SOIL NITRATES AS INFLUENCED BY ORCHARD SODS AND SOIL MANAGEMENT

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David Alan Wolfe

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presented by

David Alan Wolfe

**has been accepted towards fulfillment
of the requirements for**

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SOIL NITRATES AS INFLUENCED BY ORCHARD SODS AND SOIL MANAGEMENT

By

David Alan Wolfe

A THESIS

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INTRODUCTION

An adequate supply of nitrogen is necessary for good growth and production in fruit trees, but in areas subject to extreme winter temperatures, the nitrogen supply is critical because of the possibility of winter injury. Fruit growers generally prefer to have a slight decrease in nitrogen of the plant late in the season so that the trees will enter the dormant period more resistant to cold winter temperatures.

The use of mulches, sod covers and other soil management practices has been shown to have an influence upon tree performance. In general, the influence of these practices has been associated with soil moisture depletion or conservation. However, mulches, sod covers and both the kind and amount of fertilizer have been found to influence the nitrogen status of fruit trees. There has been limited study of the influence of these practices upon the supply of soil nitrates.

This study was designed to investigate the extent and nature of the influence that various soil management practices and fertilizer applications have upon the supply of soil nitrates.

LITERATURE REVIEW

Many reports have been written that give the advantages and disadvantages of clean cultivation, sod and sod-mulch methods of soil management. In many instances, however, the differences in response of the various soil management programs have been associated with soil moisture depletion. Some of the earlier research showed that the sod covers and mulches resulted in nitrogen deficiency.

Soil nitrates are thought to be the form of inorganic nitrogen used by most plants. The quantities of soil nitrates in the soil have been considered to be dependent upon the vegetation, the soil type, the soil microorganism's population and environmental conditions such as temperature and moisture. The most favorable environment according to Waksman (1952) for microbial population is a temperature of 27.5° C, abundance of oxygen, enough moisture to function, a pH of greater than 4.6, and a calcium carbonate buffer in the soil.

Lyon, Heinicke and Wilson (1923) indicated that the poor growth of apple trees in sod was due to low soil nitrates. The low soil nitrates under the sod could not be accounted for entirely by grass and tree growth and probably was not leached out. It was thought the soil microorganisms had converted part of the nitrate to nitrite and ammonia. Later Lyon, Heinicke and Wilson (1925) found nitrates to be a

limiting factor on plum and cherry trees growing in sod and that considerable quantities of soil nitrates were produced but were being used in growth of sod. Waksman (1952) found that the soil atmosphere in the grass root zone had a high carbon dioxide content. As a result of the high carbon dioxide content, the roots of the tree penetrated deep into the soil where there was a lack of oxygen but less carbon dioxide and soil nitrates.

Partridge (1941) found wide differences between some of the common grasses used in the orchards in relation to their competition for moisture and nutrients with fruit trees. These differences were thought to be due to penetration and concentration of the root systems. Kentucky bluegrass and quackgrass had the largest root system and utilized the most moisture and nutrients while fescue and timothy had the smallest root systems and utilized the least moisture and nutrients.

Summarizing the literature, Russell (1950) stated that in grassland soils most of the inorganic nitrogen is in the form of ammonium. Fertilizer effected the relatively constant levels of ammonium and nitrates for short periods only. The ratio of nitrate to ammonium depended mainly on rate of oxidation of ammonium, the uptake of nitrates by plants and loss of nitrates by leaching.

Albrecht (1922) found that mulches limited the quantities of soil nitrates as compared to cultivation. He associated the decrease in soil nitrates under mulch to lower soil temperatures under the mulch, and to higher soil moisture that caused a reduction in aeration. These conditions were unfavorable for maximum microbial activity. Leaching, also, might be an important factor in a low level of nitrates under mulches as Turk and Partridge (1941) reported that percolation of water was much greater under mulches than under unmulched soils.

Beaumont and Crooks (1933) found that soil nitrates accumulated only slightly during the first three years of mulching but accumulated constantly and in large amounts during the fourth year. It was thought that reduction of the carbon-nitrogen ratio by microbial action during the first three years was sufficient to allow nitrates to accumulate in the fourth year. They thought that the accumulated nitrates were produced by nitrification in the lower layers of the decomposing mulch and were carried into the soil by leaching action. Turk and Partridge (1947) found that there was less production of soil nitrates in a heavy soil than in a light soil. They concluded that a major portion of nitrification under mulches must occur at the soil-mulch interface. Lack of aeration and higher soil moisture also influenced the production of soil nitrates according to Turk and Partridge (1947).

In a 26 to 42-year-old soil management experiment, Havis (1942) found that aggregation of soil was greatest for sod-mulch and least for clean cultivation. There was little difference between soil management practices during the two to six year period but soil aggregation was more rapid under the mulch. This aggregation of the soil was not in direct relationship to the organic matter content of the soil. Beaumont and Crooks (1933) believed that the increase in soil nitrates under a mulch was associated with the rate of soil aggregation.

Judkins and Rollins (1944) found that clean cultivation during the first years of a peach orchard resulted in better yields than mulches. Hibbard (1944) also found clean cultivation during the first years of an orchard resulted in the best growth but reported severe erosion. Toenjes (1941) reported higher yield for the first ten years of cultivation of an apple orchard, but a reversal occurred the second ten years. Kenworthy (1953) suggested cultivation depleted soil structure, organic matter and reduced moisture penetration. Such effects of cultivation may have been responsible for the findings of Toenjes (1941).

Weeks, Smith and Drake (1950) and Wander and Gourley (1943) reported that mulching increased total quantities of nitrogen, potassium, calcium, magnesium and phosphorus in soils. Simulating orchard grass mulch in lysimeter studies, Harley, Moon and Regeimbal (1950) found that high-nitrogen hay released more nitrogen, calcium, and magnesium than a low-nitrogen hay. Carolus and Woltz (1944) reported a decrease in soil nitrates when phosphorus and potassium were added to cropped soils. They considered the decrease in soil nitrates to be associated with the increase in plant growth.

PROCEDURE

The investigations were conducted on established plots located at the Graham Horticultural Experiment Station near Grand Rapids, Michigan. The soil at the Experiment Station is a Miami silt loam with a field capacity of approximately 15 per cent moisture and a wilting point of approximately 5 per cent moisture. The plots used in these investigations were located in a peach orchard and in a field of sod plots.

Sod Plots

The sod plots were those established by Higdon (1953). They consisted of a field of approximately 1.1 acres that was divided into plots, 27 x 27 feet. Each of the plots was divided into two subplots that were 13.5 x 27 feet. The North subplot was mowed on June 16, while the South subplot was unmowed. Since the mowed portions of the covers were removed, the mowed and unmowed subplots for each sod were considered as separate treatments in the statistical analysis. Three plots, relatively free from contamination with quack-grass and weeds, were selected for each of the following sods: Chewing fescue (*Festuca ruba*, variety *commutata*), Kentucky bluegrass (*Poa pratensis*), redtop (*Agrostis alba*), alfalfa (*Medicago sativa*), white Dutch clover (*Trifolium repens*), ladino clover (*Trifolium repens*,, variety *latum*). The

quackgrass was established vegetatively in the fall of 1950. The other sod covers, except alfalfa, were seeded in 1950 while the alfalfa was seeded in the fall of 1951. The field had been limed and well fertilized prior to establishing the sod covers.

In addition to the sod plots, three plots were selected from the cultivation and mulching treatments. The cultivated plots, 27 x 27 feet, were not cultivated until August 14 but were cultivated about every two weeks for the remainder of the season. The mulch plots were subdivided into quarter plots, 13.5 x 13.5 feet, and each quarter was mulched with a different material. Grass hay, wheat straw, sawdust and low-grade alfalfa were used as mulch materials. Each sub-plot received approximately 48 pounds of air dry material.

Peach Plots

The trees in the peach plots were planted in 1948. The experimental design and replanting limited the selection of treatments. Two, more or less separate, studies were conducted in the peach orchard. The first study consisted of a normal application of nitrogen to two cultivars (Redhaven and Halehaven) growing in sod, cultivation with a winter cover, and sod-mulch. The second study used one cultivar (Redhaven) with five fertilizer treatments and with sod and sod-mulch management. Three replicate trees were used for each combination of treatments in each study.

The fertilizer treatments involved normal nitrogen (N), double nitrogen (NN), double nitrogen in split applications (N-N), double nitrogen with phosphorus (NNPP)*, and double nitrogen with phosphorus and potassium (NNPPKK)*. Table I shows the rates of fertilizer application for each year. Different forms of nitrogen fertilizer were used but the rate of applying nitrogen was calculated on the basis of ammonium sulfate. Superphosphate was used as a source of phosphorus. 0-20-20 was applied to those plots receiving phosphorus and potash. The sod was Chewing fescue and was established when the trees were planted. The cover crop was rye and was seeded in late July. Each tree in the mulched plots received 35 pounds of straw in 1948, 50 pounds of grass and weeds in 1950, and 75 pounds of grass and weeds in 1952.

Sampling

Soil areas including all treatments were sampled five times at two-week intervals. Sampling began July 13 for the sod plots and July 20 for the peach plots.

Two cores were taken with a Veihmeyer soil sampling tube to the depth of nine inches. The lowest three inches of each core were combined for one sample. The sampling was

*The treatments receiving phosphorus and potassium are designated as PP and KK because certain other plots received only half as much phosphorus and potassium as the plots used.

TABLE I

AMOUNT OF FERTILIZER APPLIED IN THE PEACH ORCHARD FOR EACH YEAR, 1948-1953 (LBS./TREE)

Rows*	Fertilizer	Equiva- lent units	1948	1949	1950	1951	1952	1953
6,9,14	N	20-0-0	0.0	0.33	0.67	1.0	1.33	1.67
5,13	NN	20-0-0	0.0	0.67	1.33	2.0	2.67	3.33
4,12	N-N**	20-0-0	0.0	0.67	1.33	2.0	2.67	3.33
2,10	NN	20-0-0	0.0	0.67	1.33	2.0	2.67	3.33
	PP	0-20-0	6.0	0.0	2.0	2.0	4.0	4.0
3,11	NN	20-0-0	0.0	0.67	1.33	2.0	2.67	3.33
	PP	0-20-0	6.0	0.0	2.0	2.0	4.0	4.0
	KK	0-0-20	6.0	0.0	2.0	2.0	4.0	4.0

*Rows 2, 3, 4, 5, 6 were in sod; rows 10, 11, 12, 13, 14 were in sod-mulch and row 9 was in cultivation with cover crop.

**The nitrogen was a total of the split applications. Applications were usually in early May and late June.

made within two feet of the edge of the subplots in the sod plots and three feet from the trunk of the peach trees.

