UNIVERSITY OF MARYLAND
Agricultural Experiment Station

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Results of cooperative investigations
by the Maryland Agricultural Experiment Station
and the Maryland Tobacco Improvement Foundation, Inc.

G. L. Steffens and O. E. Street

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This publication presents the results of cooperative work made possible by the support and interest of the Maryland Tobacco Improvement Foundation, Inc., in the research program on Maryland tobacco conducted by the Maryland Agricultural Experiment Station. The Foundation is a non-profit corporation engaged in research and educational work on tobacco. The University of Maryland gratefully acknowledges its assistance in the performance of this project and the publication of the results.

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INTRODUCTION

Use of winter cover crops for soil improvement and for erosion protection has been an acceptable practice under many types of agriculture. Cover crops have been successfully utilized following truck crops, corn, cotton, tobacco, and other intensively cultivated crops.

Farmers of the Southern Maryland area formerly used a cropping system in which a crop of tobacco was followed by a crop of winter wheat, after which the fields were allowed to lie idle for 2 or 3 years. Native weeds and grasses were permitted to grow and fall on the soil during the resting period. The vegetation formed a ground cover which was allowed to accumulate and was plowed under in the spring preceding tobacco.

This system was employed with a great deal of success for many years, but more recently other cropping systems have been used, for the most part out of necessity. For economic reasons the Maryland tobacco farmer in many instances can no longer allow his fields to lie idle for 2 or 3 years. The shift in farming practices of the area has been toward a more balanced agriculture with a great deal of emphasis on livestock. Then, too, the modern concept of soil conservation has emerged with stress on particular plant species and methods to protect the soil from erosion.

Many farmers in the area have separated the tobacco cropping system from the other crops grown on the farm in order to utilize for tobacco only that soil which is best suited for the crop. In most cases this means the production of tobacco on the same fields year after year. With the continuous culture of tobacco the use of winter cover crops has played, and is continuing to play, an important role.

With tobacco, quality and yield are of the utmost importance. However, many times there is more or less incompatibility or antagonism between these two factors, with a compromise being the best result obtainable in the final analysis. The use of cover crops for Maryland tobacco is no exception, since previous work (5, 6, 10, 13, 23)* has shown that cover crops, as such, have not always given consistent results. The information herein reported deals primarily with the yield, quality, soil-plant relationships, and chemical composition of tobacco following winter cover crops to determine some of the fundamental principles underlying their use.

REVIEW OF LITERATURE

Several reports (5, 6, 13) showed that under Maryland conditions winter cover crops, especially legumes, could not always be relied upon to give satisfactory results with tobacco if grown more

* **Numbers in parentheses refer to literature cited at the end of the bulletin.**

than 2 or 3 years in continuous culture. On the basis of 21-year results from a field experiment with Maryland tobacco (6), rye produced no improvement in either yield or quality of the crop, when compared with tobacco grown continuously with no cover crop. Crimson clover as a cover crop caused moderate increases in yield and in acre value, but there was only a slight improvement in tobacco quality. Tobacco following vetch as a cover crop showed a decided increase in yield, but the quality of the leaf was poor.

It is interesting to note (23) that Maryland tobacco following ragweed (*Ambrosia artemisiifolia* L.) and horseweed (*Erigeron canadensis* L.) was superior in both yield and quality when compared with tobacco after bare fallow. The best results were obtained when weeds were allowed to grow and fall on the soil for at least two seasons.

More recent results with winter cover crops in connection with soil conservation practices for Maryland (10) showed that tobacco could be grown after a mixed cover crop of wheat and vetch for at least 7 years without decreased yield or value. A more detailed study of a single year's results indicated that better returns from the tobacco crop could be expected when the winter cover crop contained vetch in mixture with non-legumes, such as wheat, rye, or ryegrass, than when vetch or any one of the three non-legumes was used alone.

Different cover crops vary in the amount and, to some extent, in the type of constituents they contain and thus produce different effects on the soil. Welch, Nelson, and Krantz (43) concluded from work with legume and non-legume winter cover crops that, of the chemical elements considered, nitrogen was the most important contributor. As long as the nitrogen of plant residue was in an organic form it remained, to a very large extent, unavailable to plants growing in the soil (2). The first step in the breakdown of nitrogenous plant residues — the most important group being the proteins—is the conversion of the nitrogen into the ammonium form. The over-all oxidation of ammonium ions to nitrate is the final step. Both of these conversion processes are performed by soil microorganisms. If conditions for nitrification are favorable, even when nitrogen is supplied to the soil as ammonium salts, much of the nitrogen may appear as nitrate (34, 36).

From greenhouse experiments using culture solutions, a better growth of tobacco was obtained by supplying nitrogen in the nitrate form rather than in the ammonium form (2, 12, 24, 38). Most of the literature indicated that the ammonium form was thought to be toxic to plants. Tiedjens and Robbins (39) showed that ammonium ions, per se, were not toxic to certain crop plants and could be absorbed and assimilated by plants in large quantities. The most important factor necessary to bring about equally good growth of plants when supplied with nitrogen either in the nitrate or ammonium form was the pH of the culture solution. These workers showed that when nitrogen was supplied in the form of nitrate the nutrient solution should be kept at about pH 4 to 5. When nitrogen was supplied to the plants in the ammonium form, the solution had to be kept close to neutral.

Sideris, Krauss, and Young (34) working with pineapple plants found the distribution of the various nitrogenous fractions in different sections of the leaves and stems was not much different for plants grown in soil supplied with nitrogen either in the form of nitrate or ammonium salts. They attribute the similarity to the rapid conversion of ammonium to nitrate ions in the soil and to the simultaneous absorption of both ions by the plant.

Nightingale (29), after a thorough review of the available literature, concluded that under field conditions the principal source of nitrogen for plant growth was in the nitrate form. He stated that nitrogenous materials were quickly converted to nitrate under cultivation so that no matter what form of nitrogen was applied to a soil, the plants absorbed mainly nitrate nitrogen.

Mature plants decomposed more slowly than younger plants when incorporated into the soil (31, 42, 44) because of a shift in the chemical makeup of the plant. Whiting (44) concluded that the solubility of the nitrogen was the most important factor affecting the rate of nitrification. When the plant material contained at least 1.7 percent nitrogen, the supply seemed to be adequate for microbial needs (42). If the material contained less than 1.7 percent nitrogen, a lag period could be expected before ammonium was released and additional available nitrogen was freed before the plant material could be completely decomposed. An excess of 1.7 percent would allow a rapid liberation of nitrogen in an available form.

Broadbent and Norman (4) found that after the addition of material high in energy to a soil, the microbial population increased to a great extent and became more active. With the aid of N^{15}, they showed that the effect might be due to the low microbial activity when the available energy material became depleted. If more carbonaceous material was added, nitrogen release did not necessarily follow because the nitrogen was immobilized in the new microbial population. If, on the other hand, sufficient nitrogen was contained in the added material, the release of the nitrogen from the previously formed residues was accelerated.

Under field conditions, Lewis and Hunter (22) demonstrated that total nitrogen increased and organic carbon either increased or was maintained by the yearly additions of green manure crops to a Coastal Plain soil. Morgan, Jacobson, and LeCompte (27) reported after a 10-year lysimeter study, that organic matter losses were higher from fallow soil than from cropped soil. Cover crops of rye, oats, and timothy produced net gains in soil organic matter. Anderson, Swanback, and Street (1) failed to show that soil organic matter increased from the use of cover crops. The organic matter content of the soil declined on all plots, but declined to a lesser extent on cover crop plots.

Morgan and Street (26) observed that cover crops caused a retention of n u t r i e n t elements which was accreditable in part to decreased leaching during the fall period, and in part to cover crop utilization of those nutrient elements. Morgan, Jacobson, and Le-Compte (27) finally concluded that the chief effect of cover crops in conserving various soil nutrients was associated with d e c r e a s e d leaching of nitrate n i t r o g e n. Krantz, Ohlrogge, and Scarseth (20) noted that ammonium cations were relatively immobile in the soil because they were absorbed by the base exchange complex whereas nitrate anions moved freely with the soil water.

MATERIALS AND METHODS

A field experiment was established in the fall of 1949 at the University of Maryland Tobacco Experimental Farm, Upper Marlboro, Md., to study the effects of various legume and nonlegume winter cover crops on the growth and quality of Maryland tobacco. Agronomic information for the 1950, 1951, and 1952 crops was obtained as a Maryland Agricultural Experiment Station project by the junior author. The findings presented in this paper for the 1953 and 1954 growing seasons were the result of more intensified investigations into some of the fundamental soil-plant relationships and their effect on the yield, dollar-per-acre return, and dollars per hundred pounds of tobacco following the cover crops.

The Field Experiment

Ten treatments were included in the experiment, with nine being replicated three times in restricted randomized blocks and the tenth replicated four times in an unrandomized fashion. Since the tenth treatment was designed to encourage the growth of volunteer vegetation in the between-crop periods and, hence, could not be disked in the fall, it was plotted as strips adjoining the randomized blocks. The arrangement of the experiment is shown in Figure 1.

The plot size was 39 by 36 feet, allowing 12 rows of tobacco, 3 feet apart, to be grown in the randomized plots. The unrandomized plots were 18 by 175.5 feet, and in each, six rows of tobacco were grown. In 1953 and 1954 the plants were spaced 22 inches apart within the row, resulting in a basis of 7,920 plants per acre. In 1950, 1951, and 1952 the plants were spaced 30-inches apart within the row making, on an acre basis, 5,808 plants. One reason for the increase was to provide more adequately for removal of plants during the growing period for chemical studies.

The cover crops involved, treatment numbers, and the rate of seeding of each cover crop in pounds per acre are given in Table 1. In treatment No. 7 (ryegrass plus nitrogen) 40 pounds of nitrogen per acre was applied in the form of ammonium nitrate at the time of spring plowing.

The soil had been mapped as Monmouth fine sandy loam, which is a well-drained soil of the greensand belt with a heavy substratum

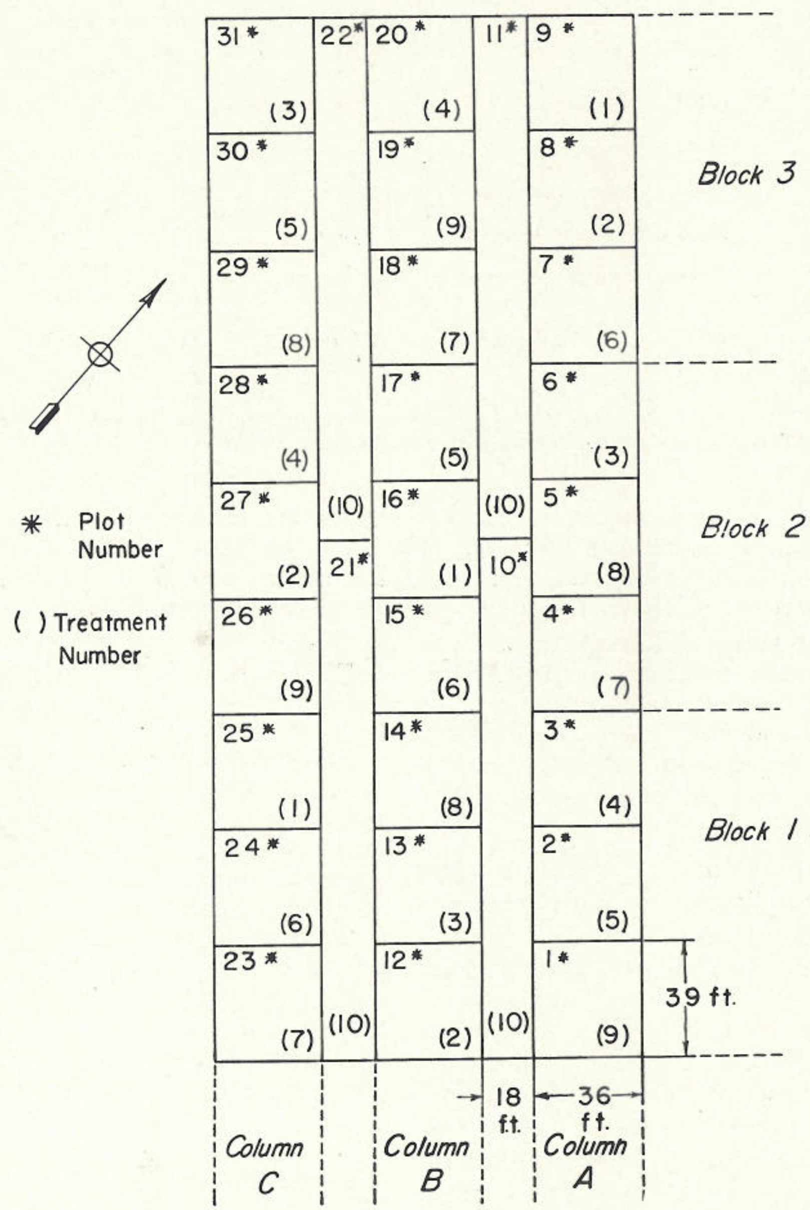

Figure 1. Field plot diagram for tobacco following winter cover crops, University of Maryland Tobacco Experimental Farm, Upper Marlboro, Md.

