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EXPERIMENTS WITH LEGUMES IN ALABAMA

By

R. Y. BAILEY

J. T. WILLIAMSON

J. F. DUGGAR

AGRICULTURAL EXPERIMENT STATION

OF THE

ALABAMA POLYTECHNIC INSTITUTE

M. J. FUNCHESS, *Director*

AUBURN, ALABAMA

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* Station Staff as of March 1, 1930
** Assigned by the State Department of Agriculture and Industries
***In cooperation with U. S. Department of Agricultural Economics and Georgia Experiment Station

EXPERIMENTS WITH LEGUMES IN ALABAMA

By

R. Y. BAILEY
Assistant Agronomist

J. T. WILLIAMSON
Associate Agronomist

J. F. DUGGAR
Research Professor in Farm Management

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Experiments With Legumes in Alabama

INTRODUCTION

ONE of the first problems studied at the Alabama Experiment Station was that of soil fertility. This phase of work has received the attention of this station for more than thirty-five years and is still considered a problem of major importance. Many experiments have been conducted for the purpose of studying the effects of legumes turned under on the yields of succeeding crops. Other experiments have been conducted for the purpose of determining which legumes are best suited to Alabama conditions and for the purpose of studying some of the problems involved in the successful growing of these legumes.

Prior to 1910 this station conducted a number of tests with winter legumes in co-operation with Alabama farmers. For some reason legumes planted in these tests failed more often than the legumes in the tests at Auburn. When the Local Experiment Fund was made available in 1911, co-operative tests which were supervised by a station representative were started. The purpose of these earlier tests was to determine why legumes were grown less successfully over the State than at Auburn and to find out which legumes were best adapted to Alabama conditions.

The results of this earlier work emphasized the need of phosphorus and the inoculation of legumes by the proper bacteria. Consequently, all of the experiments with winter legumes conducted by the Alabama station have received phosphorus; and if the land had not already been properly inoculated bacteria were applied.

This bulletin records results of experiments with legumes by the Alabama Experiment Station from 1896 through 1929. With the exception of analyses of legumes, the data reported have been obtained through investigations carried on in the field. The greater part of the results herein reported has been obtained from experiments at Auburn; co-operative experiments, however, have afforded a part of the data as well as giving valuable leads for planning experiments on the station farm.

Experiments were conducted to study the influence of legumes on the yields of succeeding crops; residual effect of legumes; influence of fertilizers and lime on yields of legumes; time, method, and rate of seeding legumes; yields of legumes at different stages of growth; nitrogen content of legumes; seed production of legumes; and the effect of low temperatures on legumes.

INFLUENCE OF LEGUMES ON CROP YIELDS

The Value of Legumes in Rotation.—The value of legumes in the cropping system has been shown by a long, continued experiment conducted at the Alabama Experiment Station; the average results by ten year periods are given in Table 1. Plots 1 and 2 in this experiment were planted to corn each year since the experiment was started. Cowpeas were planted in the corn middles on Plot 1, at the last cultivation from the beginning of the experiment until 1925, after which fall planted vetch was substituted for cowpeas planted in the summer. All cowpeas and vetch were plowed under for the next crop of corn. No legumes were planted on Plot 2. The average results on Plot 2 show a steady decline in yield. Plot 1, which has been planted to corn each year with legumes in the corn middles, has produced slightly more corn during the last ten years than during the first ten years of the experiment. This plot is now producing more than twice as much corn as Plot 2. A study of the yields for the first twenty years shows that cowpeas planted in the corn middles did not maintain the yield of corn on Plot 1. The cowpeas that were turned under on this plot resulted in

FIGURE 1.—Austrian winter peas following continuous corn. At this stage, the growth amounted to 12,000 pounds of green material per acre. (Plot 1, Old Rotation Experiment. Photographed and sampled March 29, 1930.) See Table 1.

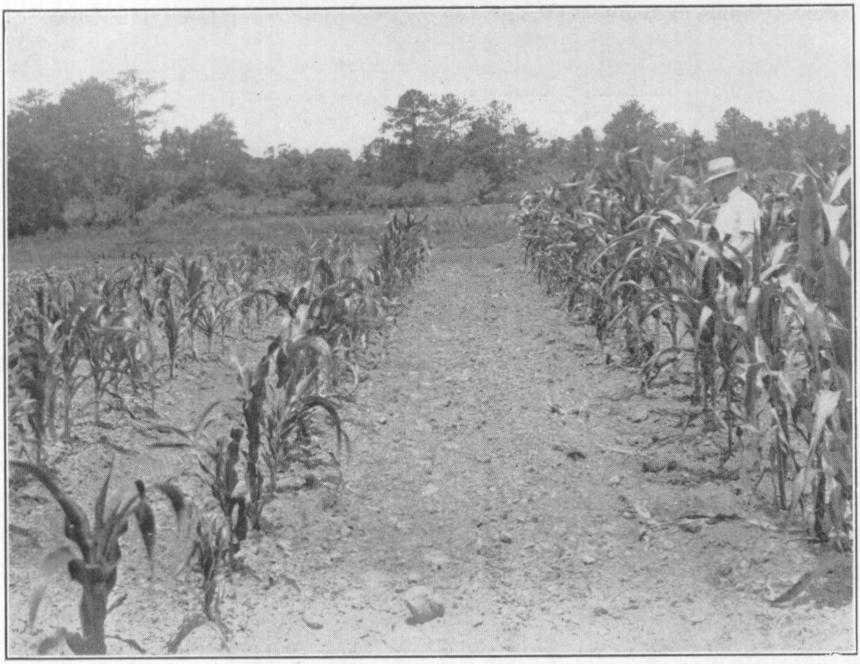

FIGURE 2.—The 34th consecutive crop of corn with and without legumes annually. Corn on right following legumes yielded 33.8 bushels; on left, without legumes, corn produced 8.9 bushels per acre. (Plots 1 and 2, Old Rotation Experiment. Photographed June 20, 1929.) See Table 1.

an increase of 6 bushels of corn per acre over Plot 2 during the second ten-year period, 1906-1915. Vetch was substituted for cowpeas in 1925; since that time the average yield on Plot 1 has increased slightly above that for the first ten years.