The samples were placed in glass bottles with rubber stoppers and shaded while in the field to prevent moisture loss and temperature increases. The samples were immediately screened and extracted with sodium acetate. Soil nitrates were determined by use of a rapid microchemical method (Peech, 1945) that used an alkaloid brucine solution as an indicator. The soil nitrates were determined with field moisture rather than on dried samples. Soil moisture was determined by drying for each sample.

RESULTS

Sod Plots

The measurements of soil nitrates showed that the treatments may be grouped into three distinct classes as shown in Figure 1. Soil nitrates were markedly lower for the grass and legume sods than for the mulches and clean cultivation. Soil nitrates for the legume sods were higher than for the grass sods.

As shown in Table II and Figure 2, soil nitrates were significantly lower for the legume and grass sods than for the mulches and clean cultivation. Except for the relatively low level of soil nitrates found for unmowed alfalfa and mowed white Dutch clover, soil nitrates were significantly higher for the legumes than for the grass sods.

Soil nitrates were significantly higher for timothy than for quackgrass when both sods were unmowed. Otherwise, there were no significant differences between the grass sods. Mowing did not result in a significant change in soil nitrates. However, mowing fescue appeared to increase soil nitrates while mowing redtop appeared to decrease soil nitrates.

The lowest level of soil nitrates for the legume sods was found with unmowed alfalfa which was significantly lower

Figure 1. A comparison of soil nitrates (lbs./acre) for grass sods, legume sods, clean cultivation and mulching. (Average - July 13 to September 7).

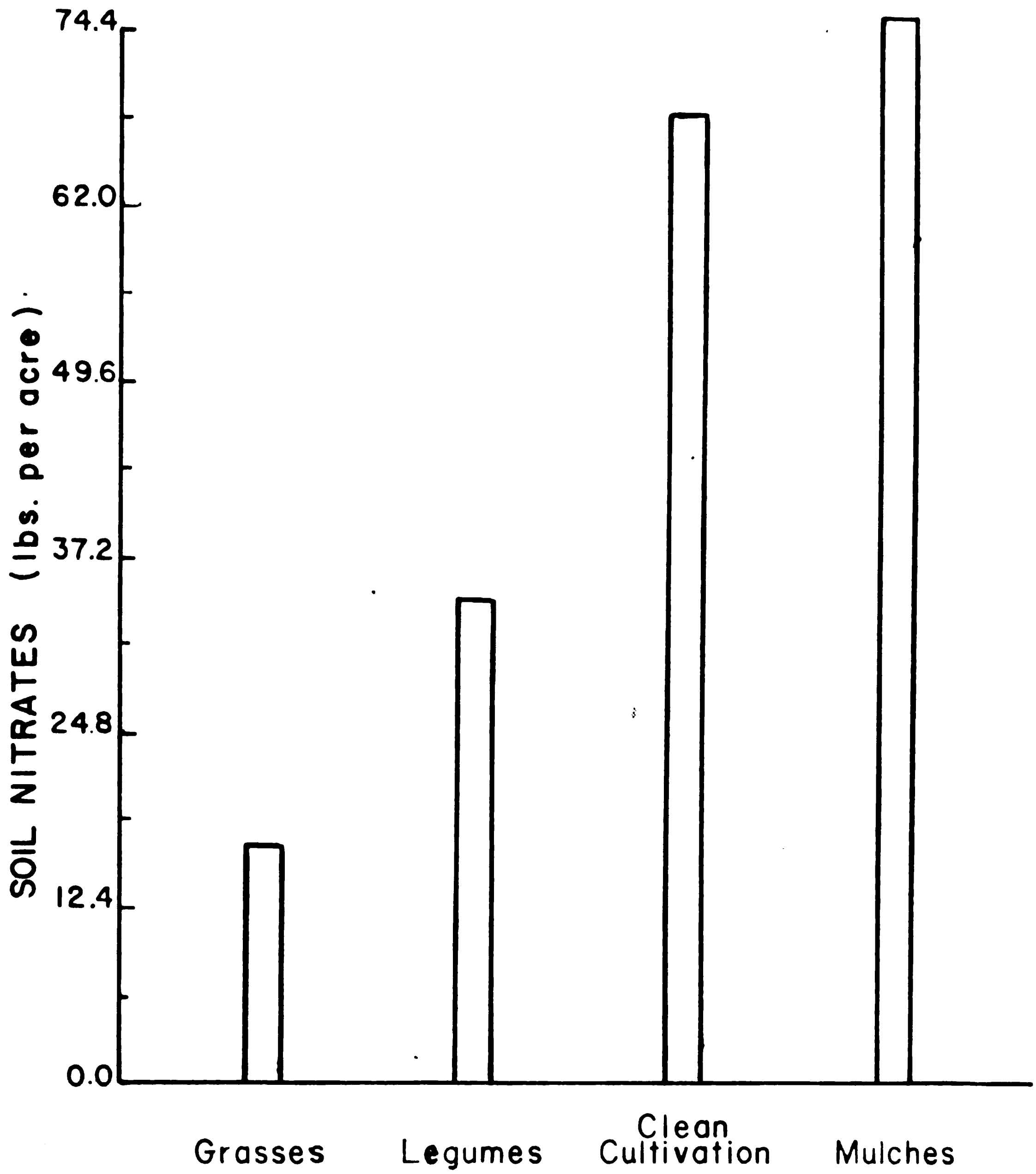

74.4
62.0
49.6
37.2
24.8
12.4
0.0
SOIL NITRATES (lbs. per acre)
Grasses
Legumes
Clean Cultivation
Mulches

FIGURE I

TABLE II

SOIL NITRATE IN RELATION TO MOWED AND UNMOWED SOD COVERS, CLEAN CULTIVATION AND MULCH MATERIALS

(Average - July 13 to September 7)

Cover	Soil nitrates-lbs./acre	
	Unmowed	Mowed
Grass Sods		
Fescue	15.69	18.85
Timothy	22.83	21.82
Quackgrass	13.83	14.14
Kentucky bluegrass	14.94	15.87
Redtop	17.55	14.57
Legume Sods		
Alfalfa	27.90	37.26
White Dutch clover	37.57	30.32
Ladino clover		39.74
Mulches		
Clean cultivation	68.88	
Alfalfa mulch	78.37	
Grass mulch	94.80	
Sawdust mulch	62.12	
Straw mulch	68.20	

Least significant difference:	5%	1%
All treatments	11.53	15.19
Sods only	8.12	10.73

Figure 2. Soil nitrates (lbs./acre) in relation to various sod covers, clean cultivation and mulch materials.
(Average - July 13 to September 7).

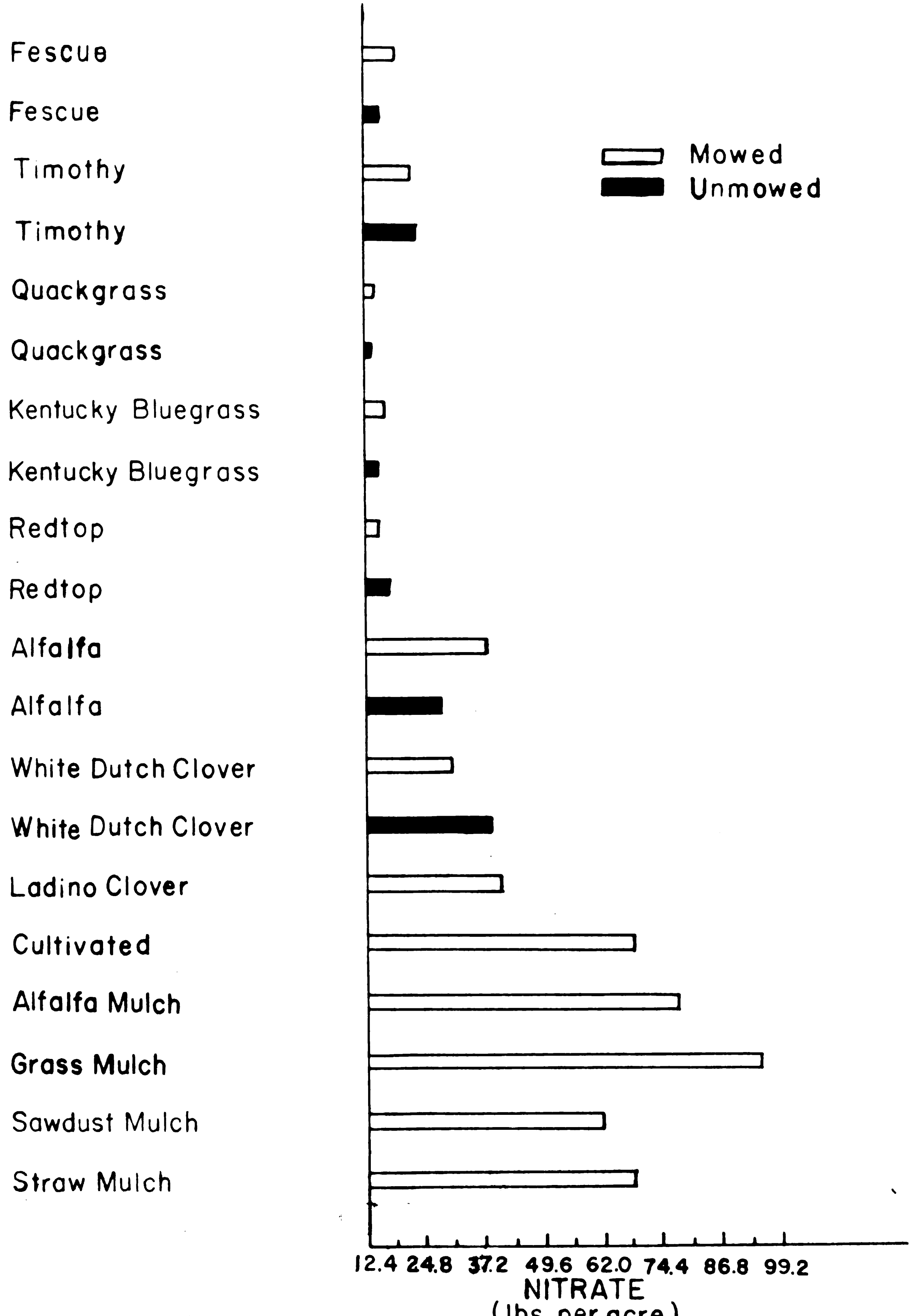

Fescue
Fescue
Timothy
Timothy
Quackgrass
Quackgrass
Kentucky Bluegrass
Kentucky Bluegrass
Redtop
Redtop
Alfalfa
Alfalfa
White Dutch Clover
White Dutch Clover
Ladino Clover
Cultivated
Alfalfa Mulch
Grass Mulch
Sawdust Mulch
Straw Mulch
Mowed
Unmowed
12.4 24.8 37.2 49.6 62.0 74.4 86.8 99.2
NITRATE
(lbs. per acre)

