BULLETIN 280 JUNE, 1951

STUDIES of ORGANIC MATERIALS for VEGETABLE CROPS

AGRICULTURAL EXPERIMENT STATION
of the ALABAMA POLYTECHNIC INSTITUTE
E. V. Smith, *Director* Auburn, Alabama

CONTENTS

FIRST PRINTING 3M, JUNE, 1951

STUDIES *with* ORGANIC MATERIALS *for* VEGETABLE CROPS

L. M. WARE, *Horticulturist*
W. A. JOHNSON, *Assistant Horticulturist*

RESULTS of studies with use of organic materials on vegetable crops extending over a period of years are presented in this bulletin.

As used herein, the term "organic materials" is applied to materials added to the soil either as green manures, as animal manures, or as mulching materials. The term "organic matter" is used to apply to these materials or other organic substances in the soil in the various stages of decomposition. "Humus" is used in the sense of the more or less stable end-product resulting from the process of decomposition of organic materials. Furthermore, the effects attributed to organic materials are considered to be the combined effects of the nitrogen, minerals, and carbonaceous matter that these materials contain and all effects that these have on plant growth and soil properties.

REVIEW OF LITERATURE

A close relationship exists between the organic matter of the soil, nitrogen of the soil, and soil fertility. The more stable forms of nitrogen are directly related to the organic matter and exist primarily as constituents of the soil humus *(25)*.

Jenny *(11)* has shown that organic matter in southern soils is low and that in regions having a similar precipitation-evaporation ratio for each drop of 10°C in mean annual temperature, the average organic matter content of the soil increases two or three times. Marbut *(14)* has shown that nitrogen is low in the red and yellow soils, which are characteristic soils of the South. Funchess *(7)* has emphasized the seriousness of the low organic and nitrogen content of southern soil and the need of adding nitrogen for satisfactory yields.

Since the South has a high mean annual temperature, a high rainfall, and in general light soils, decomposition of organic matter and subsequent loss of nitrogen by leaching are high. It is, therefore, difficult to maintain and even more difficult to increase the organic matter in southern soils *(10, 15, 21)*. Repeated applications, however, of large quantities of organic materials may slowly increase the soil organic matter content *(8, 20, 29)*.

Nitrogen available to crops may be released from applications of organic materials very soon after they are added *(3, 13, 29)*. The amount of nitrogen released for plant use, however, is largely determined by the ratio of carbon to nitrogen *(4, 6, 12, 18, 19, 23)*. In general, nitrates accumulate upon decomposition of materials having a carbon-nitrogen ratio less than 20 or 30 to 1.

SCOPE OF INVESTIGATION

The investigation has included studies of the immediate and residual effects of organic materials grown on the land and turned under, and of those introduced and incorporated in the soil or left on the surface as a mulch. The materials have included those high in nitrogen and those low in nitrogen.

The value of organic materials has been measured by their effects on crop yields, on soil nitrates and soil moisture levels during the growth of crops, and by changes in the total nitrogen and organic matter content of the soil. The effectiveness of organic materials in supplying the nitrogen requirements of growing crops has been determined by comparison of yields of crops receiving organic materials and different rates of commercial nitrogen. Special attention has been given to studies dealing with the value of organic materials as one of a number of practices in intensive agriculture. Phases of this work have been reported in earlier publications *(26, 28, 29, 30)*.

METHODS AND PROCEDURES

Only general methods and procedures are given at this point. Details are explained under each separate phase of the study as reported.

The investigation was conducted at the Main Station, Auburn, in specially constructed concrete field bins *(27)*. The bins were 1/320- and 1/640-acre in size. Before the experiments were

started, the soil in each series was composited among all bins and within each bin.

Yields of crops were obtained by separate harvest periods and by different grades. Soil samples for analysis were taken by compositing the soil from eight borings at specified points in the bins. The samples represented the top 8 inches of soil. Current nitrate and moisture levels were obtained by determining the amount of nitrates and moisture in the soil at stated intervals during growth of the crops. Samples for total nitrogen and organic matter determinations were taken once yearly in the fall. The phenoldisulphonic acid method was used for nitrate determinations *(22)*, the oven-dry method for moisture determinations *(2)*, the Kjeldahl method modified to include nitrates for total nitrogen determinations *(2)*, and the chromic acid method for organic matter determinations *(1)*.

The studies consisted of a number of series conducted in different sets of bins. The series designations correspond to bin number or numbers.

In many instances, yields are expressed as the average of a number of crops over a number of years. The averages represent the total yields of all crops for the number of years involved, divided by the total number of crop years.

Residual effects of organic materials were determined by continuing the experiment for a number of years after the last application of the materials. Records were kept on yields, soil organic matter content, and total nitrogen content during the residual period.

Two phases of the investigation were conducted on a Norfolk soil of medium fertility (Series A4 and A7), two phases on a Chesterfield soil of medium fertility (Series B14 and B23), and four phases on a Chesterfield soil of low fertility (Series B1-B3, Series B2, Series B15-16, and Series B19-B21).

In most series, one ton per acre of limestone was applied to all treatments at the beginning of the experiment. Minor or trace elements were applied at 3-year intervals to all Chesterfield soils. The minor elements consisted of 12.5 pounds of $CuSO_4.5H_20$, 25.0 pounds of $MgSO_4.7H_2O$, 5.0 pounds of $MnSO_4.4H_2O$, 12.5 pounds of $ZnSO_4.7H_20$, 12.5 pounds of $FeSO_4.7H_20$, and 5.0 pounds of H_3BO_3 per acre. Detailed treatments for each series are given in the tables.

PRESENTATION OF DATA

In presenting each phase of study, there is given a brief statement of its purpose, specific procedures used, and results obtained. Data relating to crop yields are presented first, and are followed by data on other effects. Certain relationships are then shown between the measured effects on the soil and crop yields.

Effects of Winter and Summer Green-Manure Crops on Yields of Succeeding Vegetable Crops on Chesterfield Soil of Low Fertility

This phase of the study consisted of growing and turning under of legume and nonlegume green-manure crops. A summer crop and a fall crop of vegetables followed turned winter cover crops, while a fall crop and a spring crop followed summer cover crops on the same plots. The soil was a Chesterfield of low fertility. All plots received a standard amount of phosphorus and potash. Nitrogen treatments consisted of 0, 30, and 60 pounds per acre of nitrogen, each with and without a legume. The nonlegume was grown only on plots receiving the highest rate of nitrogen. Treatments were in quadruplicates. Series B15-16 was assigned to this study.

The primary objectives of this phase were to determine: (1) Increases in yields of vegetables resulting from turning of summer and winter legumes where no commercial nitrogen had been added, (2) amount of commercial nitrogen required to give increases in yield equivalent to those from legumes, (3) increases in yield from the legume when different amounts of commercial nitrogen were used, (4) increases in yield from different amounts of commercial nitrogen when a legume was turned, and (5) increases in yield from nonlegumes with commercial nitrogen.

The upper rate of commercial nitrogen was set at 60 pounds per acre, an amount which was considered adequate to establish the foregoing objectives. The data show that this rate was adequate to establish all but the second objective.

The average yields of all crops in each group for all years are given in Table 1. Comparative effects of selected treatments are shown graphically in Figure 1. The yields of the individual crops are given in Appendix Tables 1, 2, and 3, and manure crop weights given in Appendix Table 4.

Effects of Winter Green-Manure Crops on Yields of Summer Vegetables

The average yield of five summer vegetables without commercial nitrogen and without winter legume was 3,236 pounds per acre (Table 1). The turning of a crop of vetch increased the yield to 12,400 pounds, whereas the addition of 30 pounds of commercial nitrogen per acre increased the yield to only 6,937 pounds; the addition of 60 pounds of commercial nitrogen increased yield

TABLE 1. AVERAGE YIELDS AND INCREASES IN YIELD OF SUMMER AND FALL VEGETABLES FOLLOWING TURNED WINTER COVER CROPS AND OF FALL AND SPRING VEGETABLES FOLLOWING TURNED SUMMER COVER CROPS RECEIVING DIFFERENT RATES OF NITROGEN, CHESTERFIELD SOIL OF LOW FERTILITY, SERIES B15-16, 1940-1949

Fertilizer grades, 1,000 lb. per acre[1]	Kinds of cover crops turned	Yields per acre		Increases in yields from use of turned cover crops	
		Without cover crops	With cover crops	Amount	Per cent
		Pounds	*Pounds*	*Pounds*	
		SUMMER VEGETABLES FOLLOWING WINTER COVER CROPS[2]			
0-10-6	Vetch	3,236	12,400	9,164	283
3-10-6	Vetch	6,937	14,342	7,405	107
6-10-6	Vetch	8,929	15,386	6,457	72
6-10-6	Rye	8,929	14,335	5,406	61
6-10-6	Rye(R)[3]	8,929	12,769	3,840	43
		FALL VEGETABLES FOLLOWING WINTER COVER CROPS[4]			
0-10-6	Vetch	2,558	6,733	4,175	163
3-10-6	Vetch	8,174	11,670	3,496	43
6-10-6	Vetch	11,563	13,991	2,428	21
6-10-6	Rye	11,563	13,547	1,984	17
6-10-6	Rye(R)[3]	11,563	12,707	1,144	10
		FALL VEGETABLES FOLLOWING SUMMER COVER CROPS[4]			
0-10-6	Cowpea	3,075	13,931	10,856	353
3-10-6	Cowpea	10,063	18,450	8,387	83
6-10-6	Cowpea	15,127	20,808	5,681	38
6-10-6	Corn	15,127	15,943	816	5
6-10-6	Corn(R)[3]	15,127	14,122	−1,005	−7
		SPRING VEGETABLES FOLLOWING SUMMER COVER CROPS[5]			
0-10-6	Cowpea	1,654	2,945	1,291	78
3-10-6	Cowpea	5,291	6,355	1,064	20
6-10-6	Cowpea	7,891	8,658	767	10
6-10-6	Corn	7,891	8,809	918	12
6-10-6	Corn(R)[3]	7,891	8,225	334	4

[1] One ton limestone and 10 pounds of borax per acre were applied to all treatments at the beginning of the experiment. Minor elements were applied to all treatments once each 3 years, beginning with an application in 1945.

[2] Summer crops consisted of beans, lima beans, eggplant, pepper and tomatoes.

[3] The cover crop was cut and removed from area.

[4] Fall crops consisted of Chinese cabbage, collards, kohlrabi, mustard, onions, tendergreen and turnip.

[5] Spring crops consisted of beans, beets, cabbage, carrots, chard, lettuce, onions, potatoes, radish, and spinach.

to only 8,929 pounds. The winter legume, therefore, increased the average yield of summer vegetables about 2.5 times as much as 30 pounds of commercial nitrogen or about 1.6 times as much as 60 pounds of commercial nitrogen. The higher rate of commercial nitrogen for this group was not adequate to establish the maximum value of legumes expressed in pounds of commercial nitrogen. This is established in another phase on the same soil.

Turning under vetch on plots receiving no commercial nitrogen increased the average yield of summer vegetables 9,164 pounds per acre. On plots receiving 30 pounds of commercial nitrogen, the turning of vetch increased yields 7,405 pounds and on plots receiving 60 pounds of commercial nitrogen 6,457 pounds.

The average yield of all summer crops following vetch was 12,400 pounds per acre without the addition of any commercial

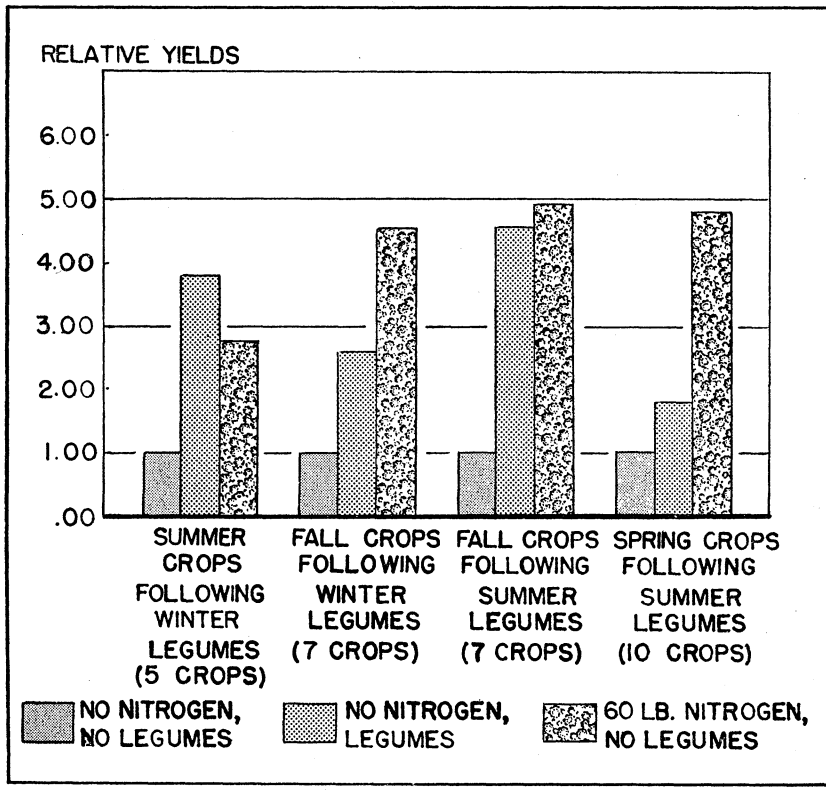

FIGURE 1. Comparative yields of vegetable crops from use of legumes and commercial nitrogen, Chesterfield soil of low fertility, Series B15-16.

nitrogen. The average yield of plots receiving vetch was increased from 12,400 pounds to 14,342 pounds per acre by the addition of 30 pounds per acre of commercial nitrogen and increased to 15,386 pounds by the addition of 60 pounds of commercial nitrogen. The average yields of summer vegetables on plots receiving 60 pounds of commercial nitrogen and a turned crop of nonlegume was only 1,051 pounds less than the yield on plots receiving 60 pounds of nitrogen and a legume.

Individual crops showed considerable differences in response to green-manure crops (Appendix Table 1). Increases resulting from vetch were 269 per cent for beans, 197 per cent for lima beans, 316 per cent for eggplants, 574 per cent for peppers, and 226 per cent for tomatoes. The yield increase of each of the individual crops following legumes was highly significant when used with no nitrogen, with 30 pounds, and with 60 pounds per acre of nitrogen. The increases in yield resulting from turning of the nonlegumes were also highly significant or significant in the case of all crops except lima beans.

Effects of Winter Green-Manure Crops on Yields of Fall Vegetables

Average yields for all years of seven fall vegetables following winter green-manure crops and receiving the several comparative treatments are given in Table 1. Yields of the individual crops are given in Appendix Table 2. The fall crops followed on the same plots as the summer crops just discussed.

Increases in yields of fall crops following vetch were considerably less than increases in yields of summer crops immediately following the turning of vetch; the effects on fall crops, however, were pronounced, and the general pattern of response somewhat similar. Thirty pounds of commercial nitrogen increased the average yield of fall vegetables approximately 35 per cent more than vetch, while 60 pounds of commercial nitrogen increased the yield 116 per cent more.

Increases in yield from the legume for most of the individual crops were generally significant or highly significant when used with each rate of nitrogen. The yield increases of Chinese cabbage, mustard, tendergreen, and turnip from use of the nonlegume were significant or highly significant, whereas increased yields of collards, kohlrabi, and onion were not significant (Appendix Table 2).

Effects of Summer Green-Manure Crops on Fall Vegetables

Fall vegetables and later spring vegetables in this phase of the study were grown on the same plots after summer cover crops were turned. The average results for all crops are given in Table 1, while those for individual crops are presented in Appendix Table 2.

On fall vegetables the effects of turning a summer legume were quite similar to those on summer vegetables following a turned winter legume crop. The average yield of the seven fall vegetables was increased from 3,075 pounds per acre to 13,931 pounds by turning a crop of cowpeas, while 30 pounds of commercial nitrogen increased the yield to 10,063 pounds and 60 pounds of commercial nitrogen to 15,127 pounds. The average yield was increased almost as much from the legume as from 60 pounds of commercial nitrogen per acre. Even though 30 and 60 pounds of nitrogen per acre were added, legumes still gave pronounced increases.

The data in Appendix Table 2 indicate some differences between the individual fall vegetables in their response to commercial nitrogen and turned cover crops; the pattern of response, however, of the several crops is very similar. Yield increases of crops following the legume in most instances were highly significant; in only one instance was yield increase from the nonlegume significant.

Effects of Summer Green-Manure Crops on Yields of Spring Vegetables

The average yield of the 10 spring vegetables following summer green-manure crops is given in Table 1, and the yield of each crop is given in Appendix Table 3.

Turning under a crop of cowpeas increased the average yield of spring vegetables from 1,654 pounds to 2,945 pounds, while the addition of 30 pounds of commercial nitrogen increased the yield to 5,291 pounds and the addition of 60 pounds of commercial nitrogen to 7,891 pounds. It is obvious, therefore, that the yield of spring crops was not increased very much by turning under cowpeas the previous summer followed by a fall vegetable crop. Evidently, the soil had been subjected to leaching winter rain. Thirty pounds of commercial nitrogen gave increases in yield almost three times as large as the legume. Turning the

legume gave an increase of only 20 per cent after 30 pounds of commercial nitrogen per acre had been added, while an increase of only 10 per cent resulted from the turned legume after 60 pounds of commercial nitrogen had been added. The turning of a nonlegume gave an increase of 12 per cent after addition of 60 pounds per acre of commercial nitrogen.

Differences in yield of individual spring crops resulting from a turned summer legume were generally not significant. In no instance was the yield of a spring crop as high from applications of organic material as from 30 pounds of commercial nitrogen.

Effects of Different Organic Materials on Vegetable Yields at Different Production-Intensity Levels on Chesterfield Soil of Low Fertility

The purposes of this phase of the study were to determine: (1) yields possible by progressively increasing fertilizer rates and organic materials singularly and in combinations, (2) relative value of different kinds of organic materials at three production-intensity levels, and (3) relative value of commercial fertilizers and different organic materials.

The soil was a Chesterfield of low fertility. The series consisted of B19-B21. Treatments at the low production-intensity level consisted of applying 1,000 pounds of fertilizer per acre (6-10-6 grade), 6 tons of stable manure, and cowpeas grown at this level and turned. Treatments at the medium-intensity level consisted of 1,500 pounds of fertilizer per acre, 12 tons of stable manure per acre, and cowpeas produced at this level. Corresponding treatments at the high-intensity level were 2,000 pounds of fertilizer per acre, 18 tons of stable manure per acre, and cowpeas grown at this level and turned. Corn as a nonlegume was also grown at each intensity level; on the check plot the corn was removed and on another plot it was turned.

Average yields of the seven spring crops and the six fall crops are given in Table 2; relative effects of selected treatments are shown graphically in Figure 2. Yields of the individual spring crops are given in Appendix Table 5 and those of the individual fall crops are presented in Appendix Table 6. Tonnages of cover crops turned by years are given in Appendix Table 7, and the approximate nitrogen content of each of the materials is given in Appendix Table 9.

The average yields of spring crops were increased from 4,161

pounds per acre to 12,706 pounds as the fertilizer rate was increased from 1,000 pounds per acre to 2,000 pounds per acre plus 18 tons of animal manure per acre. The average yields of fall crops were increased from 8,132 pounds to 26,816 pounds per acre as the fertilizer was increased from 1,000 to 2,000 pounds per acre, 18 tons of animal manure were added, and a crop of cowpeas was turned.