Table 1. Seeding rates and treatment designations of winter cover crops to precede tobacco

Treatment number	Cover crop	Seeding rates			
			Lbs./A.		Lbs./A.
1	Wheat	Wheat	90		
2	Wheat and hairy vetch	Wheat	45	Vetch	20
3	Hairy vetch	Vetch	40		
4	Crimson clover	Crimson clover	20		
5	Domestic ryegrass	Ryegrass	25		
6	Rye and hairy vetch	Rye	45	Vetch	20
7	Domestic ryegrass[1] plus N	Ryegrass	25		
8	Domestic ryegrass and hairy vetch	Ryegrass	12.5	Vetch	20
9	Winter oats and hairy vetch	Winter oats	32.5	Vetch	20
10	Native vegetation				

[1]Forty pounds per acre of nitrogen applied at the time of plowing.

from deposits medium to moderately high in glauconite (40). It is moderately well adapted to the production of Maryland tobacco.

The strain of tobacco grown was Catterton medium broadleaf. This strain has shown resistance to black root rot, *Thielaviopsis basicola* (Berk. & Br.) F. and is rather extensively grown in the Southern Maryland area (3).

The winter cover crops were sown in September and plowed under the following spring, near the first of May. A 4-8-12 commercial tobacco fertilizer was applied uniformly over the area at the rate of 1,000 pounds per acre with a Cole lister the day before planting. The tobacco plants were set with a mechanical transplanter around the first of June. When approximately two-thirds of the blossoms were open, the tobacco was topped (usually 10 days to 2 weeks before harvest). Harvesting was carried out in the usual manner—cutting the plants and spearing them on sticks which were then hung in a barn to air-cure. Treatments were harvested at different times to permit all plots to become as nearly mature as possible.

In the fall and winter the tobacco which had been harvested from the plots was stripped. During this operation, the cured leaves were separated into four grades known as "farmer" grades. These grades, starting from the lowest position on the stalk, were seconds, bright, dull bright, and dull. The yield in pounds per acre included the moisture present in the leaves at the time of stripping (10-15 percent).

Distribution of Rainfall

The distribution of rainfall for the growing seasons of the years 1950 through 1954, inclusive, is presented in Figure 2. The rainfall was sufficient and the distribution fair for the years 1950, 1951 and 1952. For 1953 there were several drought periods followed by rather heavy rains, and in 1954 the entire growing season was extremely dry.

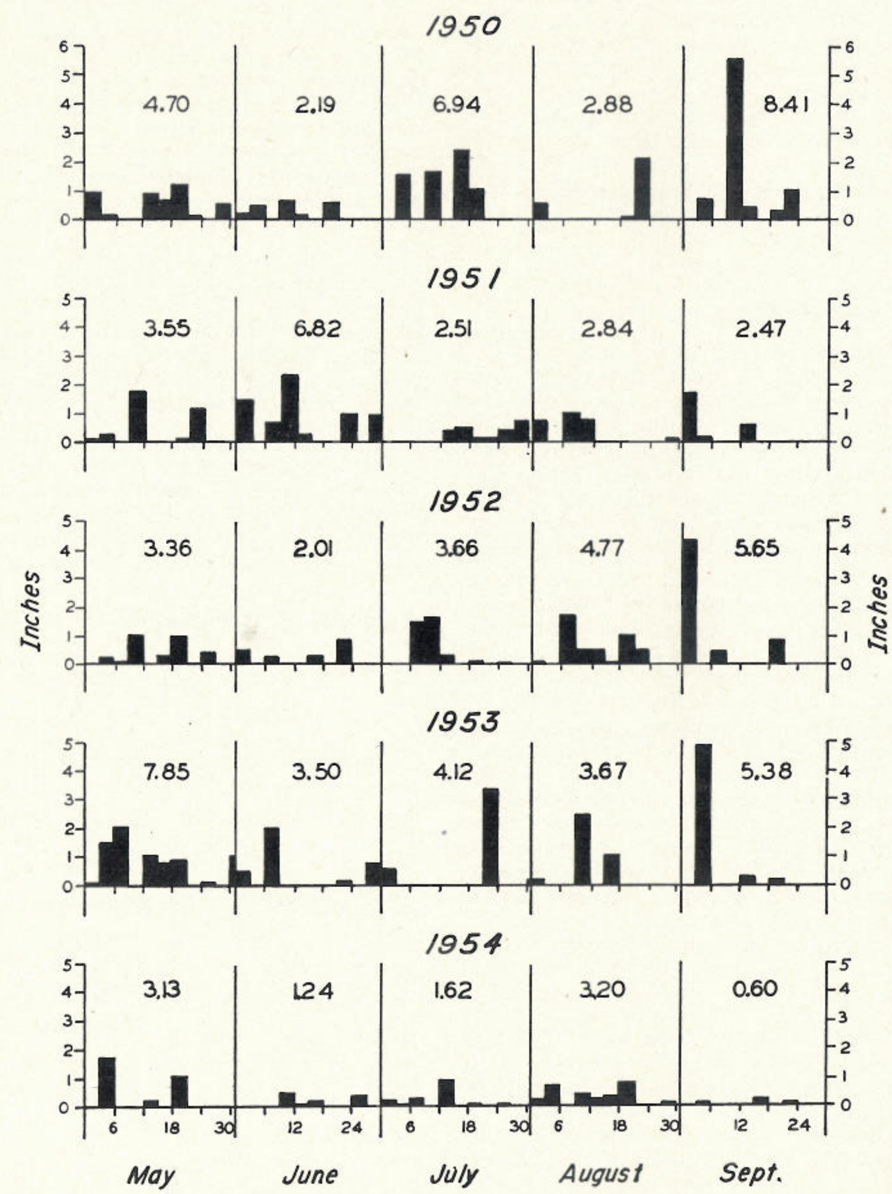

Figure 2. Rainfall in inches for 3-day periods covering 5 months, May through September, University of Maryland Tobacco Experimental Farm, Upper Marlboro, Md.

Sampling Technique

1. Cured tobacco leaf

A random three-hand sample from each of the four farmer grades from each plot was retained for grading and analytical purposes. The three-hand samples were graded into standard government grades and priced according to the assigned grade. The prices attached to the grades for the 1953 and 1954 crops were obtained from averages by grade of the 1953 crop. The values for 1950, 1951, and 1952 were based on market prices of government grades for each separate year.

2. Cover crops

Before plowing in the spring of 1953 and 1954 three 0.5 square meter areas were cut from each of the cover crop plots by hand. On the treatments involving grass-legume combinations, hand separations into the two components were made. The samples were dried in an oven at 80° C. for 24 hours and all yields calculated on the oven-dry weight basis.

In order to sample the roots, a core of soil 3 inches in diameter by 12 inches in depth was removed by means of a special soil-sampling tube from the 0.5 square meter areas from which the forage had been removed. Three borings per plot were made on the last two replicates only, thus giving six soil cores for each treatment. After the roots were washed free of soil on two wire screens, they were back-washed into cheese cloth and placed in an oven to dry. This operation was carried out only for the 1954 season.

3. Soil

Ten soil cores from each plot were taken with a soil probe, starting in the spring near the time of plowing and ending a month to 6 weeks after harvest. The samples were to a depth of 8 inches and the core was 1 inch in diameter. After thorough mixing, approximately 150 g. of soil was placed in an aluminum moisture can for analysis. Until the tobacco was planted and for 25 days thereafter, no soil samples were taken near the applied fertilizer. After that time five cores per plot were taken between the tobacco rows and five were taken between the plants in the row.

4. Green tobacco plants

Tobacco plants were removed from each plot at weekly intervals beginning 34 days after planting in 1953 and 20 days after planting in 1954. The "entire" plant was taken by shoveling 8 inches on either side and removing as many roots as possible with the plant. The number of plants taken from each plot ranged from four at the outset to one at harvest time.

To obtain samples for nitrate nitrogen tissue tests, several of the most physiologically mature leaves near the base of the plant were removed. Basal portions of the midribs approximately 6 cm. long were cut from the leaves and stored in the refrigerator in stoppered bottles (33).

The same plants were used for growth rate and nitrogen uptake studies and dried in a forced draft forage drier at about 49° C. with sub-samples dried at 80° C. for 24 hours.

Analytical Methods

1. Total nitrogen—Plant material

Total nitrogen was determined by the modified salicylic-thiosulfate semimicro Kjeldahl method (32). The leaf tissue (including midribs of the cured leaves) was ground to pass a 40-mesh screen (15 mesh per cm.) with a semimicro Wiley mill. The stem and root portions of the tobacco samples were ground in a laboratory size hammer-mill to pass a perforated screen with openings 0.033 inches (0.84 mm.) in diameter. After digestion, distillation was carried out by means of a Kemmerer-Hallett distillation unit (18). The distillate was collected in a receiver charged with a boric acid solution (35) which was titrated with a standardized 0.05N sulfuric acid solution using a mixed indicator (21).

2. Total nitrogen—Soil

The macro-Kjeldahl method was employed (21). This method did not detect nitrogen in the nitrate form.

3. pH—Soil

Eighteen ml. of distilled water was added to 20 g. of soil at field moisture, stirred, and then allowed to stand 1 hour. The pH was determined by means of a glass electrode pH meter (30).

4. Nitrate nitrogen—Soil

The method of Harper (16) was employed with several modifications. Twenty-five g. of soil at field moisture was placed in a 6-ounce bottle, 50 ml. of 0.013N $Cu(CH_3COO)_2.H_2O$ added, and, after being stoppered, was shaken intermittently over a several-hour period and then allowed to stand overnight. The clear liquid was decanted off with a wash bottle device into a 250 ml. beaker; approximately 3 g. of $Ca(OH)_2$ was added and, after stirring, the solution was warmed on a water bath to 55° C. The extract was filtered (the first few ml. discarded) and a 10 ml. aliquot pipetted into an evaporating dish and brought to dryness. Two ml. of phenoldisulfonic acid was added, the dish rotated to wet all of the salts; then allowed to stand 10 minutes. Approximately 15 ml. of water was added, and the solution was washed into a 100 ml. volumetric flask. Ten percent NH_4OH was used to develop the yellow color. The intensity of the color was read on a Coleman photoelectric colorimeter, using a 430 millimicron filter (17).

Fifty g. of the soil at field moisture was weighed back into the moisture can and allowed to air-dry for 48 hours. The p.p.m. of nitrate as nitrogen was calculated on an air-dry soil basis.

5. Nitrate nitrogen—Plant tissue test

The midrib sections which were stored in the refrigerator overnight were cut with a razor blade into pieces measuring no more than 3 mm. in size. After thorough mixing, a 5 g. portion was macerated in a semimicro metal jar on a Waring blender with 25 ml. of 2 percent acetic acid and approximately 0.5 g. of powdered charcoal. The steps that followed were conducted as outlined by Carolus (8). The intensity of the yellow color was also determined on a Coleman colorimeter. The p.p.m. of nitrate as nitrogen was reported on a fresh-weight basis.

6. Acid insoluble or "protein" nitrogen—Cured tobacco leaf

One hundred mg. of oven-dry plant tissue was boiled in 15 ml. of dilute acetic acid for 5 minutes (14). The soluble nitrogen was filtered off and the residue was washed with hot dilute acetic acid and then dried at 80° C. for 24 hours. The insoluble residue was analyzed by the modified salicylic-thiosulfate semimicro Kjeldahl method as outlined in analytical method 1.

7. Total steam volatile alkaloids —Cured tobacco leaf

A sample of the oven-dry tobacco (200 mg.) was introduced into the distillation chamber (weight obtained by difference) of a Griffith-Jeffrey still (15). Two ml. of 30 percent NaOH and 0.5 g. of NaCl were added (no water used) and the sample steam-distilled. Approximately 200 ml. of distillate was collected in a receiver charged with 3 ml. of a 1-to-4 HCl-water solution. The distillate was diluted to 250 ml. and the spectral density of the acidified distillate was measured on a Beckman model DU spectrophotometer in the ultraviolet region (45). Results were reported as percentage of total steam volatile alkaloids calculated as nicotine.

8. Fire-holding capacity—Cured tobacco leaf

The fire-holding capacity of leaves of the bright grade was determined and the duration of glow or burn reported in seconds. The middle of the lamina of each of 25 leaves per plot was ignited by means of an electric coil. Twenty-four hours prior to ignition, the tobacco leaf samples were placed in a chamber which was kept at 24° C. and 80 percent relative humidity.

9. Burn and Aroma—Cured tobacco leaf

The same samples kept under the controlled conditions as indicated in analytical method 8 were used in characterizing the burn and aroma. These tests were conducted on an empirical basis in order to correspond to testings of like nature done by company leaf buyers on the warehouse floor. Since the evaluation of both burn and aroma was of an arbitrary nature, a panel of three experts assigned values. These experts lighted the leaves of the samples with a candle and first noted the type of burn (color of ash, duration of burn, etc.) and then characterized the aroma of the smoke. The burn and aroma characteristics were each assigned numerical values from 1 to 20, with 1 being the lowest and 20 the highest value.

10. Statistical analysis

Because of the restricted randomized design of the field plots, a modified form of the analysis of variance for the Latin square was used (9). A variance component was separated out for both blocks and columns. A similar modification which separated a variance component for blocks and columns was used where the data were analyzed by the split-plot technique. Missing values also were calculated, using the formula for the Latin square.

RESULTS

Yield, Acre Return, and Value of Cured Tobacco

The yearly yields of cured tobacco leaf are shown in Table 2. Average yields for the five-year period were not comparable for statistical purposes because the yields for the first three years were based on a population of 5,808 plants per acre, while those for the last two years were based on a population of 7,920 per acre. However, the average for the five-year period, as well as the averages for the two shorter periods, is shown in the table. The effect of treatment was significant at the 1 percent level for each of the 5 years and also for the averages of the two periods.