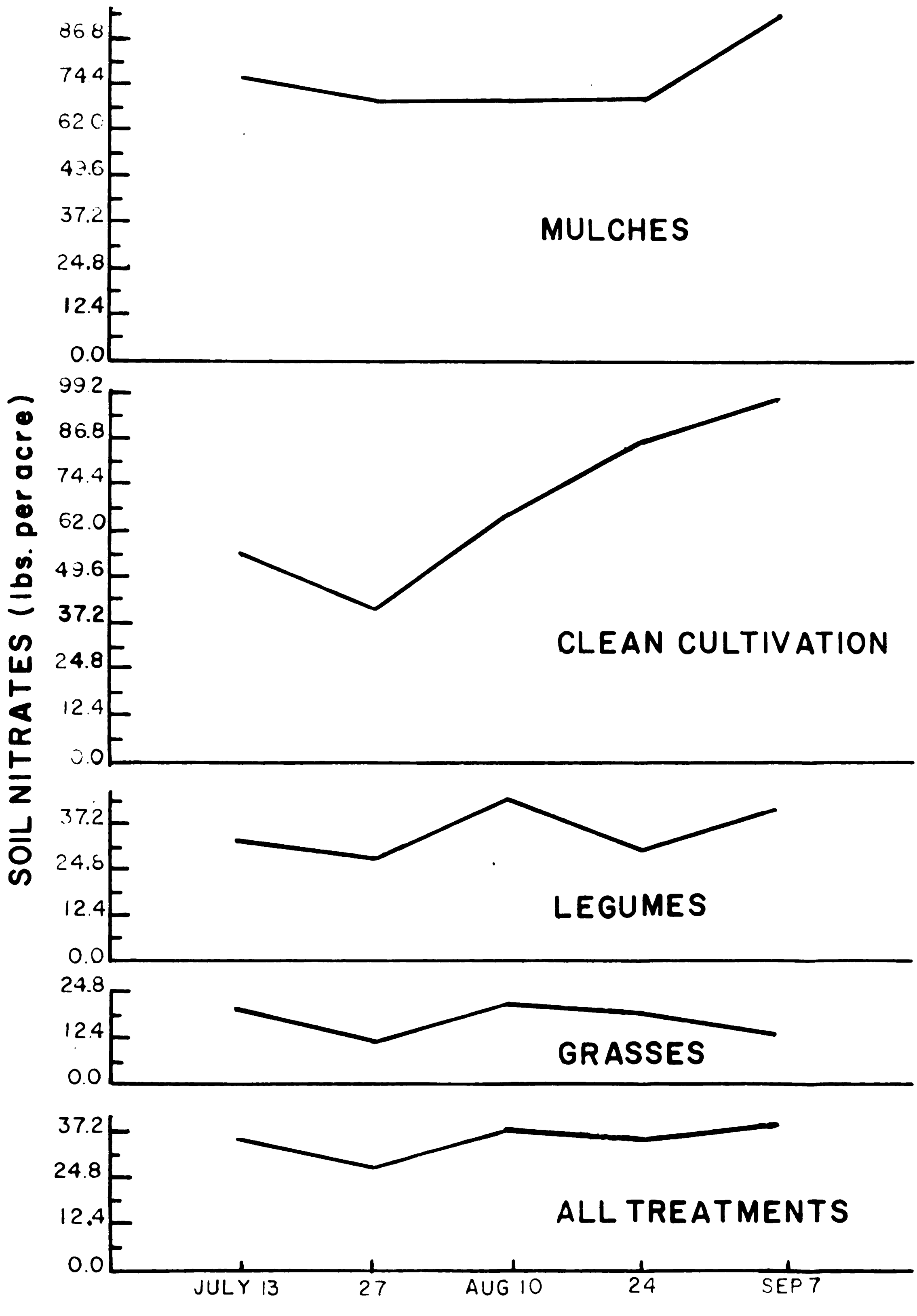
FIGURE 2

than mowed alfalfa, unmowed white Dutch or ladino clover. There was no significant difference in soil nitrates as a result of mowing white Dutch clover, but mowing decreased soil nitrates for white Dutch clover.

Grass mulch resulted in the soil being significantly higher in soil nitrates than the other mulches and clean cultivation. Alfalfa mulch resulted in soil nitrates being higher than for clean cultivation and mulches of straw and sawdust.

The interaction of treatment with weeks was not significant and the biweekly variations in soil nitrates for the major groups of covers, as shown in Figure 3, showed that soil nitrates were consistently high for the mulch plots. There appeared to be an increase in soil nitrates for the mulches between August 24 and September 7. In the cultivated plots, soil nitrates were initially lower than for the mulches but increased sharply and continued to increase for the remainder of the season. The highest level of soil nitrates for a soil management practice (97 lbs. per acre) was found for clean cultivation on September 7. The legumes and grasses showed similar biweekly variation in soil nitrates with the legumes varying somewhat more than the grasses. The biweekly variation of all treatments showed that there was a significant decrease in soil nitrates for the sampling of July 27.

Figure 3. Biweekly variation of soil nitrate (lbs./acre) in relation to mulching, clean cultivation, legume sods and grass sods.



SOIL NITRATES (lbs. per acre)
86.8
74.4
62.0
49.6
37.2
24.8
12.4
0.0
MULCHES
99.2
86.8
74.4
62.0
49.6
37.2
24.8
12.4
0.0
CLEAN CULTIVATION
37.2
24.8
12.4
0.0
LEGUMES
24.8
12.4
0.0
GRASSES
37.2
24.8
12.4
0.0
ALL TREATMENTS
JULY 13
27
AUG 10
24
SEP 7

FIGURE 3

Peach Plots

The study of soil nitrates in relation to normal nitrogen applications to two cultivars with three methods of soil management showed a significant difference between management practices (Table III). Soil nitrates for clean cultivation were more than double that found for either sod or sod-mulch (Figure 4). Soil nitrate for sod-mulch was not significantly higher than that found for sod.

The significant interaction between cultivars and management practices, Figure 5, showed that soil nitrates for Redhaven were significantly higher than for Halehaven when in cultivation with winter cover crop. However, soil nitrates for Halehaven were higher than for Redhaven when in sod-mulch. Biweekly variation in soil nitrates showed that there was a significant reduction in soil nitrates between July 20 and August 3, as shown in Table III. Also, there was a significant increase in soil nitrates between August 31 and September 14.

The interaction of biweekly variation in soil nitrates with soil management practices was not significant. As shown in Figure 6, the biweekly variation in soil nitrates for sod and sod-mulch was similar to the average for all treatments. However, the soil nitrates for clean cultivation showed a marked reduction from the initial level of 78.7 pounds per acre to 21.1 pounds per acre for the second

TABLE III

SOIL NITRATES (LBS./ACRE) UNDER PEACH TREES AS INFLUENCED BY SOIL MANAGEMENT, VARIETY AND TIME OF SAMPLING

Soil Management
(Average - July 20 to September 14)

Sod	Cultivation	Sod-mulch
15.15	55.61	21.89

Least significant difference:	5%	1%
Management	11.97	15.93

Management x Variety
(Average - July 20 to September 14)

Halehaven			Redhaven		
Sod	Cultivation	Sod-mulch	Sod	Cultivation	Sod-mulch
15.87	34.66	28.27	14.38	76.57	15.50

Least significant difference:	5%	1%
Management x Variety	43.34	57.60

Time of Sampling
(Average for all treatment)

July 20	Aug. 3	Aug. 17	Aug. 31	Sept. 14
38.13	18.85	31.37	24.74	41.23

Least significant difference:	5%	1%
Time of sampling	15.50	20.58

Figure 4. A comparison of soil nitrates (lbs./acre) in relation to sod, cultivation and sod-mulch management. (Average - July 20 to September 14).

Figure 5. A comparison of soil nitrates (lbs./acre) as effected by the interaction of cultivar with management practices. (Average - July 20 to September 14).