The average yields of the seven spring vegetables were increased from 4,161 to 5,458 to 5,584 pounds per acre as the fertilizer rate was increased from 1,000 to 1,500 to 2,000 pounds per acre, with no manures added or turned. The increases in yield of spring crops at the three intensity levels from turning cowpeas were 735 pounds per acre at the 1,000-pound fertilizer rate, 1,025 pounds at the 1,500-pound rate, and 950 pounds at

TABLE 2. AVERAGE YIELDS AND INCREASES IN YIELD OF SPRING AND FALL VEGETABLES FROM USE OF DIFFERENT KINDS OF MANURES AT DIFFERENT PRODUCTION-INTENSITY LEVELS, CHESTERFIELD SOIL OF LOW FERTILITY, SERIES B19-B21, 1940-47

Treatments[1]				Average yields per acre						Average yields of cover crops turned
Fertilizer, 6-10-6 per acre	Manures			Spring crops[3]			Fall crops[4]			
	Animal per acre	Green[2]		Total	Increases from use of manures		Total	Increases from use of manures		
		Cowpea	Corn							
Lb.	*Tons*			*Lb.*	*Lb.*	*Pct.*	*Lb.*	*Lb.*	*Pct.*	*Lb.*
1,000	0	--	R	4,161			8,132			
1,000	0	T	--	4,896	735	18	15,373	7,241	89	12,218
1,000	6	--	R	7,844	3,683	89	16,748	8,616	106	
1,000	6	T	--	8,390	4,229	102	24,523	16,391	202	22,705
1,000	6	--	T	8,161	4,000	96	19,428	11,296	139	15,316
1,500	0	--	R	5,458			10,186			
1,500	0	T	--	6,483	1,025	19	16,776	6,590	65	12,678
1,500	12	--	R	10,003	4,545	83	23,329	13,143	129	
1,500	12	T	--	11,280	5,822	107	26,089	15,903	156	24,735
1,500	12	--	T	11,270	5,812	106	24,926	14,740	145	23,226
2,000	0	--	R	5,584			10,336			
2,000	0	T	--	6,534	950	17	16,346	6,010	58	13,220
2,000	18	--	R	12,706	7,122	128	25,924	15,588	151	
2,000	18	T	--	12,144	6,560	117	26,816	16,480	159	27,458
2,000	18	--	T	12,033	6,449	115	24,827	14,491	140	29,495

[1] Minor elements were applied to all treatments once each 3 years beginning with an application in 1945.

[2] In treatment marked T, the green manures were turned; those marked R were removed.

[3] Spring crops consisted of beans, beets, cabbage, carrots, English peas, lettuce, and potatoes.

[4] Fall crops consisted of broccoli, Chinese cabbage, kohlrabi, mustard, onions, and turnips.

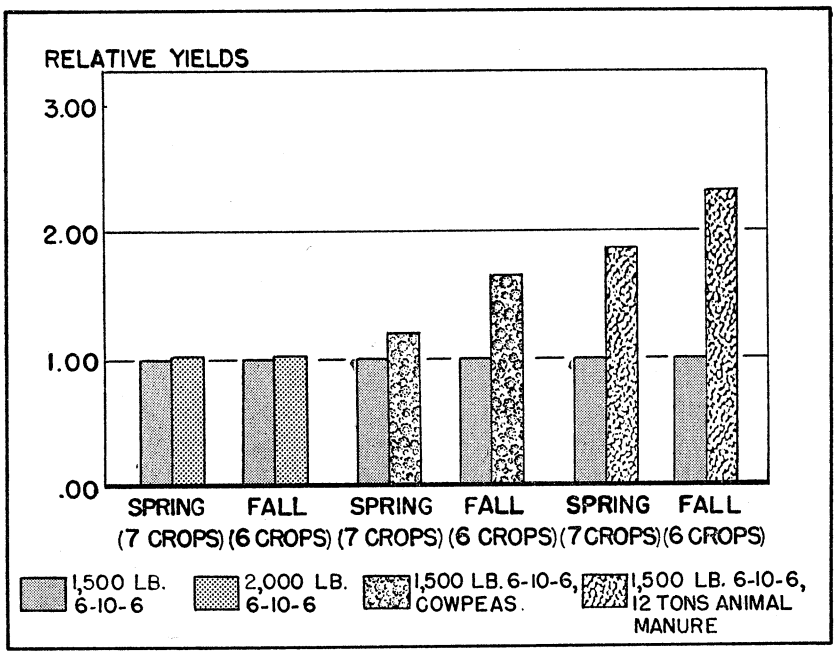

FIGURE 2. Comparative yields of vegetable crops from additional fertilizer and added manures, Chesterfield soil of low fertility, Series B19-B21.

2,000-pound rate. The corresponding average increases from the application of stable manure at the three intensity levels were 3,683, 4,545, and 7,122 pounds per acre. It should be kept in mind that different rates of stable manure were added at the three intensity levels and that the stable manure was added in late winter just prior to the spring crops, whereas the cowpeas represent the growth made at the three respective levels and turned during the preceding summer. Yield increases from animal manure averaged considerably higher on plots receiving the higher fertilizer rates. The increases, however, were not in proportion to the increases in amount of manure applied. Increasing the rate of animal manure three times with the corresponding increase in fertilizer rates increased crop yield 92 per cent.

The average yield of the six fall vegetables increased from 8,132 to 10,186 to 10,336 pounds per acre as the fertilizer rates were increased from 1,000 to 1,500 to 2,000 pounds per acre, with no manures added or turned. Cowpeas grown and turned just prior to planting the fall crops increased the average yield 7,241 pounds per acre at the 1,000-pound fertilizer rate, 6,590 pounds per acre

at the 1,500-pound rate, and 6,010 pounds per acre at the 2,000-pound rate. On the other hand, the animal manures applied in late winter followed by an intervening spring crop of vegetables increased the average yields of fall vegetables 8,616 pounds, 13,143, and 15,588 pounds per acre, respectively, after the three fertilizer rates had been applied. The yield increases from the animal manure applied in late winter were 19 per cent higher at the 1,000-pound fertilizer rate, 99 per cent higher at the 1,500-pound rate, and 159 per cent higher at the 2,000-pound rate than the cowpeas grown and turned immediately before the fall crops were planted.

It is pointed out that commercial nitrogen above 90 pounds per acre failed to give increases in yield of fall or spring crops, whereas the addition of cowpeas or animal manure on plots receiving 90 pounds of commercial nitrogen resulted in marked increases in yield.

Effects of Winter and Summer Legumes on Yields of Succeeding Crops of Vegetables on Norfolk Soil of Medium Fertility

The purpose of this phase of the study was to determine the value of a turned legume crop in providing nitrogen requirements of vegetable crops on a soil somewhat heavier than the Chesterfield of low fertility. The topsoil was an introduced Norfolk sandy loam of moderate fertility, which was placed on a subsoil of Cecil clay. Four index crops were used to measure the relative value of legumes and commercial nitrogen. The treatments consisted of five rates of nitrogen with and without a legume crop grown and turned. The nitrogen rates were 0, 20, 40, 60, and 80 pounds per acre of commercial nitrogen. The study comprised Series A4. In Table 3 are given the average total and marketable yields of each crop for the 5-year period.

Sweet corn and sweetpotato were used to measure the value of a winter legume on summer vegetables. Turnip was used to measure the value of a summer legume on a fall vegetable, while Irish potato was used to measure the value of a summer legume on a spring vegetable.

The total yield of sweet corn receiving a turned crop of vetch but no commercial nitrogen was 8,642 pounds per acre. This yield was nearly equal to that obtained from 60 pounds per acre of commercial nitrogen. The turned vetch increased the yield of

corn 6,963 pounds per acre where no commercial nitrogen was added, 6,051 pounds where 20 pounds of nitrogen was applied, 3,245 pounds where 40 pounds of nitrogen was added, 2,011 pounds where 60 pounds of nitrogen was applied, and 1,422 where 80 pounds was added. The increase from vetch on limed plots receiving 80 pounds of nitrogen was 3,386 pounds per acre.

Increases in yield of marketable corn resulting from a turned legume were 4,901, 5,438, 4,009, 1,809, and −258 pounds per acre when 0, 20, 40, 60, and 80 pounds per acre of nitrogen were added, respectively. On plots receiving lime and 80 pounds per acre of nitrogen, turned legumes resulted in an increase of 3,462 pounds per acre of marketable corn.

Total yield of sweetpotatoes receiving vetch but no commercial nitrogen was just below the yield on plots receiving 60 pounds per acre of commercial nitrogen; marketable yields on the vetch plots were about the same as those on plots receiving 40 pounds per acre of commercial nitrogen without the legume.

The total yield and the yield of marketable roots of fall turnips following a crop of turned cowpeas were somewhat below those of crops receiving 40 pounds of commercial nitrogen. The

TABLE 3. YIELDS OF SPRING, SUMMER, AND FALL VEGETABLES RECEIVING DIFFERENT RATES OF NITROGEN WITH AND WITHOUT TURNED LEGUMES, NORFOLK SOIL OF MEDIUM FERTILITY, SERIES A4, 1943-47

Fertilizer grades, 1,000 lb. per acre	Yields per acre of different vegetables							
	Corn, sweet (5-yr. av.)		Sweet potatoes (5-yr. av.)		Fall turnips (5-yr. av.)		Spring potatoes (5-yr. av.)	
	W'out winter legume	With winter legume	W'out winter legume	With winter legume	W'out summer legume	With summer legume	W'out summer legume	With summer legume
	Lb.	*Lb.*	*Bu.*	*Bu.*	*Lb.*	*Lb.*	*Bu.*	*Bu.*
	TOTAL YIELDS							
0-10-7	1,679	8,642	185	407	10,626	27,053	46	50
2-10-7	4,610	10,661	325	400	14,281	32,021	86	87
4-10-7	7,540	10,785	374	438	29,986	36,401	129	139
6-10-7	9,013	11,024	423	426	36,290	38,676	174	178
8-10-7	10,261	11,683	468	487	37,373	38,993	223	207
8-10-7[1]	12,025	15,411	486	490	39,362	41,904	194	206
	MARKETABLE YIELDS[2]							
0-10-7	747	5,648	118	253	6,266	14,609	12	19
2-10-7	2,095	7,533	224	253	8,201	16,211	37	40
4-10-7	3,589	7,598	246	292	16,436	18,122	62	72
6-10-7	5,893	7,702	278	259	19,400	18,519	95	100
8-10-7	7,216	6,958	308	322	19,760	18,426	123	123
8-10-7[1]	9,028	12,490	303	281	20,729	19,496	118	121

[1] Limestone was applied in 1943 at the rate of 1.5 tons per acre.
[2] Marketable yields for turnips represent the yield of roots.

total yield following cowpeas was 27,053 pounds per acre, whereas the yield following the addition of 40 pounds of commercial nitrogen was 29,986 pounds. Summer legumes resulted in only slight increases in yields of roots beyond the 40-pound rate of commercial nitrogen. On the other hand, the total yields of turnips continued upward through the 60- to 80-pound rates of commercial nitrogen.

The yields of spring potatoes were not appreciably affected by the turned crop of cowpeas the preceding summer. This was true for total yields and also for yields of marketable potatoes.

Comparative Effects of Different Kinds of Organic Materials on Yield of Vegetables

In Series B14 and A7, data are available on the comparative value of different forms of organic materials with other factors constant.

Results from Series B14. This study consisted of a comparison of crop yields from the use of animal manure, vetch, and rye. All treatments received 1,000 pounds per acre of a 6-10-4 fertilizer. The manure consisted of an annual application of 12 tons per acre; the rye and vetch turned were the amounts grown on the land. Minor elements were added to all treatments. The soil was a Chesterfield of medium fertility. Results are given in Table 4.

Animal manure increased yields of the individual crops considerably more than either vetch or rye. Rye gave yields as high as vetch. The yields of crops receiving animal manure and vetch were substantially the same as those receiving animal manure alone.

Results from Series A7. This study consisted of a comparison of crop yields from use of fixed quantities of introduced materials and from use of cowpeas and vetch grown as manure crops. The introduced materials consisted of 2 tons of dry sericea lespedeza per acre added in late winter and of 6 tons of green crotalaria per acre turned in summer. Early-planted spring crops were started where necessary before the vetch was turned by laying-off the rows, adding the fertilizer, and turning the vetch between rows at a later period. When sweetpotatoes were grown as a summer crop, 12,000 pounds of cowpeas per acre was introduced. All treatments received an application of 1,000 pounds

TABLE 4. AVERAGE YIELDS OF SPRING AND FALL VEGETABLES RECEIVING DIFFERENT KINDS OF MANURES, CHESTERFIELD SOIL OF MEDIUM FERTILITY, SERIES B14, 1940-48

Treatments[1]				Average yields per acre							
	Manures			Summer crops				Fall crops			
		Green[2]		Corn, sweet		Tomatoes		Beans, pole		Potatoes	
Fertilizer, 6-10-4 per acre	Animal	Kind	Average amount per acre	Total (4-yr. av.)	Increases in yield	Total (4-yr. av.)	Increases in yield	Total (4-yr. av.)	Increases in yield	Total (4-yr. av.)	Increases in yield
Pounds	*Tons*		*Pounds*	*Pounds*	*Pounds*	*Bushels*	*Bushels*	*Bushels*	*Bushels*	*Bushels*	*Bushels*
1,000	0	0	0	4,686		376		108		36	
1,000	12	0	0	9,059	4,373	709	333	195	87	50	14
1,000	0	Vetch	9,734	6,454	1,768	467	91	123	15	41	5
1,000	0	Rye	11,298	7,553	2,867	461	85	145	37	40	4
1,000	12	Vetch	14,334	9,212	4,526	697	321	147	39	49	13

[1] Minor elements were applied to all treatments once each year through 1945; thereafter applications were made each 3 years.
[2] Vetch and rye were grown on plots and turned; animal manure was applied in late winter.

TABLE 5. AVERAGE YIELDS AND INCREASES IN YIELDS OF SPRING AND EARLY SUMMER AND FALL VEGETABLES RECEIVING DIFFERENT KINDS OF MANURES, NORFOLK SOIL OF MEDIUM FERTILITY, SERIES A7, 1939-48

Treatments[1]			Yields and increases in yields per acre					
	Manures[2]		Spring and early summer crops[3]				Fall crops[4]	
Fertilizer, 6-10-4 per acre	Kind	Amount per acre	Marketable	Increases in marketable from manures	Total	Increases in total from manures	Total	Increases in total from manures
Lb.		*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*
1,000	0	0	6,976		9,306		9,501	
1,000	Standard	16,000	12,049	5,073	14,193	4,887	15,251	5,750
1,000	Vetch	9,934	10,462	3,486	13,071	3,765	12,041	2,540
1,000	Cowpeas	14,217	9,260	2,284	11,529	2,223	12,085	2,584

[1] Irrigation was used as a standard practice with all crops.
[2] Standard manure treatment consisted of the addition of 2 tons per acre of dry sericea lespedeza in late winter and 6 tons of green crotalaria in summer. Vetch and cowpeas were grown and turned.
[3] Spring and early summer crops consisted of beans, cabbage, potatoes, sweet corn, squash, and sweetpotatoes.
[4] Fall crops consisted of broccoli, lettuce, onion, tendergreen, and turnip.

per acre of 6-10-4 fertilizer and one-inch-per-week irrigation when rainfall failed to supply this quantity. The soil was a Norfolk sandy loam of medium fertility. Results are presented in Table 5.

The average yields of spring and early summer crops were increased 4,887 pounds per acre by the introduced lespedeza and crotalaria, 3,765 by the vetch in late winter, and 2,223 by the cowpeas turned late in the previous summer. Yield increases of fall crops from the crotalaria and sericea were 5,750 pounds per acre, from vetch, 2,540 pounds, and from cowpeas 2,584 pounds.

SPECIAL STUDIES DEALING WITH MANURES, COMMERCIAL FERTILIZERS, AND MINOR ELEMENTS

This study was conducted on a soil that had failed to make satisfactory yields when any amount of commercial fertilizers was used. The purpose was to determine the extent to which increasing the nitrogen and dividing the fertilizer application would overcome the difficulty as compared to additions of manures, lime, and minor elements.

The standard fertilizer rate in this experiment was 1,500 pounds per acre. Nitrogen supplied in the two fertilizer grades amounted to 90 and 180 pounds per acre. Fertilizers were applied as one application and as four applications. The organic materials consisted of 12 tons per acre of animal manure and of cowpeas grown

on the land. The minor-element mixture included copper, magnesium, manganese, zinc, iron, and boron. Treatments and results are given in Table 6.

Data show that yields of spring and fall crops on this soil receiving 90 and 180 pounds per acre of nitrogen whether applied in one or four applications were comparatively low without manures. The yields of spring and fall crops receiving four applications of a commercial fertilizer containing 180 pounds of nitrogen ranged from one-twentieth to one-half as great as yields of those receiving four applications of commercial fertilizer containing 90 pounds of nitrogen plus stable manure. Lime did not greatly affect yields, and only in the case of beets were yields appreciably affected by minor elements. Much greater differences occurred between treatments in the spring than in the fall. Satisfactory yields occurred in the spring only when animal manure was used with divided applications of the commercial fertilizer. In the fall, yields from crops receiving manure were practically the same irrespective of whether commercial fertilizer was applied in one or in four applications.

Effects of Mulching Materials on Crop Yields

The term "mulching materials," as used in this phase of study, is applied to materials added either to the surface of the soil or incorporated in the soil.

With exception of mulch paper, the mulching materials added large quantities or organic matter to the soil and considerable quantities of nitrogen in the case of certain types of materials (Appendix Table 9). To a considerable degree, mulching materials may affect the water-holding capacity and temperature of the soil as well as surface temperatures. The effects of the materials on crop yields only are discussed here.

Five materials were used as surface mulches. In establishing the surface mulch, 1.5 inches of each material except the paper mulch was added to the first crop; thereafter a 1.5-inch mulch was maintained by adding fresh material before planting the spring and the fall crops.

Five mulching materials or combinations were incorporated in the soil. The amounts of the incorporated materials are indicated in the tables.

In Table 7, the yields of two summer crops and two fall crops are given. Composition of the mulch was an important factor in

TABLE 6. YIELDS OF SPRING AND FALL VEGETABLES RECEIVING FERTILIZERS CONTAINING DIFFERENT AMOUNTS OF NITROGEN APPLIED IN SINGLE AND DIVIDED APPLICATIONS, MANURES, LIMESTONE, AND MINOR ELEMENTS, CHESTERFIELD SOIL OF LOW FERTILITY, SERIES B2, 1945-49

Treatments						Yields of vegetables per acre				
						Spring			Fall	
Fertilizer grades, 1,500 lb. per acre	Number applications of fertilizer[1]	Manures[2]		Limestone per acre[3]	Minor elements per acre[4]	Beets, Total	Carrots, Total	Mustard, Total	Tendergreen, total	Turnip, total
		Animal per acre	Green							
N-P-K	*No.*	*Tons*		*Tons*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*
						(5-yr. av.)	(5-yr. av.)	(5-yr. av.)	(6-yr. av.)	(6-yr. av.)
6-8-4	1	0	0	0	0	34	2,027	1,713	12,124	15,728
12-8-4	1	0	0	0	0	30	2,438	1,716	10,790	12,557
6-8-4	4	0	0	0	0	841	7,580	6,133	11,347	16,368
12-8-4	4	0	0	0	0	507	2,772	6,570	10,442	15,644
6-8-4	1	12	0	0	0	3,944	9,899	5,211	22,710	31,683
6-8-4	4	12	0	0	0	10,790	17,641	12,879	23,209	34,111
6-8-4	4	12	0	1	0	11,201	21,261	13,298	24,744	32,732
						(3-yr. av.)	(3-yr. av.)	(3-yr. av.)	(3-yr. av.)	(3-yr. av.)
6-8-4	4	12	0	1	0	12,288	23,450	10,867	29,747	29,312
6-8-4	4	0	Cowpeas	1	0	6,297	17,216	7,636	14,912	18,649
6-8-4	4	0	0	1	0	4,564	12,832	7,284	17,197	16,985
6-8-4	4	0	0	1	72.5	10,733	12,755	7,142	15,584	19,386

[1] When one application of fertilizer was made, all fertilizer was applied one week before planting; when four applications were made, one-fourth of fertilizer was applied before planting and the balance applied in three applications at 2-week intervals after crop was planted.