The value of legumes was further shown by the results obtained from other plots in this experiment. Plot 6 has grown cotton continuously without legumes. The yield of seed cotton declined from 803 pounds in the first ten-year period to 349 pounds per acre as the average for the ten-year period from 1920 to 1929, inclusive. Plots 3 and 8 were planted to cotton each year; vetch was planted in the fall to be turned under the following spring for cotton. During the first ten-year period these two plots produced an average yield of 813 pounds of seed cotton per acre; an average of 678 pounds the second ten years; and an average of 756 pounds in the last ten years, 1920 to 1929, inclusive. On Plots 5 and 9 a two-year rotation of cotton, with vetch planted in the cotton middles in the fall, and cowpeas was followed from 1896 until 1923. Vetch and cowpeas were plowed under for succeeding crops. In 1923, and thereafter, the cowpeas were cut for hay and followed by vetch in the fall to be turned the following spring for cotton. This treatment resulted

TABLE 1.—The Effect of Legumes Turned Under on the Yield of Succeeding Crops.

Plot No.	Fertilizers[5]. Lbs. per acre		Cropping system	3 yr. av.[6] yield of vetch. Lbs. green matter per acre	Average yields of crops		
	Super-phosphate	Kainit			First 10 years 1896-1905	Second 10 years 1906-1915	Last 10 years 1920-1929[4]
					Corn—bushels per acre		
1	160	160	Corn each year. Peas at last cultivation[1]	12,918	19.2[3]	16.2	19.4
2	160	160	Corn each year, no peas		17.1[3]	10.2	8.2
					Seed Cotton—pounds per acre		
6	160	160	Cotton continuously, no legumes		803	573	349
3 & 8	160	160	Cotton and vetch continuously Vetch as cover crop	9,570	813	678	756
5 & 9	160	160	Cotton and vetch. Cowpeas[2]	10,904	890	958[3]	1,041

[1] Changed to corn and vetch in 1925.

[2] In 1923 and after, peas cut for hay and followed by vetch.

[3] Only 9 crops.

[4] Cotton and corn failed on all plots in 1925, due to drought. Ten year average of 9 crops.

[5] In the fall of 1921, 400 pounds superphosphate were applied to the west half of each plot. This was repeated on the same half of each plot in the fall of 1922. The east half of all plots received 800 pounds of superphosphate in the spring of 1923 to equalize the phosphate application. In the fall of 1923, and each fall since, 400 pounds of superphosphate per acre have been applied to the whole of each plot.

[6] Yields for 1926, 1927, and 1929.

in an increase of 151 pounds of seed cotton per acre for the last ten years over the average for the first ten years.

Each plot in the experiment discussed above was fertilized alike so that the differences obtained in yields were due to the legumes that were turned under. Vetch crops were poor prior to 1923. Beginning in 1923, and thereafter, each plot has received an application of 400 pounds of superphosphate per acre in the fall. Since this additional phosphorus treatment was started, the vetch crops have been entirely satisfactory. A comparison of the cotton yields on Plots 3 and 8 for the second ten years with the yields for the last ten years shows that the increased amount of vetch turned under materially increased the yields of cotton. This is especially interesting since the average for the last ten years is a ten year average of only nine crops.

The value of legumes in the cropping system and the effect of phosphorus on legumes are clearly shown by the data presented in Table 2. In this experiment cowpeas and vetch were used as much as possible in a three-year rotation of corn, cot-

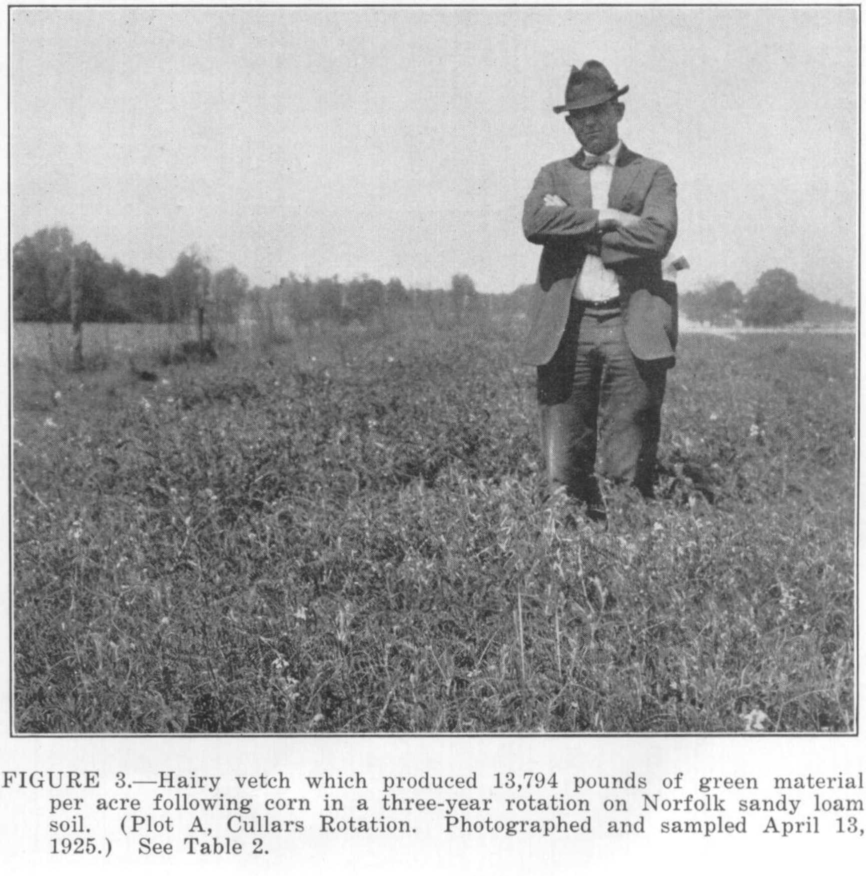

FIGURE 3.—Hairy vetch which produced 13,794 pounds of green material per acre following corn in a three-year rotation on Norfolk sandy loam soil. (Plot A, Cullars Rotation. Photographed and sampled April 13, 1925.) See Table 2.