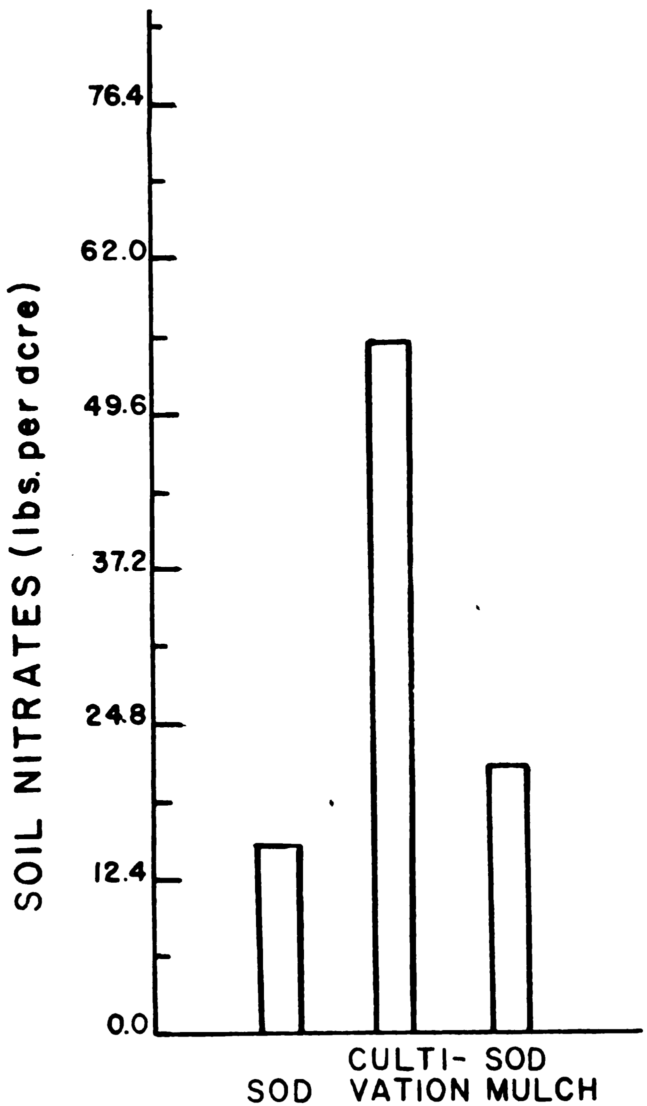


FIGURE 4

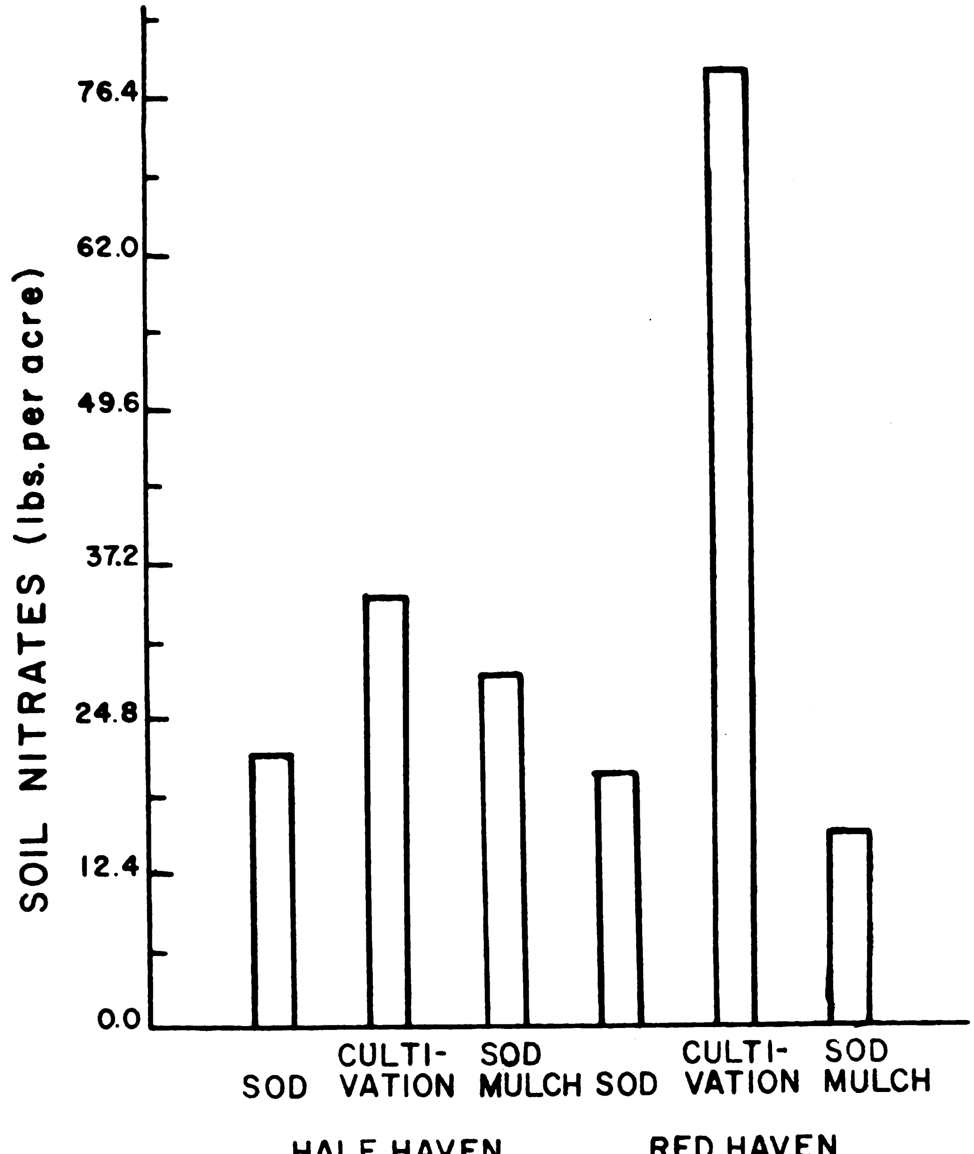
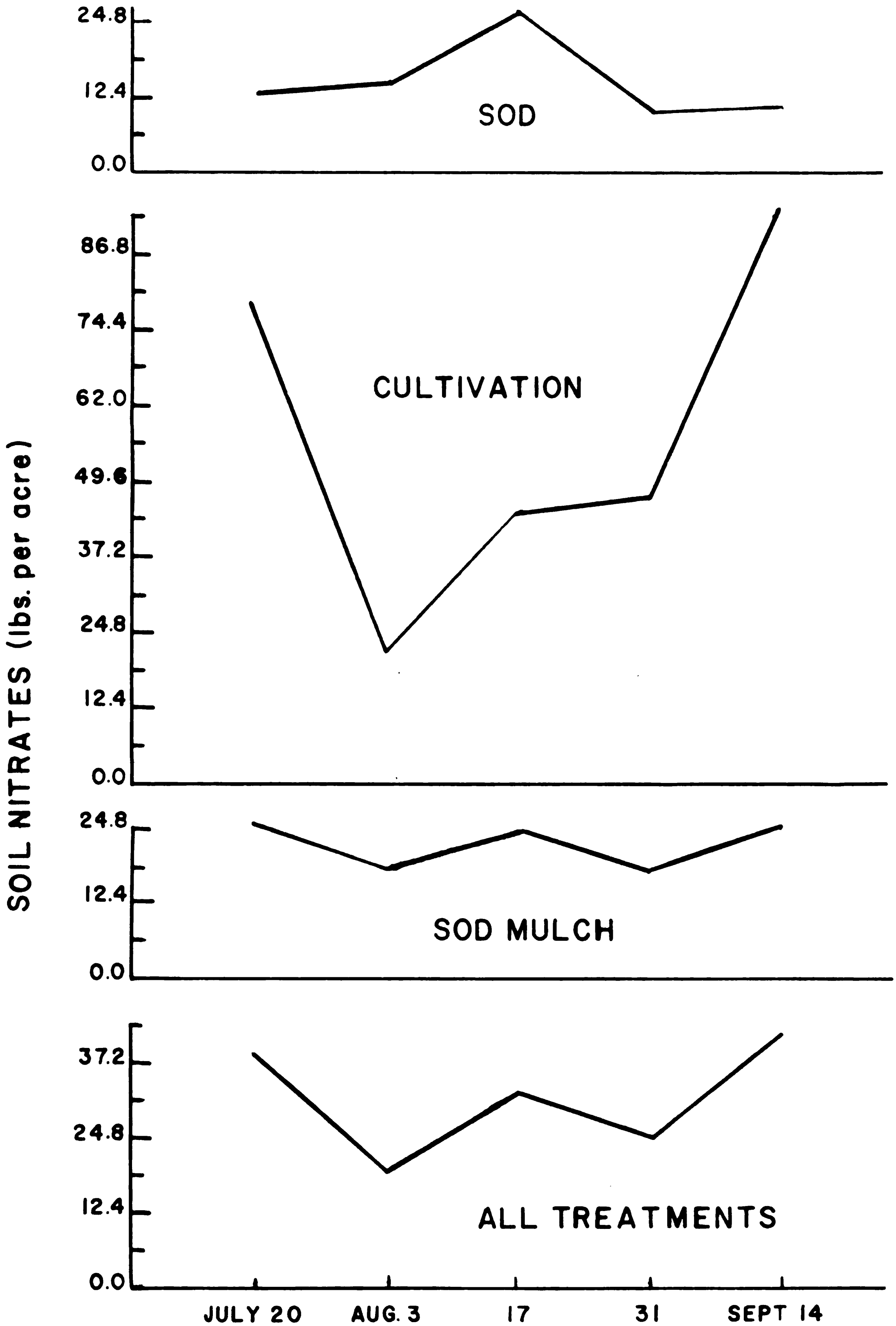


FIGURE 5

Figure 6. Biweekly variation of soil nitrate (lbs./acre) in relation to sod, cultivation, sod-mulch and all treatments.



SOIL NITRATES (lbs. per acre)
24.8
12.4
0.0
SOD
86.8
74.4
62.0
49.6
37.2
24.8
12.4
0.0
CULTIVATION
24.8
12.4
0.0
SOD MULCH
37.2
24.8
12.4
0.0
ALL TREATMENTS
JULY 20
AUG. 3
17
31
SEPT 14

FIGURE 6

sampling. After this sharp reduction, soil nitrates increased to a level of 88.0 pounds per acre on September 14.

The study of fertilizer applications in relation to soil management showed that soil management, fertilizer applications and time of sampling had a significant influence upon soil nitrates (Table IV). There was, also, a significant interaction of fertilizers with soil management and with time of sampling.

Soil nitrates found under sod-mulch, as shown in Figure 7, were essentially double that found under sod. Double applications of nitrogen (NN) more than tripled the level of soil nitrates found for single applications of nitrogen (N) (Figure 8). Making split applications of nitrogen (N-N) significantly increased soil nitrates above that found for single applications of double nitrogen (NN). The addition of phosphorus and potash (NNPPKK) to the fertilizer application significantly decreased soil nitrates. However, the addition of phosphorus (NNPP) to the fertilizer application did not influence the level of soil nitrates.

The average level of soil nitrates (Table IV) was highest on July 20 and was followed with a significant decrease on August 3. This decrease was followed with an increase on August 17 that failed to be significant. There was another significant decrease in soil nitrates between August 17 and August 31 and a significant increase in soil nitrates between August 31 and Septebmer 14.

TABLE IV

SOIL NITRATES (LBS./ACRE) UNDER PEACH TREES AS INFLUENCED BY SOIL MANAGEMENT, FERTILIZER APPLICATIONS AND DATE OF SAMPLING

Soil management or Time of sampling	Fertilizer applications					
	N	NN	N-N	NNPP	NNPPKK	Average
			Management x Fertilizer			
Sod	13.57	20.09	33.73	46.31	23.87	27.28
Sod-mulch	15.50	69.44	91.76	46.25	29.26	50.22
			Fertilizer x Sampling Date			
July 20	16.80	51.83	72.54	113.83	33.85	57.78
August 3	11.66	44.02	60.33	21.08	19.22	31.25
August 13	19.28	55.37	61.07	35.71	29.74	42.22
August 31	11.35	22.94	53.01	18.79	19.90	25.17
September 14	13.64	49.79	66.96	20.03	20.03	38.50
Average for fertilizers	14.57	44.76	62.74	46.31	26.54	

Least significant difference:	5%	1%
Between managements	8.49	11.22
Between fertilizers	13.27	17.55
Between samplings	13.27	17.55
Management x fertilizers	18.79	24.86
Fertilizer x samplings	29.76	39.37

Figure 7. Soil nitrates (lbs./acre) under sod and sod-mulch management.
(Average - July 20 to September 14).

Figure 8. Soil nitrates (lbs./acre) under various fertilizer treatments.
(Average - July 20 to September 14).