[2] Animal manure was applied in August of each year.

[3] One ton of limestone was applied at beginning of experiment.

[4] Minor element mixture was applied once each year.

TABLE 7. AVERAGE YIELDS AND INCREASES IN YIELD FROM USE OF DIFFERENT MULCHING MATERIALS, CHESTERFIELD SOIL OF MEDIUM FERTILITY, SERIES B23, 1940-49

Treatments[1]		Average yields and increases in yield per acre							
		Summer crops				Fall crops			
Mulching materials		Corn, sweet		Tomatoes		Beans, pole		Potatoes	
Kind	Amounts per acre[2]	(3-yr. av.) 1946-7, 1949 Total	Gains from mulch materials	(4-yr. av.) 1940-43 Total	Gains from mulch materials	(4-yr. av.) 1944, 1946-48 Total	Gains from mulch materials	(4-yr. av.) 1940-43 Total	Gains from mulch materials
		Lb.	*Lb.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*
None		4,725		406		107		22	
Mulch paper	1-inch layer surface	6,195	1,470	434	28	139	32	22	0
Sericea lespedeza straw	1.5-inch surface	8,413	3,688	682	276	235	128	68	46
Pine straw	1.5-inch surface	5,527	802	422	16	205	98	55	33
Oat straw	1.5-inch surface	8,319	3,594	451	45	292	185	52	30
Peanut hulls	1.5-inch surface	10,941	6,216	720	314	266	159	69	47
Peanut hulls	1.5-inch incorporated[2]	8,907	4,182	722	316	226	119	45	23
Peanut hulls	3.2 tons incorporated	6,577	1,852	535	129	161	54	40	18
Peanut hulls	4.8 tons incorporated	7,358	2,633	589	183	192	85	36	14
Sericea lespedeza straw	1.6 tons incorporated	8,069	3,344	506	100	172	65	31	9
Sericea lespedeza straw	3.2 tons incorporated	7,972	3,247	517	111	193	86	32	10
Sericea lespedeza straw	4.8 tons incorporated	9,370	4,645	617	211	207	100	36	14
Corn stalks—winter Green corn stalks—summer	3.2 tons incorporated 9.6 tons incorporated	6,451	1,726	501	95	164	57	39	17
Crotalaria—winter Green soybean stalks—summer	3.2 tons incorporated 9.6 tons incorporated	7,225	2,500	523	117	167	60	34	12
Alabama peat	6.4 tons incorporated	6,862	2,137	448	42	148	41	29	7
Alabama peat and lime[3]	6.4 tons incorporated	7,027	2,302	500	94	175	68	30	8

[1] All crops received 1,280 pounds 6-10-4 fertilizer per acre. Minor elements were applied to all treatments once each 3 years beginning in 1945.

[2] Mulching materials were applied to each of two crops per year. The surface mulches were applied to a depth of 1.5 inches the first year and thereafter enough material was applied to maintain the 1.5-inch-depth. The same amount of peanut hulls was applied to the treatment with the 1.5-inch incorporated as was applied to the surface mulch treatment. For 1.5-inch mulch, it required the first year 25, 21, 20, and 16 tons of lespedeza straw, pine straw, peanut hulls, and oat straw per acre, respectively; to maintain this amount as a mulch it required 8.0, 7.5, 6.5, and 7.5 tons per acre per crop, respectively.

[3] One ton of dolomitic limestone per acre was applied at the beginning of the experiment.

determining the effect on yields of the mulching material. Pine straw, a material low in nitrogen, gave relatively small increases in yields of summer crops, while oat straw gave intermediate increases. Lespedeza sericea straw and peanut hulls, both somewhat higher in nitrogen, resulted in large increases in yield of the summer crops.

Yield increases from the legume types of mulching materials were determined largely by the amounts of the materials applied. A surface mulch of lespedeza straw resulted in an average increase of 3,688 pounds per acre in yield of sweet corn and 276 bushels in the yield of tomatoes. Incorporation of 1.6, 3.2, and 4.6 tons per acre of lespedeza gave average yield increases of sweet corn of 3,344, 3,247, and 4,645 pounds per acre, and increases of 100, 111, and 211 bushels per acre of tomatoes, respectively. Yield increases of corn of 1,852, 2,633, 4,182, and 6,216 pounds per acre resulted from 3.2 tons of peanut hulls incorporated in the soil, 4.8 tons incorporated, equivalent of 1.5 inches incorporated, and 1.5 inches as a surface mulch. Increases in yield of tomatoes were similar to those of corn for corresponding treatments.

Increases in yield of fall crops from increased amounts of peanut hulls and lespedeza straw were very similar to those of summer crops. Pine straw and oat straw mulches, however, gave relatively larger yield increases in the fall than in the summer.

Paper mulch and Alabama peat gave only moderate increases in yields.

Effects of Organic Materials on Grade of Vegetables

Data presented thus far have dealt primarily with total yields. The yield of marketable products and percentage relation to total yields are of great importance to the vegetable grower. Records by grades were obtained in all series on crops normally graded. Data on the yield of marketable products and on the percentage of marketable grades are given for several series.

In Table 8 and Table 9 are the results from Series B14 and Series B19-B21, respectively. Additional data on marketable yields from Series A4 and from Series A7 are given in Table 3 and Table 5.

In general, the data show large increases in yield of marketable grades from organic materials where large increases have been obtained in total yields. The increases in the percentage of marketable grades are not generally as pronounced as the actual in-

TABLE 8. YIELDS AND PERCENTAGE MARKETABLE GRADES OF VEGETABLES RECEIVING DIFFERENT MANURE TREATMENTS, CHESTERFIELD SOIL OF MEDIUM FERTILITY, SERIES B14, 1940-48

Treatments[1]			Yields and percentage yields of marketable grades per acre					
	Manures		Corn, sweet, summer (4-yr. av.)		Tomatoes, summer (4-yr. av.)		Potatoes, fall (4-yr. av.)	
Fertilizer, 6-10-6 per acre	Animal per acre	Green[2]	Total marketable	Per cent marketable	Total marketable	Per cent marketable	Total marketable	Per cent marketable
Pounds	*Tons*		*Pounds*	*Per cent*	*Bushels*	*Per cent*	*Bushels*	*Per cent*
1,000	0	0	2,420	54	246	67	27	73
1,000	0	Vetch	3,874	60	322	69	30	73
1,000	0	Rye	5,022	66	307	67	28	70
1,000	12	0	6,291	69	507	72	40	80
1,000	12	Vetch	6,946	75	485	70	39	80

[1] Minor elements were applied to all treatments once each year through 1945 and thereafter applications were made once each 3 years.
[2] Green manure crops were grown and turned.

creases in yield; however, they are consistent. A few instances are cited.

In Series B14 (Table 8), the yield of marketable corn was increasd from 2,420 pounds to 6,946 pounds per acre as a result of adding animal manure and vetch, while the percentage of marketable grades was increased from 54 to 75 per cent. The yield of marketable tomatoes was increased from 246 to 507 bushels per acre as a result of adding animal manure; the percentage of marketable grades, however, increased only from 67 to 72 per cent. Yield of marketable grades of fall potatoes were not affected as much as the other two crops.

In Series B19-B21, the yield of marketable spring cabbage on plots receiving 1,000 pounds per acre of a 6-10-6 fertilizer, was increased from 4,294 pounds per acre to 7,413 pounds from cowpeas turned the previous summer, while the percentage of marketable cabbage was increased from 37 to 49 per cent (Table 9). Six tons of animal manure increased the yield of marketable heads from 4,294 to 10,307 pounds per acre and the percentage of marketable heads from 37 to 53 per cent.

RESIDUAL EFFECTS OF REPEATED APPLICATIONS OF ORGANIC MATERIALS ON VEGETABLE YIELDS

In addition to information on the effects immediately following the addition of organic materials, it is important to know what effects may be expected in later years. In a number of series,

TABLE 9. YIELDS AND PERCENTAGE OF MARKETABLE GRADES OF VEGETABLES RECEIVING DIFFERENT MANURES, AT DIFFERENT PRODUCTION-INTENSITY LEVELS, CHESTERFIELD SOIL OF LOW FERTILITY, SERIES B19-B21, 1940-47

Treatments[1]				Yields and percentage yields of marketable grades per acre											
Fertilizer, 6-10-6 per acre	Manures			Beets, spring (3-yr. av.)		Cabbage, spring (4-yr. av.)		Carrots, spring (4-yr. av.)		Kohlrabi, fall (3-yr. av.)		Lettuce, spring (3-yr. av.)		Potatoes, spring (5-yr. av.)	
	Animal per acre	Green[2]		Total marketable	Per cent marketable	Heads marketable	Per cent marketable	Total marketable	Per cent marketable	Total marketable	Per cent marketable	Total marketable	Per cent marketable	Total marketable	Per cent marketable
		Cowpea	Corn												
Lb.	*Tons*			*Lb.*	*Pct.*	*Lb.*	*Pct.*	*Lb.*	*Pct.*	*Lb.*	*Pct.*	*Lb.*	*Pct.*	*Bu.*	*Pct.*
1,000	0	--	R	282	34	4,294	37	2,538	58	1,344	40	1,920	35	38	58
1,000	0	T	--	679	45	7,413	49	2,403	60	2,572	64	2,172	35	42	58
1,000	6	--	R	2,317	69	10,307	53	5,652	79	3,609	71	5,581	35	56	62
1,000	6	T	--	3,200	76	9,262	51	6,711	76	4,510	68	5,291	31	77	67
1,000	6	--	T	2,833	74	9,577	52	6,749	82	4,681	66	5,499	32	69	68
1,500	0	--	R	491	47	6,321	41	2,432	60	2,205	58	2,569	28	57	65
1,500	0	T	--	1,591	70	10,125	51	4,266	75	2,205	60	2,415	25	52	64
1,500	12	--	R	4,677	84	11,663	55	8,660	85	4,364	74	6,136	29	94	70
1,500	12	T	--	4,885	88	15,914	61	9,639	85	4,211	65	9,361	37	85	67
1,500	12	--	T	4,783	85	14,045	56	9,962	86	4,633	73	8,632	35	100	72
2,000	0	--	R	781	60	6,374	41	3,328	67	1,855	51	2,266	24	56	68
2,000	0	T	--	1,242	66	11,232	56	3,676	68	2,087	59	2,871	28	57	68
2,000	18	--	R	6,119	89	16,352	59	11,124	87	4,889	73	10,044	38	133	73
2,000	18	T	--	6,071	92	15,247	58	10,714	88	4,129	75	10,398	38	114	73
2,000	18	--	T	5,674	89	16,010	60	9,969	90	5,051	75	10,756	39	109	72

[1] Minor elements were applied to all treatments once each 3 years beginning with an application in 1945.
[2] In treatments marked T, the green manures were grown and turned; those marked R were removed.

studies were continued for 3 years after applications of organic materials were discontinued. Results obtained in Series B19-B21 are presented.

In Table 10, are given the average and relative yields of four fall vegetable crops produced over a 9-year period when organic materials were added, and the yields of the same crops after the organic applications were discontinued. The same information is given for spring crops in Table 11. Treatments are indicated in the tables. Results are graphically presented in Figures 3 and 4. The animal manures were added in late winter before spring vegetables were planted; the cowpeas and corn were turned in late summer before fall vegetables were planted. The study was made at each of three production-intensity levels. The last application of the organic materials was made in 1947, when yields for that year were below average.

During the period when manures were being added, turning under cowpeas increased average yields of fall vegetables 76

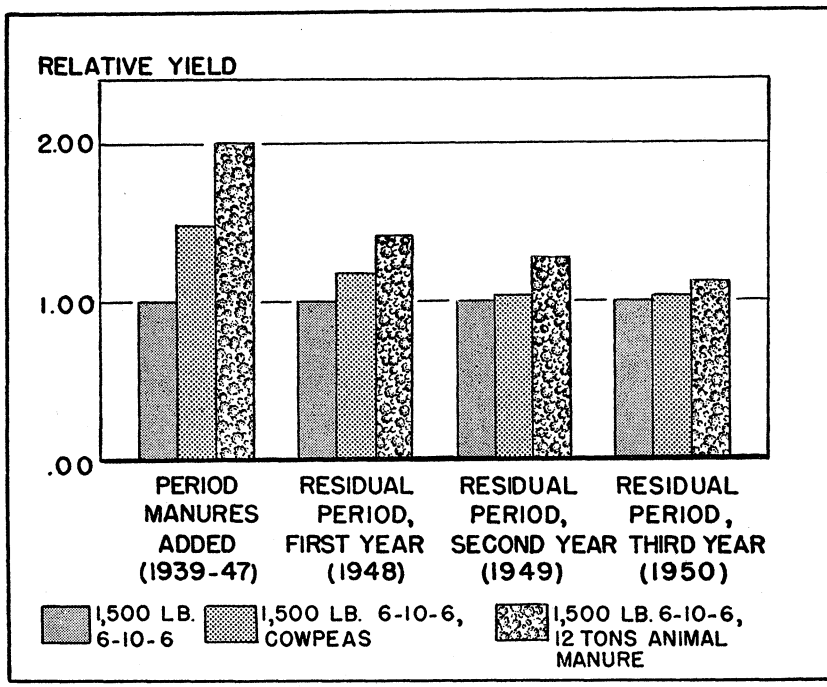

FIGURE 3. Residual effects of manures on average yields of four fall vegetables, Chesterfield soil of low fertility, Seris B19-B21.

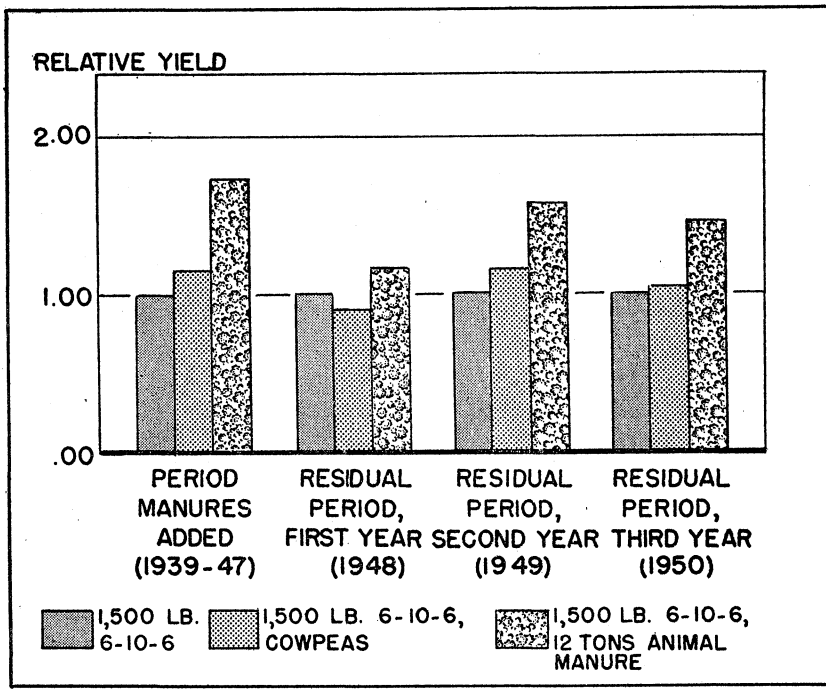

FIGURE 4. Residual effects of manures on average yields of four spring vegetables, Chesterfield soil of low fertility, Series B19-B21.

per cent at the low-intensity level, 48 per cent at the medium-intensity level, and 53 per cent at the high-intensity level. At the low-intensity level one year after the last application of organic materials, the yields of plots on which cowpeas were turned averaged 30 per cent higher than those of plots without cowpeas, and averaged 19 per cent higher after 2 years. At the medium-intensity level, yields on plots one year after the last crop of cowpeas was turned were 18 per cent, and after 2 years 4 per cent above the check plots. At the high-intensity level, the yields were 20 per cent the first year and 27 per cent the second year above the check plots. By the third year, practically all differences had disappeared at each level.

Yields of fall vegetables on plots receiving animal manures during the treatment period averaged 92 per cent above the check plots at the low-intensity level, 101 per cent at the medium-intensity level, and 119 at the high-intensity level. One and 2 years after the last manure application, yields were 31 and 26

TABLE 10. RESIDUAL EFFECTS OF MANURES ON THE YIELDS OF FALL VEGETABLES, CHESTERFIELD SOIL OF LOW FERTILITY, SERIES B19-B21, 1939-50

Treatments[1]				Average yields per acre[4]					Relative yields				
Fertilizer, 6-10-6 per acre	Manures			First period, manures added[3]		Residual period, no manures added			First period, manures added[3]		Residual period, no manures added		
	Animal per acre	Green[2]											
		Cow-pea	Corn	1939-47	1947	1948	1949	1950	1939-47	1947	1948	1949	1950
Lb.	*Tons*			*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
0	0	--	R	458	0	349	986	90					
1,000	0	--	R	8,742	5,469	10,089	8,727	10,076	100	100	100	100	100
1,000	0	T	--	15,354	9,430	13,155	10,425	10,515	176	172	130	119	104
1,000	6	--	R	16,815	10,007	13,181	10,954	10,994	192	183	131	126	109
1,000	6	T	--	22,798	13,197	17,574	13,226	12,486	261	241	174	152	124
1,000	6	--	T	18,884	12,288	14,890	11,030	11,347	216	225	148	126	113
1,500	0	--	R	11,124	8,090	14,659	11,673	12,793	100	100	100	100	100
1,500	0	T	--	16,508	9,549	17,306	12,096	12,937	148	118	118	104	101
1,500	12	--	R	22,321	12,678	20,739	14,921	14,307	201	157	141	128	112
1,500	12	T	--	23,936	17,053	22,199	15,159	14,435	214	211	151	130	113
1,500	12	--	T	24,274	16,042	20,605	14,598	14,486	218	198	141	125	113
2,000	0	--	R	10,555	6,499	15,709	11,354	13,430	100	100	100	100	100
2,000	0	T	--	16,187	8,269	18,870	14,474	13,574	153	127	120	127	101
2,000	18	--	R	23,156	14,983	23,751	16,576	14,534	219	231	151	146	108
2,000	18	T	--	23,472	16,659	24,083	17,571	16,246	222	256	153	155	121
2,000	18	--	T	23,139	15,744	21,645	15,319	13,804	219	242	138	135	103

[1] Minor elements were applied to all treatments once each 3 years beginning with an application in 1945.
[2] In treatments marked T, the green manures were turned; those marked R were removed.
[3] The last year green manures were turned was 1947.
[4] Fall crops consisted of collard, kohlrabi, mustard, and turnip.

