the original costs were paid, the high fertility treatment would give the grower approximately $3.72 more per tree than the low fertility treatment.

An alternative to renovating an old orchard by the use of large amounts of fertilizer is to pull out the old trees and replant the orchard. The expenses to be considered would be tree removal cost of $1.41 (26), cost of buying and planting a new tree of $0.70, spray costs of $0.44 (17) and fertilizing, cultivating and pruning costs of $0.50, making a total of approximately $3.05 per tree for the four-year period.

Although the above figures are quite approximate, they provide a basis for deciding on the course of action to follow. As pointed out, the old renovated trees in the high fertility plots could return about \$8.30 per tree per year after the four-year period. In all probability the tree would maintain similar production for a number of years and would bring in a fair income to the grower. Nevertheless, the orchard would still consist of old trees, which would have to be continually forced into production and eventually would have to be pulled out and new trees planted. If the young trees had been planted when the experiment started, they would have been well established in the four-year period, although it would be several more years before they would produce enough fruit to pay for the original cost and the upkeep during the early years of growth and give any profit to the grower. After 8 to 10 years, the young trees would be producing as much and probably more fruit than the old trees and the production costs would be somewhat lower. Then the orchardist would realize more profit on the young trees than on the old ones.

The economic aspects of rejuvenation, therefore, would depend on the financial requirements of the grower. If it is essential that he maintain his immediate earnings, a rejuvenation program would be advisable. If, on the other hand, he is in a position to forgo some of his immediate income and follow a long term plan, a tree removal and replanting program should eventually lead to greater profits.

# DISCUSSION

All the results described in detail in the foregoing sections point to the fact that the positive and definite rejuvenating effects obtained from the use of fertilizers were in relation to the amount of fertilizer used. To a somewhat lesser extent, improvements in tree vigor and yield were also obtained from the use of mulches and cover crops. In addition to these clear-cut results, there were several inter-relationships which should be pointed out. As the tree absorbs nutrients, the first response is usually in the vegetative parts, which include the leaves, trunk and shoots. By means of this growth there is an accumulation of storage material in the tree which will eventually produce new axillary buds. Since it takes two years to produce a blossom from an axillary bud, the effects of fertilizers could hardly be expected to influence fruit production for at least two years. The results of this study clearly showed this time relationship.

One of the earliest responses to fertilizers was that of cover crops, which showed a differential effect in 1947, after the Ladino plots had been established. Since cover crops are surface rooted as compared to trees, they would be expected to respond to large applications of fertilizer in a relatively short time. The fact that there was little difference in cover crop growth between the high and the medium fertility plots but considerable difference between the medium and low plots for both Ladino and bluegrass, showed the need for phosphorus and potash in the cover crop plots. The high and medium fertilizer applications contained both phosphorus and potash, while the low fertilizer applications contained neither. These elements, as well as nitrogen, were therefore needed for adequate cover crop growth.

Considering the growth of the tree itself, the trunk cross sectional area and shoot growth responded to the fertilizer treatments at different times. The percentage increase in trunk area showed an immediate response in the first year, the values being proportional to the amount of fertilizer applied. At the same time, the shoot growth measurements were not proportional to the amount of fertilizer applied, but were apparently influenced by the original condition of the trees. After the second year, shoot growth showed the same proportional relationship, although the actual downward trend was not checked until 1949, when recovery of shoot growth was really apparent. In the first three years of the experiment when the shoot growth was very small, the percentage increase in trunk area in each fertility level continued at about the same rate, Figures 4 and 5. In the final year, when there was considerable shoot growth on each fertility level, the trunk area increase was smaller than in the previous years.

By the second year, 1947, the leaves of the trees had also responded in proportion to the fertilizer applications. Mean figures for dried weight of the leaves and for their chlorophyll and nitrogen content all showed this relationship. When these values were compared with one another, only total nitrogen and leaf weight were found to be statistically correlated. In 1949, data again showed that leaf weight, chlorophyll and nitrogen values responded in proportion to the amounts of fertilizer used, but to an even greater extent than in 1947. In 1949, the correlation between total nitrogen and chlorophyll was 0.90 for all data together, and thus was more significant than in 1947. Correlation between total nitrogen and leaf weight was about the same as for 1947 at the same sampling period. The relationship between leaf weight and chlorophyll was greater in 1949 than in 1947 but still was not statistically significant.

A comparison of the actual values for leaf analyses in 1947 with those for 1949 showed that all the trees had improved in vigor with the various treatments. The dry weight of the leaves was much greater at the latter date. The average value for the low fertility in 1949, 200.4 mg. per leaf, was higher than the average value for the high fertility level in 1947, 139.3 mg. per leaf. The chlorophyll content per square centimeter was approximately the same in the two years, but since the leaves were larger in 1949, the total chlorophyll content of the leaves was larger. In 1949, the percentage of nitrogen for each fertility level was considerably above that in 1947. As with leaf weight, the percentage of nitrogen for the low fertility plots in 1949, was higher than the percentage of nitrogen in the high fertility plots in 1947.