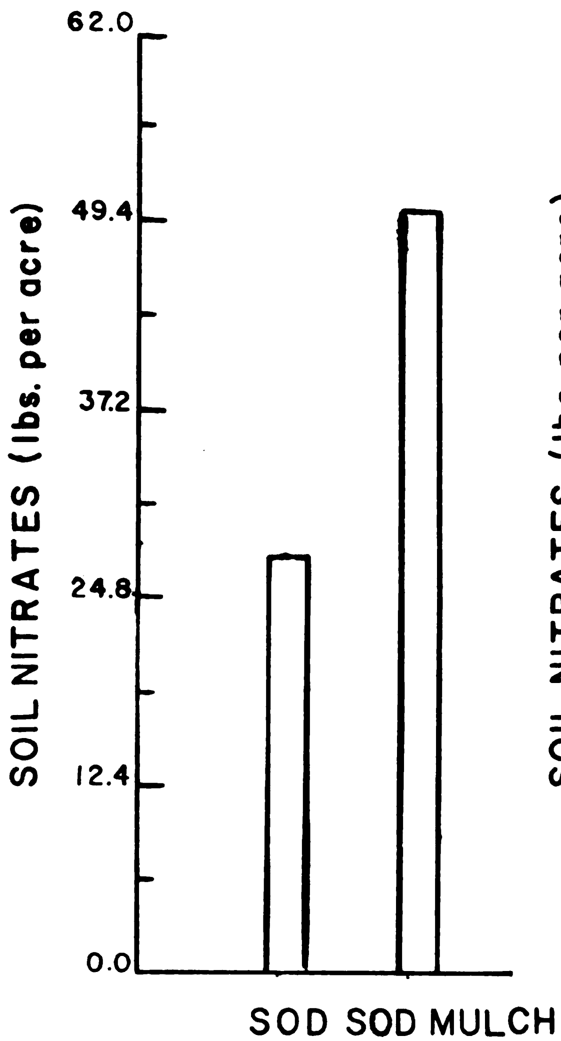


FIGURE 7

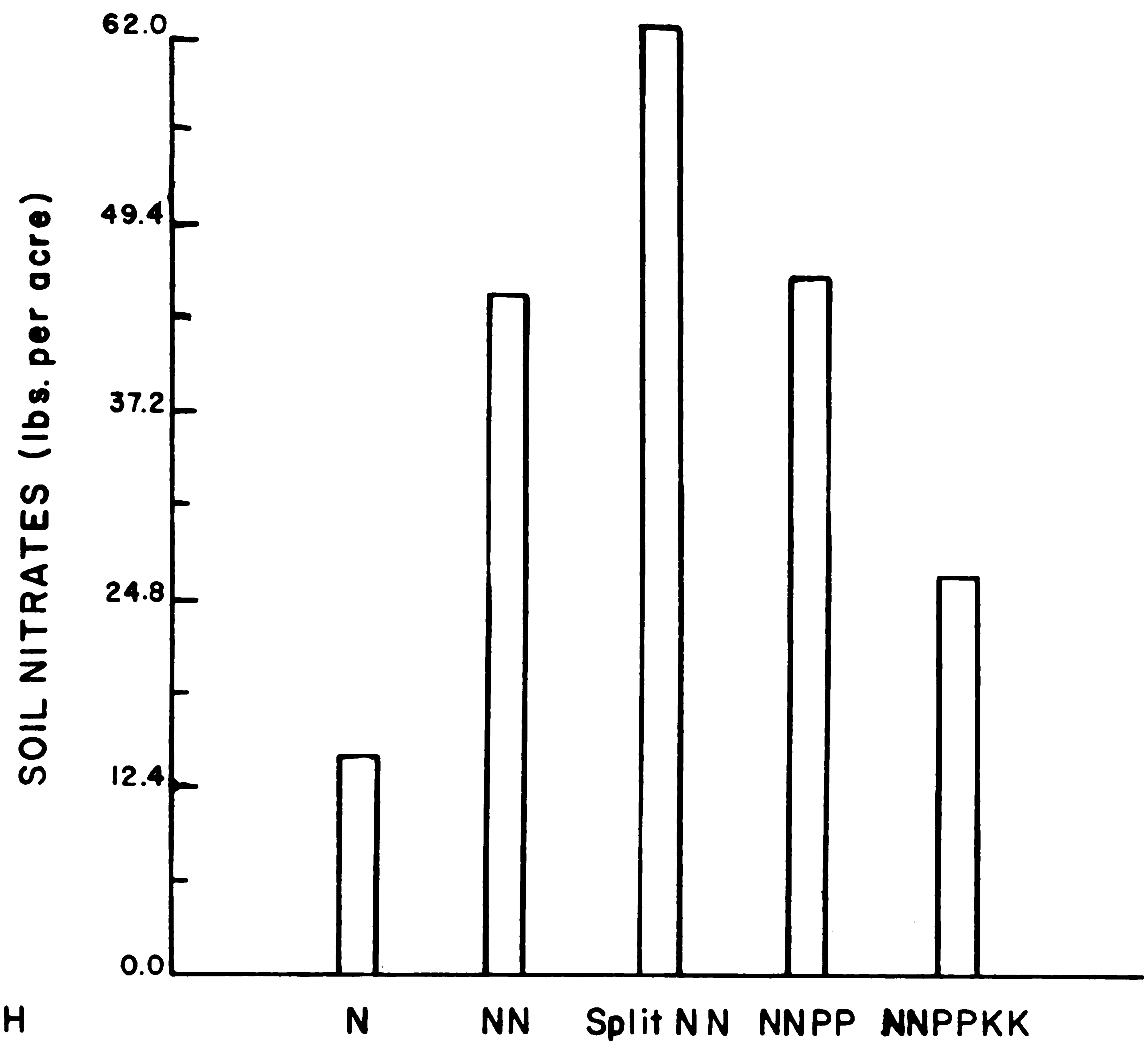


FIGURE 8

The interaction between soil management and fertilizer applications (Figure 9) showed that the sod-mulch significantly increased soil nitrates when double nitrogen (NN) or split nitrogen (N-N) applications were made. The addition of either phosphorus or phosphorus and potassium to double nitrogen (NNPP or NNPPKK) significantly decreased soil nitrates from that of double nitrogen (NN). In the sods, the addition of phosphorus to double nitrogen (NNPP) significantly increased soil nitrates over that of double nitrogen (NN) and the addition of potassium to phosphorus and double nitrogen (NNPPKK) significantly decreased soil nitrates from that of double nitrogen and phosphorus (NNPP). Using either phosphorus or phosphorus and potash with double nitrogen did not result in any difference between sod and sod-mulch in the level of soil nitrates.

The interaction of fertilizer applications with sampling dates (Figure 10) showed that there was a significant decrease in soil nitrates for the double nitrogen (NN) between August 17 and August 31. The decrease in soil nitrates for the NNPP treatment between July 20 and August 3 persisted for the remainder of the season. The unusually high level of soil nitrates for the NNPP treatment on July 20 resulted in the apparent reduction in soil nitrates associated with the use of phosphorus in the fertilizer application not being illustrated in the average value. Although there were no significant changes in soil nitrates for the other treatments when

Figure 9. A comparison of soil nitrates (lbs./acre) for various fertilizers as influenced by sod and sod-mulch management. (Average - July 20 to September 14).

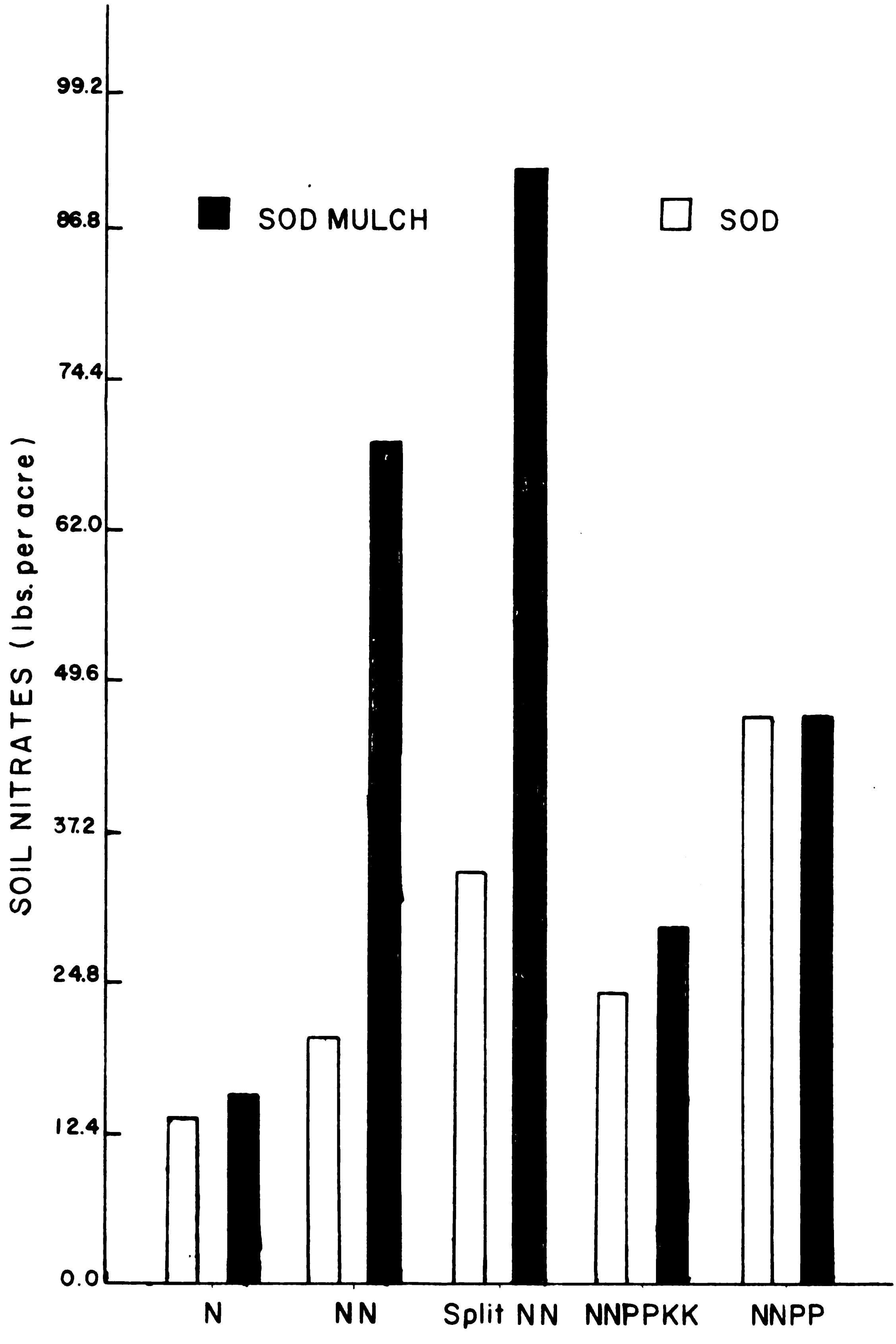

99.2
86.8
74.4
62.0
49.6
37.2
24.8
12.4
0.0
SOIL NITRATES (lbs. per acre)
SOD MULCH
SOD
N
NN
Split NN
NNPPKK
NNPP

FIGURE 9

Figure 10. Biweekly variation of soil nitrates (lbs./acre) in relation to fertilizer applications.