TABLE 11. RESIDUAL EFFECTS OF MANURES ON THE YIELDS OF SPRING VEGETABLES, CHESTERFIELD SOIL OF LOW FERTILITY, SERIES B19-B21, 1940-50

Treatments[1]				Average yields per acre[4]					Relative yields				
Fertilizer, 6-10-6 per acre	Manures			First period, manures added[3]		Residual period, no manures added			First period, manures added[3]		Residual period, no manures added		
	Animal per acre	Green[2]											
		Cow-pea	Corn	1940-47	1947	1948	1949	1950	1940-47	1947	1948	1949	1950
Lb.	*Tons*			*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
0	0	--	R	1,713	4,090	1,743	892	742					
1,000	0	--	R	6,628	8,180	9,886	7,780	10,591	100	100	100	100	100
1,000	0	T	--	7,312	9,193	10,578	7,646	11,001	110	112	107	98	104
1,000	6	--	R	11,427	14,763	13,730	8,526	13,060	172	180	139	110	123
1,000	6	T	--	12,112	14,305	14,064	10,326	12,797	183	175	142	133	121
1,000	6	--	T	11,774	14,244	12,640	10,807	13,948	178	174	128	139	132
1,500	0	--	R	8,234	9,996	14,189	9,897	12,874	100	100	100	100	100
1,500	0	T	--	9,672	13,699	12,995	11,582	13,628	117	137	92	117	106
1,500	12	--	R	14,258	16,128	16,438	15,718	18,745	173	161	116	159	146
1,500	12	T	--	16,482	20,897	14,850	13,541	17,732	200	209	105	137	138
1,500	12	--	T	16,393	21,774	15,945	16,117	18,364	199	218	112	163	143
2,000	0	--	R	8,446	12,081	15,643	9,293	13,510	100	100	100	100	100
2,000	0	T	--	9,855	12,025	14,021	10,140	13,482	117	100	90	109	100
2,000	18	--	R	18,495	22,232	17,089	14,290	21,599	219	184	109	154	160
2,000	18	T	--	17,622	19,681	16,735	14,785	20,117	209	163	107	159	149
2,000	18	--	T	17,463	20,128	15,566	17,427	20,822	207	167	100	188	154

[1] Minor elements were applied to all treatments once each 3 years beginning with an application in 1945.
[2] In treatments marked T, the green manures were turned; those marked R were removed.
[3] The last year in which green manures were turned was 1947.
[4] Spring crops consisted of cabbage, carrots, lettuce, and potatoes.

per cent higher at the low-intensity level, 41 and 28 per cent higher at the medium-intensity level, and 51 and 46 per cent higher at the high-intensity level than the checks. By the third year the differences were about 10 per cent.

Residual effects of animal manures in combination with cowpeas or corn were not very different from those of animal manure alone.

Residual effects of cowpeas on spring crops were quite different from those on fall crops (Table 11). During the period when organic materials were being applied, yields of all spring vegetables following turned crops of cowpeas averaged only 10 per cent higher than the average check plot yields at the low-intensity level and 17 per cent higher at the medium- and high-intensity levels. While fluctuating somewhat, yields of spring crops during the residual period indicated very little residual effect from turning under cowpeas. Three years after organic materials were discontinued, plots that had animal manure applications averaged 23, 46, and 60 per cent higher yields than the check plots at the three intensity levels.

It is pointed out that the yield of fall crops at the high-intensity level was 27 per cent above that of the check plots 2 years after the last application of cowpeas, whereas the yield of spring crops during the period when the cowpeas were being turned was only 17 per cent above that of the check plots at the same intensity level.

Effect of Added Organic Materials on Soil Organic Matter Content

As previously stated, it is difficult under southern conditions to increase the organic matter content of a soil by addition of organic materials. In a number of series, annual determinations were made of organic matter in the soil. In other series, these determinations were made at less frequent intervals.

Results of Studies in Series B19-B21

In Table 12 are given the data on organic matter content of the soil for the different organic treatments in Series B19-B21.

The organic matter content of the soil in the series was quite low; however, some of the treatments applied repeatedly over a period of years gave highly significant increases in the amounts of organic matter content.

TABLE 12. ORGANIC MATTER CONTENT OF SOIL RECEIVING DIFFERENT KINDS OF MANURES OVER A PERIOD OF YEARS AT DIFFERENT PRODUCTION-INTENSITY LEVELS, CHESTERFIELD SOIL OF LOW FERTILITY, SERIES B19-B21, 1940-46

Treatments				Organic matter content of soil		
Fertilizer, 6-10-6 per acre[1]	Manures			1940	1945	Average all years (1940-46)
	Animal	Green[2]				
		Cowpea	Corn			
Pounds	*Tons*			*Per cent*	*Per cent*	*Per cent*
0	0	--	R	0.52	0.62	0.64
1,000	0	--	R	.57	.62	.66
1,500	0	--	R	.60	.64	.66
2,000	0	--	R	.59	.64	.66
1,000	0	T	--	.62	.72	.71
1,500	0	T	--	.71	.71	.74
2,000	0	T	--	.62	.74	.72
1,000	6	--	R	.67	.93	.90
1,000	6	--	T	.67	1.00	.93
1,000	6	T	--	.74	1.07	.93
1,500	12	--	R	.69	1.16	1.02
1,500	12	--	T	.79	1.29	1.07
1,500	12	T	--	.72	1.41	1.14
2,000	18	--	R	.81	1.53	1.17
2,000	18	--	T	.79	1.45	1.26
2,000	18	T	--	.74	1.74	1.28
Least significant difference at			.05 level	.12	.14	.07
			.01 level	.16	.19	.09

[1] Fertilizer was applied to each of two crops year year; manures were applied once each year.

[2] In treatments marked T, green manures were turned; those marked R were removed.

Increases in the organic matter content was closely related to the amount and kind of organic materials added. Animal manures affected the organic matter content considerably more than green manures. The average organic matter content at the end of 6 years was 0.62 per cent for treatments receiving 1,000 pounds of fertilizer but no organic materials.

On plots on which no cover crop was turned under, the organic content of the soil in plots receiving annually different amounts of animal manure were as follows: 6 tons of manure per acre, 0.93 per cent; 12 tons, 1.16 per cent; and 18 tons, 1.53 per cent. These amounts represent increases in actual percentages of organic matter of 0.31, 0.54, and 0.91 for the three rates, respectively[1]. A difference of 0.14 per cent was sufficient for sta-

[1] Represent increases in the percentage of organic matter content and not percentage increases.

tistical significance at the .05 degree level and of 0.19 per cent at the .01 degree level.

The average increases in actual percentage of soil organic matter content at the three production-intensity levels for the 6th year range from 0.07 to 0.10 on plots receiving a crop of cowpeas when used without animal manure. When cowpeas were used in combination with 6 tons of animal manure per acre, the increase in percentage attributable to the legume was 0.14. However, when cowpeas were used with 12 tons of animal manure, the increase in percentage of organic matter content attributable to the legume was 0.25; and when used with 18 tons of animal manure the credit to the legume was 0.21. The last two differences, while quite low, were highly significant statistically.

Results of Studies in Series B14

Data on organic matter content of soil receiving different organic materials and treatments are given in Table 13 for series B14. Treatments are given in the table.

The organic matter content of the soil in plots receiving no organic materials was 0.74 per cent at the end of 7 years. The amounts of soil organic matter of plots receiving the different organic materials were as follows: vetch, 1.03 per cent; rye, 1.10 per cent; 12 tons manure, 1.38; and 12 tons manure plus vetch, 1.52 per cent. A difference of 0.28 in percentage content

TABLE 13. ORGANIC MATTER CONTENT OF SOIL RECEIVING DIFFERENT KINDS OF MANURES OVER A PERIOD OF YEARS, CHESTERFIELD SOIL OF MEDIUM FERTILITY, SERIES B14, 1940-46

Treatments				Organic matter content of soil		
	Manures[1]					
Fertilizer, 6-10-4 per acre	Animal	Green		1940	1946	Average of 5 years (1940-42, 1945-46)
		Kind	Average amount per acre			
Pounds	*Tons*		*Pounds*	*Per cent*	*Per cent*	*Per cent*
1,000	0	0	0	0.66	0.74	0.76
1,000	12	0	0	.79	1.38	1.09
1,000	0	Vetch	9,734	.74	1.03	.93
1,000	0	Rye	11,298	.76	1.10	.90
1,000	12	Vetch	14,334	.81	1.52	1.21
Least significant difference at			.05 level	.12	.28	.09
			.01 level	.17	.40	.12

[1] Vetch and rye were grown and turned; animal manure was applied in late winter.

TABLE 14. ORGANIC MATTER AND TOTAL NITROGEN CONTENT OF SOIL RECEIVING DIFFERENT KINDS OF MANURES OVER A PERIOD OF YEARS, NORFOLK SOIL OF MEDIUM FERTILITY, SERIES A7, 1938-45

Treatments[1]			Organic matter and total nitrogen content of soil			
Fertilizer, 6-10-4 per acre	Manures[2]		Organic matter content			Total nitrogen 1945
	Kind	Average amounts per acre	1940	1945	(1940-45)	
Pounds		*Pounds*	*Per cent*	*Per cent*	*Per cent*	*p. p. m.*
1,000	None	0	1.07	1.07	1.07	293
1,000	Standard[2]	16,000	1.82	1.67	1.69	472
1,000	Vetch	9,934	1.43	1.33	1.36	403
1,000	Cowpeas	14,217	1.12	1.12	1.12	338
Least significant difference at		.05 level	.34	.10	.09	40
		.01 level	.46	.16	.12	53

[1] Irrigation was used as a standard practice with all crops.
[2] Standard manure treatment consisted of the addition of 2 tons per acre of dry sericea lespedeza in late winter and 6 tons of green crotalaria in summer. Vetch and cowpeas were grown and turned.

was significant. The average amount turned annually was 9,734 pounds of vetch and 11,298 pounds of rye per acre. The amount of vetch turned on plots also receiving animal manure was 14,334 pounds per acre.

Results of Studies in Series A7

Data on the organic content of the soil in Series A7 and the treatments are given in Table 14. The addition of 2 tons of dried lespedeza sericea and 6 tons of green crotalaria per year by the end of 8 years had increased the organic matter content of the soil from 1.07 per cent to 1.67 per cent. Turning annually an average of 9,934 pounds of vetch per acre had resulted in an increase in the soil organic matter content from 1.07 to 1.33 per cent. An average of 14,217 pounds of cowpeas per acre turned under had increased the percentage from 1.07 to 1.12. Increases from vetch and the standard treatment were highly significant.

Results of Studies in Series B23

Data on organic matter content of the soil receiving different mulching materials and the different treatments are given in Table 15.

The mulching materials on the surface were not included in the sample. On treatments receiving a surface mulch, there

TABLE 15. ORGANIC MATTER AND TOTAL NITROGEN CONTENT OF SOILS RECEIVING DIFFERENT MULCHING MATERIALS, CHESTERFIELD SOIL OF MEDIUM FERTILITY, SERIES B23, 1940-49

Treatments[1]		Organic matter and total nitrogen content of soil					
Mulching materials		Organic matter					Total nitrogen
Kind	Amount per acre[2]	1940	1942	1945	1948	(4-yr. av.)	1949
		Pct.	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*p.p.m.*
None		0.66	0.76	0.76	0.62	0.71	317
Mulch paper	1-inch layer surface	.64	.72	.69	.62	.67	307
Sericea lespedeza straw	1.5-inch surface	.71	1.45	2.38	1.52	1.52	847
Pine Straw	1.5-inch surface	.64	.98	1.43	1.72	1.19	594
Oat Straw	1.5-inch surface	.69	1.00	1.41	1.86	1.24	782
Peanut Hulls	1.5-inch surface	.67	.97	1.33	2.00	1.24	693
Peanut hulls	1.5-inch incorporated[2]	.86	1.88	1.93	1.98	1.67	1040
Peanut hulls	3.2 tons incorporated	.72	1.19	1.14	1.17	1.05	540
Peanut hulls	4.8 tons incorporated	.71	1.45	1.28	1.45	1.22	619
Sericea lespedeza straw	1.6 tons incorporated	.67	1.09	1.07	1.10	.98	579
Sericea lespedeza straw	3.2 tons incorporated	.69	1.03	1.38	1.59	1.17	629
Sericea lespedeza straw	4.8 tons incorporated	.71	1.22	1.80	2.05	1.45	787
Corn stalks—winter Green corn stalks—summer	3.2 tons incorporated 9.6 tons incorporated	.66	1.07	1.02	1.24	1.00	451
Crotalaria—winter Green soybean stalks—summer	3.2 tons incorporated 9.6 tons incorporated	.59	.98	1.00	1.31	.97	481
Alabama peat	6.4 tons incorporated	.59	1.48	2.26	3.40	1.93	1074
Alabama peat and lime[3]	6.4 tons incorporated	.67	1.48	2.52	3.40	2.02	1094
Least significant	.05 level	.16	.33	.28	.64	.21	144
difference at	.01 level	.22	.45	.38	.88	.29	200

[1] All crops received 1,280 pounds of 6-10-4 fertilizer per acre.

[2] Mulching materials were applied to each of two crops per year. The surface mulches were applied to a depth of 1.5 inches the first year and thereafter enough material was applied to maintain the 1.5-inch-depth. The same amount of peanut hulls was applied to the treatment with the 1.5-inch incorporated as was applied to the surface mulch treatment. For 1.5-inch mulch it required the first year 25, 21, 20, and 16 tons of lespedeza straw, pine straw, peanut hulls, and oat straw per acre, respectively; to maintain this amount as a mulch it required each year 8.0, 7.5, 6.5, and 7.5 tons per acre per crop, respectively.

[3] One ton of dolomitic limestone per acre was applied at the beginning of the experiment.

was considerable incorporation of the materials into the soil, although the materials were raked to the centers between rows at the time land was prepared, fertilized, and planted.

At the end of 9 years, the organic matter content of the soil in plots receiving no mulching materials was 0.62 per cent. For the same year, the organic content of the soil receiving the surface mulch of sericea was 1.52 per cent, of pine straw 1.72 per cent, of oat straw 1.86 per cent, and of peanut hulls 2.00 per cent. Soils receiving 3.2 tons per acre of incorporated peanut hulls by the 9th year had an organic matter content of 1.17 per cent; those receiving 4.8 tons of peanut hulls, a content of 1.45 per cent; and those receiving the same amount as the 1.5-inch surface mulch but incorporated in the soil, a content of 1.98 per cent. Soils that had received 1.6 tons, 3.2 tons, and 4.8 tons per acre annually of sericea lespedeza incorporated into the soil showed an organic matter content of 1.10, 1.59, and 2.05 per cent, respectively. The organic matter content of soils receiving 6.4 tons per acre annually of Alabama peat was 3.40 per cent. These differences were highly significant.

Effects of Added Organic Materials on the Total Nitrogen Content of the Soil

The close relationship between soil organic matter and the more stable forms of nitrogen has been pointed out. The amount of total soil nitrogen was determined at occasional intervals in most but not all of the series. Samples for total nitrogen were taken in late fall. In all instances at least one vegetable crop was grown between the turning or application of organic materials and taking of samples. Since the samples, however, were taken before heavy winter rains, there were often considerable quantities of inorganic nitrogen included in the total nitrogen determinations.

Results of Studies in Series A7

The amounts of total nitrogen in the soil for Series A7 are given in Table 14. Treatments are indicated in the table.

The total nitrogen content of the soil in plots receiving no organic materials was 293 p.p.m. at the end of 8 years; it was 338 p.p.m. in soils on plots receiving cowpeas, 403 p.p.m. in soils on plots receiving vetch, and 472 p.p.m. in soils on plots in which sericea and crotalaria were introduced. These differ-

ences were highly significant for the vetch and the standard treatment, and significant for cowpeas.

Results of Studies in Series B23

Data on soil nitrogen in Series B23 are given in Table 15. The data show a range of soil nitrogen content from 307 p.p.m. to 1,074 p.p.m. The amount of nitrogen in the soil reflected rather closely the amount and nitrogen content of the mulching materials added. It must be kept in mind that each treatment received the equivalent of 76.8 pounds per acre of commercial nitrogen twice annually and that the bacteria decomposing the materials will make use of the nitrate nitrogen added if the nitrogen in the materials is low.

The soil receiving surface mulches of pine straw, peanut hulls, oat straw, and lespedeza sericea straw in the order named had nitrogen content of 594, 693, 782, and 847 p.p.m. On plots where peanut hulls equivalent to the 1.5-inch surface mulch were incorporated, the soil contained 1,040 p.p.m. of nitrogen.

The nitrogen content of the soil receiving 1.6, 3.2, and 4.8 tons per acre per year of dry lespedeza sericea in the order named was 579, 629, and 787 p.p.m. The application of 6.4 tons per acre annually for 8 years of Alabama peat gave a soil with 1,074 p.p.m. of nitrogen.

Increases were generally highly significant except for the green materials in combinations.

Effects of Added Organic Materials on Soil Nitrates During the Growing Season

Organic materials added to the soil may make nitrates available to crops in at least two important ways. Materials high in nitrogen upon decomposition may release nitrates within a short time after the materials have been applied; or the nitrogen in the more permanent forms of organic matter in the soil built up from repeated addition of organic materials may slowly decompose, releasing a part of the nitrogen existing as a component part of the organic complex. It must be realized that soil nitrates fluctuate greatly and often within a short period of time. This is because they are absorbed by crops, leached by heavy rains, and subject to conversion to organic forms through the cycles of microbial activity. The amount of nitrates in the soil, however, is a general index of the amount and composition of organic matter and activity of micro-organisms in the soil.

In a number of series, periodical nitrate determinations were made during the growing season of the crops under study. A few selected data are presented.

Results of Studies in Series B14

In Table 16 are given the average nitrate contents of the soil in Series B14 for each of the four periods at which determinations were made during 1944 and 1946-48. Also, there are given the average nitrate contents of the soil for the four periods for each of the 4 years. The crop grown was sweet corn, which is a very heavy feeder of nitrogen. Commercial nitrogen at rates of 0, 60, 90, and 120 pounds per acre were added. Differences in nitrates in plots receiving and not receiving organic treatments at the same fertilizer rate provide a basis for measuring the effects of added organic materials. The total amounts of nitrogen were divided; in 1944 and 1946 two applications were made, while in 1947 and 1948 the nitrogen was applied in three applications.

The data indicate wide variations in nitrate content between years, between periods during the growing seasons, and between treatments. Differences between treatments by years are generally significant or highly significant.

Soil nitrates were relatively high during the first three periods of growth. As the crop began to use large amounts of nitrates, they were greatly reduced. During the last period of growth, they were very low in the case of certain treatments.

When no commercial nitrogen or organic nitrogen was added, the average nitrate content for the four periods for the 4 years was 8 p.p.m.; the average content where 60 pounds of commercial nitrogen per acre was added was 23 p.p.m. in one set of duplicated plots and 22 p.p.m. in another. On plots receiving 60 pounds per acre of commercial nitrogen, 12 tons of animal manure increased the average nitrate content to 41 p.p.m., a crop of vetch increased the content to 38 p.p.m., and a crop of rye raised the average to 33 p.p.m. The average nitrate content of the soil in the four periods was 76 p.p.m. in plots receiving 12 tons of animal manure and vetch. At the second period the average nitrate content for the 4 years was 107 p.p.m. for the combination treatment, and 65 p.p.m. for the animal manure alone and 67 p.p.m. for the vetch alone.