Table 2. Yield of cured tobacco leaf following winter cover crops

Cover crop	Yield[1]							5-year average
	1950	1951	1952	1950, 1951, 1952 average	1953	1954	1953 and 1954 average	
	Lbs./A.	Lbs./A.	Lbs./A.	Lbs./A.	Lbs./A.	Lbs./A.	Lbs./A.	Lbs./A.
Wheat	[2]1,111	[2]1,336	[2]1,268	1,238	[2]1,118	[2]1,203	1,160	1,207
Wheat and vetch	1,022	1,553	1,298	1,291	1,424	1,475	1,450	1,354
Vetch	1,208	1,838	1,605	1,550	1,558	[2]1,643	1,601	1,570
Crimson clover	1,238	1,336	1,381	1,318	1,215	1,528	1,372	1,340
Ryegrass	964	1,169	1,149	1,094	884	1,061	973	1,045
Rye and vetch	1,059	1,468	1,203	1,244	1,283	1,319	1,301	1,266
Ryegrass[3] plus N	1,104	1,331	1,383	1,273	1,147	[2]1,384	1,266	1,270
Ryegrass and vetch	1,034	1,542	1,580	1,385	1,477	[2]1,667	1,572	1,460
Winter oats and vetch	1,010	1,527	1,435	1,324	1,466	1,597	1,532	1,407
Native vegetation	[4]1,050	[4]1,266	[4]1,080	[4]1,132	[4]1,094	[4]1,206	[4]1,150	1,139
L.S.D. (0.05)	117	151	179	92	145	188	160	
L.S.D. (0.01)	164	210	250	128	203	267	227	

[1]Average of three replicates.
[2]Value for one of the three replicates computed.
[3]Forty pounds per acre of nitrogen applied at the time of plowing.
[4]Four replicates, not included in the statistical analysis.

Tobacco following vetch produced the highest yields for both periods; tobacco after ryegrass and vetch, and after winter oats and vetch were the second and third highest, respectively. Tobacco after ryegrass was the lowest yielding treatment for both periods and the native vegetation was next lowest. The wheat treatment was third from the lowest. The relative positions of the four treatments between the two extremes changed very slightly. Even though Treatment ten (native vegetation) could not be included in the statistical analysis, it appeared that ryegrass alone as a winter cover crop depressed the yield of tobacco as compared with this no-cover treatment. Legumes, either alone or in combination with non-legumes, generally increased the yield of tobacco, compared with non-legumes alone.

A cursory examination of the yields for the entire period, compared with those for the last two years, disclosed a high degree of regularity. The relative ranking from highest to lowest was reversed only with the rye and vetch treatment, compared with the ryegrass plus nitrogen treatment, two very similar treatments in terms of yields.

The lack of effect of treatment in the first crop year can be noted. It serves to emphasize the uniformity of performance and rank in the later years.

The value per hundred pounds of cured tobacco (Table 3) is indicative of the quality of the crop. The values for 1950, 1951, and 1952 were not comparable statistically because they were based on separate yearly grade prices. The values for 1953 and 1954 were comparable. No significant differences due to treatment were observed for the 1950 crop, but the 1951 crop showed a significant difference due to treatment at the 5 percent level. The effect of treatment on the subsequent three crops and the 1953 and 1954 average was significant at the 1 percent level.

In 1951 and 1952 it appeared that legumes alone, and in some instances legumes in combinations with nonlegumes, reduced the quality of the tobacco crop. For 1953, and 1954, drier years, tobacco following nonlegume cover crops was very low in quality. The over-all tobacco quality was lower for the 1953 than for the 1954 crop, although the 1954 growing season was drier. This may have been due in part to the late plowing (May 13) of the cover crops in 1953, along with the early setting of the tobacco plants (May 22). Only 9 days elapsed between the two operations.

For the 5-year period it would appear that ryegrass plus the addition of 40 pounds per acre of nitrogen and the combinations, wheat and vetch, winter oats and vetch, and ryegrass and vetch, maintained the over-all tobacco quality in respect to market value.

Table 3. Value per hundred pounds of cured tobacco leaf following winter cover crops

Cover crop	Value[1]					
	1950	1951	1952	1953	1954	1953 and 1954 average
	$/cwt.	$/cwt.	$/cwt.	$/cwt.	$/cwt.	$/cwt.
Wheat	[2]59.8	[2]58.1	[2]57.7	[2]47.7	[2]57.7	52.7
Wheat and vetch	57.7	53.3	53.6	55.2	63.9	59.6
Vetch	58.4	51.4	45.9	55.8	[2]61.5	58.7
Crimson clover	58.3	53.6	54.4	50.3	63.0	56.5
Ryegrass	59.6	57.3	54.9	42.3	57.3	49.8
Rye and vetch	60.0	54.9	56.7	53.4	62.2	57.8
Ryegrass[3] plus N	57.2	54.5	56.6	52.8	[2]66.6	59.7
Ryegrass and vetch	61.2	55.7	51.1	55.6	[2]57.2	56.4
Winter oats and vetch	58.3	53.5	55.1	56.1	61.9	59.0
Native vegetation	[4]61.0	[4]57.5	[4]54.4	[4]50.6	[4]56.1	[4]53.4
L.S.D. (0.05)	N.S.	3.1	3.5	5.5	4.4	3.5
L.S.D. (0.01)	N.S.	N.S.	4.8	7.7	6.3	5.0

[1]Average of three replicates.
[2]Value for one of the three replicates computed.
[3]Forty pounds per acre of nitrogen applied at the time of plowing.
[4]Four replicates, not included in the statistical analysis.

Table 4 shows the dollar-per-acre return from cured tobacco following the various cover crops. Even though the effect of treatment on yield was highly significant for all 5 years, the effect of treatment on dollar-per-acre return was significant only at the 5 percent level for the 1950 crop, was significant at the 1 percent level for the 1951 crop, and was not significant for the 1952 crop. There was a highly significant difference due to treatment for the 1953 crop, the 1954 crop, and the two-year average. In the earlier years of the test, yields and values in dollars per hundred pounds tended to follow opposite trends, hence the resultant values in dollars per acre were not too widely different.

For the 1953 and 1954 average, vetch as a winter cover crop produced the highest return, followed by winter oats and vetch, and then by ryegrass and vetch. The lowest return was obtained when using ryegrass as a cover crop: wheat and the native vegetation treatment were equal for the 2-year average. In all cases legumes alone or in combination, and ryegrass plus nitrogen increased the dollar-per-acre return compared with nonlegumes alone. The greater difference between the extremes of acre value as the experiment progressed would indicate a cumulative effect of the treatments.

Table 4. Dollar-per-acre return from cured tobacco leaf following winter cover crops

Cover crop	Acre return[1]					
	1950	1951	1952	1953	1954	1953 and 1954 average
	$/A.	$/A.	$/A.	$/A.	$/A.	$/A.
Wheat	[2]666	[2]776	[2]731	[2]534	[2]695	615
Wheat and vetch	590	830	696	787	942	865
Vetch	703	947	736	870	[2]1,011	941
Crimson clover	722	715	752	613	963	788
Ryegrass	574	670	633	378	611	494
Rye and vetch	636	805	683	688	818	754
Ryegrass[3] plus N	633	725	789	618	[2]922	770
Ryegrass and vetch	633	857	807	821	[2]953	887
Winter oats and vetch	591	818	790	834	990	912
Native vegetation	[4]643	[4]728	[4]587	[4]554	[4]676	[4]615
L.S.D. (0.05)	78	69	N.S.	140	116	118
L.S.D. (0.01)	N.S.	96	N.S.	195	165	167

[1]Average of three replicates.
[2]Value for one of the three replicates computed.
[3]Forty pounds per acre of nitrogen applied at the time of plowing.
[4]Four replicates, not included in the statistical analysis.

Winter Cover Crop Dry Matter Yield and Nitrogen Content

Table 5 shows the average amount of dry matter produced, the percent total nitrogen, and the pounds per acre of nitrogen contained in the tops of the cover crops for 1953 and 1954. Generally, the yearly variation in the percent total nitrogen of a cover crop was not as marked as the variation in its dry weight. Even though the seeding rates were the same in both years, the proportion of legumes to nonlegumes of the combinations was very different in some instances. The average amount of nitrogen contained in the tops of the different cover crops ranged from approximately 10 to 98 pounds per acre. The average amount of dry matter produced also varied over a wide range.

The dry matter, percent total nitrogen, and the total nitrogen content of the roots of the cover crops for 1954 are presented in Table 6. In several instances as much as one-half of the total nitrogen of the entire plant was contained in the roots. In the case of ryegrass, much more dry matter and nitrogen was contained in the roots than in the tops.

Only one year's data were available for the dry-matter production and the total nitrogen content of roots, and when these were added to the 2-year average values for the tops, some indication of the total amount of dry matter and the total amount of nitrogen incorporated in the soil by winter cover crops was obtained. The summary is presented in Table 7, and shows that the amount of dry matter produced by various cover crops was not vastly different in most cases. The total amount of nitrogen contained in the cover crops ranged from approximately 43 to 188 pounds per acre. Any treatment that contained a legume had at least 118 pounds per acre of nitrogen incorporated into the soil at the time of spring plowing. The nonlegume cover crops contained, at the most, 57.5 pounds per acre of nitrogen, and native vegetation contributed 27.1 pounds per acre. The highest amount of nitrogen, 188.7 pounds per acre, was obtained with vetch grown alone.

Table 5. Dry matter, percent total nitrogen, and total nitrogen content of the tops of winter cover crops at the time of spring plowing

Cover crop	Component	1953 and 1954 average[1]		
		Dry matter	Total nitrogen	Total nitrogen
		Lbs./A.	percent	Lbs./A.
Wheat	Wheat	[2]1,679	[2]1.12	[2]18.8
Wheat and vetch	Wheat	1,679	1.48	24.4
	Vetch	1,952	3.79	74.3
	Total	3,631		98.7
Vetch	Vetch	[3]3,305	[3]3.53	[3]116.5
Crimson clover	Crimson clover	2,489	2.76	69.2
Ryegrass	Ryegrass	1,106	0.92	10.4
Rye and vetch	Rye	3,541	0.85	30.3
	Vetch	1,376	3.57	50.3
	Total	4,917		80.6
Ryegrass[4] plus N	Ryegrass	[3]1,535	[3]0.97	[3]15.4
Ryegrass and vetch	Ryegrass	[3]1,351	[3]1.73	[3]24.5
	Vetch	[3]1,681	[3]3.93	[3]66.2
	Total	3,032		90.7
Winter oats and vetch	Winter oats	1,824	1.62	27.1
	Vetch	1,608	3.84	61.3
	Total	3,432		88.4
Native vegetation	Weeds	[5]722	[5]1.80	[5]12.7

[1]Average of three replicates each year unless otherwise noted.
[2]Average of two replicates, 1953 and 1954.
[3]Average of three replicates in 1953 and two replicates in 1954.
[4]Forty pounds per acre of nitrogen applied at the time of plowing.
[5]Average of four replicates each year.

Table 6. Dry matter, percent total nitrogen, and total nitrogen content of the roots of winter cover crops at the time of spring plowing

Cover crop	1954[1]		
	Dry matter 12 inch depth	Total nitrogen	Total nitrogen 12 inch depth
	Lbs./A.	percent	Lbs./A.
Wheat	2,370	1.02	24.2
Wheat and vetch	3,593	1.71	61.4
Vetch	2,778	2.60	72.2
Crimson clover	2,142	2.31	49.5
Ryegrass	6,202	0.76	47.1
Rye and vetch	3,796	1.04	39.5
Ryegrass[2] plus N	4,190	0.78	32.7
Ryegrass and vetch	5,788	1.32	76.4
Winter oats and vetch	3,656	1.73	63.2
Native vegetation	744	1.94	14.4

[1]Average of three samplings from each of two replicates.
[2]Forty pounds per acre of nitrogen applied at the time of plowing.

Table 7. Total dry matter and total nitrogen content of the roots and tops of winter cover crops at the time of spring plowing

Cover crop	Whole plants	
	Total dry matter[1]	Total nitrogen[1]
	Lbs./A.	Lbs./A.
Wheat	4,049	43.0
Wheat and vetch	7,224	160.1
Vetch	6,083	188.7
Crimson clover	4,631	118.7
Ryegrass	7,308	57.5
Rye and vetch	8,713	120.1
Ryegrass[2] plus N	5,725	48.1
Ryegrass and vetch	8,820	167.1
Winter oats and vetch	7,088	151.6
Native vegetation	1,466	27.1

[1]Tops—2-year average; roots—1-year only.
[2]Forty pounds per acre of nitrogen applied at the time of plowing, but after sampling of cover crops.