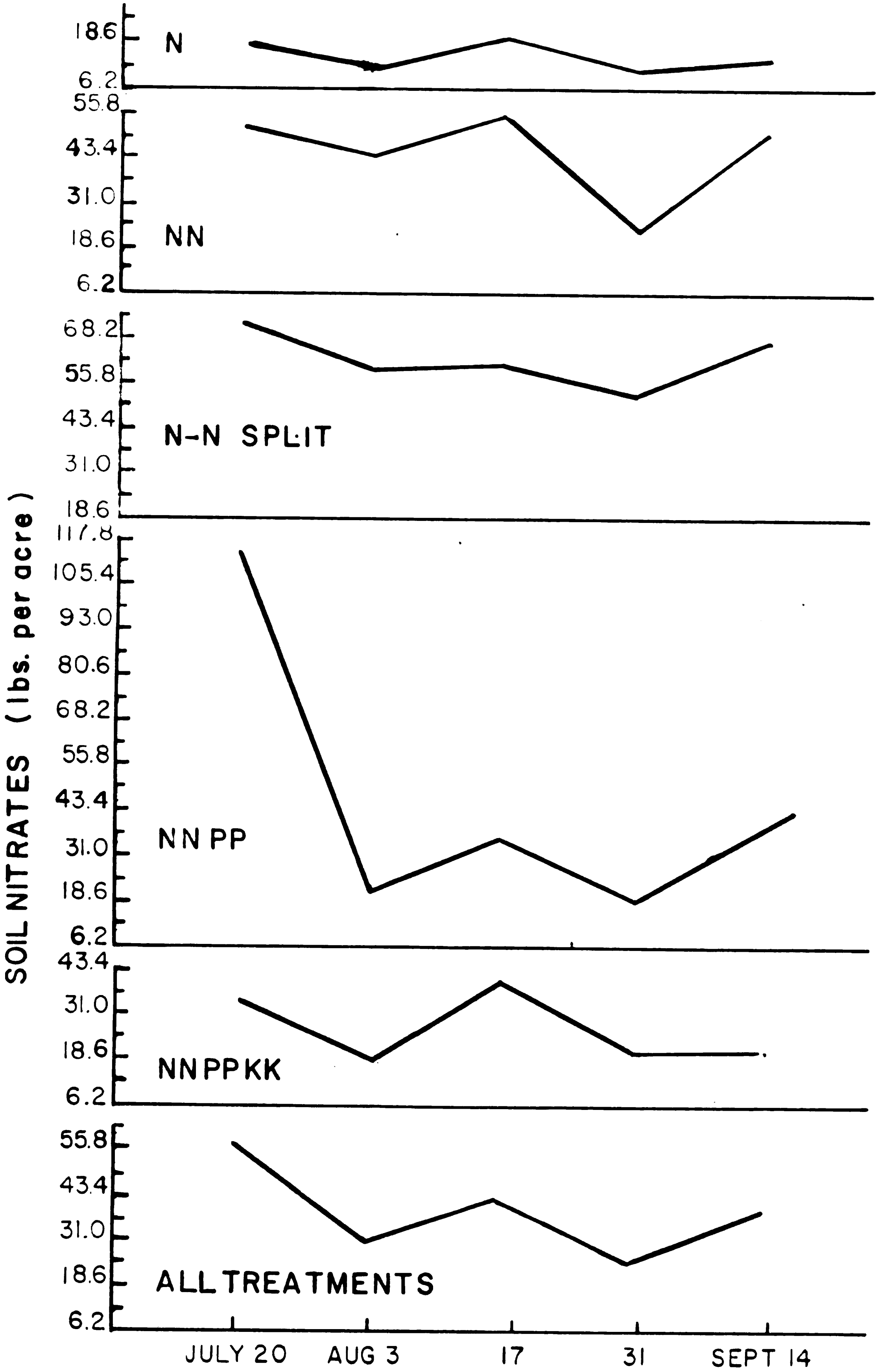

SOIL NITRATES (lbs. per acre)
N
NN
N-N SPLIT
NNPP
NNPPKK
ALL TREATMENTS
18.6
6.2
55.8
43.4
31.0
68.2
117.8
105.4
93.0
80.6
JULY 20
AUG 3
17
31
SEPT 14

FIGURE 10

samples on different dates, there appeared to be a general reduction in soil nitrates for all treatments, on August 3 and August 31.

DISCUSSION

The level of soil nitrates is generally considered an index of biological activity (Russell, 1950). Soil management practices and fertilizer applications may influence the supply of soil nitrates by releasing additional nitrates and indirectly by modifying the environmental factors that influence biological activity. Also, the level of soil nitrates may be reduced by growth of trees and the sod covers.

Sods generally have been reported (Russell, 1950) to result in most of the inorganic nitrogen being in the ammonium form with relatively little in the nitrate form. All the "sod plots" showed a low but relatively constant level of soil nitrates. The major factor influencing the level of soil nitrates under sod was believed to be a result of the use of nitrate by the sods. Also, the sod growth may result in a higher level of carbon dioxide in the soil atmosphere. This higher level of carbon dioxide may reduce nitrification in the soil of the root zone. Also the high carbon dioxide or other natural factors such as drought may increase the rate of dying of rootlets and excretion by the plant of other carbonaceous substances which could result in microorganisms assimilating nitrates in decomposing such organic matter.

The physiological character of various grasses may account for the different level of soil nitrates found. Quackgrass had the least soil nitrate while timothy had the most, which agrees with Partridge (1941), who found that quackgrass competed more vigorously than timothy for soil nitrates because of a larger root system.

The legumes were similar to the grasses but had a higher level of soil nitrates. The higher level of soil nitrates for the legumes was most likely the result of fixation of nitrogen from the air by the bacteria of the nodules. The fixed nitrogen not only aids in satisfying the demand for nitrogen by the legume but may, upon decomposition add additional nitrate to the soil.

Mowing was of the greatest significance on the legume sods. Mowing alfalfa resulted in an increase in soil nitrates. Possibly the mowing of alfalfa resulted in rapid regrowth and probably a greater fixation of nitrogen. Mowing white Dutch clover reduced soil nitrate. The regrowth of the clover was retarded because soil moisture was low. The soil moisture for white Dutch clover at the first sampling was 6.04 per cent moisture or 10.4 per cent of the available soil moisture (dry soil basis) while at the last sampling soil moisture was at the wilting point.

On the fescue sod in the peach orchard, double nitrogen (NN) resulted in higher soil nitrates than normal nitrogen (N) and double nitrogen in two applications (N-N) produced more soil nitrates than the double nitrogen (NN). When phosphorus was added to double nitrogen (NNPP), the highest level soil nitrates was found under the sod. When both phosphorus and potassium (NNPPKK) were added, the soil nitrates were lower than for the double nitrogen (NN). The results for the various nitrogen treatments seemed to show in general a relationship to the amount and time of application of fertilizer. The addition of either phosphorus or phosphorus and potassium with double nitrogen probably increased the growth and decomposition cycle of the fescue and in this manner made more nitrates available to the peach tree.

The application of a fertilizer appeared to increase soil nitrates for short periods only. Since the soil was very dry (9.14 per cent moisture or 41 per cent of the available soil moisture, dry soil basis), it would appear to be unlikely that all the applied nitrogen fertilizer was used in sod or tree growth.

Mulches might be considered as insulators that alter the environmental conditions by decreasing soil temperatures and decreasing the rate of evaporation thus providing more constant environmental conditions. These constant conditions were shown to result in a more continuous supply of soil nitrates (Figure 3). The mulch plots in the peach orchard had greater variation in soil nitrates than those mulch plots not in the peach orchard. This may have been associated with the uptake of nitrates by the trees and to the presence of quackgrass growing in the mulched peach plots.

Leaching could not be considered to be a factor in the variation of soil nitrates in this experiment as the soil moisture was generally low except when mulch was used in the "sod plots". If any leaching occurred it should have been evidenced in the curve for mulch in the "sod plots" as these plots lacked vegetation to utilize soil moisture and soil nitrates and the mulch plots could be expected to have the greatest percolation.

One of the disadvantages of a mulch cited by Albrecht (1922) has been that a mulch limits the production of nitrates in a soil by not providing as favorable environmental conditions for nitrification. However, the type of mulching material may tend to offset this disadvantage. Harley, Moon, and Regeimbal (1950) have indicated that a high nitrogen hay produces more nitrates than a low nitrogen hay. The nitrogen content of the material may have been a factor in the production of the high soil nitrates under the grass mulch and the low grade alfalfa mulch.

Applications of fertilizer to the mulched trees showed that at the Graham Station not only was a nitrogen fertilizer necessary but that either phosphorus or phosphorus and potassium with double nitrogen increased yields (Table V). The nitrates under the double nitrogen plus phosphorus (NNPP) treatment were lower for most of the sampling periods than the double

TABLE V

YIELD AND CIRCUMFERENCE OF PEACH TREES UNDER SOD AND SOD-MULCH MANAGEMENT AS INFLUENCED BY FERTILIZERS NN, NNPP, NNPPKK (1953)

	Sod-mulch			Sods		
	NN	NNPP	NNPPKK	NN	NNPP	NNPPKK
Yield (lbs./tree)	112.00	187.00	188.00	87.00	120.00	148.00
Trunk circumference (inches)	12.50	13.75	13.91	11.08	11.50	12.50

nitrogen alone but not as low as when both phosphorus and potassium were added to the double nitrogen. From the trunk circumference data (Table 5) and the soil nitrate data, it would appear that the trees depleted soil nitrates more when phosphorus was added, and still more when both phosphorus and potassium were added to the nitrogen fertilizer.

Mulches have been found (Toenjes, 1941; Judkins and Rollins, 1944; and Weeks, Smith and Drake, 1950) beneficial in orchards due to a consistent high level of nitrates and providing other nutrients that may be lacking, thereby increasing the efficiency in the supply of nitrates. Mulches have been found (Hibbard, 1944) to give better growth responses as mulching as renewed. This may be associated with a new supply of readily available nutrients; the steadily increasing supply of nutrients being released by decomposition of organic matter and the improvement of aggregation in the soil. The effect of the mulch upon soil nitrates may be advantageous in the spring but might be disasterous in the fall by preventing hardening off of the tree. Winter injury occurred predominately in the sod-mulch part of the orchard in 1949.