TABLE 16. NITRATE CONTENT OF SOIL RECEIVING DIFFERENT MANURE TREATMENTS DURING THE GROWTH OF SWEET CORN, CHESTERFIELD SOIL OF MEDIUM FERTILITY, SERIES B14, 1944, 1946-48

Treatments				Average nitrate content of soil during the growth of sweet corn								
Fertilizer, 6-10-6 per acre	Manure		Irrigation per week[2]	Average nitrates by two- and three-week periods for all years[3]					Average nitrates by years for first three periods[4]			
	Animal per acre	Green[1]		1st	2nd	3rd	4th	Av.	1944	1946	1947	1948
Lb.	*Tons*		*In.*	*p.p.m.*	*p.p.m.*	*p.p.m.*	*p.p.m.*	*p.p.m.*	*p.p.m.*	*p.p.m.*	*p.p.m.*	*p.p.m.*
1,000	0	0	0	15	38	33	5	23	20	36	19	38
0	0	0	0	4	9	10	7	8	6	3	8	13
1,000	12	0	0	37	65	52	11	41	50	63	47	45
1,000	0	Vetch	0	32	67	46	7	38	41	39	45	67
1,000	0	Rye	0	27	56	40	10	33	30	56	31	47
1,000	0	0	1	28	33	42	6	27	17	53	19	49
1,000	12	0	1	62	67	54	7	48	26	71	43	103
1,000	0	Vetch	1	56	68	34	4	41	24	44	43	98
1,000	0	0	0	18	35	30	5	22	23	38	15	33
1,000	12	Vetch	1	89	104	55	11	65	39	74	71	145
1,000	6	Vetch	1	72	84	41	7	51	39	49	84	91
1,000	6	Rye	1	53	63	46	10	43	23	67	39	87
1,000	12	Vetch	0	66	107	98	32	76	59	76	91	134
1,000[5]	12	Vetch	1	73	79	58	12	56	38	66	68	107
1,500	12	Vetch	1	88	100	73	14	69	42	63	85	157
2,000	12	Vetch	1	94	111	99	17	80	60	87	77	181
1,000	0	Rye	1	48	56	36	6	37	26	50	37	73
		Average		51	67	50	10	45				
Least significant difference at			.05 level					17	16	22	21	55
			.01 level					24	22	31	30	76

[1] Green manure crops were grown and turned under.

[2] Irrigation consisted of the application of 1 inch of water per week if rainfall the preceding week failed to supply this amount and plants or soil indicated a need for water.

[3] Average nitrates are for each period for the 4 years.

[4] The average nitrates by years are for the first three periods for each year.

[5] Minor elements were applied to all treatments except this one.

Results of Studies in Series B19-B21

The average nitrate contents of the soil in Series B19-B21 during the growing season for spring and fall crops are given in Table 17. Data are for 4 separate years and for a 7-year average.

Soil nitrates and increases in nitrates resulting from use of manures were considerably higher in the fall than in the spring. The 7-year average nitrate content of the soil during the fall in plots receiving 2,000 pounds of fertilizer per acre was 16 p.p.m. higher in plots receiving a summer legume, 50 p.p.m. higher in those receiving 18 tons of animal manure and 76 p.p.m. higher in those receiving 18 tons of animal manure and a legume than in plots receiving no organic materials. The corresponding nitrate increases in the spring were 3, 9, and 10 p.p.m. Differences between treatments of 10 p.p.m. in the fall and of 4 p.p.m. in the spring were required for high significance.

Effects of Added Organic Materials on Soil Moisture During the Growing Season

Organic matter in the soil is known to affect to some extent the amount of water held by soils. This may in part account directly and indirectly for yield increases. It may also affect biological activity resulting in changes in organic content and the forms of soil nitrogen.

Data from Series B19-B21 are presented to indicate effects of organic materials on moisture in the soil during the growing period of fall and spring crops.

The moisture percentages for each year represent the average of three determinations and the percentages for each period the average of the 3 years. Results are presented in Tables 18 and 19.

During the spring growing season, the differences in average soil moisture of plots receiving no organic materials and of those receiving 6, 12, or 18 tons of animal manure per acre were highly significant. Differences in the average moisture content between plots receiving 6 and 12 tons and also between those receiving 12 and 18 tons of manure per acre were likewise highly significant. At no intensity level were the average differences due to a turned legume significant. Differences were significant between treatments consisting of nonlegumes turned and nonlegumes removed at the medium- and high-intensity levels, but not at the low-intensity level. The average difference in soil moisture content

TABLE 17. NITRATE CONTENT OF SOIL RECEIVING DIFFERENT KINDS OF MANURES AT DIFFERENT PRODUCTION-INTENSITY LEVELS WHEN GROWING SPRING AND FALL VEGETABLES, CHESTERFIELD SOIL OF LOW FERTILITY, SERIES B19-B21, 1940-46

Treatments				Average nitrate content of soil during growth of vegetables[3]									
	Manures			Spring					Fall				
Fertilizer, 6-10-6[1] per acre	Animal per acre	Green[2]		1940	1941	1945	1946	Av. (7-yr.) 1940-46	1940	1941	1945	1946	Av. (7-yr.) 1940-46
		Cowpea	Corn										
Pounds	*Tons*			*p.p.m.*	*p.p.m.*	*p.p.m.*	*p.p.m.*	*p.p.m.*	*p.p.m.*	*p.p.m.*	*p.p.m.*	*p.p.m.*	*p.p.pm.*
0	0	--	R	0	4	5	6	3	4	7	9	3	6
1,000	0	--	R	7	18	9	16	13	10	26	67	20	28
1,500	0	--	R	10	23	13	25	17	11	45	104	27	38
2,000	0	--	R	15	26	17	29	20	14	44	110	36	44
1,000	0	T	--	7	20	11	17	12	15	34	99	19	39
1,500	0	T	--	9	26	16	25	18	16	53	133	27	55
2,000	0	T	--	18	30	16	32	23	18	62	169	37	60
1,000	6	--	R	6	20	17	18	14	18	37	109	28	41
1,000	6	--	T	8	18	23	21	17	19	61	103	32	48
1,000	6	T	--	8	19	22	24	17	22	65	148	43	65
1,500	12	--	R	9	25	25	30	21	25	79	153	52	65
1,500	12	--	T	14	27	31	36	26	28	77	151	54	68
1,500	12	T	--	11	26	30	28	22	30	92	171	76	85
2,000	18	--	R	19	33	35	46	29	34	80	222	81	94
2,000	18	--	T	16	28	40	50	31	37	89	197	97	101
2,000	18	T	--	12	33	42	45	30	39	103	243	97	120
Least significant difference at		.05 level		6	6	5	8	3	5	15	30	3	8
		.01 level		8	8	7	11	4	7	20	40	4	10

[1] Fertilizer was applied to each of 2 crops per year; animal manure was applied once each year.
[2] In treatments marked T, green manures were turned; those marked R were removed.
[3] Nitrate content is the average of all nitrate determinations made during the growth period.

of plots receiving no manure and of those receiving 18 tons of animal manure and a turned nonlegume was 2.93 per cent. A difference in percentage of 0.56 was highly significant.

During the growth of fall crops, the average differences were significant between treatments receiving no organic treatments and those receiving 12 and 18 tons per acre of animal manure and manure crops; differences were not significant between treatments receiving no organic materials and those receiving only manure crops.

It should be pointed out that increases in soil moisture resulting from the addition of organic materials do not mean equiv-

TABLE 18. AVERAGE SOIL MOISTURE CONTENT DURING THE GROWING PERIOD OF SPRING VEGETABLES OF SOIL RECEIVING DIFFERENT KINDS OF MANURES AT DIFFERENT PRODUCTION-INTENSITY LEVELS, CHESTERFIELD SOIL OF LOW FERTILITY, SERIES B19-B21, 1945-47

Treatments[1]				Average moisture content of soil during the growing period						
Fertilizer, 6-10-6 per acre	Manures			By periods for all years[3]			By years for all periods[4]			
	Animal per acre	Green[2]								
		Cowpea	Corn	1st	2nd	3rd	1945	1946	1947	Average
Lb.	*Tons*			*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
0	0	--	R	7.04	5.90	6.80	6.61	6.31	6.82	6.58
1,000	0	--	R	7.21	5.95	6.92	6.78	6.56	6.74	6.69
1,500	0	--	R	6.92	6.00	6.74	6.74	6.34	6.56	6.55
2,000	0	--	R	7.14	6.05	6.77	6.80	6.40	6.76	6.65
1,000	0	T	--	7.26	6.18	7.12	6.91	6.57	7.07	6.85
1,500	0	T	--	7.27	6.11	7.14	7.05	6.44	7.03	6.84
2,000	0	T	--	7.16	6.43	6.78	6.90	6.56	6.90	6.79
1,000	6	--	R	7.70	6.88	7.52	7.40	6.86	7.83	7.36
1,000	6	--	T	7.98	7.15	7.53	7.59	7.15	7.93	7.55
1,000	6	T	--	8.05	7.10	7.48	7.53	6.96	8.15	7.54
1,500	12	--	R	8.34	7.68	7.87	7.81	7.25	8.83	7.96
1,500	12	--	T	9.41	8.00	8.31	8.48	7.48	9.76	8.57
1,500	12	T	--	8.71	7.95	8.03	8.33	7.29	9.07	8.23
2,000	18	--	R	10.07	8.73	8.76	9.11	7.63	10.82	9.19
2,000	18	--	T	10.72	9.00	9.03	8.83	8.13	11.79	9.58
2,000	18	T	--	10.32	9.07	9.04	9.03	8.30	11.11	9.48
Least significant difference at				.05 level			.59	1.42	.77	0.42
				.01 level			.79	1.90	1.02	0.56

[1] Fertilizer was applied to each of two crops per year; animal manure was applied once each year.

[2] In treatments marked T, green manures were turned; those marked R were removed.

[3] The average moisture content by periods is the moisture content in the soil at approximately 3, 6, and 9 weeks after crop was planted.

[4] The average moisture content by years is for the first three periods for each year.

TABLE 19. AVERAGE SOIL MOISTURE CONTENT DURING THE GROWING PERIOD OF FALL VEGETABLES OF SOIL RECEIVING DIFFERENT KINDS OF MANURES AT DIFFERENT PRODUCTION-INTENSITY LEVELS, CHESTERFIELD SOIL OF LOW FERTILITY, SERIES B19-B21, 1945-47

Treatments[1]				Average moisture content of soil during the growing period						
Fertilizer, 6-10-6 per acre	Manures: Animal per acre	Green[2]: Cowpea	Green[2]: Corn	By periods for all years[3]: 1st	2nd	3rd	By years for all periods[4]: 1945	1946	1947	Average
Lb.	*Tons*			*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
0	0	--	R	5.21	5.42	6.61	5.78	5.16	6.29	5.74
1,000	0	--	R	5.29	5.47	6.61	6.05	5.10	6.22	5.79
1,500	0	--	R	5.17	5.50	6.94	5.97	5.05	6.59	5.87
2,000	0	--	R	5.30	5.42	6.42	5.98	4.89	6.28	5.71
1,000	0	T	--	5.37	5.43	6.62	6.07	5.00	6.36	5.81
1,500	0	T	--	5.30	5.50	6.21	6.14	4.90	5.97	5.67
2,000	0	T	--	5.16	5.50	6.66	6.04	5.11	6.17	5.77
1,000	6	--	R	5.61	5.60	6.59	6.21	5.18	6.41	5.93
1,000	6	--	T	5.67	5.83	7.05	6.65	5.47	6.43	6.18
1,000	6	T	--	5.50	5.77	7.25	6.54	5.28	6.71	6.17
1,500	12	--	R	5.84	5.86	7.63	6.78	5.72	6.82	6.44
1,500	12	--	T	6.06	6.18	7.64	7.45	5.61	6.82	6.63
1,500	12	T	--	5.95	5.89	7.21	7.09	5.62	6.33	6.35
2,000	18	--	R	6.45	6.46	8.68	7.58	6.23	7.78	7.20
2,000	18	--	T	6.67	6.76	8.55	7.70	6.37	7.91	7.33
2,000	18	T	--	6.46	6.69	8.08	7.54	6.31	7.38	7.08
Least significant difference at				.05 level			.30	.38	.77	0.46
				.01 level			.41	.51	1.03	0.62

[1] Fertilizer was applied to each of two crops per year; animal manure was applied once each year.

[2] In treatments marked T, green manures were turned; those marked R were removed.

[3] The average moisture content by periods is the moisture content in the soil at approximately 3, 6, and 9 weeks after crop was planted.

[4] The average moisture content by years is for the first three periods for each year.

alent increases in available moisture. The wilting percentage of Chesterfield soil receiving 12 tons of animal manure per acre was approximately 0.50 higher than that of soil receiving no organic materials.

RESIDUAL EFFECTS OF ADDED ORGANIC MATERIALS ON THE SOIL ORGANIC MATTER CONTENT

The data presented have shown that repeated applications of organic materials to the soil result in appreciable increases in soil organic matter. The persistence of this organic matter in the soil after treatments end is important.

Presented in Table 20 are the data on organic matter content of the soil in Series B19-B21 for 1 and 3 years following the last use of organic materials. Certain of these data are presented graphically in Figure 5. The data indicate that increases in organic matter content of the soil resulting from use of organic materials are maintained for a number of years.

The organic matter content of the soil receiving 6 tons of animal manure and a legume was 1.09 per cent the last year manures were used and 0.98 per cent 3 years later. The corresponding percentages for the treatments receiving 12 tons per acre of animal manure and a summer legume were 1.33 and 1.16 per cent; for treatments receiving 18 tons of animal manure and a summer le-

TABLE 20. RESIDUAL EFFECTS ON ORGANIC MATTER CONTENT OF SOIL FROM USE OF DIFFERENT KINDS OF MANURES AT DIFFERENT PRODUCTION-INTENSITY LEVELS, CHESTERFIELD SOIL OF LOW FERTILITY, SERIES B19-B21, 1947-49

Treatments[1]				Organic matter content in soil		
Fertilizer, 6-10-6 per acre	Manures			Last year of first period 1947[3]	Residual period	
	Animal per acre	Green[2]			1948	1950
		Cowpea	Corn			
Lb.	*Tons*			*Pct.*	*Pct.*	*Pct.*
0	0	--	R	0.57	0.48	0.54
1,000	0	--	R	.57	.50	.54
1,500	0	--	R	.69	.62	.60
2,000	0	--	R	.62	.57	.62
1,000	0	T	--	.60	.57	.59
1,500	0	T	--	.81	.75	.64
2,000	0	T	--	.66	.67	.69
1,000	6	--	R	.66	.67	.86
1,000	6	--	T	.88	.81	.84
1,000	6	T	--	1.09	.95	.98
1,500	12	--	R	1.20	1.14	1.12
1,500	12	--	T	1.43	1.19	1.24
1,500	12	T	--	1.33	1.22	1.16
2,000	18	--	R	1.64	1.36	1.33
2,000	18	--	T	1.64	1.54	1.38
2,000	18	T	--	1.66	1.69	1.26
Least significant difference at		.05 level		.16	.16	.10
		.01 level		.21	.21	.16

[1] Fertilizer was applied to each of two crops per year; animal manure was applied once each year.

[2] In treatments marked T, green manures were turned; those marked R were removed. During residual period corn was grown in all plots and tops removed; the roots were left in the soil.

[3] The last year of the first period was the last year in which manures were applied.

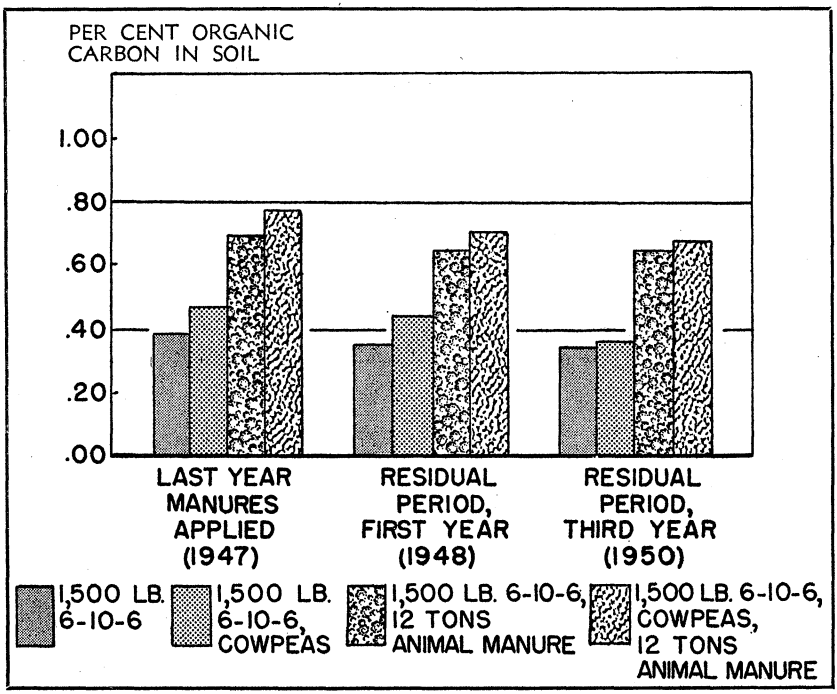

FIGURE 5. Residual effects of added manures on organic matter in the soil, Chesterfield soil of low fertility, Series B19-B21.

gume, the percentages were 1.66 and 1.26. The organic matter added by successive applications of organic materials are not, therefore, quickly lost.

Interrelation of Soil Treatments and the Organic Matter, Total Nitrogen, Nitrates, and Moisture in the Soil

The data reported thus far have dealt primarily with effects of organic treatments on crop yields or on the soil constituents. Little attention has been given the interrelations of treatments and the several soil constituents.

Data in Table 21, which show certain relationships, have been arranged in ascending order of intensity of treatments. Presented according to different treatments are the amounts of organic matter, total nitrogen, nitrates, and moisture of the soil during the spring and fall growing seasons.