Relationship of Soil Nitrate to Plant Nitrate Nitrogen of Plant Tissue Tests

Rainfall, and thus soil moisture, influences the formation of nitrate nitrogen from plant residues for its utilization by growing plants. Soil moisture also materially affects the uptake of the nitrate nitrogen once it is present in the soil. Figure 3 and Appendix Table 1

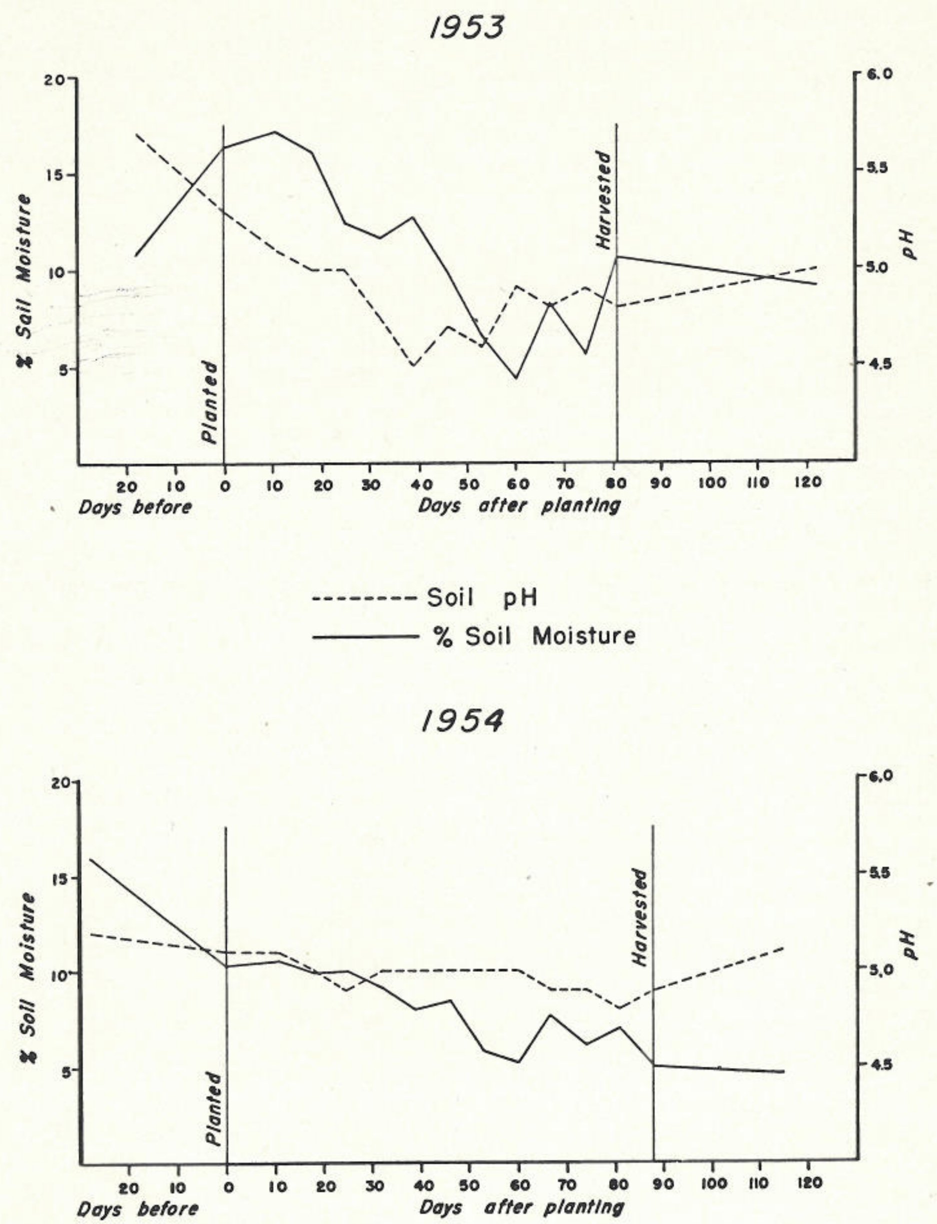

Figure 3. Soil pH and moisture, tobacco following winter cover crops.

show the average percentage of soil moisture on an air-dry weight basis for the 1953 and 1954 growing seasons. For 4 weeks during the latter part of the 1953 growing season, soil moisture was well below 10 percent, whereas the earlier part of the same season was rather wet. The soil during the first 3 or 4 weeks after the tobacco was planted in 1954, contained approximately 10 percent moisture. After that time, the moisture content of the top 8 inches of soil remained below 10 percent.

Soil pH during the two growing seasons is also shown in Figure 3. The values for the various treatments were only slightly different, so an average of all treatments was included for each date. The fluctuation of soil pH was much more evident in the 1953 than in the 1954 season. In both seasons, the pH of the soil was higher during the early part and then tended to drop, rising again at the end of the season after the tobacco was harvested.

The concentration of nitrate nitrogen as N in the air-dry soil and in green plant tissue from tests on midrib sections during the 1953 and 1954 growing seasons is presented for each treatment in Figures 4 through 8, and Appendix Tables 2 through 5. The values for the wheat cover crop (Figure 7) are the average of only two replicates each year. The 1954 values for the vetch treatment (Figure 4), the ryegrass plus N treatment and the ryegrass and vetch treatment (Figure 5) are the averages of two replicates only. The native vegetation treatment values (Figure 8) are the averages of four replicates.

In general, the accumulation of nitrates both in the soil and in the midribs of tobacco plants was greater for the 1954 season than for 1953. This, no doubt was related to the drier soil conditions of the latter year (7, 20). Higher soil nitrate values prevailed on only five treatments that contained sufficient nitrogen to permit a greater accumulation. These treatments were vetch, ryegrass and vetch, crimson clover, wheat and vetch, and winter oats and vetch.

For soil nitrates, a peak in the curve was observed toward the middle of the growing season. In 1953 it occurred, in most cases, between 30 and 48 days after planting. The accumulation started earlier and extended over a longer period in the 1954 season. The accumulation of soil nitrate was very marked in both years for the vetch treatment (Figure 4). The initial rise was much sharper, the peak was higher, and the end-of-season descent did not dip as low as for other treatments. Compared to treatments containing legumes, the ryegrass treatment showed only a small accumulation of soil nitrate (Figure 4). Wheat (Figure 7) and native vegetation (Figure 8) treatments also were very low in soil nitrates.

The curves for nitrate nitrogen of fresh tobacco midribs closely followed those of the soil nitrates. The plant nitrate curves appeared to follow the soil nitrate curves better for those treatments with less nitrogen contained in the cover crops, e.g., ryegrass, than for those with higher amounts of nitrogen in the cover crops, e.g., vetch (Figure 4). It is notable that the nitrate content of the midribs of tobacco grown following

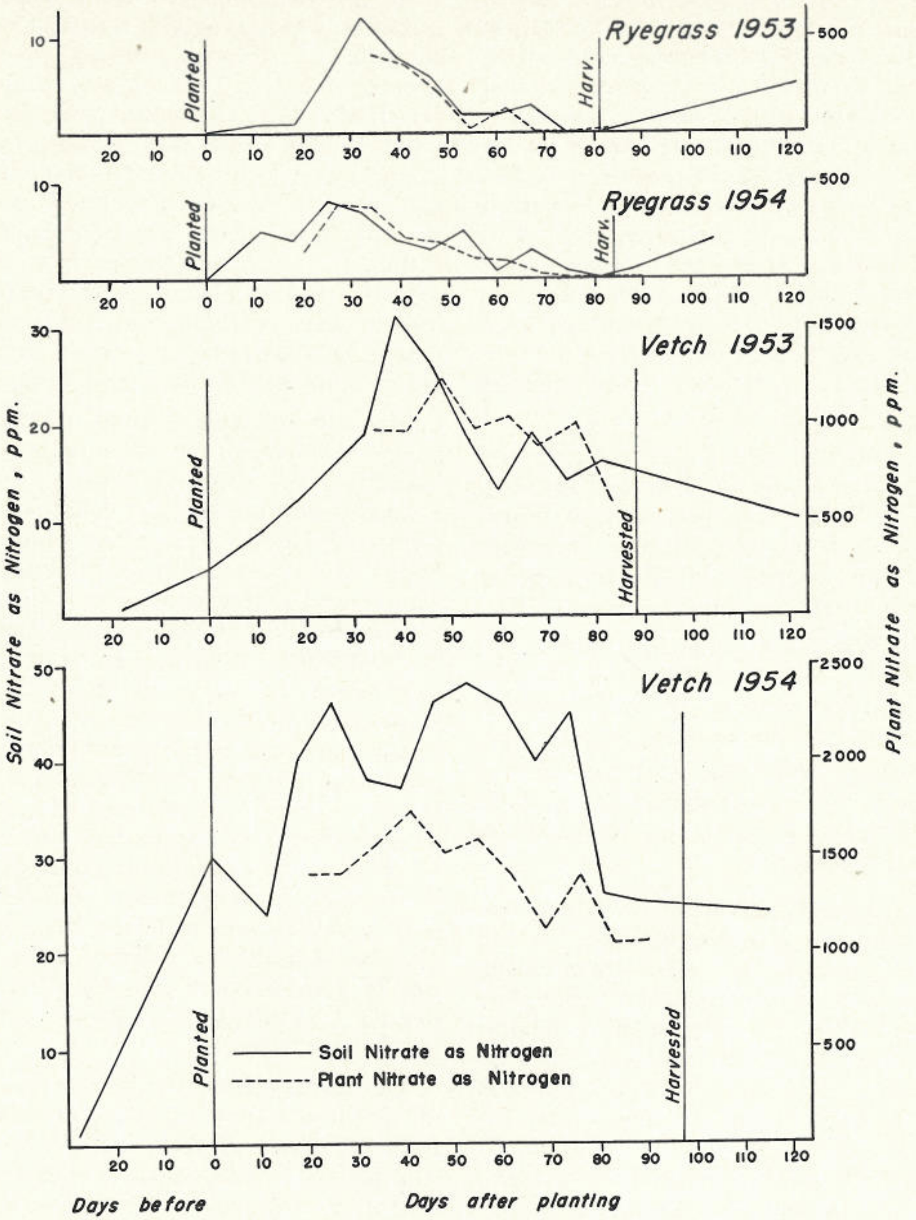

Figure 4. Soil and plant nitrate nitrogen, tobacco following ryegrass (above) and vetch (below) as winter cover crops.

vetch alone, or in combination with a nonlegume, remained at a high level throughout the growing season. Appendix Tables 4 and 5 indicate that in 1953 the vetch treatment maintained an average cell content of nitrogen as nitrates of 960 p.p.m., while in the drier year of 1954, it maintained an unusually high average level of 1387

p.p.m. In the latter year, all combinations involving vetch, except rye and vetch, displayed trends of the same magnitude as vetch alone. The depressing effect of rye in the mixture was indicated in both soil and plant nitrates. Treatments employing only nonlegumes

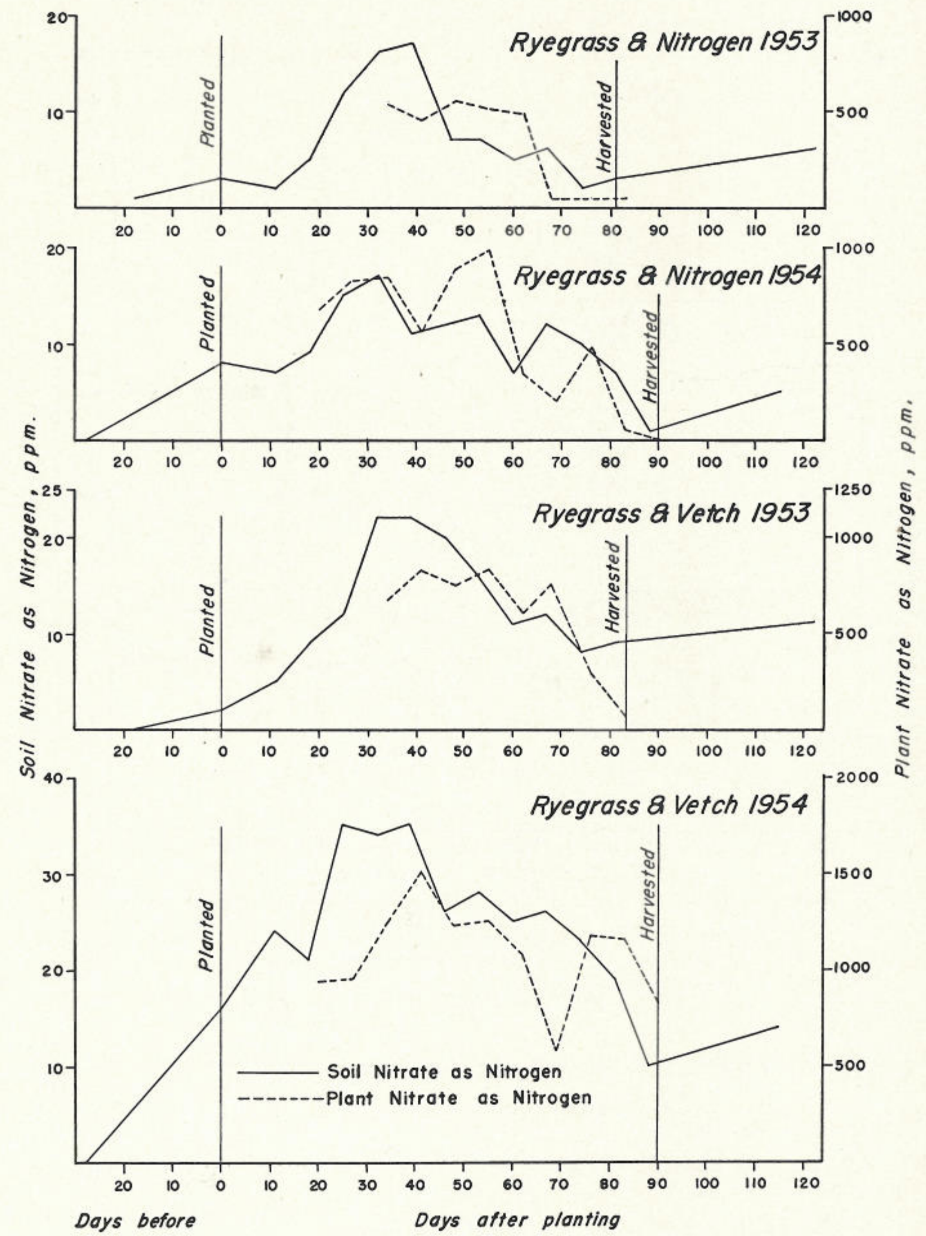

Figure 5. Soil and plant nitrate nitrogen, tobacco following ryegrass plus nitrogen (above) and ryegrass and vetch (below) as winter cover crops.

reached starvation levels of plant nitrates in the latter part of the growing season. Neither extreme of nitrate level is desirable as the tobacco approaches maturity, as a very high level stimulates continued vegetative development, while at the low end of the plant nitrate scale, the plant loses its lower leaves.