TABLE 2.—Influence of Legumes Turned Under on the Yields of Cotton and Corn Grown in a Three Year Rotation.

Plot	Fertilizer treatment Pounds per acre	Legumes in the cropping system*	Average yields last 9 years		Increase due to legumes	
			Seed cotton. Pounds per acre	Corn. Bushels per acre	Seed cotton. Pounds per acre	Corn. Bushels per acre
A	240-Superphosphate 50-Muriate of potash	Summer and winter	514	32.0	397	24.2
B	240-Superphosphate 50-Muriate of potash	None	117	7.8	---	---
C	None	None	98	11.7	---	---
1	None	Summer and winter	221	20.9	123	8.2

* Two year average yields of green matter turned under were: Plot A, 9,661 and Plot 1, 2,311 pounds per acre.

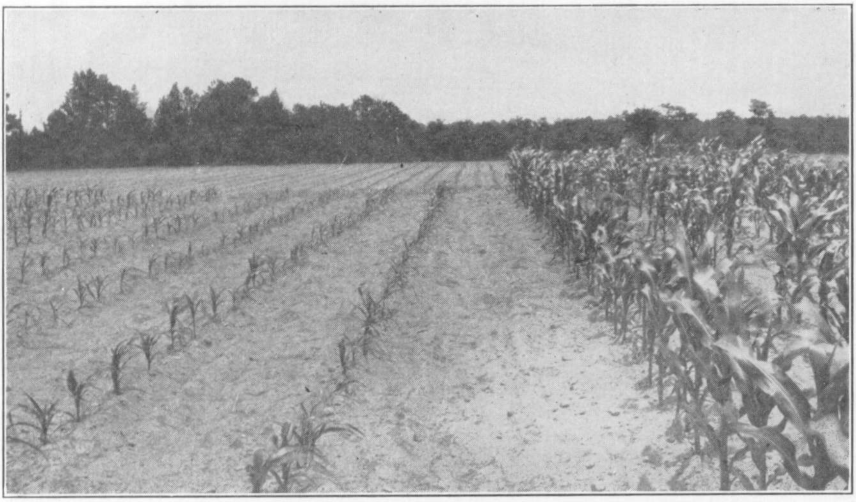

FIGURE 4.—Corn in a three-year rotation. The plot on the right, following legumes, produced 43.2 bushels per acre; the plot on the left, without legumes, produced 4.5 bushels per acre. (Plots A and B, Cullars Rotation. Photographed June 20, 1929.) See Table 2.

ton, and oats. Plots A and B were fertilized exactly alike, the only difference in treatment being that Plot A had summer and winter legumes in the rotation. Plots A and 1 had legumes in the rotation, but Plot 1 received no phosphate and potash.

Plot A, which had legumes in the rotation, produced more than four times as much cotton and corn during the last nine years as Plot B which had no legumes. A comparison of the yields on Plots A, B, C, and 1 shows that phosphate and potash alone did not increase the yield of corn and increased the yield of cotton only 19 pounds of seed cotton per acre. When applied in the cropping system with legumes, phosphate and potash resulted in an increase of 11 bushels of corn and 293 pounds of seed cotton per acre.

In another experiment conducted at the Alabama Experiment Station, stable manure, nitrate of soda, and winter legumes as sources of nitrogen for cotton and corn were compared. This experiment was started in the fall of 1924. Each treated plot in the experiment received essentially the same phosphorus and potash. The stable manure plots received five tons of manure per acre each spring. The manure was applied broadcast and turned under. The nitrate of soda plots received 325 pounds of nitrate of soda per acre annually. The vetch plots received one ton of ground limestone per acre every five years for the benefit of the vetch, which was allowed to grow until about April 1 before being turned under. The experiment was divided into two sections on which cotton and corn were alternated.

FIGURE 5.—Monantha vetch following corn. This vetch, which preceded the cotton shown in Figure 6, produced 14,983 pounds of green material per acre. (Plot 4, Manure-Nitrate-Vetch Experiment. Photographed and sampled March 22, 1927.) See Table 3.

FIGURE 6.—Cotton, following the monantha vetch shown in Figure 5, which produced 1,626 pounds of seed cotton per acre. (Plot 4, Manure-Nitrate-Vetch Experiment. Photographed September 8, 1927.) See Table 3.

FIGURE 7.—Cotton without legumes in a two-year rotation. This crop produced 426 pounds of seed cotton per acre. This is a companion plot to the one shown in Figure 6. (Plot 5, Manure-Nitrate-Vetch Experiment. Photographed September 8, 1927.) See Table 3.

The average yields for five years and other details of this experiment are presented in Table 3.

Plots 4 and 9, on which vetch was turned under, have produced slightly more cotton and 4.8 bushels of corn per acre less than plots which received 325 pounds of nitrate of soda per acre. Stable manure produced 240 pounds more seed cotton and 7.4 bushels more corn per acre than vetch. Vetch was killed by cold in 1928 and destroyed by rabbits on Plot 9 in 1929. The average yields represent the results of four crops of vetch on Plot 4 and three crops on Plot 9 as compared with five applications of manure and nitrate of soda on Plots 2, 3, 7, and 8.

TABLE 3.—Influence of Stable Manure, Nitrate of Soda, and Vetch on the Yields of Cotton and Corn.