Cultivation has been the generally accepted method of growing peaches as it provided the tree with sufficient nitrates when young, it aided in hardening off the tree, especially when used in conjunction with a fall cover crop.

The cultivated plots in the peach orchard were higher in soil nitrates than the sod-mulch while in the "sod plots", the clean cultivation was lower than the grass mulch and alfalfa mulch. The weed growth in the cultivated plots not in the peach orchard during the first part of the sampling period may have accounted for the cultivated plots having a lower average of soil nitrates.

The relationship of fertilizer to soil nitrates is varied. The normal nitrogen (N), double nitrogen (NN), and the double nitrogen in split applications (N-N) effected soil nitrates, generally, in proportion to the amount of fertilizer and the time of application. The biweekly variation of double nitrogen with phosphorus (NNPP) was very high at the start but dropped to a lower level after the first sampling. A possible answer might be that the phosphorus was not available for use by the tree and the tree did not take up the nitrates until the phosphorus became available.

The general biweekly trends were similar for most of the treatments. There was a general tendency for alternate sampling periods to show either a relatively high or a relatively low level of soil nitrates.

In most instances the relatively low levels of soil nitrates were sometimes significantly below the relatively high levels. The treatments that had the highest average levels of soil nitrate showed the most variation. For example, the clean cultivation showed more variation than sod-mulch; sod-mulch showed more variation than legumes and legumes more variation than grasses. A comparison of the soil nitrate to temperature, (Bureau of the Weather, 1953), and rainfall records (Figure 11) showed no close correlation even if soil temperature was considered to follow the air temperature by 7 to 10 days (Baten and Eichmeier, 1951). For the first period of low soil nitrates, the low temperature from July 21 to July 25 seemed not to be of sufficient duration to effect the soil nitrate level. The incidence of rain was not sufficient to leach away the soil nitrates. There was an indication that increased growth was the major cause of low soil nitrate at the second sampling. Some moisture had accumulated from the rains of July 19 and 23 and may have stimulated growth.

The second period of low soil nitrates occurred at the fourth sampling and the dry conditions point to the fact that growth had essentially stopped. The soil nitrate may have been assimilated by the microorganisms of the soil in the process of decomposing carbonaceous material derived from the sod and, thus, accounting in part for the level of soil nitrates. The use of soil nitrates by sod, trees and microorganisms and the low temperatures prevented maximum accumulation of soil nitrates that may have been actually offset by an increased production of soil nitrates resulting from increased aeration in the drier soil.

Figure 11. Daily mean air temperature (upper) and daily rainfall (lower), beginning one week prior to the start of sampling.

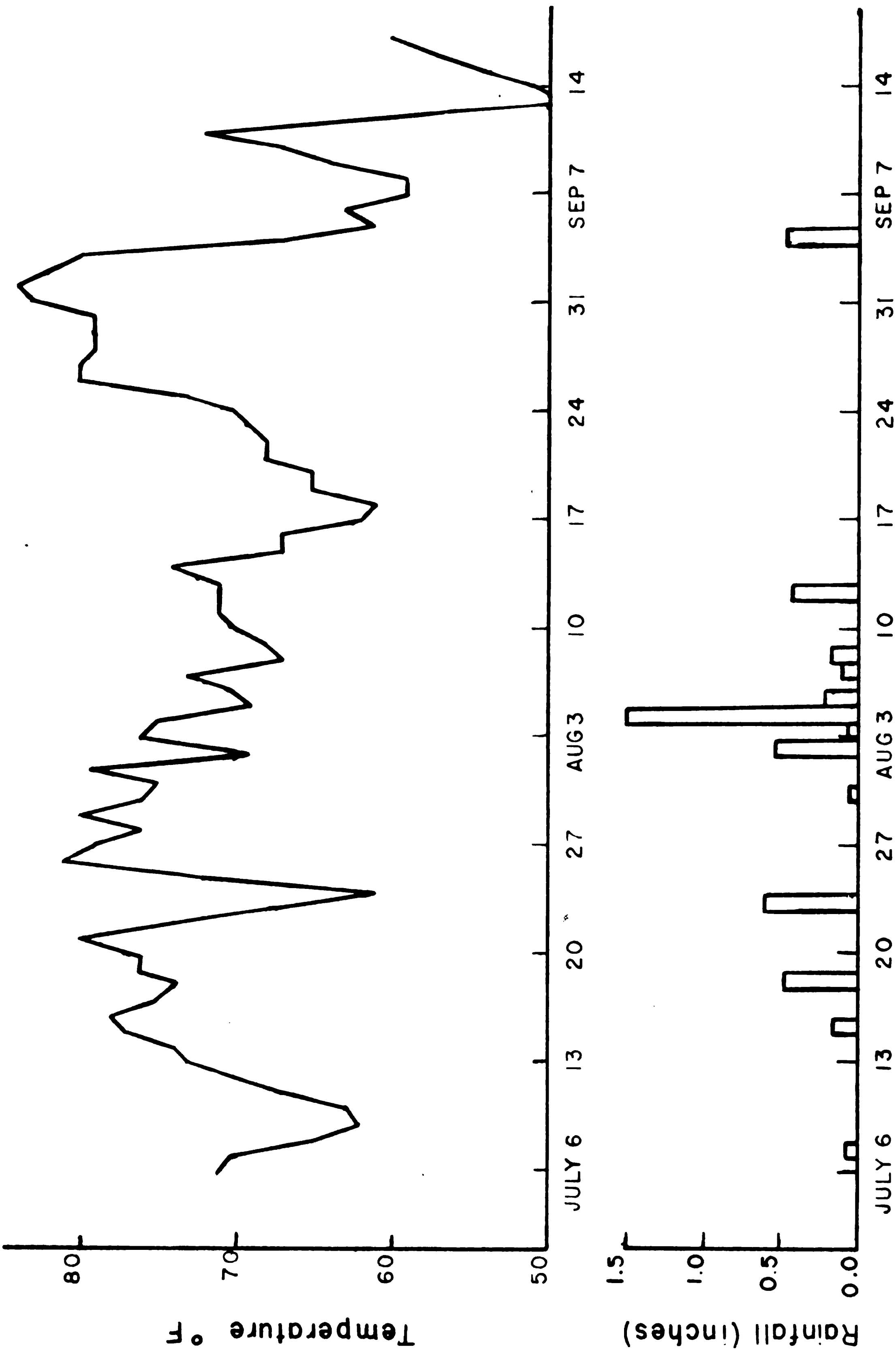

Temperature °F
80
70
60
50
Rainfall (inches)
1.5
1.0
0.5
0.0
JULY 6
13
20
27
AUG 3
10
17
24
31
SEP 7
14

FIGURE 11

SUMMARY

The experiment was conducted on a Miami Silt Loam. Soil samples were taken from two areas: (1) sod plots that included various sods, clean cultivation and mulches, and (2) a peach orchard that was in sod, cultivation and sod-mulch with various fertilizer treatments. Soil nitrates were determined by Peech's Rapid Microchemical Test using Brucine as the reagent.

In the "sod plots", the soil nitrates under mulches were higher and more constant than for cultivation. Grass mulch had the highest level of soil nitrates, followed by the alfalfa, straw and sawdust mulch. Legumes were lower in soil nitrates than cultivation and mulching, and higher than grass sods. The quackgrass sod had the lowest level of soil nitrate. There were no significant differences between mowed and unmowed grass sods. The mowing of alfalfa increased soil nitrates while mowing white Dutch clover decreased soil nitrates.

The application of normal nitrogen (N), phosphorus and potassium with double nitrogen (NNPPKK) and phosphorus with double nitrogen (NNPP) to the peach plots showed no significant differences between the soil nitrates of sod and sod-mulch. But application of double nitrogen (NN) and double

nitrogen split (N-N) indicated the soil nitrates of the sod-mulch were significantly-higher than that of the sod.

The very high soil nitrates for double nitrogen with phosphorus (NNPP) of July 20 prevented the average for (NNPP) showing the much lower soil nitrate values of the following samplings.

The biweekly variation in soil nitrates for cultivation was the greatest of any of the soil management practices. Cultivation with normal nitrogen in the peach orchard produced three times as much soil nitrates as resulted from normal nitrogen with sod and sod-mulch.

The biweekly variation of soil nitrates was similar for most treatments and could not be attributed closely to rainfall or temperature.

LITERATURE CITED

Albrecht, W. A. 1922. Nitrate accumulation under straw mulch. Soil Sci. 14: 299-305.

Baton, W. D. and A. H. Eichmeier. 1951. A summary of weather conditions at East Lansing, Michigan prior to 1950. Mich. Agr. Exp. Sta. 62 pp.

Beaumount, A. B. and G. C. Crooks. 1933. The influence of a mulch on soil nitrate. Soil Sci. 33: 121-124.

Harley, C. P., H. H. Moon and L. O. Regeimbal. 1950. The release of certain nutrient elements from simulated orchard grass mulch. Proc. Amer. Soc. Hort. Sci. 56: 17-23.

Havis, L. A. 1942. Aggregation of orchard soil under mulch. Proc. Amer. Soc. Hort. Sci. 40: 28-31.

Hibbard, A. D. 1944. Growth of young peach trees under different systems of soil management. Proc. Amer. Soc. Hort. Sci. 44: 66-70.

Higdon, R. J. 1953. Soil moisture depletion by various grasses and legumes used as orchard sods. Unpublished Ph.D. Thesis, Michigan State College.

Judkins, W. and H. A. Rollins. 1943. The effect of sod, cultivation and mulch treatments on soil moisture, soil nitrate and tree growth in a young peach orchard. Proc. Amer. Soc. Hort. Sci. 43: 7-10.

__________ and I. W. Wander. 1945. Effect of mulch on growth and yield of peach trees. Proc. Amer. Soc. Hort. Sci. 46: 183-186.

Kenworthy, A. L. 1953. Moisture in orchard soils as influenced by age of sod and clean cultivation. Mich. Agr. Exp. Sta. Quart. Bull. 35(4): 454-459.

Lyon, T. L., A. J. Heinicke, and B. D. Wilson. 1923. The relation of soil moisture and nitrates to the effects of sod on apple trees. Cornell Univ. Agr. Exp. Sta. Memoirs 63, 26 pp.

____. 1925. The relation of soil moisture and nitrate to the effects of sod on plum and cherry trees. Cornell Univ. Agr. Exp. Sta. Memoirs 91, 21 pp.

Partridge, N. L. 1941. Comparative water usage and depth of rooting of some species of grass. Proc. Amer. Soc. Hort. Sci. 39: 426-434.

Peech, M. and L. English. 1945. Rapid microchemical soil tests. Soil Sci. 57: 167, 195.

Russell, E. J. 1950. Soil Condition and Plant Growth. 8th ed. Revised by E. W. Russell. New York: Longmans, Green and Co. pp. 292-293.