The data show that as the treatments became more and more intensive the amount of organic matter, total nitrogen, nitrates,

TABLE 21. RELATION OF SOIL TREATMENTS TO SOIL ORGANIC MATTER CONTENT AND TOTAL SOIL NITROGEN AND TO NITRATES AND MOISTURE OF SOIL DURING GROWING SEASON, CHESTERFIELD SOIL OF LOW FERTILITY, SERIES B19-B21, 1940-48

Treatments arranged in order of increasing intensiveness				Soil organic matter		Total soil nitrogen	Fall growing season		Spring growing season	
Fertilizer per acre 6-10-6	Manures			Average 1940-46	Amount 1945	1948	Soil nitrates[2]	Soil moisture[3]	Soil nitrates[2]	Soil moisture[3]
	Animal per acre	Green[1]								
		Cowpea	Corn				Average of 7-years	Average of 3-years	Average of 7-years	Average of 3-years
Pounds	*Tons*			*Per cent*	*Per cent*	*p.p.m.*	*p.p.m.*	*Per cent*	*p.p.m.*	*Per cent*
0	0	--	R	0.64	0.62	178	6	5.74	3	6.58
1,000	0	--	R	.66	.62	199	28	5.79	13	6.69
1,500	0	--	R	.66	.64	202	38	5.87	17	6.55
2,000	0	--	R	.66	.64	214	44	5.71	20	6.65
1,000	0	T	--	.71	.72	231	39	5.81	12	6.85
1,500	0	T	--	.74	.71	226	55	5.67	18	6.84
2,000	0	T	--	.72	.74	240	60	5.77	23	6.79
1,000	6	--	R	.90	.93	293	41	5.93	14	7.36
1,000	6	--	T	.93	1.00	300	48	6.18	17	7.55
1,000	6	T	--	.93	1.07	360	65	6.17	17	7.54
1,500	12	--	R	1.02	1.16	439	65	6.44	21	7.96
1,500	12	--	T	1.07	1.29	396	68	6.63	26	8.57
1,500	12	T	--	1.14	1.42	494	85	6.35	22	8.23
2,000	18	--	R	1.17	1.53	571	94	7.20	29	9.19
2,000	18	--	T	1.26	1.45	641	101	7.33	31	9.58
2,000	18	T	--	1.28	1.74	696	120	7.08	30	9.48
Least significant difference at		.05 level		.07	.14	69	8	0.46	3	0.42
		.01 level		.09	.19	92	10	0.62	4	0.56

[1] In treatments marked T, the green manures were turned; those marked R were removed.
[2] The average represents determinations made at four periods each year for 7 years.
[3] The average represents determinations made at three periods each year for 3 years.

and moisture in the soil progressively increased. With only very minor exceptions, the order of treatments and the order of amounts of organic matter, nitrogen, nitrates, and moisture were similar. Organic treatments determined the organic matter, total nitrogen content of the soil, and soil moisture during the growing season. Nitrogen in the fertilizer affected soil nitrates about as much as organic treatments.

Relationship Between Soil Nitrates During the Growing Season and Crop Yields

It has been shown that organic treatments affect the amount of nitrates in the soil during the early and mid periods of growth, although crops remove large quantities of nitrogen. A very close relationship has been found between soil nitrates and crop yields. This relationship is shown in Figures 6, 7, and 8.

Yield increases followed very closely increases in soil nitrates. The yields with all crops shown except sweet corn continued to increase up to the highest amount of nitrates found. With sweet-corn, yields did not increase for increases in nitrate above 64 p.p.m.

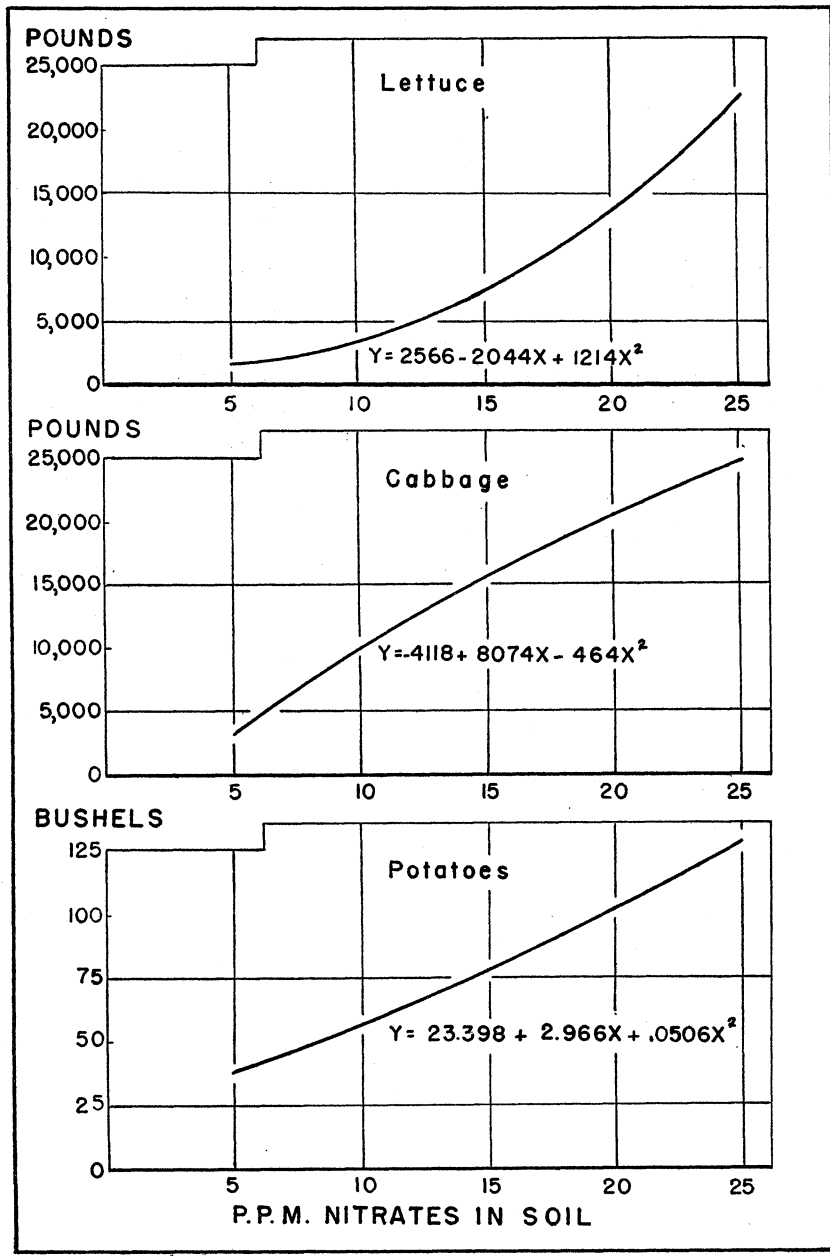

FIGURE 6. Relation of soil nitrates to yields of different spring vegetable crops, Chesterfield soil of low fertility, Series B19-B21.

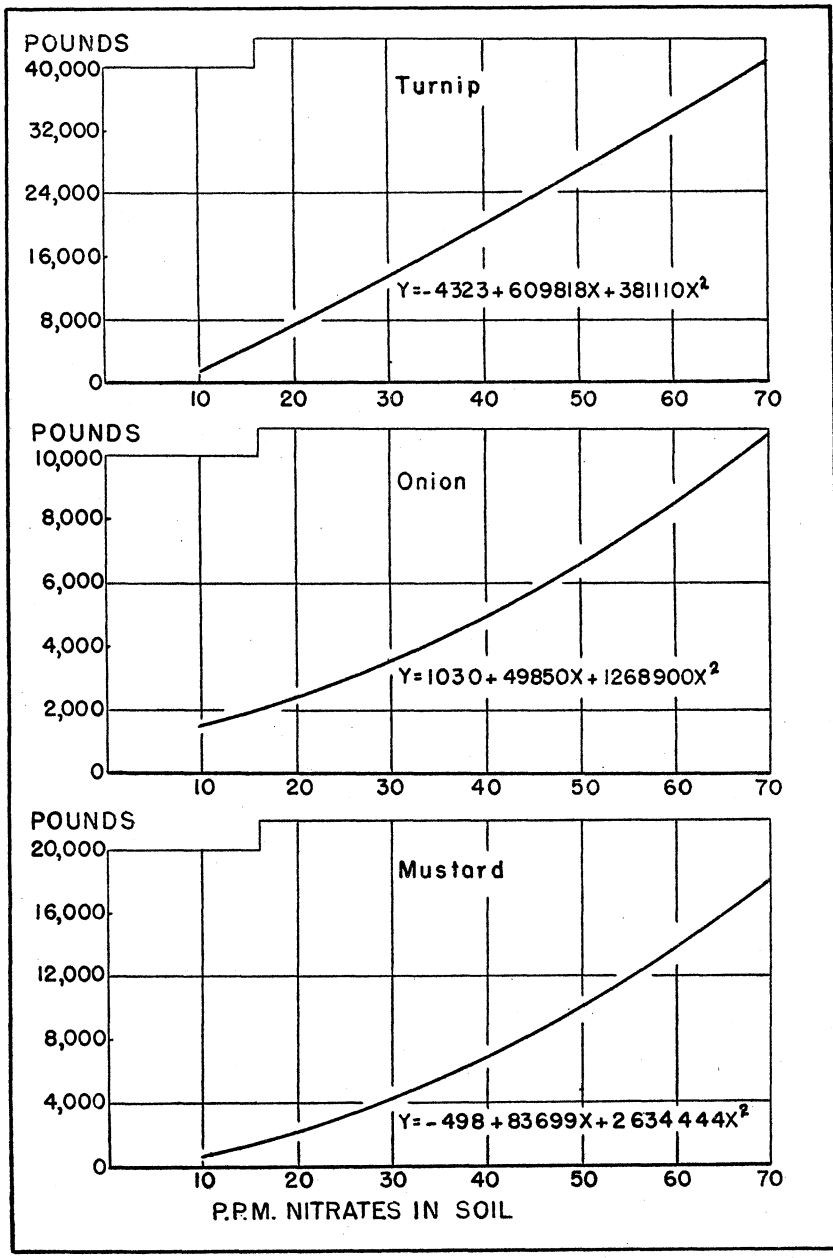

FIGURE 7. Relation of soil nitrates to yields of different fall vegetable crops, Chesterfield soil of low fertility, Series B19-B21.

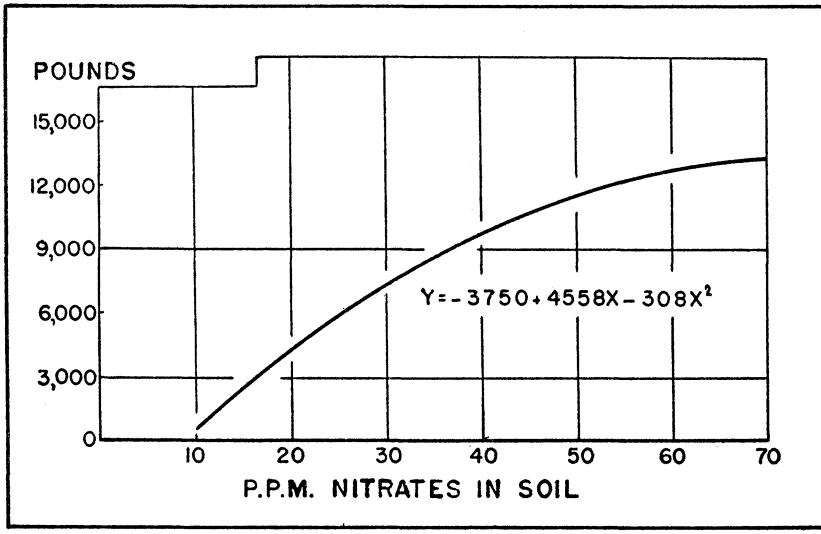

FIGURE 8. Relation of soil nitrates to yield of sweet corn, Chesterfield soil of medium fertility, Series B14.

DISCUSSION

There are a number of ways in which uses of organic materials on vegetable crops differ from their uses on field crops. Vegetables are grown on fewer acres of land, are more intensively handled, and in general offer possibility of higher gross returns per acre than field crops. These facts make possible and feasible use on vegetable crops of larger amounts of materials and the use of materials not available in large enough quantities for field crops. This is especially true for home and market garden areas.

A few of the differences in the kinds and amounts of organic materials used with field and vegetable crops and differences in their effects on soils are briefly discussed.

Increasing Organic Matter and Total Nitrogen in the Soil

Many investigators and workers have pointed out the low amount of organic matter in the soils of the South and the difficulty of increasing the amount present *(7, 10, 11, 14, 21)*. It is frequently stated that methods used in organic matter determinations are not accurate enough to measure the small increases obtained by turning under of organic materials. This may be

true for certain materials applied in certain quantities but not for other materials applied in different quantities.

This investigation indicates that only very small increases in organic matter content of the soil were obtained from turning under legumes or nonlegumes over a period of 6 to 9 years. The increases usually have not been significant, or where significant the increases were too low to be of practical importance (Tables 12, 13, 14, 15).

Turning under 6, 12, or 18 tons of animal manure per acre over a period of years not only has given increases in soil organic matter that are statistically significant but increases that should be of practical value (Table 12). Likewise, the use of mulching materials either on the surface or incorporated in the soil has increased the organic matter content of the soil very materially (Table 15).

Increases in total nitrogen in the soil have followed increases in soil organic matter content as a result of the addition of organic materials (Tables 14, 15).

Not only did certain of the organic treatments increase the organic and total nitrogen content of the soil during the period of application but the residual effects are apparent for 2 and 3 years after the last application with indications that the effects will persist for a number of years longer.

These results are not necessarily contrary to the general results obtained in the South *(10, 15, 21)*. They do point to the differences that result in use of different kinds of organic materials applied in quantities not generally feasible with field crops. These results, as do the results with field crops, show only small increases in soil organic matter from turning under cover crops (Tables 12, 13, 14, 15).

Increases in Soil Nitrates from Use of Organic Materials

Increases in soil nitrates resulting from use of organic materials do not necessarily depend upon increases in the more stable forms of organic and total nitrogen content of the soil. Turning under legumes may liberate considerable amounts of nitrates within a short period. The nitrate content of the soil is extremely variable. Nitrates are subject to leaching and to use by growing crops and by soil bacteria; nitrate formation, furthermore, is subject to variations in temperature and moisture conditions of the soil. Despite these factors, average increases in soil nitrates, as determined

in the soil during the growing season over a period of years, were obtained by adding legumes, animal manures, and combinations of animal and green manures. The increases resulting from turning under legumes alone were not very high, but often were high enough for significance (Tables 16, 17). Increases from animal manure or from combinations of animal manure and green-manure crops generally exceeded considerably the amounts necessary for high significance. The nitrate content of soil and differences in nitrate content due to organic treatments were considerably higher during summer and fall periods than during the spring period (Tables 16, 17). Furthermore, yields were very closely related to nitrates found in the soil during the early- and mid-growing periods.

Use of Nonlegumes and Low-Nitrogen Materials

Caution is generally necessary in the use of nonlegumes as green-manure crops because of the depression of nitrates following their use with subsequent reduction in crop yields *(6, 12, 19, 23)*. This would be expected where adequate nitrogen is not available in the soil or where liberal quantities of commercial nitrogen have not been added. In growing vegetables, usually adequate quantities of commercial nitrogen are added in addition to such amounts as may be supplied by the cover crop. In this study, rye resulted in yields of the several crops as high as vetch when 1,000 pounds per acre of a fertilizer, carrying 60 pounds of nitrogen, was used with both (Table 4). The soil nitrates likewise were about as high in the soil receiving nonlegumes as in those receiving legumes where 60 pounds per acre of commercial nitrogen had been added (Table 16).

Furthermore, the average yields of vegetables were not reduced by heavy mulches of pine straw or of oat straw where 76.8 pounds of commercial nitrogen per acre had been added; yield of fall crops were actually increased 100 per cent or more by these materials (Table 7).

Relative Value of Organic Materials and of Commercial Nitrogen in Producing Vegetables

It is generally assumed that nitrogen is the principal factor responsible for crop yield increases resulting from use of organic materials. Evidence from long-time experiments shows that the same yield may be produced from adequate quantities of com-

mercial nitrogen as from legumes (3, 8). Data from this study do show a very close relationship between treatments, nitrates found during the growing season, and crop yields. They show, however, that on certain soils, large yield increases are obtained from the use of animal manures and legumes after adequate quantities of commercial nitrogen have been added (Figure 2). The distinction is made here between the addition of adequate quantities of nitrogen and the presence and accessibility of this nitrogen to the growing crop when it is needed. The ultimate measure of relative value is in crop response.

On a Norfolk soil of average fertility, commercial nitrogen gave yields as high as legumes; furthermore, after maximum or near-maximum yields were reached from use of commercial nitrogen, only small or no yield increases were obtained by the further addition of legumes (Table 3).

Results with commercial nitrogen and organic materials were quite different on a Chesterfield soil of low fertility (Table 2, Figure 2). The average yields of six fall vegetables increased from 8,132 to 10,186 to 10,336 pounds as fertilizers containing 60, 90, and 120 pounds of commercial nitrogen per acre were applied; yet after 120 pounds of commercial nitrogen per acre was applied, yields were increased to 16,346 pounds by addition of cowpeas or increased to 25,924 by addition of animal manure (Table 2). On the other hand, the additional 30 pounds of commercial nitrogen above the 90-pound rate resulted in no yield increase. The addition of cowpeas to the plots receiving 90 pounds of commercial nitrogen, however, resulted in a yield increase from 10,186 to 16,776 pounds per acre; the addition of animal manure increased the yield from 10,186 to 23,329 pounds per acre. Minor elements were applied to all treatments.

On another Chesterfield soil of low fertility, a commercial fertilizer carrying 180 pounds per acre of nitrogen produced only 507 pounds of beets per acre, while the commercial fertilizer carrying 90 pounds per acre of nitrogen and animal manure resulted in a yield of 10,790 pounds; corresponding yields for the same treatments of carrots were 2,772 and 17,641 pounds, and of mustard 6,570 and 12,879 pounds (Table 6). The yields of fall tendergreen for corresponding treatments were 10,442 and 23,209 pounds, and for fall turnips 15,644 pounds and 34,111 pounds per acre. The addition of minor elements without animal manure resulted in an increase in the yield of beets but did not increase the yields of other crops. From previous studies at this

Station, it has been shown that yield increases were not obtained from applications above 90 to 120 pounds per acre of commercial nitrogen (28).

Residual Effects of Added Organic Materials

Results of these studies show that the addition of organic materials increases the organic and total nitrogen content of the soil and that these increases are reflected in increased crop yields during the time of the application and for a few years after the last application (Tables 10, 11). The data, however, show that by the end of 3 years the effects on vegetable yields from green manures largely disappeared and the effects of animal manure were greatly reduced (Figures 3 and 4). The loss in soil organic matter after the last application has been less rapid (Table 20, Figure 5).

These results are in contrast with results from some of the long-time experiments. Hall (8) states that barnyard manure on the Rothamstead Station applied at the rate of 14 tons per acre over a period of 20 years was affecting crop yields 47 years after the last application. In this study on a light, open, Chesterfield soil under conditions of high rainfall and high temperatures, residual effects have disappeared at a very rapid rate, with indications that after 4 or 5 years differences in yield will have little practical significance. It should be pointed out that in most of the long-time experiments with organic materials no commercial nitrogen was added to the contrasting treatments. In this study different rates of commercial nitrogen have been added during both the period of application and the residual period. The addition of commercial nitrogen would reduce the contrast between treatments.

SUMMARY

Results are presented in this bulletin of studies with the use of organic materials on vegetable crops.

The term "organic materials," as used in this publication, is applied to materials added to the soil either as green manure, as animal manure, or as mulching material.

The investigation included studies of the immediate and residual effects of organic materials grown on the land and turned under and of those introduced and incorporated in the soil or left on the surface as a mulch.

The value of organic materials was measured by effects on

crop yields and on soil nitrates and soil moisture during the growth of crops, and by changes in the total nitrogen and organic matter content of the soil.

Studies were conducted in specially constructed field bins on composited soils.

Four phases of the investigation were conducted on a Chesterfield soil of low fertility, two phases on a Chesterfield soil of medium fertility, and two phases on a Norfolk soil of medium fertility.

On a Chesterfield soil of low fertility (Table 1), turning under a winter legume increased the average yields of summer vegetables 283 per cent and of fall vegetables 163 per cent; the average yields of fall vegetables were increased 353 per cent and of spring vegetables 78 per cent by turning under summer legumes.