The increased percentage nitrogen together with the increased leaf size accentuated the total amount of nitrogen per leaf and consequently the differences between treatments.

Finally in 1949, yield responded to the fertilizer treatment. The light crop in the first three years of the experiment made it impossible to detect yield differences during this early period. The higher yields in 1949 were directly related to the amounts of fertilizer used. In the same year and in all fertility levels, shoot growth increased more than in any previous year in the experiment, while the percentage increase in trunk area was smaller than for any previous year since 1946. These data serve to emphasize the inter-relationship between the various parts of the tree and their effect on tree performance.

When the various covers were considered separately, there were apparent discrepancies in yields from the three fertility plots. These may be explained, in part, by a careful comparison with shoot growth, trunk area and leaf analyses. The increased yield from the bluegrass and straw in the medium fertility plots, as shown in Figure 11B, may be associated with the higher increase in trunk area, according to Figure 5B, and the higher actual shoot growth, as shown in Table IV and Figure 4C. This larger shoot growth and trunk area increase may in turn be associated with the relatively larger leaf weights and the higher amounts of nitrogen found in the leaves from these plots.

There was a similar relationship for the Ladino and especially for pea vine treatments in the low fertility plots. Yield was higher than in the straw and bluegrass plots and may have been related to the higher percentage trunk area increase and higher actual shoot growth. These values may also be associated with the greater weight and nitrogen content of the leaves.

Among the mulch and cover crop treatments, pea vines were outstanding in their effect on tree performance. This mulching material produced the greatest average value for shoot growth and trunk area increase as well as the largest leaf weight, chlorophyll and nitrogen values. This effect was much more apparent in the low than in the high fertility plots. Ladino was less effective than pea vines, but better than straw or bluegrass in increasing these measurements in the low fertility plots.

A further improvement in the general condition of the tree was shown by the greater leaf weight found in 1949 as compared to that in 1947. This improvement, however, was not the same for all mulches and cover crops, nor for all fertilizer levels, as shown in Table XVI. The pea vine plots produced the largest increase of leaf weight, 141.5 mg. per leaf, as compared to 108.0, 89.1 and 68.5 for the blue-grass, Ladino and straw plots, respectively. The pea vines also maintained this increase in leaf weight at the three fertilizer levels, indicating that this mulching material had a decided effect on leaf weight increase at all three levels of fertility.

In considering the overall picture, of utmost importance is the effect that the various treatments had on the health and vigor of the leaves. The dry weight, as previously noted, had increased on each fertility level in 1949, being almost twice as heavy as they had been in 1947. In each of these two years the chlorophyll per square centimeter remained approximately the same, varying only in relation to the fertility level. The percentage of nitrogen in the leaves, on the other hand, was higher on each fertility level in 1949 than it had been in 1947. Therefore, the total amount of nitrogen in each of the heavier leaves was considerably greater in 1949 than in 1947. These facts all indicate that the condition of the leaves had made a decided improvement. As a result of this general improvement in the leaves after four years of continuous heavy feeding, the condition of the whole tree had started to improve. The trunk area had increased and the terminal growth was greater. Thus the

TABLE XVI

LEAF WEIGHT INCREASE FROM 1947 TO 1949 WITHIN THE DIFFERENT FERTILITY LEVELS AND GROUND COVERS

| Ground cover | Weight per leaf | | | |
|---|---|---|---|---|
| | Fertility level | | | Average |
| | High (mg.) | Medium (mg.) | Low (mg.) | (mg.) |
| Pea vine | 143.0 | 133.9 | 147.6 | 141.5 |
| Straw | 99.3 | 99.0 | 67.2 | 88.5 |
| Ladino | 115.1 | 83.8 | 68.3 | 89.1 |
| Bluegrass | 134.0 | 101.7 | 88.3 | 108.0 |
| Average | 122.9 | 104.4 | 92.0 | |

trees had recovered sufficiently to produce better yields in 1949 and to continue their improvement in future years.

SUMMARY

Treatments which were designed to rejuvenate an old apple orchard included the use of three rates of fertilizer applications which crossed over straw and pea vine mulch plots and Ladino and bluegrass cover crop plots. Results were recorded in the field by means of shoot growth, trunk circumference and yield of the trees, and by weights of the cover crops. In the laboratory, dry weight and chlorophyll and nitrogen content of the leaves were determined.

The higher fertilizer applications were effective in increasing trunk area, cover crop weights, leaf weight, nitrogen and chlorophyll content of the leaves, shoot growth and finally yield, in that relative order.

The effects on growth were in proportion to the amounts of fertilizer used.

The increase in leaf weight, leaf nitrogen and chlorophyll stimulated tree growth which in turn increased yield.

Among the mulch and cover crop treatments, pea vines were outstanding in their beneficial effect on tree performance. This effect was more apparent in the low than in the medium or high fertility plots.

A program of rejuvenation as conducted under the conditions of this experiment, would give temporary economic benefits. Over a long period of time, however, a tree removal and replanting program might be more profitable.

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