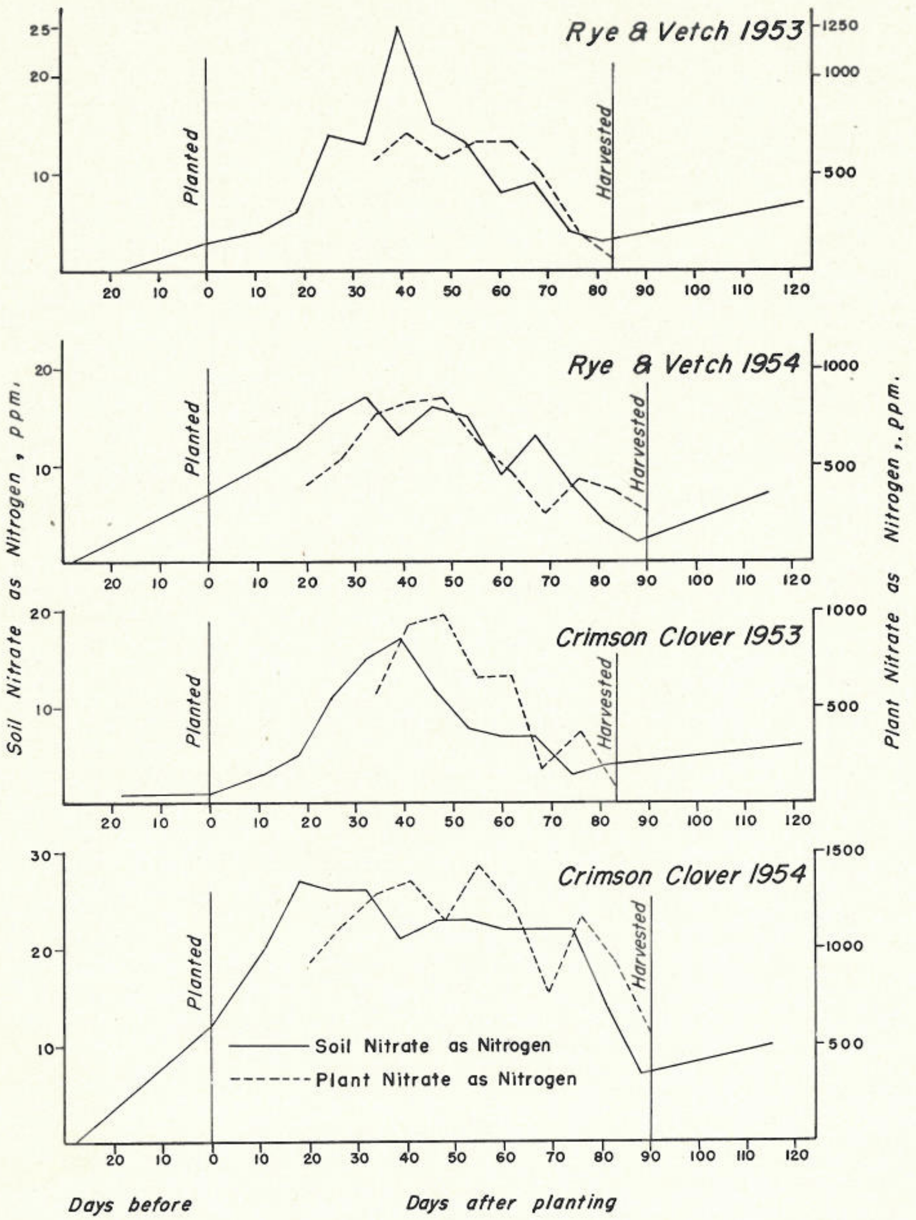

Figure 6. Soil and plant nitrate nitrogen, tobacco following rye and vetch (above) and crimson clover (below) as winter cover crops.

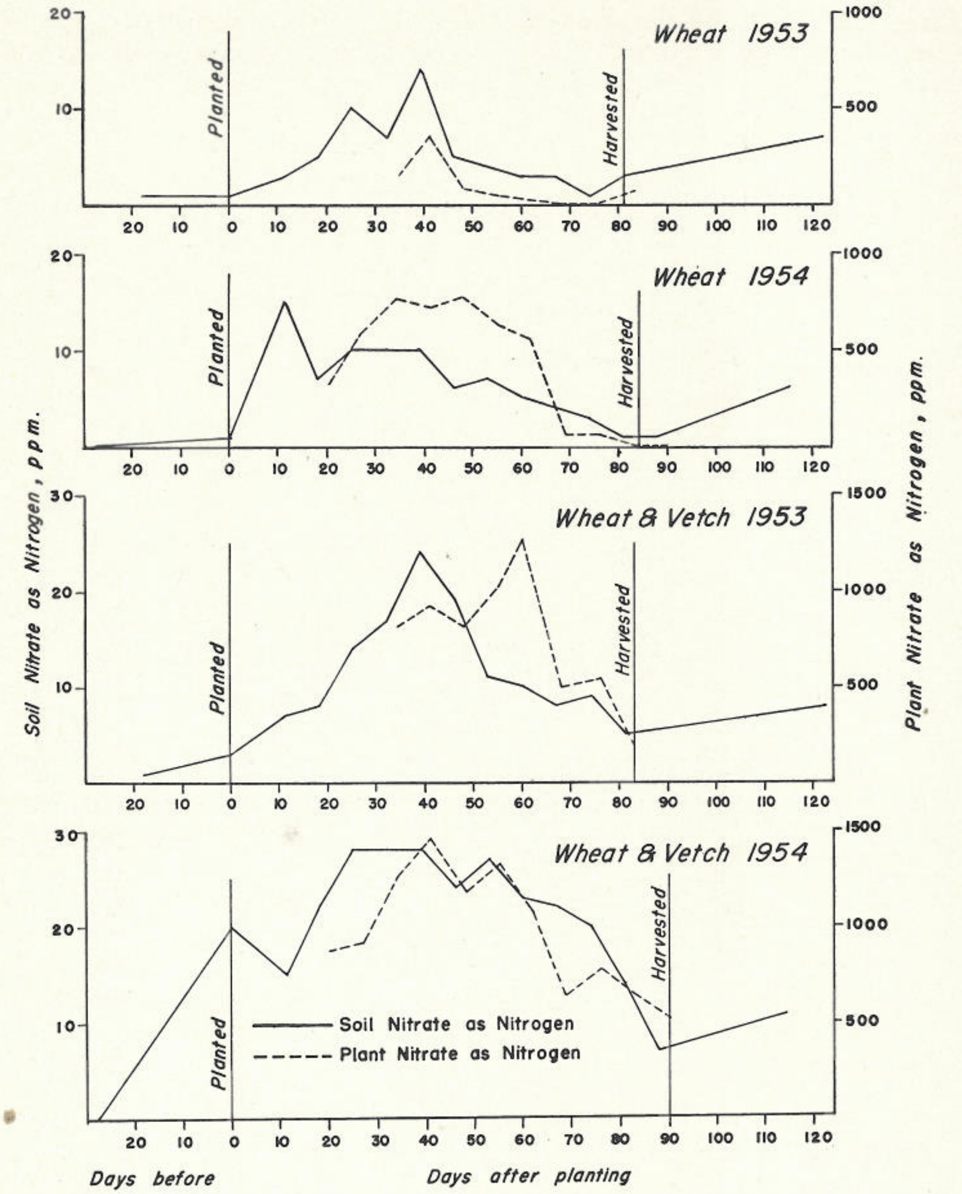

Figure 7. Soil and plant nitrate nitrogen, tobacco following wheat (above) and wheat and vetch (below) as winter cover crops.

Uptake of Nitrogen in Relationship to Growth of Tobacco

The 2-year average dry matter yield and total nitrogen of the entire tobacco plants following vetch and crimson clover are shown in Figure 9, and following ryegrass, and rye and vetch, in Figure 10, and Appendix Table 6. The four treatments were chosen because

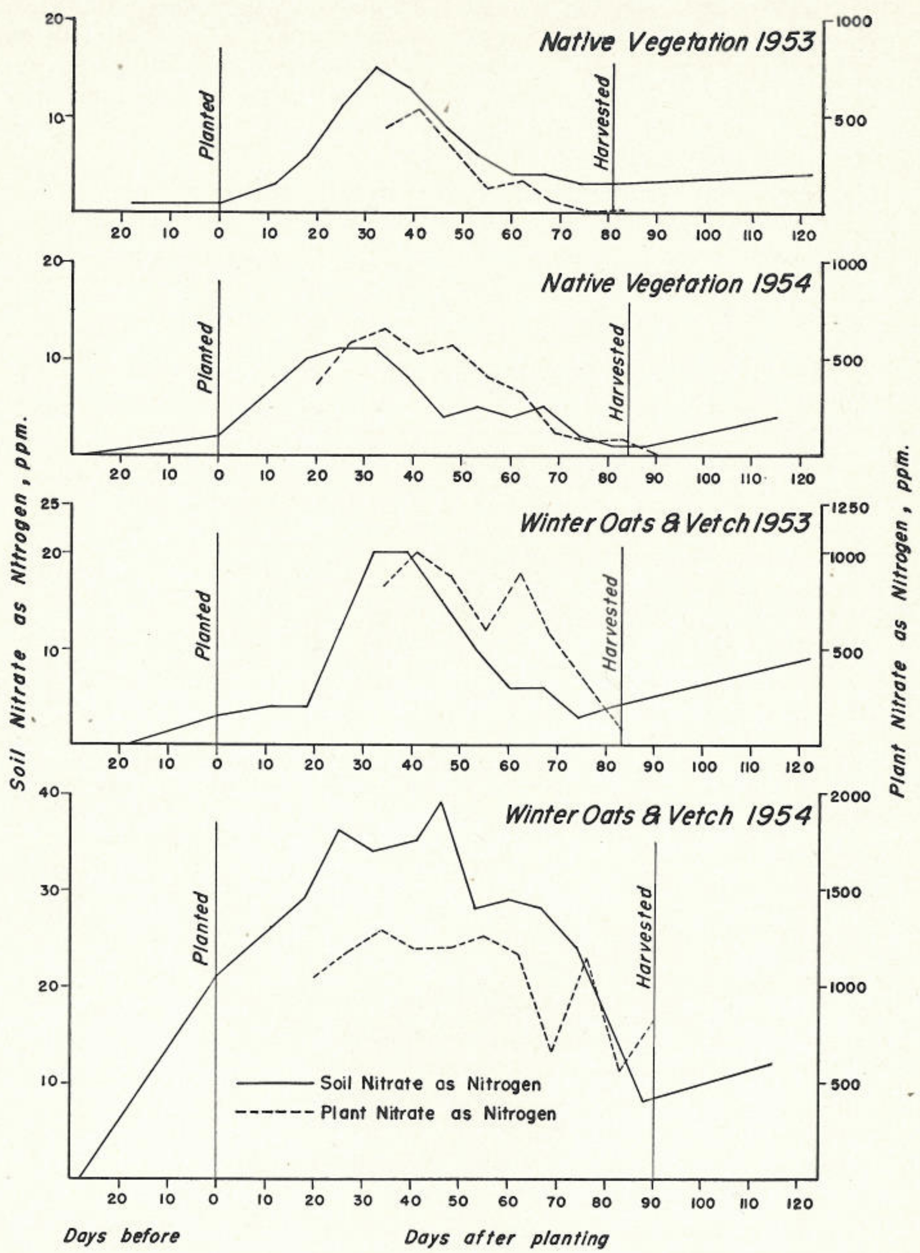

Figure 8. Soil and plant nitrate nitrogen, tobacco following native vegetation (above) as a check and winter oats and vetch (below) as a winter cover crop.

the highest amount of nitrogen was added to the soil by vetch, the least by ryegrass, and intermediate amounts by crimson clover, and rye and vetch. The 1954 growing season (90 days) was 1 week longer than the 1953 season (83 days). To obtain a 2-year average,

values for the 1954 season were moved back 1 week. The shapes of the 1954 growth curves coincided remarkably well with the 1953 curves when the adjustment had been made. The growth of the tobacco during the 1954 season was retarded because of the dry