The average yield of summer vegetables on the Chesterfield soil of low fertility was increased about 60 per cent more from a turned winter legume than from 60 pounds per acre of commercial nitrogen; the average yield of fall vegetables after an intervening crop of summer vegetables was increased from turned winter legumes somewhat less than from 30 pounds of commercial nitrogen. The average yield of fall vegetables was increased from turned summer legumes nearly as much as that from 60 pounds per acre of commercial nitrogen, while the yield of spring vegetables was increased about one-third as much as that from 30 pounds of commercial nitrogen.

After 30 pounds per acre of commercial nitrogen was added to the Chesterfield soil of low fertility, a turned winter legume increased the yield of summer vegetables 107 per cent and the yield of fall vegetables 43 per cent. Turned summer legumes increased the yield of fall vegetables 83 per cent but of spring vegetables only 20 per cent after 30 pounds of commercial nitrogen had been added.

On a second Chesterfield soil of low fertility (Table 2), summer legumes and animal manures gave large increases in yields of fall vegetables after applications of commercial nitrogen adequate for maximum production had been added. The average yield of six fall crops from the application of 90 pounds of commercial nitrogen, normally adequate for near-maximum yields, was only 10,186 pounds; additional fertilizer carrying 30 pounds of nitrogen gave practically no increase in yield. The addition of cowpeas, however, gave yields of 16,766 pounds, or the addition of 12 tons of animal manure yielded 23,329 pounds. Animal ma-

nures at the rates applied increased yields more than did turning under legumes or nonlegumes grown on the soil.

On the Norfolk soil of medium fertility, commercial nitrogen, in general, produced yields as high as green manures. When rates of nitrogen sufficient for maximum yields without a manure had been added, turning under a legume gave little or no increase in yield (Table 3).

Surface mulches of legume origin resulted in yield increases of summer vegetables ranging from 68 to 132 per cent, while those of a nonlegume origin gave increases ranging from 4 to 76 per cent. The increases in yield of fall vegetables from surface mulches of legume and nonlegume origin ranged from 92 to 214 per cent (Table 7).

On a Chesterfield soil of low fertility receiving 2,000 pounds per acre of a 6-10-6 fertilizer throughout the experiment and organic material for the first 9 years, average yield increases of fall vegetables 2 years after the last addition or organic materials were as follows: 27 per cent where cowpeas had been turned, 46 per cent where 18 tons of animal manure per acre had been added, and 55 per cent where 18 tons of manure had been added and cowpeas had been turned (Table 10).

On plots on which cowpeas had been turned annually for 9 years, the average yield of spring vegetables, 3 years after the last crop was turned, was practically the same as the check; the average yield of plots receiving 18 tons of animal manure was 60 per cent higher than the plot receiving no organic materials (Table 11).

The repeated turning of crops of legumes or nonlegumes on a light Chesterfield soil failed to give differences in soil organic matter content high enough for significance when used without other sources of materials; small but significant differences in soil organic matter were obtained from summer cover crops when used in combination with animal manure (Table 12).

On a Chesterfield soil of low fertility, the repeated application of 6, 12, and 18 tons of animal manure per acre by the 6th year had resulted in increases in soil organic matter content of 0.31, 0.54, and 0.89 per cent, respectively. An increase of 0.19 per cent was adequate for high significance (Table 12).

Material increases in total soil nitrogen resulted from repeated applications of organic materials to the soil for a period of years. On a Norfolk soil after eight treatments, the amounts of total nitrogen in the plots were as follows: check plot, 293 p.p.m.;

plots in which lespedeza and crotalaria were introduced, 472 p.p.m.; plots in which crops of vetch and crops of cowpeas were turned, 403 p.p.m. and 338 p.p.m., resectively (Table 14).

Organic mulches had increased the amount of total nitrogen in the soil after 10 applications from 317 p.p.m. to amounts ranging from 500 to 1,000 p.p.m. (Table 15).

Nitrates in the soil during the growing period of crops were increased by turning under legumes, by application of animal manures, and by combination of the two treatments. In general, the increases were above those required for high significance in the fall but barely significant in the spring (Table 17).

Nitrate levels were closely related to amount of commercial nitrogen and organic materials added (Table 16, 17).

Yields were closely related to the amounts of soil nitrates during the growing season (Figure 8).

LITERATURE CITED

(1) ALLISON, L. E. Organic soil carbon by reduction of chromic acid. Soil Sci. 40: 311-320. 1935.

(2) ANONYMOUS. Official and tentative methods of analysis of the association of official agricultural chemists, 4th edition. George Banta Publishing Company, Menasha, Wis. 1935.

(3) BAILEY, R. Y., WILLIAMSON, J. T., and DUGGAR, J. F. Experiments with legumes in Alabama. Ala. Agr. Expt. Sta. Bul. 232. 1930.

(4) BLAIR, A. W., and PRINCE, A. L. The influence of heavy applications of dry organic matter on crop yields and on nitrate content of the soil. Soil Sci. 25: 281-287. 1928.

(5) BRIGGS, L. J., and MCLANE, J. W. The moisture equivalent of soils. U. S. Dept. Agr. Bur. Soils Bul. 45. 1907.

(6) BROWN, P. E., and ALLISON, L. E. The influence of some common humus-forming materials of narrow and wide nitrogen-carbon ratios on bacterial activity. Soil Sci. 1: 49-75. 1916.

(7) FUNCHESS, M. J. Nitrogen in southern agriculture. Proc. Eleventh Ann. Conv. Nat. Fert. Assoc. 1934-35.

(8) HALL, A. D. The book of the Rothamsted experiments. E. P. Dutton & Company, N. Y. 1917.

(9) HARPER, H. J. The accurate determination of nitrates in soils. Ind. Eng. Chem. 16: 180-183. 1924.

(10) JENNY, HANS. Soil fertility losses under Missouri conditions. Mo. Agr. Expt. Sta. Bul. 324. 1933.

(11) ———. A study of the influence of climate upon the nitrogen and organic matter content of the soil. Mo. Agr. Expt. Stat. Res. Bul. 152. 1930.

(12) JENSEN, H. L. On the influence of the carbon : nitrogen ratios of organic material on the mineralisation of nitrogen. Jour. Agr. Sci. 19: 71-82. 1929.

(13) JONES, RANDALL J. Nitrogen losses from Alabama soils in lysemeters as influenced by various systems of green manure crop management. Jour. Amer. Soc. Agron. 34: 574-585. 1942.

(14) MARBUT, C. F. The relation of soil type to organic matter. Jour. Amer. Soc. Agron. 21: 943-950. 1929.

(15) MILLER, M. F. Studies in soil nitrogen and organic matter maintenance. Mo. Agr. Expt. Sta. Res. Bul. 409. 1947.

(16) LYON, T. L., and WILSON, B. D. Some relations of green manure to the nitrogen in the soil. N. Y. Agr. Expt. Sta. Memoir 115. 1928.

(17) RICHARDS, L. A., and WEAVER, L. R. Fifteen-atmosphere percentage as related to the permanent wilting percentage. Soil Sci. 56: 331-339. 1943.

(18) SALTER, R. M., and SCHOLLENBERGER, C. J. Farm manure. Ohio Agr. Expt. Sta. Bul. 605. 1939.

(19) SALTER, F. J. The carbon-nitrogen ratio in relation to the accumulation of organic matter in soils. Soil Sci. 31: 413-430. 1931.

(20) STURKIE, D. G., and GRIMES, J. C. Kudzu, its value and use in Alabama. Ala. Agr. Expt. Sta. Cir. 83. 1939.

(21) THOMPSON, L. J. JR., and SMITH, F. B. Organic matter in Florida soils. Fla. Agr. Expt. Sta. Bul. 433. 1947.

(22) WRIGHT, C. H. Soil analysis, physical, and chemical methods. Thomas Murby & Co., London. 1934.

(23) WAKSMAN, S. A. Influence of microorganisms upon the carbon-nitrogen ratio in the soil. Jour. Agr. Sci. 14: 555-562. 1924.

(24) ———. On the origin and nature of the soil organic matter or soil "humus": V. The role of microorganism in the formation of "humus" in the soil. Soil Sci. 22: 421-436. 1926.

(25) ———. Humus. The Williams and Wilkins Company. Baltimore. 1936.

(26) WARE, L. M. The effects of fertilizers, organic materials, and irrigation on the yield of certain truck crops. Proc. Amer. Soc. Hort. Sci. 39: 363-366. 1941.

(27) ——— and JOHNSON, W. A. Use of field bins for experimental studies with vegetable crops. Proc. Auburn Conf. on Statistics Applied to Research. pp. 54-60. 1948.

(28) ———. Fertilizer studies with vegetable crops on representative soils in Alabama. Ala. Agr. Expt. Sta. Bul. 269. 1949.

(29) ———. Some effects of repeated applications of manures and fertilizers on the organic, nitrate, and moisture content of soil and on the yield of truck crops. Proc. Amer. Soc. Hort. Sci. 53: 375-386. 1949

(30) ———. Value of irrigation with different fertility treatments for vegetable crops. Ala. Agr. Expt. Sta. Bul. 276. 1950.

APPENDIX

APPENDIX TABLE 1. YIELDS AND INCREASES IN YIELDS OF SUMMER VEGETABLES FOLLOWING TURNED WINTER COVER CROPS AND RECEIVING DIFFERENT RATES OF NITROGEN, CHESTERFIELD SOIL OF LOW FERTILITY, SERIES B15-16, 1940-49

Crops	Fertilizer grades, 1,000 lb. per acre[1]	Kind of cover crops turned[2]	Yields per acre[3]		Increases from use of cover crops	
			Without cover crops	With cover crops	Amount	Per cent
Beans, bush	0-10-6	Vetch	36	133	97	269
Total, bu.	3-10-6	Vetch	71	150	79	111
(5-yr. av.)	6-10-6	Vetch	123	178	55	45
	6-10-6	Rye	123	142	19	15
	6-10-6	Rye (R)	123	135	12	10
Beans, lima	0-10-6	Vetch	67	199	132	197
Total, bu.	3-10-6	Vetch	132	210	78	59
(5-yr. av.)	6-10-6	Vetch	171	221	50	29
	6-10-6	Rye	171	188	17	10
	6-10-6	Rye (R)	171	176	5	3
Eggplant	0-10-6	Vetch	7,434	30,908	23,474	316
Total, lb.	3-10-6	Vetch	16,152	36,292	20,140	125
(5-yr. av.)	6-10-6	Vetch	20,198	38,019	17,821	88
	6-10-6	Rye	20,198	36,253	16,055	79
	6-10-6	Rye (R)	20,198	33,415	13,217	65
Pepper, Pimento	0-10-6	Vetch	764	5,148	4,384	574
Total, lb.	3-10-6	Vetch	2,803	5,497	2,694	96
(3-yr. av.)	6-10-6	Vetch	3,181	6,780	3,599	113
	6-10-6	Rye	3,181	5,979	2,798	88
	6-10-6	Rye (R)	3,181	3,554	373	12
Tomatoes	0-10-6	Vetch	74	241	167	226
Marketable, bu.	3-10-6	Vetch	150	289	139	93
(4-yr. av.)	6-10-6	Vetch	190	310	120	63
	6-10-6	Rye	190	303	113	59
	6-10-6	Rye (R)	190	257	67	35

[1] One ton limestone and 10 pounds of borax were applied per acre to all treatments at the beginning of the experiment. Minor elements were applied to all treatments once each 3 years, beginning with an application in 1945.

[2] Cover crops marked (R) were cut and tops removed.

[3] Least significant differences at the .05 and .01 levels for bush beans are 18 and 25, for lima beans 21 and 29, for eggplant 5,427 and 7,430, for pimento pepper 1,549 and 2,125, and for tomatoes 45 and 62, respectively.

APPENDIX TABLE 2. YIELDS AND INCREASES IN YIELDS OF FALL VEGETABLES FOLLOWING TURNED WINTER AND SUMMER COVER CROPS AND RECEIVING DIFFERENT RATES OF NITROGEN, CHESTERFIELD SOIL OF LOW FERTILITY, SERIES B15-16, 1940-49

Crops	Fertilizer grades, 1,000 lb. per acre[1]	Kind of cover crops turned[2]	Yields per acre[3]		Increases from use of cover crops	
			Without cover crops	With cover crops	Amount	Per cent
Cabbage, Chinese	0-10-6	Vetch	1,140	6,698	5,558	488
Total, lb.	3-10-6	Vetch	6,007	13,645	7,638	127
(3-yr. av.)	6-10-6	Vetch	13,512	18,249	4,737	35
	6-10-6	Rye	13,512	18,513	5,001	37
	6-10-6	Rye (R)	13,512	18,227	4,715	35
	0-10-6	Cowpea	3,043	24,568	21,525	707
	3-10-6	Cowpea	14,929	30,204	15,275	102
	6-10-6	Cowpea	27,298	35,858	8,560	31
	6-10-6	Corn	27,298	26,492	-806	-3
	6-10-6	Corn (R)	27,298	26,761	-537	-2
Collards	0-10-6	Vetch	2,555	6,236	3,681	144
Total, lb.	3-10-6	Vetch	8,348	11,415	3,067	37
(5-yr. av.)	6-10-6	Vetch	11,204	12,694	1,490	13
	6-10-6	Rye	11,204	12,156	952	8
	6-10-6	Rye (R)	11,204	10,501	-703	-6
	0-10-6	Cowpea	2,399	11,489	9,090	379
	3-10-6	Cowpea	8,578	15,070	6,492	76
	6-10-6	Cowpea	12,528	17,074	4,546	36
	6-10-6	Corn	12,528	14,241	1,713	14
	6-10-6	Corn (R)	12,528	12,052	-476	-4
Kohlrabi	0-10-6	Vetch	503	2,564	2,061	410
Marketable, lb.	3-10-6	Vetch	2,713	3,601	888	33
(3-yr. av.)	6-10-6	Vetch	3,494	4,138	644	18
	6-10-6	Rye	3,494	2,982	-512	-15
	6-10-6	Rye (R)	3,494	3,007	-487	-14
	0-10-6	Cowpea	784	5,043	4,259	543
	3-10-6	Cowpea	3,537	5,618	2,081	59
	6-10-6	Cowpea	4,395	5,564	1,169	27
	6-10-6	Corn	4,395	4,642	247	6
	6-10-6	Corn (R)	4,395	2,966	-1,429	-33
Mustard	0-10-6	Vetch	1,907	6,118	4,211	221
Total, lb.	3-10-6	Vetch	6,151	8,688	2,537	41
(2-yr. av.)	6-10-6	Vetch	9,306	12,413	3,107	33
	6-10-6	Rye	9,306	13,492	4,186	45
	6-10-6	Rye (R)	9,306	12,499	3,193	34

(*Continued*)

[1] One ton limestone and 10 pounds of borax were applied per acre to all treatments at the beginning of the experiment. Minor elements were applied to all treatments once each 3 years, beginning with an application in 1945.

[2] Cover crops marked (R) were cut and tops removed.

[3] Least significant differences:

	Vetch		Cowpea	
	.05	.01	.05	.01
Chinese cabbage	3878	5312	7820	10726
Collards	2419	3302	2381	3264
Kohlrabi	1638	2240	1536	2112
Mustard	1626	2227		

APPENDIX TABLE 2. (*Continued*) YIELDS AND INCREASES IN YIELDS OF FALL VEGETABLES FOLLOWING TURNED WINTER AND SUMMER COVER CROPS AND RECEIVING DIFFERENT RATES OF NITROGEN, CHESTERFIELD SOIL OF LOW FERTILITY, SERIES B15-16, 1940-49

Crops	Fertilizer grades, 1,000 lb. per acre[1]	Kind of cover crops turned[2]	Yields per acre[3]		Increases from use of cover crops	
			Without cover crops	With cover crops	Amount	Per cent
Mustard	0-10-6	Cowpea	1,959	12,807	10,848	554
Total, lb.	3-10-6	Cowpea	6,196	17,232	11,036	178
(2-yr. av.)	6-10-6	Cowpea	10,435	19,597	9,162	88
	6-10-6	Corn	10,435	12,871	2,436	23
	6-10-6	Corn(R)	10,435	10,416	-19	0
Onion	0-10-6	Vetch	2,462	4,488	2,026	82
Total, lb.	3-10-6	Vetch	4,510	5,244	734	16
(3-yr. av.)	6-10-6	Vetch	5,436	5,585	149	3
	6-10-6	Rye	5,436	5,248	-188	-3
	6-10-6	Rye(R)	5,436	4,787	-649	-12
	0-10-6	Cowpea	2,487	4,885	2,398	96
	3-10-6	Cowpea	4,732	7,978	3,246	69
	6-10-6	Cowpea	6,519	9,297	2,778	43
	6-10-6	Corn	6,519	6,144	-375	-6
	6-10-6	Corn(R)	6,519	5,982	-537	-8
Tendergreen	0-10-6	Vetch	416	1,773	1,357	326
Total, lb.	3-10-6	Vetch	4,486	7,910	3,424	76
(1-yr. av.)	6-10-6	Vetch	8,397	11,245	2,848	34
	6-10-6	Rye	8,397	12,883	4,486	53
	6-10-6	Rye(R)	8,397	12,646	4,249	51
	0-10-6	Cowpea	537	6,854	6,317	1,176
	3-10-6	Cowpea	4,576	12,781	8,205	179
	6-10-6	Cowpea	9,338	18,227	8,889	95
	6-10-6	Corn	9,338	12,844	3,506	38
	6-10-6	Corn(R)	9,338	8,512	-826	-9
Turnip	0-10-6	Vetch	6,097	13,739	7,642	125
Total, lb.	3-10-6	Vetch	18,358	23,809	5,451	30
(4-yr. av.)	6-10-6	Vetch	23,115	27,589	4,474	19
	6-10-6	Rye	23,115	25,902	2,787	12
	6-10-6	Rye(R)	23,115	24,657	1,542	7
	0-10-6	Cowpea	7,298	24,785	17,487	240
	3-10-6	Cowpea	20,469	33,363	12,894	63
	6-10-6	Cowpea	27,548	35,503	7,955	29
	6-10-6	Corn	27,548	28,294	746	3
	6-10-6	Corn(R)	27,548	24,958	-2,590	-9

[1] One ton limestone and 10 pounds of borax were applied per acre to all treatments at the beginning of the experiment. Minor elements were applied to all treatments once each 3 years, beginning with an application in 1945.

[2] Cover crops marked (R) were cut and tops removed.