Plot	Fertilizer treatment. Pounds per acre	Five-year average*** yield of vetch. Pounds green matter per acre	Yields per acre Five-year average 1925-1929	Average increase over checks
			Pounds seed cotton	
1 & 5	No fertilizer		331	
2	5 Tons manure 400 Superphosphate		1,471	1,140
3	325 Nitrate of soda 600 Superphosphate 100 Muriate of potash		1,222	891
4	Vetch* 600 Superphosphate** 100 Muriate of potash	7,007	1,231	900
			Bushels of corn per acre	
6 & 10	No fertilizer		7.9	
7	5 Tons manure		38.3	30.4
8	325 Nitrate of soda 200 Superphosphate 100 Muriate of potash		35.7	27.8
9	Vetch* 400 Superphosphate** 100 Muriate of potash	6,855	30.9	23.0

* One ton of lime per acre was applied to Plots 4 and 9 every 5 years.

** Plots 4 and 9 received 400 pounds of superphosphate and 100 pounds of muriate of potash per acre in the fall when vetch was planted. The plot on which cotton was planted received 200 pounds of superphosphate before cotton was planted in the spring.

*** Monantha vetch on Plots 4 and 9 was killed by cold in 1928. Austrian winter peas that were planted on these plots in January produced only 1900 pounds of green matter per acre. Rabbits damaged vetch and Austrian winter peas on Plot 9 so severely in 1929 that only 809 pounds of green matter per acre were produced.

FIGURE 8.—Corn following vetch in a two-year rotation on Norfolk sandy loam soil; yield, 44.9 bushels per acre. (Plot 4, Manure-Nitrate-Vetch Experiment. Photographed July 11, 1926.) See Table 3.

FIGURE 9.—Corn without legumes in a two-year rotation, yielded 5.3 bushels per acre. (Plot 5, Manure-Nitrate-Vetch Experiment. Photographed July 11, 1926.) Compare with Figure 8. See Table 3.

The Value of Legumes in Continuous Cropping Systems.—During the last five years, 1925 to 1929 inclusive, experiments were conducted at the Alabama Experiment Station to study the effect of vetch turned at different dates on the yields of cotton and corn. Vetch was turned on approximately the following dates: March 25, April 5, and April 15. Cotton and corn were usually planted about ten days or two weeks after the vetch was turned.

The corn experiment, the results of which are shown in Table 4, included plots that were fertilized with nitrate of soda at

FIGURE 10.—Hairy vetch which produced 5,881 pounds of green material per acre. (Plot 12, Time of Turning Vetch for Corn Experiment. Photographed and sampled April 13, 1926.) See Table 4.

different rates. Two plots adjacent to each vetch plot were planted on the same date as the vetch plot. The rate of application of nitrate of soda was increased as the date of turning the vetch was delayed because of the increasing amount of nitrogen applied by the late-turned vetch. The experiment was divided into two sections for spacing tests, one section being spaced 18 inches and the other 36 inches in the drill. Each plot in the experiment was fertilized alike with phosphate and potash.

The average yields of corn following vetch turned March 25, April 5, and April 15 were 22.6, 29.3, and 29.5 bushels per

TABLE 4.—Yields of Corn Following Vetch Turned at Different Stages of Growth.

Plot	Fertilizer treatment.* Pounds per acre	Planting date	Date of turning vetch	Four-year average*** yield of legumes. Pounds green matter per acre	Average yields 1925**-1929, bus.		Increase due to treatment, bus.	
					Spacing		Spacing	
					18″	36″	18″	36″
1, 5, 9 and 13	None	April 5			7.1	8.9		
2	100 Nitrate of soda	April 5			13.9	13.0	6.8	4.2
3	200 Nitrate of soda	April 5			19.4	15.2	12.3	6.4
4	Vetch ***	April 5	March 25	5,259	22.6	19.6	15.5	10.8
6	200 Nitrate of soda	April 20			22.1	20.9	15.0	12.1
7	300 Nitrate of soda	April 20			25.4	21.7	18.3	12.9
8	Vetch ***	April 20	April 5	8,849	29.3	24.9	22.2	16.1
10	200 Nitrate of soda	May 1			22.1	19.4	15.0	10.6
11	400 Nitrate of soda	May 1			26.6	22.3	19.5	13.5
12	Vetch ***	May 1	April 15	12,072	29.5	25.8	22.4	17.0

* All plots received 400 pounds of superphosphate and 50 pounds of muriate of potash per acre in 1925 and 1926. One ton of 16 per cent basic slag per acre was applied to Plots 4, 8, and 12 in the fall of 1926, and on all other plots in the spring of 1927. No fertilizer has been applied since the spring of 1927. Hereafter, all plots will receive 1 ton of basic slag and 250 pounds of muriate of potash per acre once every 5 years.

** Yields in 1925 were very low due to drought.

*** Vetch was killed by cold in January 1928.

FIGURE 11.—Corn following early-turned vetch produced 26.1 bushels per acre. (Plot 4, Time of Turning Vetch for Corn Experiment. Photographed July 11, 1926.) See Table 4.

acre, respectively. The plot on which vetch was turned under made a higher average yield in each case than the adjacent nitrate plots that were planted at the same time. Plots 3, 6, and 10 received 200 pounds of nitrate of soda per acre, but were planted at different dates. There was a variation of only 2.7 bushels per acre in the yields on plots planted April 5, April 20, and May 1. Vetch was killed by cold in 1928 and the yields shown in Table 4 represent a comparison of four crops of vetch and five applications of nitrate of soda. The average yields of corn on untreated plots were higher on the 36 inch spacing section, whereas, on the treated plots the yields were higher when spaced 18 inches apart.