Toenjes, W. 1941. Twenty years results in a Michigan apple orchard. Mich. Agr. Exp. Sta. Spec. Bull. 313: 1-18.

Turk, L. M. and N. L. Partridge. 1941. Effect of mulching material on moisture loss from soils. Proc. Amer. Soc. Hort. Sci. 38: 59-62.

__________________________________. 1947. Effect of various mulching materials on orchard soil. Soil Sci. 64: 111-118.

U. S. Bureau of the Weather. 1954. Local climatological data with comparative data, 1953, for Grand Rapids airport, Grand Rapids, Michiga. Washington 25, D. C.: U. S. Government Printing Office 2-2-54--405.

Waksman, S. A. 1952. Soil Microbiology. New York: John Wiley and Sons, Inc. p. 258.

Weeks, W. D., C. T. Smith and M. Drake. 1950. Residual effect of heavy mulching in a bearing apple orchard on soil nutrients. Proc. Amer. Soc. Hort. Sci. 56: 1-4.

APPENDIX

TABLE VI

SOIL NITRATES (LBS./ ACRE) OF THE "SOD PLOTS" AS INFLUENCED BY COVERS, MOWING, MULCHING, TIME OF SAMPLING AND REPLICATIONS

Week beginning	Replication or average	Fescue		Timothy		Quackgrass		Kentucky bluegrass		Redtop	
		Mowed	Unmowed	Mowed	Unmowed	Mowed	Unmowed	Mowed	Unmowed	Mowed	Unmowed
July 13	1	51.46	12.40	34.10	44.64	17.36	13.64	12.40	16.12	13.02	14.26
	2	14.26	22.32	24.18	20.46	20.46	16.12	14.26	15.50	14.26	16.12
	3	14.26	12.40	23.56	30.38	12.40	24.18	28.52	19.22	13.02	17.36
	Ave.	26.65	15.70	27.27	31.82	16.73	17.97	18.39	16.94	13.43	15.91
July 27	1	6.20	4.96	10.54	14.26	6.20	4.96	4.96	10.54	12.40	13.02
	2	10.54	11.16	53.32	11.16	11.16	6.82	6.82	8.68	10.54	10.54
	3	12.40	13.02	9.30	12.10	10.54	10.54	12.40	11.78	8.06	14.88
	Ave.	9.71	9.71	24.39	12.60	9.30	7.44	8.06	10.33	10.33	12.81
Aug. 10	1	17.98	26.66	28.52	26.66	6.20	6.20	8.68	6.20	19.22	20.46
	2	45.26	8.06	20.46	22.32	15.50	23.56	42.28	17.98	13.64	19.22
	3	22.32	42.78	24.18	25.42	28.52	11.78	21.08	15.50	17.98	27.28
	Ave.	28.51	25.83	24.38	24.79	16.73	13.84	24.17	13.22	16.94	22.31
Aug. 24	1	17.36	19.98	14.88	38.44	20.46	17.98	20.46	30.38	16.12	17.36
	2	23.56	11.78	21.08	27.28	14.26	22.32	13.64	12.40	14.88	20.46
	3	11.78	14.88	17.36	16.12	13.64	13.02	20.46	26.66	17.98	26.66
	Ave.	17.56	14.88	17.77	27.27	16.11	19.77	18.18	23.14	16.32	21.49
Sept. 7	1	10.54	16.12	11.16	20.46	10.54	10.54	10.54	6.82	21.08	19.22
	2	11.78	4.96	12.40	14.26	11.78	12.40	10.54	11.78	17.36	13.64
	3	13.64	15.50	22.32	17.98	13.02	13.64	10.54	14.26	8.68	12.40
	Ave.	11.98	12.19	15.29	17.56	11.78	12.19	10.54	10.95	15.70	15.08

TABLE VI Continued

Week beginning	Replication or average	Alfalfa		White Dutch clover		Ladino	Cultivation	Mulch			
		Mowed	Unmowed	Mowed	Unmowed			Alfalfa	Grass	Sawdust	Straw
July 13	1	12.40	17.98	21.08	59.52	70.06	48.98	94.86	82.46	59.52	82.46
	2	34.72	29.76	19.22	30.38	24.18	99.20	55.80	111.60	48.98	86.80
	3	62.00	27.28	17.36	19.22	28.52	17.98	57.66	94.86	78.12	62.00
	Ave.	36.36	25.00	19.21	36.36	40.91	55.37	69.42	96.28	62.19	77.06
July 27	1	13.64	14.88	14.26	15.50	17.98	38.44	62.00	86.80	51.46	62.00
	2	19.22	26.66	21.08	26.66	36.58	53.32	62.00	90.52	62.00	90.52
	3	53.32	23.56	21.08	53.32	45.26	30.38	99.20	107.26	20.46	51.46
	Ave.	28.72	21.69	18.80	31.82	33.26	40.70	74.38	94.83	44.63	69.97
Aug. 10	1	51.46	36.58	48.98	62.00	57.66	86.80	70.06	82.46	48.98	15.50
	2	70.06	38.44	22.32	26.66	59.52	62.00	107.26	82.46	74.40	45.26
	3	47.12	30.38	28.52	38.44	28.52	48.98	45.26	115.94	74.40	74.40
	Ave.	56.20	35.12	33.26	42.35	48.55	65.91	74.17	93.59	65.91	45.04
Aug. 24	1	22.32	25.42	27.28	15.50	34.72	82.46	90.52	99.20	86.80	94.86
	2	17.36	14.26	42.78	42.78	29.76	90.52	94.86	78.12	29.76	53.32
	3	24.18	62.00	29.76	34.72	23.56	82.46	42.78	15.72	45.26	62.00
	Ave.	21.28	33.88	33.26	30.99	29.34	85.12	76.03	80.99	53.92	70.04
Sept. 7	1	16.12	29.76	24.18	62.00	74.40	70.06	99.20	138.26	103.54	40.92
	2	36.58	19.22	57.66	24.18	38.44	90.52	119.66	111.60	99.20	90.52
	3	78.12	22.32	59.52	53.32	26.66	130.82	74.40	74.40	48.98	111.60
	Ave.	43.59	23.76	47.10	46.49	46.49	97.10	97.72	108.05	83.88	80.99

TABLE VII

SOIL NITRATES (LBS./ACRE) UNDER PEACH TREES AS INFLUENCED BY SOIL MANAGEMENT APPLICATION OF FERTILIZER, TIME OF SAMPLING AND REPLICATION

Week beginning	Replication or average	Sod					Sod-mulch				
		N	NN	Split N-N	NNPPKK	NNPP	N	NN	Split N-N	NNPPKK	NNPP
July 20	1	19.22	42.78	130.82	94.86	99.20	23.56	173.60	15.50	20.46	86.80
	2	10.54	20.46	48.98	19.22	15.50	27.28	14.88	151.90	24.18	151.90
	3	9.92	12.40	47.12	17.98	205.84	10.54	47.12	40.92	26.66	124.00
	Ave.	13.22	25.21	75.62	44.01	106.81	20.45	78.51	69.42	23.76	120.86
Aug. 3	1	9.92	10.54	10.54	20.46	29.76	13.64	107.26	151.90	34.72	13.64
	2	17.36	15.50	14.26	21.08	22.32	11.16	8.06	51.46	26.66	16.12
	3	8.68	15.50	47.12	7.44	17.36	9.30	107.26	86.80	4.96	27.28
	Ave.	11.98	13.84	23.97	16.32	23.14	11.36	74.17	96.69	22.11	19.01
Aug. 17	1	34.72	42.78	15.50	42.78	62.00	19.22	55.80	119.66	28.52	29.76
	2	17.98	14.26	25.42	27.28	34.72	13.64	22.32	53.32	62.00	51.46
	3	14.88	23.56	48.98	16.12	12.40	15.50	173.60	103.54	62.00	24.18
	Ave.	22.52	26.86	29.96	28.72	36.36	16.11	83.88	92.14	50.82	35.12
Aug. 31	1	7.44	19.22	14.26	9.92	10.54	12.40	15.50	157.48	5.58	12.40
	2	11.16	12.40	27.28	19.22	14.26	13.64	6.82	62.00	14.26	21.08
	3	12.40	13.64	34.72	13.02	17.98	11.16	70.06	22.32	57.66	36.58
	Ave.	10.33	15.08	25.41	14.05	14.26	12.40	30.78	80.57	25.83	23.35
Sept. 14	1	9.30	25.42	13.64	15.50	19.22	16.12	107.26	166.16	12.40	28.52
	2	9.30	21.08	8.68	17.98	59.52	17.98	8.68	173.60	34.72	57.66
	3	11.16	12.40	19.22	15.50	74.40	17.98	124.00	20.46	24.18	13.02
	Ave.	9.92	19.63	13.84	16.32	51.03	17.35	79.95	120.03	23.76	33.06

TABLE VIII

SOIL NITRATES (LBS./ACRE) UNDER PEACH TREES WITH NORMAL APPLICATION OF NITROGEN AS INFLUENCED BY VARIETY, SOIL MANAGEMENT, TIME OF SAMPLING AND REPLICATION

Week beginning	Replication or average	Halehaven			Redhaven		
		Sod	Cultivation	Sod-mulch	Sod	Cultivation	Sod-mulch
July 20	1	14.26	26.66	18.60	19.22	27.28	23.56
	2	14.26	22.32	62.00	10.54	103.54	27.28
	3	12.40	51.46	9.30	9.92	223.82	10.54
	Ave.	13.64	33.47	29.96	13.22	118.18	20.45
Aug. 3	1	10.54	14.26	59.52	9.92	14.26	13.64
	2	21.08	17.98	8.68	29.76	55.80	11.16
	3	11.78	6.20	6.82	8.68	30.38	9.30
	Ave.	14.46	12.81	25.00	16.11	33.47	11.36
Aug. 17	1	53.32	25.42	53.32	34.72	62.00	19.22
	2	15.50	28.52	17.98	24.18	51.46	13.64
	3	20.46	22.32	24.18	14.88	74.40	15.50
	Ave.	29.75	25.41	31.82	22.52	62.60	16.11
Aug. 31	1	4.96	11.16	38.44	7.44	7.44	12.40
	2	12.40	14.26	16.12	11.16	62.00	13.64
	3	11.78	34.72	12.40	12.40	151.90	11.16
	Ave.	9.71	20.04	22.31	10.33	73.76	12.40
Sept. 14	1	10.54	179.80	14.88	9.30	55.80	11.16
	2	13.02	22.32	65.72	9.30	138.26	17.98
	3	11.78	42.78	14.88	9.92	94.83	17.98
	Ave.	11.78	81.61	31.82	9.92	94.83	17.35