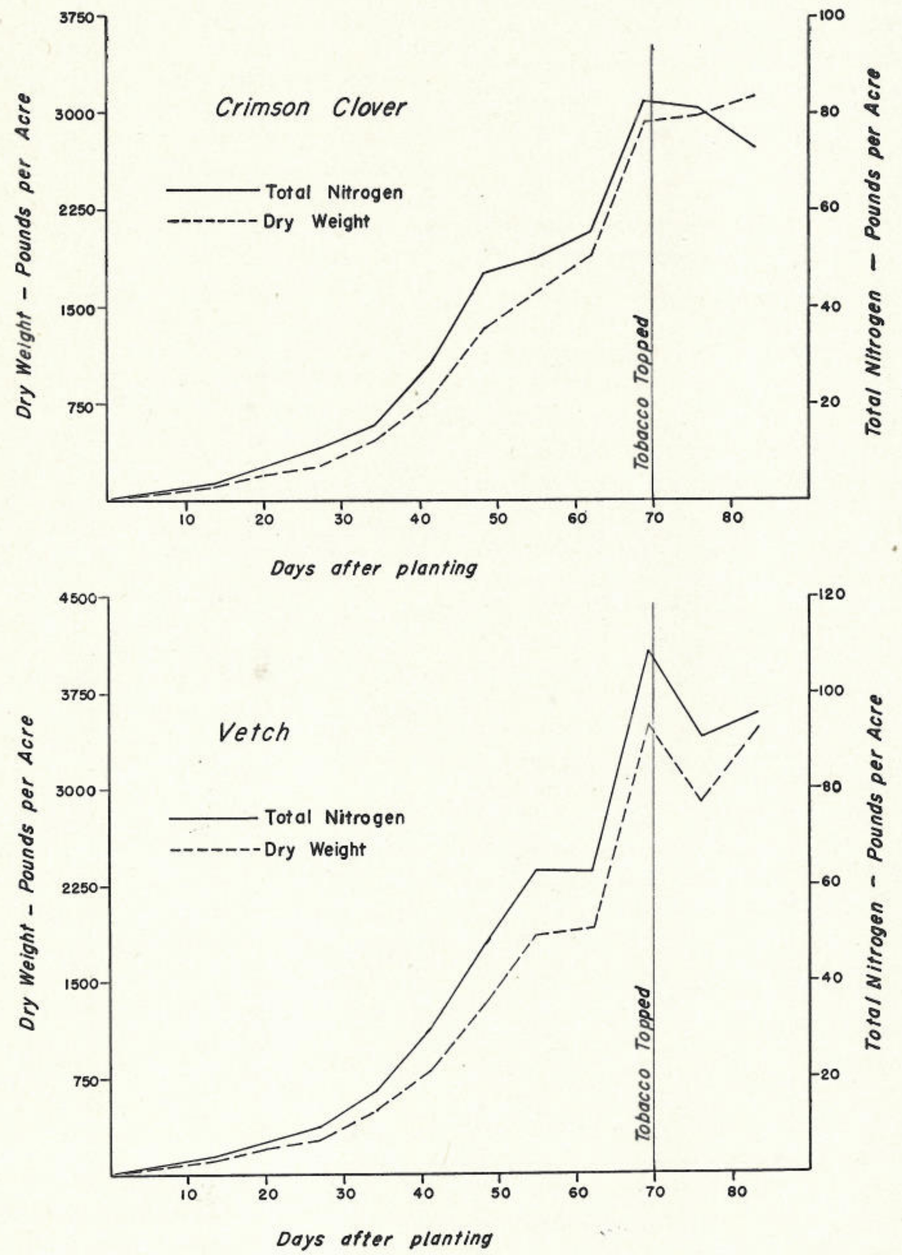

Figure 9. Dry matter and total nitrogen of entire topped plants during growth period following vetch, and crimson clover as winter cover crops.

soil conditions. The pounds per acre of total nitrogen of the 1954 crop for 55 days and for 83 days after planting was estimated because these leaf samples were destroyed by fire. Values for pounds per acre of total nitrogen are not shown for 20 days after planting.

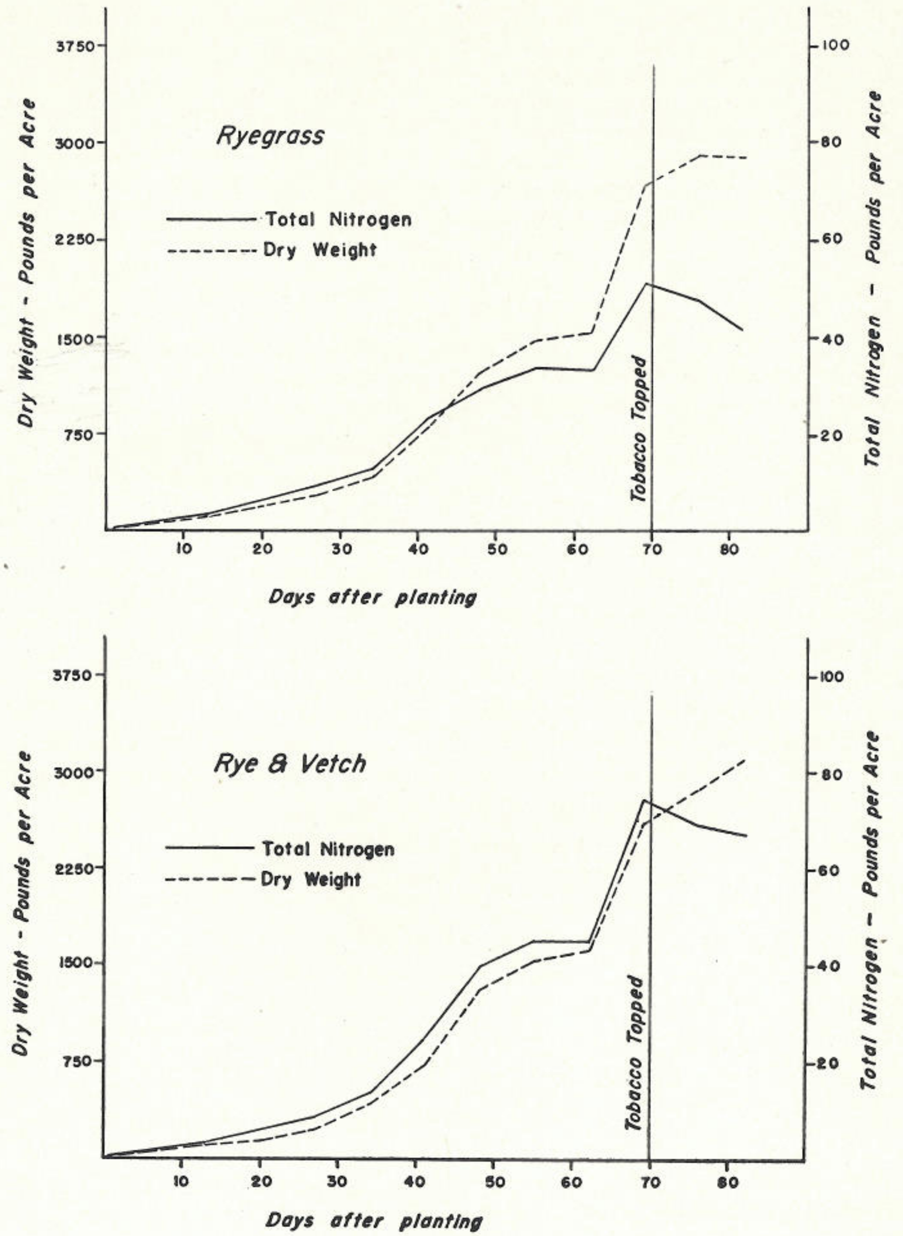

Figure 10. Dry matter and total nitrogen of entire topped tobacco plants during growth period following ryegrass, and rye and vetch as winter cover crops.

Upon examination of the dry-weight curve for the vetch treatment (Figure 9) it was found that the dry-matter yield of tobacco plants dropped the first week after topping but increased again to its previous status by the last sampling date. The pounds per acre of nitrogen of the entire plants followed the same pattern. For the other three treatments, crimson clover (Figure 9), ryegrass, and rye and vetch (Figure 10), the dry-matter yield increased the first week after topping and then either increased further or remained constant. The amount of nitrogen decreased the last 2 weeks prior to harvest even though the yield increased or remained constant. The dry weight and the content of nitrogen of tobacco plants following ryegrass (Figure 10) was the lowest of any of the four treatments investigated. The rapid growth that took place between the 62nd and 69th day after planting can be explained by improved soil moisture conditions of this period for both growing seasons (Figure 3).

The pounds per acre of total soil nitrogen at tobacco planting and at harvest time for 1953 and 1954 are shown in Table 8. The values show no consistent trends for any of the cover crops. Differences in the pounds per acre of total soil nitrogen at planting and at harvest time are also not apparent.

Total Nitrogen, Acid Insoluble Nitrogen, and Total Steam Volatile Alkaloids of Cured Tobacco

The percentages of total nitrogen of tobacco following winter cover crops for the 1953 and 1954 average are shown in Table 9. The 1954 crop contained a higher percentage of total nitrogen for all grades than did the 1953 crop. Subjecting the data to an analysis of variance for a split-plot design with grades as sub-units, it was found that the effect of treatment, as well as grade, was significant at the 1 percent level for 1953, 1954, and for the 2-year average.

From the least significant differences of the 2-year average it was found that the grades higher on the tobacco stalk had significantly higher (1 percent level) total nitrogen percentages than any grade lower on the stalk. The wheat and vetch, vetch, crimson clover, ryegrass and vetch, and the winter oats and vetch treatments, as a group, contained the highest percentage of total nitrogen. The least significant difference of the treatment means points out that there were neither significant differences between the wheat and ryegrass treatments nor between the rye and vetch, and the ryegrass plus N treatments, at the 1 percent level. The native vegetation treatment could not be statistically analyzed.

Table 10 presents the percent acid insoluble or "protein" nitrogen of tobacco following cover crops for the 1953 and 1954 average. The 1954 crop in nearly every case contained a higher percentage of acid insoluble nitrogen than did the 1953 crop, although the differences were small. It was found that the tobacco from treatments with cover crops which contained little nitrogen had more of their

Table 8. **Total soil nitrogen at tobacco planting and harvest time following four winter cover crops**

Cover crop	1953[1]		1954[1]	
	Day tobacco planted	*Day tobacco harvested*	*Day tobacco planted*	*Day tobacco harvested*
	Lbs./A.	Lbs./A.	Lbs./A.	Lbs./A.
Vetch	1,152	1,156	[2]1,311	[2]1,319
Crimson clover	1,215	1,205	1,135	1,231
Ryegrass	1,107	1,138	1,299	1,277
Rye and vetch	1,209	1,182	1,070	1,179

[1]Average of three replicates.
[2]Average of two replicates only.

Table 9. **Percent total nitrogen by farmer grade of cured tobacco leaf following winter cover crops**

Cover crop	*Total nitrogen—percent dry weight—1953 and 1954 average*[1]				
	Seconds	*Bright*	*Dull bright*	*Dull*	*Treatment mean*
	percent	percent	percent	percent	percent
Wheat	[2]1.49	[2]1.84	[2]2.91	[2]3.72	2.49
Wheat and vetch	1.84	2.56	3.57	4.09	3.02
Vetch	[3]2.21	[3]2.77	[3]3.40	[3]4.12	3.13
Crimson clover	1.87	2.42	3.42	4.09	2.95
Ryegrass	1.36	1.67	2.58	3.43	2.26
Rye and vetch	1.67	2.18	3.05	3.87	2.69
Ryegrass[4] plus N	[3]1.55	[3]2.14	[3]3.01	[3]3.85	2.64
Ryegrass and vetch	[3]1.92	[3]2.50	[3]3.53	[3]4.40	3.09
Winter oats and vetch	1.86	2.44	3.54	4.09	2.98
GRADE MEAN	1.75	2.28	3.22	3.96	
Native vegetation	[5]1.49	[5]1.94	[5]2.80	[5]3.75	2.50

L.S.D. between:	*5 pct. level*	*1 pct. level*
two treatment means	0.21	0.30
two grade means	0.11	0.15
two grade percentages for one treatment	0.32	0.43
two treatment percentages for a given or different grade	0.35	0.48

[1]Average of three replicates for each of two years, unless otherwise noted.
[2]Value for one of the three replicates computed, 1953 and 1954.
[3]Value for one of the three replicates computed for 1954.
[4]Forty pounds per acre of nitrogen applied at the time of plowing.
[5]Four replicates each year, not included in the statistical analysis.

total nitrogen as acid insoluble nitrogen than did tobacco from treatments that contained more nitrogen in the cover crops. These data were analyzed by the split-plot method with grades as subunits. The effect of grades was highly significant for both years and for the 2-year average. The effect of treatment was significant at the 1 percent level only for 1954, and significant at the 5 percent level for 1953 and for the 2-year average.

Grades higher on the stalk had significantly higher average percentages (1 percent level) of acid insoluble nitrogen than did grades lower on the stalk. Tobacco following wheat and vetch, vetch, crimson clover, ryegrass and vetch, and winter oats and vetch contained a significantly higher (1 percent level) percentage of acid insoluble nitrogen than did tobacco following ryegrass.