The average results of the cotton experiment are presented in Table 5. Plot 3 which was turned March 25 produced 59 pounds of seed cotton per acre more than Plot 4 which was turned April 5, and 133 pounds more than Plot 6 which was turned April 15. These data indicate that early planting of cotton is a more important factor in this experiment than the increase in the growth of vetch on the later turned plots. Nitrate of soda at the rate of 300 pounds per acre was applied on

FIGURE 12.—Corn, without legumes, which produced 4.7 bushels per acre. (Plot 5, Time of Turning Vetch for Corn Experiment. Photographed July 11, 1926.) Compare with Fig. 11. See Table 4.

Plots 2 and 7 of this experiment. Plot 2 which was planted on April 5 made 49 pounds of seed cotton per acre more than Plot 7, which was planted on April 30. This further emphasizes the importance of planting cotton early. In other words, turning legumes as early as sufficient growth has been made to supply a reasonable amount of nitrogen is preferable to delaying turning until maximum growth has been made and subsequently delaying the planting date of cotton.

The data in Table 5 show that applications of 300 pounds of nitrate of soda per acre produced 68 pounds of seed cotton per acre more than early turned vetch and 152 pounds more than late turned vetch. The planting dates of the corresponding vetch and nitrate plots were the same. The increases in yields of seed cotton per acre due to vetch ranged from 593 pounds for early turned to 460 pounds for late turned vetch. All plots in this experiment were uniformly treated with phosphorus and potash.

TABLE 5.—The Effect of Vetch Turned Under at Different Stages of Growth on the Yields of Cotton.

Plot	Legume and nitrate treatment*	Date of turning vetch	Date of planting cotton	Five-year average yields of green vetch per acre	Five-year average yields of seed cotton per acre	Average increase over check plots
				Pounds	Pounds	Pounds
5 & 8	None		April 5		373	
2	Nitrate of soda		April 5		1,034	661
3	Vetch	March 25	April 5	4,542	966	593
4	Vetch	April 5	April 20	9,757	907	534
6	Vetch	April 15	April 30	9,992	833	460
7	Nitrate of soda		April 30		985	612

* Each plot in the experiment received 600 pounds of superphosphate and 75 pounds of muriate of potash per acre annually. Nitrate of soda was applied to Plots 2 and 7 at the rate of 300 pounds per acre.

RESIDUAL EFFECT OF LEGUMES

The Effect of Vetch and Annual Yellow Melilotus Turned in 1925, 1926, and 1927 on the Yields of Corn and Cotton in 1928. —The severe freeze in January 1928 killed monantha vetch and annual yellow melilotus on two soil fertility experiments. Immediately after the freeze the land on which these experiments were conducted was plowed to destroy the scattered plants that were not killed by cold. Vetch was grown on the land the three years preceding the freeze in the experiment comparing vetch turned at different dates for corn. The dates of turning vetch, planting corn, and the amounts of nitrate of soda applied to adjoining plots are shown in Table 4. The average yields of green material turned under prior to 1928 and the yields of corn in 1928 are shown in Table 6.

The data presented in Table 6 show that the vetch residue on the plot which was turned early produced more corn than 100 pounds of nitrate of soda on an adjoining plot. The plot on which vetch was turned April 5 produced more corn than adjoining plots which received 200 and 300 pounds of nitrate of soda per acre. The vetch residue on the plot which was turned late produced nearly twice as much corn as 200 pounds of nitrate of soda and approximately as much as 400 pounds of nitrate of soda on adjacent plots. The comparisons are made on the section in which corn was spaced 18 inches apart.

TABLE 6.—Residual Effect of 1925-1927 Turned Vetch on 1928 Corn Yields.

Plot	Date of turning vetch	Date of planting corn	Pounds of nitrate of soda per acre	3 yr.* av. yield of vetch. lbs. green wt. per acre 1925-1927	Yields of corn in 1928. Bushels per acre		Increase over 1928 check yields. Bushels per acre	
					Spacing		Spacing	
					18″	36″	18″	36″
1 & 5		April 5			6.1	7.3		
2		April 5	100		11.7	12.1	5.1	4.8
3		April 5	200		22.6	14.7	16.5	7.4
4	March 25	April 5		4,629	16.0	13.9	9.9	6.6
5 & 9		April 5			9.4	8.3		
6		April 20	200		22.0	15.7	12.6	7.6
7		April 20	300		26.3	16.9	16.9	8.6
8	April 5	April 20		8,147	28.9	17.6	19.5	9.3
9 & 13		April 5			12.9	7.9		
10		May 1	200		25.0	21.7	12.1	13.8
11		May 1	400		36.8	29.0	23.9	21.1
12	April 15	May 1		12,014	34.6	22.8	21.7	15.9

* Monantha vetch on these plots was killed by cold in 1928.

In another experiment vetch and annual yellow melilotus, with two rates of liming, were grown the three years preceding the freeze. The legumes were turned under each spring and followed by cotton. The fertilizer treatment and the average yields of cotton are shown in Table 10. The average yields of green material produced by the legumes in 1925 and 1927 and the cotton yields in 1928 are shown in Table 7. The yields of green material for 1926 were not recorded. Melilotus practically failed in 1925.

TABLE 7.—Residual Effect of Vetch and Annual Yellow Melilotus Turned in 1925, 1926, and 1927 on 1928 Cotton Yields.

Plot	Legume crop	Average yield green matter. Lbs. per acre 1925 & 1927	Pounds of seed cotton per acre	
			1928	Increase over yield of check plots
1, 4, 7 and 10	None		103	
2	Vetch	8,983	204	101
5	Vetch	10,713	348	245
6	Melilotus	10,010*	308	205
8	Vetch	11,393	426	323
9	Melilotus	4,810*	348	245

* 1927 yield only.

A study of the 1928 cotton yields presented in Table 7 shows that all plots on which legumes had grown produced more cotton than the check plots. The average increase of the legume plots over the check plots was 224 pounds of seed cotton per acre.