[3] Least significant differences:

	Vetch		Cowpea	
	.05	.01	.05	.01
Mustard			2816	3584
Onion	858	1178	1267	1728
Tendergreen	2464	3373	3110	4262
Turnip	2406	3296	3373	4621

APPENDIX TABLE 3. YIELDS AND INCREASES IN YIELDS OF SPRING VEGETABLES FOLLOWING TURNED SUMMER COVER CROPS AND RECEIVING DIFFERENT RATES OF NITROGEN, CHESTERFIELD SOIL OF LOW FERTILITY, SERIES B15-16, 1940-49

Crops	Fertilizer grades, 1,000 lb. per acre[1]	Kind of cover crops turned[2]	Yields per acre[3]		Increases from use of cover crops	
			Without cover crops	With cover crops	Amount	Per cent
Beans, bush	0-10-6	Cowpea	20	29	9	45
Total, bu.	3-10-6	Cowpea	38	50	12	32
(3-yr. av.)	6-10-6	Cowpea	47	64	17	36
	6-10-6	Corn	47	62	15	32
	6-10-6	Corn(R)	47	51	4	9
Beets	0-10-6	Cowpea	184	1,204	1,020	554
Marketable, lb.	3-10-6	Cowpea	3,533	5,330	1,797	51
(3-yr. av.)	6-10-6	Cowpea	6,981	8,102	1,121	16
	6-10-6	Corn	6,981	7,825	844	12
	6-10-6	Corn(R)	6,981	7,228	247	4
Cabbage	0-10-6	Cowpea	232	1,013	781	337
Marketable, lb.	3-10-6	Cowpea	2,380	3,605	1,225	51
(5-yr. av.)	6-10-6	Cowpea	6,355	6,938	583	9
	6-10-6	Corn	6,355	5,757	–598	–9
	6-10-6	Corn(R)	6,355	5,893	–462	–7
Carrots	0-10-6	Cowpea	1,042	2,902	1,860	179
Marketable, lb.	3-10-6	Cowpea	5,297	5,807	510	10
(6-yr. av.)	6-10-6	Cowpea	5,994	6,271	277	5
	6-10-6	Corn	5,994	6,504	510	9
	6-10-6	Corn(R)	5,994	6,165	171	3
Chard	0-10-6	Cowpea	1,760	2,736	976	55
Total, lb.	3-10-6	Cowpea	4,743	5,370	627	13
(5-yr. av.)	6-10-6	Cowpea	8,473	8,333	–140	–2
	6-10-6	Corn	8,473	8,493	20	0
	6-10-6	Corn(R)	8,473	8,963	490	6

(*Continued*)

[1] One ton limestone and 10 pounds of borax were applied per acre to all treatments at the beginning of the experiment. Minor elements were applied to all treatments once each 3 years, beginning with an application in 1945.

[2] Cover crops marked (R) were cut and tops removed.

[3] Least significant differences at the .05 and .01 levels for bush beans are 10 and 13, for beets 1,754 and 2,406, for cabbage 2,048 and 2,816, for carrots 1,267 and 1,741, and for chard 1,690 and 2,304, respectively.

APPENDIX TABLE 3. (*Continued*) YIELDS AND INCREASES IN YIELDS OF SPRING VEGETABLES FOLLOWING TURNED SUMMER COVER CROPS AND RECEIVING DIFFERENT RATES OF NITROGEN, CHESTERFIELD SOIL OF LOW FERTILITY, SERIES B15-16, 1940-49

Crops	Fertilizer grades, 1,000 lb. per acre[1]	Kind of cover crops turned[2]	Yields per acre[3]		Increases from use of cover crops	
			Without cover crops	With cover crops	Amount	Per cent
Lettuce	0-10-6	Cowpea	1,805	4,624	2,819	156
Total, lb.	3-10-6	Cowpea	9,638	10,970	1,332	14
(4-yr. av.)	6-10-6	Cowpea	11,523	12,550	1,027	9
	6-10-6	Corn	11,523	14,573	3,050	26
	6-10-6	Corn(R)	11,523	12,950	1,427	12
Onion	0-10-6	Cowpea	2,109	2,579	470	22
Total, lb.	3-10-6	Cowpea	5,293	5,908	615	12
(4-yr. av.)	6-10-6	Cowpea	7,677	7,350	-327	-4
	6-10-6	Corn	7,677	7,933	256	3
	6-10-6	Corn(R)	7,677	7,399	-278	-4
Potatoes	0-10-6	Cowpea	24	40	16	67
Marketable, bu.	3-10-6	Cowpea	46	64	18	39
(5-yr. av.)	6-10-6	Cowpea	62	87	25	40
	6-10-6	Corn	62	86	24	39
	6-10-6	Corn(R)	62	67	5	8
Radish	0-10-6	Cowpea	1,618	2,607	989	61
Marketable, lb.	3-10-6	Cowpea	6,074	7,082	1,008	17
(5-yr. av.)	6-10-6	Cowpea	10,291	10 572	281	3
	6-10-6	Corn	10,291	10,611	320	3
	6-10-6	Corn(R)	10,291	9,751	-540	-5
Spinach, N.Z.	0-10-6	Cowpea	7,206	10,133	2,927	41
Total, lb.	3-10-6	Cowpea	14,067	16,977	2,910	21
(3-yr. av.)	6-10-6	Cowpea	19,064	23,288	4,164	22
	6-10-6	Corn	19,064	23,526	4,462	23
	6-10-6	Corn(R)	19,064	21,956	2,892	15

[1] One ton limestone and 10 pounds of borax were applied per acre to all treatments at the beginning of the experiment. Minor elements were applied to all treatments once each 3 years, beginning with an application in 1945.

[2] Cover crops marked (R) were cut and tops removed.

[3] Least significant differences at the .05 and .01 levels for lettuce are 1,809 and 2,470, for onion 678 and 934, for potatoes 7 and 10, for radish 1,101 and 1,510, and for N. Z. Spinach 4,672 and 6,400, respectively.

APPENDIX TABLE 4. YIELDS OF DIFFERENT COVER CROPS GROWN, TURNED, OR REMOVED, CHESTERFIELD SOIL OF LOW FERTILITY, SERIES B15-16

Treatments		Yields of cover crops per acre by years											
Fertilizer grades, 1,000 lb. per acre[1]	Kinds of cover	1939	1940	1941	1942[2]	1943	1944	1945	1946	1947	1948	1949[3]	Average
		Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
						WINTER COVER CROPS							
0-10-6	Vetch		653	11,376	26,752	16,922	15,402	7,306	17,482	4,752	19,101	13,440	13,319
3-10-6	Vetch		701	10,144	23,456	14,320	14,122	5,853	19,792	3,917	13,219	13,440	11,896
6-10-6	Vetch		675	10,886	24,160	14,000	14,160	5,987	21,082	4,010	11,082	13,440	11,948
6-10-6	Rye		1,088	6,458	10,272	16,320	11,504	15,562	22,640	15,206	17,680	9,296	12,603
6-10-6	Rye(R)[4]		768	7,133	9,760	13,962	11,786	13,078	19,981	15,629	14,346	8,586	11,503
						SUMMER COVER CROPS							
0-10-6	Cowpea	11,792	9,510	13,472	12,726	18,602	19,402	23,520	13,722	20,842	19,088		16,268
3-10-6	Cowpea	12,896	9,229	12,912	12,922	19,296	19,754	23,120	10,640	15,626	11,872		14,827
6-10-6	Cowpea	13,392	9,171	13,450	12,621	19,152	21,178	23,120	8,656	17,242	14,922		15,290
6-10-6	Corn	6,358	6,957	2,922	11,344	4,176	9,536	8,000	2,704	12,560	2,240		6,680
6-10-6	Corn(R)[4]	6,838	7,062	2,061	963	3,402	7,456	5,920	2,480	12,538	1,840		5,056

[1] Fertilizer applied to each of two vegetable crops per year and not to cover crops. Minor elements were applied to all treatments once each 3 years, beginning with an application in 1945.

[2] For cowpea and corn yield, 10,000 pounds of each was introduced and turned in addition to amounts produced.

[3] Additional vetch was introduced to give yields as shown.

[4] Cover crops were grown and removed.

APPENDIX TABLE 5. YIELDS OF SPRING VEGETABLES RECEIVING DIFFERENT MANURES AT DIFFERENT PRODUCTION-INTENSITY LEVELS, CHESTERFIELD SOIL OF LOW FERTILITY, SERIES B19-B21, 1940-47

Treatments				Yields per acre of different vegetables[3]								
Fertilizer, 6-10-6 per acre[1]	Manures			Beans (4-yr. av.)	Beets (3-yr. av.)			Cabbage (4 yr. av.)		Carrots (4-yr. av.)		
	Animal per acre	Green[2]		Total[3]	Marketable		Total[3]	Marketable heads	Total[3]	Marketable		Total[3]
		Cowpea	Corn		Roots	Total				Roots	Total	
Lb.	*Tons*			*Bu.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*
0	0	--	R	3	0	0	81	967	2,831	208	247	1,248
1,000	0	--	R	43	119	282	837	4,294	11,706	1,514	2,538	4,404
1,000	0	T	--	50	277	679	1,511	7,413	15,101	1,501	2,403	4,038
1,000	6	--	R	87	1,148	2,317	3,371	10,307	19,619	3,459	5,652	7,143
1,000	6	T	--	97	1,668	3,200	4,186	9,262	18,209	4,080	6,710	8,775
1,000	6	--	T	100	1,404	2,833	3,810	9,577	18,393	4,025	6,749	8,208
1,500	0	--	R	68	192	491	1,045	6,321	15,492	1,408	2,432	4,074
1,500	0	T	--	67	781	1,591	2,287	10,125	19,777	2,580	4,266	5,687
1,500	12	--	R	129	2,428	4,677	5,589	11,663	21,144	5,098	8,660	10,199
1,500	12	T	--	120	2,710	4,885	5,538	15,914	26,303	5,805	9,639	11,312
1,500	12	--	T	126	2,564	4,783	5,598	14,045	25,171	5,984	9,962	11,616
2,000	0	--	R	70	346	781	1,297	6,374	15,562	2,067	3,328	4,963
2,000	0	T	--	70	619	1,242	1,886	11,232	20,185	2,250	3,676	5,378
2,000	18	--	R	136	3,293	6,119	6,857	16,352	27,586	6,544	11,124	12,736
2,000	18	T	--	140	4,002	6,071	6,630	15,247	26,231	6,359	10,714	12,141
2,000	18	--	T	135	3,260	5,674	6,400	16,010	26,634	5,792	9,969	11,137

(*Continued*)

[1] Minor elements were applied to all treatments once each 3 years beginning with an application in 1945.
[2] In treatments marked T, the green manures were turned; those marked R were removed.
[3] Least significant differences at the .05 and .01 levels for beans are 42 and 57, for beets 2,765 and 3,699, for cabbage 3,033 and 4,070, and for carrots 1,664 and 2,227, respectively.

APPENDIX TABLE 5. (*Continued*) YIELDS OF SPRING VEGETABLES RECEIVING DIFFERENT MANURES AT DIFFERENT PRODUCTION-INTENSITY LEVELS, CHESTERFIELD SOIL OF LOW FERTILITY, SERIES B19-B21, 1940-47

Treatments				Yields per acre of different vegetables[3]				
Fertilizer, 6-10-6 per acre[1]	Manures			English pea (4-yr. av.) Total[3]	Lettuce (3-yr. av.)		Potatoes (5-yr. av.)	
	Animal per acre	Green[2]			Marketable heads	Total[3]	Marketable	Total[3]
		Cowpea	Corn					
Pounds	*Tons*			*Bushels*	*Pounds*	*Pounds*	*Bushels*	*Bushels*
0	0	--	R	24	153	397	14	33
1,000	0	--	R	34	1,920	5,453	38	66
1,000	0	T	--	39	2,172	6,276	42	72
1,000	6	--	R	70	5,581	16,162	56	91
1,000	6	T	--	71	5,291	17,122	77	115
1,000	6	--	T	71	5,499	17,131	69	102
1,500	0	--	R	36	2,569	9,028	57	88
1,500	0	T	--	45	2,415	9,532	52	81
1,500	12	--	R	81	6,136	20,851	94	134
1,500	12	T	--	82	9,361	25,054	85	127
1,500	12	--	T	84	8,632	24,585	100	138
2,000	0	--	R	28	2,266	9,480	56	82
2,000	0	T	--	39	2,871	10,078	57	84
2,000	18	--	R	85	10,044	26,679	133	182
2,000	18	T	--	77	10,398	27,123	114	157
2,000	18	--	T	84	10,756	27,576	109	152

[1] Minor elements were applied to all treatments once each 3 years beginning with an application in 1945.
[2] In treatments marked T, the green manures were turned; those marked R were removed.
[3] Least significant differences at the .05 and .01 levels for English peas are 47 and 63, for lettuce 3,238 and 4,326, and for potatoes 19 and 26, respectively.

APPENDIX TABLE 6. YIELDS OF FALL VEGETABLES RECEIVING DIFFERENT MANURES AT DIFFERENT PRODUCTION-INTENSITY LEVELS, CHESTERFIELD SOIL OF LOW FERTILITY, SERIES B19-B21, 1940-47

Treatments				Yields per acre of different vegetables[4]								
Fertilizer, 6-10-6 per acre[1]	Manures			Broccoli (2-yr. av.) Total[3]	Chinese Cabbage (3-yr. av.) Total	Kohlrabi (3-yr. av.)			Mustard (3-yr. av.) Total	Onion (2-yr. av.) Total	Turnip (4 yr. av.)	
	Animal per acre	Green[2]				Marketable		Total				
		Cow-pea	Corn			Stems[5]	Total				Roots	Total
Pounds	*Tons*			*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
0	0	--	R	331	333	0	0	145	320	1,664	135	797
1,000	0	--	R	6,149	10,138	409	1,344	3,388	5,261	3,463	7,312	15,664
1,000	0	T	--	7,193	27,306	1,127	2,572	4,015	9,796	5,491	15,107	28,157
1,000	6	--	R	7,974	28,561	1,624	3,609	5,102	13,265	7,289	15,437	28,352
1,000	6	T	--	12,095	47,847	2,082	4,510	6,647	17,165	10,317	18,903	39,274
1,000	6	--	T	11,104	34,163	2,462	4,681	7,040	14,797	8,231	15,379	30,902
1,500	0	--	R	6,649	12,826	798	2,205	3,796	6,592	4,704	9,392	20,205
1,500	0	T	--	7,333	29,427	1,019	2,205	3,652	11,183	8,128	15,639	30,374
1,500	12	--	R	10,054	44,885	2,099	4,364	5,908	18,316	9,095	17,450	37,744
1,500	12	T	--	12,095	51,064	1,912	4,211	6,528	18,351	12,672	18,698	41,536
1,500	12	--	T	11,513	45,026	2,112	4,633	6,383	19,392	11,117	19,245	41,520
2,000	0	--	R	4,642	16,085	746	1,855	3,639	6,827	5,734	8,826	18,829
2,000	0	T	--	6,521	29,244	879	2,087	3,554	11,780	7,059	14,541	29,247
2,000	18	--	R	11,808	54,647	1,915	4,889	6,685	18,086	10,541	17,821	39,443
2,000	18	T	--	11,840	53,397	1,467	4,129	5,529	17,639	18,447	17,971	41,402
2,000	18	--	T	9,490	50,006	2,086	5,051	6,776	19,435	10,445	16,998	38,384

[1] Minor elements were applied to all treatments once each 3 years beginning with an application in 1945.
[2] In treatments marked T, the green manures were turned; those marked R were removed.
[3] Broccoli was harvested as greens; the crop was planted too late to produce heads in late winter.
[4] Least significant differences at the .05 and .01 levels for broccoli are 3,315 and 4,442, for Chinese cabbage 7,104 and 9510, for kohlrabi 1,562 and 2,086, for mustard 2,547 and 3,418, for onion 2,022 and 2,701, and for turnip 5,312 and 7,014, respectively.
[5] Enlarged stem often referred to as bulbs.

APPENDIX TABLE 7. YIELDS OF DIFFERENT COVER CROPS GROWN, TURNED, OR REMOVED, CHESTERFIELD SOIL OF LOW FERTILITY, SERIES B19-B21, 1940-47

Treatments[1]			Yields of cover crops per acre								
Fertilizer, 6-10-6 per acre	Manures: Animal per acre	Manures: Green[2]	1940	1941	1942	1943	1944	1945	1946	1947	Average
Pounds	*Tons*		*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
0	0	Corn(R)	4,928	1,200	2,336	640	3,738	1,818	762	1,840	2,158
1,000	0	Corn(R)	6,358	2,224	5,210	1,082	6,864	3,056	2,896	5,456	4,143
1,000	0	Cowpea(T)	11,286	7,872	11,520	13,200	15,786	17,088	4,458	16,538	12,218
1,000	6	Corn(R)	8,233	6,390	17,440	6,160	25,280	14,362	5,722	18,784	12,796
1,000	6	Cowpea(T)	14,458	13,062	23,520	23,322	26,880	34,128	21,120	25,152	22,705
1,000	6	Corn(T)	9,370	6,528	20,521	9,296	25,728	19,354	7,712	24,016	15,316
1,500	0	Corn(R)	8,557	3,472	7,200	2,237	9,712	4,058	2,010	8,922	5,771
1,500	0	Cowpea(T)	11,280	8,544	12,000	13,360	17,424	18,410	3,578	16,826	12,678
1,500	12	Corn(R)	13,830	14,944	27,481	13,018	35,078	26,102	14,154	33,296	22,239
1,500	12	Cowpea(T)	15,152	13,110	26,640	24,080	27,882	37,066	26,896	27,050	24,735
1,500	12	Corn(T)	12,909	14,806	29,376	13,802	37,744	29,770	15,690	31,712	23,226
2,000	0	Corn(R)	10,870	4,118	8,064	2,122	11,744	4,330	2,730	10,544	6,815
2,000	0	Cowpea(T)	11,203	8,342	12,320	12,122	17,210	19,802	5,162	19,600	13,220
2,000	18	Corn(R)	15,587	25,312	33,600	10,800	36,848	34,282	23,418	41,059	27,613
2,000	18	Cowpea(T)	13,498	13,958	29,338	24,442	32,240	39,920	34,160	32,106	27,458
2,000	18	Corn(T)	14,038	22,730	34,922	14,800	42,752	40,506	24,768	41,440	29,495

[1] Fertilizer and animal manure were applied to vegetables and not to cover crops. Minor elements were applied once each 3 years, beginning with an application in 1945.

[2] Green manure crops were grown in all plots; those marked R were removed and those marked T were turned.

APPENDIX TABLE 8. YIELDS OF WINTER AND SUMMER COVER CROPS GROWN OR TURNED, NORFOLK SOIL OF MEDIUM FERTILITY, SERIES A4, 1943-47

Fertilizer to vegetable crops, 1,000 lb. per acre	Average yields per acre		
	Winter legumes[1]		Summer legume
	For sweet corn (5-yr. av.)	For sweetpotatoes (5-yr. av.)	Cowpeas grown for fall turnips and spring potatoes (5-yr. av.)
	Pounds	*Pounds*	*Pounds*
0-10-7	13,644	10,851	24,353
2-10-7	19,213	12,991	25,282
4-10-7	18,659	14,088	26,872
6-10-7	18,296	16,511	26,186
8-10-7	14,253	17,354	23,193
8-10-7 + lime	17,770	21,992	25,770

[1] Vetch was the winter legume for sweet corn in 1943-45 and for sweetpotatoes 1943-45 and 1947. In other years blue lupine was grown and turned.

APPENDIX TABLE 9. TOTAL NITROGEN IN MATERIALS USED AS MANURES

Materials used[1]	Total nitrogen
Kind	*Per cent*
Alabama peat, dry	1.272
Corn stalks, mature dry	0.515
Corn stalks, immature green[2]	1.080
Cowpea vines, mature green	0.527
Crotalaria, mature dry	0.740
Crotalaria, mature green	0.323
Lespedeza straw[3], mature dry	0.899
Oat straw, mature dry	0.554
Peanut hulls	0.845
Pine straw	0.311
Soybean vines, mature dry	0.635
Soybean vines, mature green	0.777
Vetch, mature green	0.658
Stable manure with straw, dry	1.936

[1] All materials referred to as dry were air dried; mature dry represents plants that matured and dried before taken from field.

[2] Immature green corn stalks represent stalks of approximately one-half mature size and were grown on area following vegetables that had received high rates of fertilizer.

[3] Sericea lespedeza straw used had only a portion of its leaves.