The results of the analysis of total steam volatile alkaloids in

Table 10. **Percent acid insoluble nitrogen by farmer grade of cured tobacco leaf following winter cover crops**

Cover crop	*Acid insoluble nitrogen—percent dry weight—1953 and 1954 average*[1]				
	Seconds	*Bright*	*Dull bright*	*Dull*	*Treatment mean*
	percent	percent	percent	percent	percent
Wheat	[2]0.76	[2]0.91	[2]1.42	[2]1.80	1.22
Wheat and vetch	0.88	1.17	1.63	1.86	1.39
Vetch	[3]0.97	[3]1.21	[3]1.46	[3]1.76	1.35
Crimson clover	0.88	1.09	1.55	1.92	1.36
Ryegrass	0.75	0.86	1.28	1.70	1.15
Rye and vetch	0.81	0.99	1.44	1.83	1.27
Ryegrass[4] plus N	[3]0.79	[3]1.06	[3]1.47	[3]1.86	1.29
Ryegrass and vetch	[3]0.94	[3]1.09	[3]1.57	[3]2.02	1.41
Winter oats and vetch	0.86	1.08	1.65	1.89	1.37
GRADE MEAN	0.85	1.05	1.50	1.85	
Native vegetation	[5]0.78	[5]0.90	[5]1.38	[5]1.81	[5]1.22

L.S.D. between:	*5 pct. level*	*1 pct. level*
two treatment means	0.12	0.18
two grade means	0.06	0.07
two grade percentages for one treatment	0.15	0.20
two treatment percentages for a given or different grade	0.18	0.25

[1]Average of three replicates for each of two years, unless otherwise noted.
[2]Value for one of the three replicates computed, 1953 and 1954.
[3]Value for one of the three replicates computed for 1954.
[4]Forty pounds per acre of nitrogen applied at the time of plowing.
[5]Four replicates each year, not included in the statistical analysis.

cured tobacco by the ultraviolet absorption method for the 1953 and 1954 average are presented in Table 11. The total steam volatile alkaloids are almost entirely composed of nicotine and nornicotine. However, nicotine is the predominant alkaloid of the Catterton tobacco strain, with nornicotine being lower than 0.50 percent in most cases as indicated by paper chromatographic analysis. The 1954 crop contained a higher percentage of total alkaloids than did the 1953 crop.

When the data were subjected to an analysis of variance for the split-plot design with grades as sub-units, it was found that the effect of treatment and grade was significant at the 1 percent level for 1953, 1954, and for the 2-year average. The bright grade contained the highest percentage of total alkaloids in all but a few cases. In general, the seconds and dull bright grades were approximately equal and at a lower percentage than the bright. The dull grade tended to contain the lowest percentage of total alkaloids.

Table 11. Percent total steam volatile alkaloids as nicotine by farmer grade of cured tobacco leaf following winter cover crops

Cover crop	*Total steam volatile alkaloids—percent dry weight—1953 and 1954 average*[1]				
	Seconds	*Bright*	*Dull bright*	*Dull*	*Treatment mean*
	percent	percent	percent	percent	percent
Wheat	[2]2.47	[2]2.77	[2]2.19	[2]1.74	2.29
Wheat and vetch	2.82	3.47	3.01	2.88	3.04
Vetch	[3]3.22	[3]3.84	[3]3.41	[3]3.65	3.53
Crimson clover	3.10	3.18	2.84	2.79	2.98
Ryegrass	2.04	2.32	1.77	1.40	1.88
Rye and vetch	3.04	3.30	2.98	2.43	2.94
Ryegrass[4] plus N	[3]2.79	[3]2.71	[3]2.78	[3]2.14	2.61
Ryegrass and vetch	[3]2.91	[3]3.21	[3]3.14	[3]2.87	3.03
Winter oats and vetch	2.81	3.34	2.99	2.74	2.97
GRADE MEAN	2.80	3.13	2.79	2.52	
Native vegetation	[5]2.39	[5]2.93	[5]2.14	[5]1.86	[5]2.33

L.S.D. between:	*5 pct. level*	*1 pct. level*
two treatment means	0.40	0.57
two grade means	0.11	0.15
two grade percentages for one treatment	0.33	0.45
two treatment percentages for a given or different grade	0.49	0.68

[1]Average of three replicates for each of two years.
[2]Value for one of the three replicates computed, 1953 and 1954.
[3]Value for one of the three replicates computed for 1954.
[4]Forty pounds per acre of nitrogen applied at the time of plowing.
[5]Four replicates each year, not included in the statistical analysis.

Tobacco from the ryegrass treatment contained the lowest average percentage of total alkaloids, and tobacco from the vetch treatment contained the highest average percentage. Tobacco following wheat was close to and not significantly different (1 percent level) from tobacco following ryegrass. The average percentage of total alkaloids of the ryegrass plus nitrogen treatment was not significantly higher than the wheat and significantly lower than the vetch average only. There was no significant difference among the wheat and vetch, crimson clover, rye and vetch, ryegrass and vetch, and winter oats and vetch treatments at the 1 percent level.

Fire-holding Capacity, Burn and Aroma Characteristics of Tobacco, Following Winter Cover Crops

The fire-holding capacity of the bright grade of cured tobacco grown following winter cover crops is expressed in seconds in Table 12. The most outstanding variation was between the 2-year values. The burning quality of the 1954 tobacco crop was extremely

Table 12. Fire-holding capacity of the bright grade of cured tobacco leaf following winter cover crops

Cover crop	*Duration of burn — seconds*[1]		
	1953	*1954*	*Two-year average*
	seconds	seconds	seconds
Wheat	[2]13.5	[2]4.1	8.8
Wheat and vetch	16.4	11.1	13.8
Vetch	14.9	[2]10.7	12.9
Crimson clover	23.0	7.2	15.1
Ryegrass	18.2	3.4	10.9
Rye and vetch	13.3	8.3	10.8
Ryegrass[3] plus N	19.6	[2]6.2	12.9
Ryegrass and vetch	18.6	[2]13.9	16.3
Winter oats and vetch	19.5	10.4	14.9
Native vegetation	[4]16.7	[4]3.8	[4]10.3
L.S.D. (0.05)	N.S.	4.1	N.S.
L.S.D. (0.01)	N.S.	5.8	N.S.

[1]Average of 25 leaves from each of three replicates.
[2]Value for one of the three replicates computed.
[3]Forty pounds per acre of nitrogen applied at the time of plowing.
[4]Four replicates, not included in the statistical analysis.

poor, and the tobacco that followed nonlegume cover crops was by far lower in burning quality than any others for that year. The effect of treatment was nonsignificant for the 1953 crop and for the 2-year average, but highly significant for the 1954 crop. When Table 12 is examined closely, it becomes evident that the results of the burn tests are not consistent for the 2 years. For the 2-year average the duration of burn of tobacco following winter cover crops containing some legume was better than that following nonlegumes alone.

The ratings for burn and the aroma of the bright grade of cured tobacco following winter cover crops are presented in Table 13.

For both burn and aroma ratings, the effect of treatment was nonsignificant for the 1953 crop but highly significant for the 1954 crop. These values were assigned by a panel of experts and the burn and aroma ratings for individual treatments were not very different for either year. The more important value was the aroma, because the burn was tested under standardized conditions (Table 12). The generalization that may be made is that tobacco that followed cover crops containing legumes either alone or in combination was rated better on burn and aroma characteristics than tobacco following nonlegumes.

Table 13. Burn and aroma ratings of the bright grade of cured tobacco following winter cover crops

Cover crop	Burn values[1]		Aroma values[1]	
	1953	*1954*	*1953*	*1954*
Wheat	[4]8.1	[4]6.2	[4]7.2	[4]6.3
Wheat and vetch	10.4	10.0	10.4	10.1
Vetch	9.9	[2]10.1	10.1	[2]9.7
Crimson clover	8.8	8.2	10.6	8.3
Ryegrass	8.4	6.2	8.1	6.0
Rye and vetch	9.6	7.4	10.1	7.5
Ryegrass[3] plus N	9.6	[2]7.1	8.9	[2]6.4
Ryegrass and vetch	12.0	[2]8.6	11.8	[2]7.8
Winter oats and vetch	10.8	7.9	11.6	8.1
Native vegetation	[4]9.2	[4]7.0	[4]9.0	[4]6.3
L.S.D. (0.05)	N.S.	1.5	N.S.	1.8
L.S.D. (0.01)	N.S.	2.2	N.S.	2.6

[1]Burn and aroma values range from 1 to 20; 1 the lowest and 20 the highest rating, average of three replicates.
[2]Value for one of three replicates computed.
[3]Forty pounds per acre of nitrogen applied at the time of plowing.
[4]Four replicates, not included in the statistical analysis.

DISCUSSION OF RESULTS

A most important aspect in the study of the effects of winter cover crops on the growth and quality of Maryland tobacco is a consideration of nitrogen nutrition. This becomes quite evident when the amounts of organic nitrogen incorporated into the soil with cover crops are examined. The range in the experiments was wide and extended from 43 to 188 pounds per acre. Varying the supply of nitrogen to the tobacco crop not only affected the yield and quality, but also drastically altered the chemical composition of the cured leaf. In almost every case tobacco yields were increased by the use of legumes alone or in combination with nonlegumes as winter cover crops; but, at the same time, the percentages of total nitrogen, acid insoluble nitrogen, and total alkaloids were increased in the cured tobacco leaf.

The effect of winter cover crops containing large amounts of nitrogen on the dollars per hundred pounds and dollar-per-acre return of tobacco was not always so clear-cut. These cover crops did not seem to affect the tobacco crop so much the first several years as they did the last few, and the influence of season often tended to obscure the relationships. The trend indicated that tobacco following cover crops with legumes alone or in combination with nonlegumes benefited more in dry seasons than in normal or wet seasons. For the drier 1953 and 1954 seasons, the average dollar-per-acre return increased as more nitrogen was incorporated into the soil. The data indicate that the yield, dollar-per-acre return, and the dollars per hundred pounds with a legume-nonlegume combination cover crop were not far below the maximum obtainable under the prevailing conditions of the experiment. This generalization did not hold true in several cases for rye and vetch used as a cover crop. Ryegrass plus 40 pounds per acre of nitrogen applied at the time of plowing did not give uniformly satisfactory results.

The rate of decomposition of the cover crops, as reflected by the soil nitrate nitrogen accumulation curves, varied widely, depending upon the cover crop and season. Those cover crops with higher nitrogen content caused more accumulation of soil nitrate nitrogen than those lower in nitrogen. The soil nitrate nitrogen graphs show why tobacco on some treatments ripened later than on others, why tobacco following nonlegumes in some cases exhibited nitrogen deficiency symptoms, and why tobacco following the various cover crops contained differing percentages of nitrogenous compounds.

The relationship between the soil nitrate and plant nitrate nitrogen curves was not so good for the 1954 season as for the 1953 season in most cases, because of the effect of rainfall. When water was a limiting factor, as during the latter part of the 1954 season, nitrate nitrogen tended to accumulate in the soil and in the plants. Other workers have found this condition to exist during dry periods both in the soil (20) and in plants (7). During drought periods nitrates moved upward in the soil and accumulated at the surface as a result of the net movement of soil water. The condition for an accumulation of nitrates in plants was simply that the intake exceeded the consumption. Since only small amounts of carbohydrates are produced when water is a limiting factor (11), only a small amount of energy is available to reduce nitrate to ammonium in order to assimilate the nitrogen into amino acids and proteins. The accumulation of nitrogen by the tobacco plants under dry weather conditions is shown by the higher percentage of total nitrogen contained in the cured leaves for the 1954 crop. Generally, a lower proportion of the total nitrogen was in the acid insoluble or protein form for the 1954 crop than for the 1953 crop.

The determination of soil nitrate in the early part of the growing season showed that the amount of nitrate after the winter and early spring seasons was very low, and accumulation did not begin until about 3 to 4 weeks after the cover crops were plowed under (unless the cover crops were very high in nitrogen). The nitrate nitrogen of tobacco midribs did not show a very marked accumulation until approximately 24 days after transplanting. It is desirable that the quantity of nitrates diminish in the latter part of the growing season because delayed ripening tends to produce lower quality tobacco.

There was a definite lowering of the soil pH 40 days after the tobacco was planted in 1953. The findings were in accord with other work (37), but for the 1954 season there was only a slight decrease in soil pH although the season was much drier. This latter result was contrary to that obtained by the Connecticut workers.

For 3 to 4 weeks during the latter part of the 1953 growing season, and for approximately 10 weeks during the latter part of the 1954 growing season, the percentage of soil moisture was well below 10 percent. For a sandy loam soil Kramer (19) indicated that soil moisture between approximately 8 and 18 percent was readily available for plant growth. Between about 4 and 8 percent the soil moisture was available for plant survival but not for growth. These figures are of some value in the interpretation of the growth of tobacco during the two seasons, since the texture of the soil on which the crops grew was a fine sandy loam.

The dry weight of the entire tobacco plants followed a normal growth curve except where growth was retarded due to lack of water. After an initial period of slowly accelerating growth, a maximum was reached between approximately 30 and 65 days after planting. Shortly after this time the plants were topped and the subsequent increase or decrease in dry weight was dependent upon the treatment.

The nitrogen uptake by the tobacco plants followed the same general pattern as presented for the dry weight except in cases where cover crops contained little nitrogen and the decline in the rate of nitrogen uptake was more rapid. Morgan and Street (25) present a similar picture for the growth of the entire topped plant of Havana Seed tobacco. However, their 5-year average data do not show a drop in either the dry weight or nitrogen content after topping. Vickery, et al. (41), working with Connecticut shade-grown tobacco, reported a steady increase in the dry weight of the whole plant (excluding roots). The same observation was made for the total nitrogen content, excepting the last sampling date on which the nitrogen content was lower than for the previous sampling period. These workers offered no explanation for the drop.