The residual effect of legumes shown in Tables 6 and 7 would probably have been greater in 1928 but for the fact that heavy rains in late May and early June of that year leached some of the nitrogen out of the soil. As evidence that leaching took place, analyses of soil samples taken at different depths on July 21, 1928 showed that 73 per cent of the nitrogen found was from a layer 16 to 32 inches below the surface of the soil. These analyses also showed that 38 per cent was found at a depth of 24 to 32 inches. Further evidence of leaching was indicated by the appearance of the plants on the plots which received no nitrogen and on the legume plots which showed no visible difference in color or size before the last of June.

On Plot 9 of the experiment comparing manure, nitrate of soda, and vetch as sources of nitrogen for cotton and corn, monantha vetch was killed by cold in 1928. In 1929 monantha vetch and Austrian winter peas on this plot were so severely damaged by rabbits that only 809 pounds of green matter per acre were produced. According to the analyses made in the laboratory this green matter contained 5.2 pounds of nitrogen. By comparing the yields of the unfertilized check plot with plot 8, which received 325 pounds of nitrate of soda, it was found that one pound of nitrogen produced 0.53 bushel of corn. Calculated on this basis the 5.2 pounds of nitrogen contained in the vetch and peas turned under in 1929 would have produced 2.8 bushels of corn per acre. Plot 9 produced 15.9 bushels more corn per acre in 1929 than the check plots. Since 2.8 bushels of this difference could have been due to the legumes turned under in 1929, the residual value of 1927 turned vetch to the 1929 crop of corn may be assumed as 15.9 less 2.8 or 13.1 bushels per acre.

Effect of Kudzu on the Yields of Succeeding Crops.—In another experiment kudzu was planted in the early spring of 1916 and turned under in the spring of 1919. The kudzu made little growth in 1916, covered the ground in 1917, and made a dense growth in 1918. From 1919 through 1929 two crops of sorghum hay, four crops of corn, and seven crops of oats were grown on the area devoted to this experiment. The average yields of sorghum hay, corn, and oats are presented in Table 8.

TABLE 8.—Influence of Kudzu on the Yields of Succeeding Crops.

Plot	Growth of kudzu	Average yields of following crops		
		2 Crops sorghum hay. Pounds per acre	4 Crops corn. Bushels per acre	7 Crops oats. Bushels per acre
1	No kudzu	3,264	14.7	16.6
2	Kudzu	5,800	34.0	24.5

The results in Table 8 show that the residue from kudzu produced an average increase of 2,536 pounds of sorghum hay per acre in 1919 and 1920. The average yield of four crops of corn following kudzu was more than double the yield on the plot that had not grown kudzu. The average yield of seven crops of oats on the kudzu plot was 7.9 bushels per acre more than that on the plot which had grown no kudzu. In 1929, ten years after the kudzu was turned under, the kudzu plot produced 9.2 bushels of oats per acre more than the plot on which kudzu had never grown.

CULTURAL EXPERIMENTS WITH LEGUMES

Effect of Fertilizing Materials on the Growth of Legumes.—In order to determine the influence of superphosphate; superphosphate and ground limestone; and superphosphate, ground limestone, and stable manure on the yields of winter legumes grown in rotation, cuttings were made from plots so fertilized in rotation experiments located near Andalusia, Hackleburg, Prattville, and Sylacauga. The yields reported in Table 9 were calculated on the basis of cuttings of the green tops from two or three small areas on one-twentieth acre plots. The areas harvested totaled approximately 100 square feet. Monantha vetch was the crop harvested at Andalusia during each of the three

FIGURE 13.—Hairy vetch on unfertilized plot (No. 5) of a two-year rotation experiment on Norfolk sandy soil near Andalusia. Yield, 120 pounds of seed cotton per acre. See Figs. 14 and 15. (Photographed April 1, 1926.) See Table 9.

years; at Hackleburg hairy vetch was used in 1927 and a mixture of hairy and monantha vetch in 1929; at Prattville the crop was monantha vetch; and at Sylacauga hairy vetch was grown.

The superphosphate and stable manure were each applied immediately before planting the winter legume. The ground limestone was applied in 1923 at Hackleburg, Sylacauga, and Prattville, and in 1924 at Andalusia. The rates of application per acre were as follows: 400 pounds of superphosphate, 4,000

TABLE 9.—Influence of Superphosphate, Ground Limestone, and Stable Manure on the Yields of Winter Legumes in Rotation.

Soil treatment	Green weight per acre in pounds			
	Andalusia average 3 crops 1927-28-29	Hackleburg average 2 crops 1927 & 1929	Prattville 1929 crop only	Sylacauga 1927 crop only
No treatment	4,865	2,269	3,630	1,589
Superphosphate	13,186	10,802	5,929	8,474
Superphosphate Ground limestone	20,542	14,665	11,071	7,718
Superphosphate Ground limestone Stable manure	24,054	18.876	11,071	16.798

FIGURE 14.—Hairy vetch fertilized with phosphate (Plot No. 2) in a two year rotation on Norfolk soil near Andalusia. Yield, 330 pounds of seed cotton per acre. See Figs. 13 and 15. (Andalusia Field. Photographed April 1, 1926.) See Table 9.

pounds of ground limestone (marble dust used at Sylacauga), and 6 tons of stable manure.

The importance of superphosphate for winter legumes is emphasized by the results given in Table 9. The increase due to this material was 8,321 pounds of green matter per acre or approximately 200 per cent at Andalusia. At Hackleburg the increase was 8,533 pounds per acre with a still greater percentage increase than at Andalusia. The single crops harvested at Prattville and Sylacauga both further emphasize the importance of phosphorus.

The importance of lime under the conditions of these tests is almost as great as that of phosphate. The increases due to lime were 7,356 pounds at Andalusia, 3,863 pounds at Hackleburg, and 5,142 pounds per acre at Prattville. The slight loss at Sylacauga may be due to the possibility that enough marble dust particles to satisfy the lime requirement of the soil may have been blown from a marble refuse crushing plant located approximately a mile from the area.

Six tons of stable manure per acre used in connection with superphosphate and ground limestone increased the yield of

FIGURE 15.—Hairy vetch on limed plot (No. 6) fertilized with phosphate. Yield, 1,050 pounds of seed cotton per acre. See Figures 13 and 14. (Andalusia Field. Photographed April 1, 1926.) See Table 9.

green material per acre from 20,542 pounds to 24,054 pounds at Andalusia, from 14,665 pounds to 18,876 pounds at Hackleburg, from 7,718 pounds to 16,798 pounds at Sylacauga, and caused no increase on the single crop harvested at Prattville.

In another experiment conducted by the Alabama Experiment Station at Auburn on Norfolk sandy loam soil during the past five years, vetch and annual yellow melilotus were grown during the winter on plots that were cropped each year to cotton. Plots 5 and 6 of this experiment received an application of two tons of ground limestone per acre every five years. Plots 8 and 9 received 400 pounds of 16 per cent basic slag annually instead of superphosphate as a source of phosphorus and an additional application of one-half ton of basic slag per acre every five years. On Plot 3, which had no lime, annual yellow melilotus failed each year. Although the plants on this plot were inoculated and supplied with sufficient phosphorus and potash, none of them lived long enough to make growth. The average results of this experiment in Table 10 show that on Plots 6 and 9 the addition of lime increased the growth of melilotus, which when turned under resulted in an increase of 378 pounds of seed cotton per acre on Plot 6 and 312 pounds on Plot 9. These results show that Plot 6, which received ground limestone, produced 66

TABLE 10.—Effects of Vetch and Annual Yellow Melilotus With and Without Lime on the Yield of Cotton.

Plot No.	Fertilizer treatment. Pounds per acre	Legume crop	Average[4] yields of legumes. Lbs. of green matter per acre	Pounds of seed cotton per acre — Five-year average 1925-1929	Increase over average of check plots
1, 4, 7, and 10	400 Superphosphate 50 Muriate of potash	None		260	---
2	400 Superphosphate 50 Muriate of potash	Vetch	7,418	728	468
3	400 Superphosphate 50 Muriate of potash	Annual yellow melilotus[3]	None	237	–23
5	400 Superphosphate 50 Muriate of potash 2 Tons lime[1]	Vetch	8,157	794	534
6	400 Superphosphate 50 Muriate of potash 2 Tons lime[1]	Annual yellow melilotus	5,537	638	378
8	400 Basic slag 50 Muriate of potash ½ Ton basic slag[2]	Vetch	8,080	719	459
9	400 Basic slag 50 Muriate of potash ½ Ton basic slag[2]	Annual yellow melilotus	2,648	572	312

[1] Lime every 5 years.
[2] When Plots 5 and 6 were limed.
[3] Melilotus failed on this plot due to a lack of lime.
[4] Average of 3 crops of vetch and 2 crops of melilotus.

pounds of seed cotton per acre more than Plot 9, which received basic slag. The average results and other details of this experiment are presented in Table 10.

The difference between cotton yields on vetch and melilotus plots that were limed was due largely to the fact that the stand of melilotus was reduced by freezing some years when vetch was not injured.

A further study was made on the fields at Hackleburg, Sylacauga, Prattville, and also at Cusseta to determine the influence of ground limestone on the yields of summer legumes. The summer legume on which yields were taken followed an oat crop which was grown after corn in a regular three-year rotation. Either cowpeas or soybeans were used as the summer legume on these areas. Table 11 gives the average green weight from three limed and three unlimed plots on each area from 1923 to 1929.

TABLE 11.—Effect of Lime on the Yield of Summer Legumes Following Oats in a Three Year Rotation.

Rotation: Winter Legume, Cotton, Winter Legume, Corn, Oats, Summer Legume

Field	Soil type	Pounds green material per acre*		Percentage increase from liming
		Unlimed**	Limed**	
Hackleburg	Ruston loam	5,139	8,172	59
Sylacauga	Decatur clay loam	3,911	5,259	34
Prattville	Greenville sandy loam	4,957	8,293	67
Cusseta	Cecil clay loam	3,315	5,569	68
Average		4,331	6,823	58

* Average six crops at Hackleburg, five crops at Prattville, and four crops each at Sylacauga and Cusseta.

** Average of three plots.

A study of Table 11 reveals the fact that lime increased the average yield of green material by 34 per cent on Decatur soil, 59 per cent on Ruston soil, 67 per cent on Greenville soil, and 68 per cent on Cecil soil. The average increase due to liming was 58 per cent.

Time, Rate, and Methods of Seeding Winter Legumes.—An experiment comparing the effect of different methods of seeding hairy vetch, monantha vetch, and Austrian winter peas was started in the fall of 1926 and completed in the spring of 1929. Plantings were made in drills 12 inches apart and broadcast September 30, October 26, November 23, and December 19. Seeding was at the rate of 20 pounds per acre for hairy and monantha vetch and 45 pounds per acre for Austrian winter peas. All plots in the experiment were harvested at the same time and the amounts of green matter per acre were determined. The average yields and other details of the experiment are shown in Table 12.

A study of the results presented in Table 12 shows that each of the three legumes made higher yields when drilled than when broadcast. The relative increase in yields due to drilling was greater on the November and December plantings than on the earlier plantings. The increase due to drilling, however, does not offset the effects of late planting. The three-year average yield of hairy vetch was low when drilled and when broadcast. The unusually poor growth of hairy vetch in this experiment was

FIGURE 16.—Austrian winter peas shown in the foreground were seeded November 23. September 29 seeding shown in the background. (Experiment on Time and Rate of Seeding Winter Legumes. Photographed April 4, 1926.) See Table 13.

TABLE 12.—Pounds of Green Material Per Acre on the Methods of Seeding Experiment of Hairy Vetch, Monantha Vetch, and Austrian Winter Peas 1927-1929.