It was expected that some difference could be found to exist between the pounds per acre of nitrogen in the soil at planting and at harvest time, since vetch added 188 and ryegrass added 57 pounds per acre of nitrogen to the soil, and the tobacco that followed removed approximately 100 pounds and 50 pounds per acre from the vetch and ryegrass treatments, respectively. As has been pointed out, no important differences were apparent for treatments, dates, or years for the 1953 and 1954 seasons.

The variation in the percentage of total nitrogen and acid insoluble nitrogen of cured leaf tobacco following the different cover crops may be explained simply on the basis of amounts of nitrogen added to the soil. The trend for these two percentage figures, an increase from the lower portions of the stalk upward, was also normal. The variation in the average percentage of total alkaloids of cured tobacco leaves may also be attributed to the amount of nitrogen which cover crops added to the soil. It was not surprising that the highest percentage of total alkaloids was found in the leaves toward the middle of the stalk (bright grades). Other workers (3, 28) have found this to be the case, especially where the whole plant was harvested and all leaves cured on the stalk. The most important factors contributing to the phenomenon are the immaturity of the upper leaves as compared to that of the lower ones and the length of time between topping and harvesting. The percentage of total alkaloids did not vary greatly for the grades of tobacco following vetch because the tobacco remained in the field a sufficient time before harvest to accumulate about the maximum amount of alkaloids in all leaves.[1]

It has been contended that proteins and related complex compounds of nitrogen tend to injure the burning properties of tobacco because these compounds are not readily combustible (14). The results of fire-holding capacity tests of tobacco of the bright grade following cover crops for the two seasons were not in accord with this theory. Leaves containing intermediate percentages of acid insoluble nitrogen tended to exhibit the best burning qualities. The duration of burn of tobacco following nonlegumes was extremely short, especially for the dry 1954 growing season.

The aroma of the smoke of the bright grades is an important criterion of tobacco quality, particularly for several of the foreign purchasers of Maryland tobacco. The results of a panel of experienced judges indicated that the aroma of smoke of tobacco following the winter cover crops in 1953

[1] **Jeffrey, R. N., 1955. Personal communication.**

and 1954 was, in general, not as good as might have been expected. However, slightly better ratings were obtained from tobacco following legumes alone or legumes in combination with nonlegumes than from tobacco following nonlegumes alone.

SUMMARY

A field experiment was conducted dealing with the effects of legume and nonlegume winter cover crops on the growth, quality, and nitrogen nutrition of Maryland tobacco. Agronomic data for a 5-year period (1950 through 1954) are presented. Intensive investigations into some of the fundamental soil-plant relationships were carried out for the last 2 years of the test. The field test involved ten treatments, i.e., two legume cover crops, two nonlegume cover crops, four legume-nonlegume cover crop combinations, one non-legume cover crop with added fertilizer nitrogen, and one with no cover crop seeded. Rainfall was sufficient and the distribution fair for the first three growing seasons, but the fourth was drier and the fifth extremely dry. The general conclusions of this investigation are as follows:

1. For the 5-year period tobacco following vetch produced the highest yields and that following nonlegumes the lowest yields. Yields of tobacco after the combinations were intermediate. The relative positions of the treatments for the dollar-per-acre return were essentially the same as for the yields. However, in most cases, a higher dollar-per-hundred pounds value was obtained following the combinations. The effects of the cover crops were less pronounced for the first several years of the test. During the drier years, the best tobacco crops were produced following cover crops containing legumes. For the 1953 and 1954 average, the dollar-per-acre return increased as more nitrogen was incorporated into the soil.

2. Determinations of the amount of total nitrogen incorporated into the soil by the cover crop roots and tops showed a range from 43 to 188 pounds per acre. Vetch grown alone contained the highest amount, the combinations contained at least 120 pounds per acre, and the nonlegumes contained no more than 57 pounds per acre. The amount of total dry matter produced by the cover crops when roots and tops were combined did not differ as widely as when tops alone were considered.

3. The weekly soil pH values showed a slight decrease during the middle part of the two growing seasons, even though the drop was not so marked for the drier year.

4. The relationship of plant to soil nitrate nitrogen is presented graphically for each treatment for the 1953 and 1954 growing seasons. Nitrate nitrogen of fresh tobacco midribs followed the trends of soil nitrate accumulation closely. Peaks occurred in both during the middle parts of the growing seasons, with accumulation being greater for the drier season. For both plants and soil, nitrate nitrogen accumulation was greater following cover crops which contained higher amounts of nitrogen.

5. Rates of dry matter increase of entire topped tobacco plants are presented in comparison to the amounts of nitrogen contained by the plants from four representative treatments. Although the cover crops added to the soil widely differing amounts of nitrogen and the tobacco that followed them removed varying amounts, no important differences could be detected in the total nitrogen of the soil.

6. The percentage of total nitrogen, acid insoluble nitrogen, and total alkaloids of cured leaf tobacco of the 1953 and 1954 crops was greater following those cover crops which contained higher amounts of nitrogen. There was a progressive increase in the percentage of total and of acid insoluble nitrogen by grade from the bottom of the tobacco stalk toward the top. The bright grades contained the highest percentage of total alkaloids. The seconds and dull bright grades were approximately equal, and the dull contained the lowest percentage. The percentage of nitrogenous constituents was higher for the crop grown in the 1954 (drier) season than for the crop grown in 1953.

7. Fire-holding capacity tests and burn and aroma ratings of the bright grade showed that for the 1954 season tobacco following cover crops containing legumes was better than tobacco following nonlegumes.

8. In general, better results were obtained by using winter cover crops which contained both legumes and nonlegumes than by using either legumes or nonlegumes alone when all of the criteria used to evaluate the growth and quality of tobacco produced in the 1953 and 1954 seasons were taken into consideration. This conclusion is based upon past experience and previous experimentation as well as on the findings obtained from this research. It is generally known that when Maryland tobacco follows vetch as a cover crop for long periods the cured leaf may be undesirable because of its heavy body and texture and dark or dull color.

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APPENDIX

Appendix Table 1. Soil reaction (pH) and air-dry moisture content of soils, tobacco following winter cover crops, averages for all treatments at various intervals

Days in Reference to Planting Date of Tobacco

Year and soil condition	18 Days before	Same day	Days after planting											
			11	18	25	32	39	46	53	60	67	74	81	122
1953														
Percent soil moisture....	10.9	16.3	17.1	16.1	12.4	11.7	12.7	9.8	6.5	4.3	8.1	5.5	10.6	9.1
Soil reaction (pH)	5.7	5.3	5.1	5.0	5.0	4.8	4.5	4.7	4.6	4.9	4.8	4.9	4.8	5.0

1954	28 Days before	Same day	Days after planting												
			11	18	25	32	39	46	53	60	67	74	81	88	115
Percent soil moisture....	15.9	10.2	10.5	9.9	10.0	9.1	8.0	8.4	5.8	5.2	7.6	6.1	7.0	5.0	4.7
Soil reaction (pH)...........	5.2	5.1	5.1	5.0	4.9	5.0	5.0	5.0	5.0	5.0	4.9	4.9	4.8	4.9	5.1

Appendix Table 2. Soil nitrate as parts per million N, air-dry weight basis, tobacco following winter cover crops, 1953

Days in Reference to Planting Date of Tobacco

Winter cover Crop	18 Days before	Same day	Days after planting											
			11	18	25	32	39	46	53	60	67	74	81	122
Wheat..........................	1	1	3	5	10	7	14	5	4	3	3	1	3	7
Wheat and vetch..........	1	3	7	8	14	17	24	19	11	10	8	9	5	8
Vetch..............................	1	5	9	12	18	19	31	26	19	13	19	14	16	10
Crimson clover	1	1	3	5	11	15	17	12	8	7	7	3	4	6
Ryegrass........................	0	0	1	1	6	12	8	6	2	2	3	0	0	5
Rye and vetch.............	0	3	4	6	14	13	25	15	13	8	9	4	3	7
Ryegrass plus N*	1	3	2	5	12	16	17	7	7	5	6	2	3	6
Ryegrass and vetch	0	2	5	9	12	22	22	20	16	11	12	8	9	11
Winter oats and vetch	0	3	4	4	12	20	20	15	10	6	6	3	4	9
Native vegetation........	1	1	3	6	11	15	13	9	6	4	4	3	3	4

*Forty pounds per acre of nitrogen applied at plowing time.

Appendix Table 3. Soil nitrate as parts per million N, air-dry weight basis, tobacco following winter cover crops, 1954

Days in Reference to Planting Date of Tobacco

Winter cover crop	28 Days before	Same day	Days after planting												
			11	18	25	32	39	46	53	60	67	74	81	88	115
Wheat....................	0	1	15	7	10	10	10	6	7	5	4	3	1	1	6
Wheat and vetch	0	20	15	22	28	28	28	24	27	23	22	20	14	7	11
Vetch......................	1	30	24	40	46	38	37	46	48	46	40	45	26	25	24
Crimson clover	0	12	20	27	26	26	21	23	23	22	22	22	14	7	10
Ryegrass...............	0	0	5	4	8	7	4	3	5	1	3	1	0	1	4
Rye and vetch......	0	7	10	12	15	17	13	16	15	9	13	8	4	2	7
Ryegrass plus N*	0	8	7	9	15	17	11	12	13	7	12	10	7	1	5
Ryegrass and vetch	0	16	24	21	35	34	35	26	28	25	26	23	19	10	14
Winter oats and vetch.................	0	21	26	29	36	34	35	39	28	29	28	24	16	8	12
Native vegetation	0	2	7	10	11	11	8	4	5	4	5	2	1	1	4

*Forty pounds per acre of nitrogen applied at plowing time.

Appendix Table 4. Plant nitrate as parts per million N, fresh weight basis (plant tissue tests), tobacco following winter cover crops, 1953

Winter cover crop	Days After Planting Date of Tobacco							
	34	41	48	55	62	68	76	83
Wheat....................................	141	351	82	50	39	3	3	75
Wheat and vetch..................	818	937	827	1,011	1,260	496	540	190
Vetch.....................................	977	966	1,237	977	1,040	886	1,008	590
Crimson clover......................	595	939	974	651	667	180	371	91
Ryegrass................................	405	365	211	36	130	13	3	18
Rye and vetch.......................	563	706	578	668	660	507	199	66
Ryegrass plus N*	542	455	549	505	488	47	53	55
Ryegrass and vetch..............	677	825	750	837	604	751	242	64
Winter oats and vetch	826	990	884	601	896	595	310	85
Native vegetation................	441	632	334	139	163	65	9	16

*Forty pounds per acre of nitrogen applied at plowing time.

Appendix Table 5. Plant nitrate as parts per million N, fresh weight basis (plant tissue tests), tobacco following winter cover crops, 1954

Winter cover crop	*Days After Planting Date of Tobacco*										
	20	*27*	*34*	*41*	*48*	*55*	*62*	*69*	*76*	*83*	*90*
Wheat	332	594	769	729	767	636	549	60	66	9	9
Wheat and vetch	873	912	1,267	1,456	1,184	1,312	1,075	644	783	646	518
Vetch	1,410	1,434	1,566	1,735	1,512	1,584	1,392	1,128	1,392	1,044	1,056
Crimson clover	927	1,120	1,287	1,344	1,152	1,426	1,216	772	1,167	939	564
Ryegrass	149	389	376	213	196	104	91	29	6	6	8
Rye and vetch	401	523	760	819	845	622	467	250	429	360	255
Ryegrass plus N*	670	825	843	557	883	981	344	202	486	66	9
Ryegrass and vetch	940	960	1,240	1,512	1,224	1,248	1,075	585	1,176	1,152	825
Winter oats and vetch	1,040	1,173	1,280	1,190	1,192	1,254	1,158	667	1,146	566	821
Native vegetation	372	585	650	526	567	411	323	120	75	84	8

*Forty pounds per acre of nitrogen applied at plowing time.

Appendix Table 6. Dry matter and total nitrogen of entire tobacco plants during growth period following vetch, crimson clover, ryegrass, and rye and vetch as winter cover crops (Data are averages of two years results.)

Winter cover crop	*Dates as Days After Planting Tobacco Crop*										
	13	*20*	*27*	*34*	*41*	*48*	*55*	*62*	*69**	*76*	*83*
	Dry matter expressed as pounds per acre										
Vetch	107	183	246	487	816	1,318	1,856	1,928	3,482	2,918	3,465
Crimson clover	111	202	268	456	762	1,332	1,603	1,881	2,938	2,987	3,212
Ryegrass	94	177	286	422	788	1,217	1,466	1,522	2,659	2,926	2,906
Rye and vetch	105	144	226	429	720	1,311	1,530	1,614	2,596	2,848	3,109
	Total nitrogen (N) expressed as pounds per acre										
Vetch	3.95	....	9.85	17.10	30.02	47.75	62.80	62.39	108.97	90.46	96.50
Crimson clover	3.66	....	10.37	15.86	28.06	46.83	49.94	55.82	82.09	81.15	73.03
Ryegrass	2.69	....	9.78	12.21	22.88	29.71	33.52	33.18	50.80	47.50	41.38
Rye and vetch	3.16	....	8.14	13.78	24.43	39.85	45.37	44.79	74.69	68.86	67.09

*Topped on 70th day after planting.

Visitors will be welcome at all times, and will be given every opportunity to inspect the work of the Agricultural Experiment Station in all its departments.

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