Date of planting	Three Year Average, 1927-1929					
	Broadcast			Drilled		
	Hairy vetch	Monantha vetch	Austrian winter peas	Hairy vetch	Monantha vetch	Austrian winter peas
September 30	2,393	8,613	5,186	3,100	10,492	6,906
October 26	1,109	5,428	3,455	1,966	5,912	5,061
November 23	442	1,890	1,928	852	3,063	3,216
December 19	113	347	651	210	903	1,283

due largely to the effect of anthracnose which seriously injured the 1928 and 1929 crops. November and December plantings of monantha vetch and Austrian winter peas failed to produce sufficient yields of green material to supply enough nitrogen for the needs of succeeding crops.

Time and rate of seeding are important factors in the production of winter legumes. The results of many winter legume experiments prior to 1927 indicated that a large per cent of the failures with these crops had been due to late planting. An experiment was conducted during the three-year period, 1927-1929, to determine the effect of the date and rate of seeding hairy vetch, monantha vetch, and Austrian winter peas. The dates and rates of seeding and the average results of this experiment are presented in Table 13.

TABLE 13.—Pounds of Green Material Per Acre on the Time and Rate of Seeding Experiment of Hairy Vetch, Monantha Vetch, and Austrian Winter Peas.

Hairy Vetch		Monantha vetch		Austrian winter peas	
Seeding rate. Pounds per acre	Yield per acre. Pounds 1927-29	Seeding rate. Pounds per acre	Yield per acre. Pounds 1927-29	Seeding rate. Pounds per acre	Yield Per acre. Pounds 1927-29
Planted September 30					
10	1,027	10	8,393	30	7,412
20	1,577	20	9,240	45	8,138
30	2,228	30	9,211	60	8,653
Planted October 26					
10	791	10	5,308	30	4,747
20	1,682	20	6,949	45	5,668
30	1,893	30	7,700	60	6,931
Planted November 23					
10	354	10	1,442	30	2,313
20	676	20	2,000	45	3,322
30	918	30	2,930	60	3,669
Planted December 19					
10	None	10	594	30	835
20	None	20	947	45	1,393
30	None	30	1,312	60	1,562

A study of the data presented in Table 13 shows that the yields of hairy vetch were low on all dates and at all rates of seeding. The yield from 20 pounds of seed per acre more than doubled the yield secured from 10 pounds on the October planting. Twenty pounds of seed produced 70 per cent as much green matter as 30 pounds when planted in September. When planted in October 20-pounds of seed produced 83 per cent as much green matter as 30 pounds. November and December plantings practically failed at all rates of seeding.

Monantha vetch produced sufficient green matter to supply approximately 60 pounds of nitrogen per acre when seeded at the rate of 10 pounds per acre on September 30. The value of early planting is well shown by the fact that 10 pounds of seed planted September 30 produced more green matter than 30 pounds planted October 26. There was no material difference in the yields secured from 20 and 30 pounds of seed. A satisfactory crop was not produced when seeded on or after November 23 regardless of the seeding rate used.

Average yields in Table 13 show that 30 pounds of Austrian winter peas planted September 30 produced as much green matter as 60 pounds planted October 26. No rate of seeding used produced a satisfactory yield of green matter when planting was delayed until November 23. The results of this experiment prove conclusively that early planting is absolutely essential to success in growing the three legumes used in this study. These data also show that a material saving can be made in the amount of seed necessary for success if planting is done early.

The advantage of early seeding is shown in Table 14 which gives the relative yields of vetches and related species grown in rows three feet apart on sandy upland soil at Auburn. The contrasted planting dates were October 1 and November 1. Only those kinds are considered that were harvested in five, four, or three years, as shown in other tables.

TABLE 14.—Increased Yield of Air-dry Matter from October over November Planting.

Kind	In entire season		To April 1	
	Pounds increase	Per cent	Pounds increase	Per cent
Monantha vetch	1,810	70	1,148	190
Woolly-pod vetch	337	11	1,024	122
Oregon vetch	–176	–5	564	76
Austrian winter peas	899	37	860	10
Hairy vetch	795	32	769	136
Crimson clover	539	21	535	97
Hungarian vetch	378	17	551	103
Tangier peas	499	14	1,450	174
Purple vetch	729	32	599	67
Average for 9 species	645	25	833	108

The average increases per acre in dry material due to early planting were 645 pounds or 25 per cent for the late harvest, and 833 pounds or 108 per cent for the early harvest.

Growth and Yields of Winter Legumes.—The rate of growth of winter legumes is of vital importance. The earlier the legumes make sufficient growth to be turned under the earlier the crop that follows may be planted. The importance of early turning of vetch for cotton is shown by the cotton yields on Plots 3, 4, and 6 in Table 4. An experiment was conducted at Auburn during a three-year period, 1927 to 1929, to determine the amount of growth that would be made by hairy vetch, monantha vetch, and Austrian winter peas planted in drills 12 inches apart at different dates in the fall and harvested at different dates in the spring. The planting dates, harvesting dates, and three-year average yields for this experiment are shown in Table 15.

TABLE 15.—Pounds of Green Material Per Acre on the Rate of Growth Test of Hairy Vetch, Monantha Vetch, and Austrian Winter Peas.

Date of Planting	Dates of harvesting				
	March 10*	March 22	April 2	April 17	May 2
	1927-29	1927-29	1927-29	1927-29	1927-29
			Hairy vetch		
Sept. 30	2,581	2,311	2,377	2,023	1,539
Oct. 26	1,569	1,633	1,792	2,136	2,072
Nov. 23	263	415	630	888	1,001
Dec. 19	82	119	160	274	344
			Monantha vetch		
Sept. 30	5,635	7,400	7,719	8,602	6,087
Oct. 26	3,245	5,408	6,027	6,596	5,000
Nov. 23	1,021	1,841	2,657	4,350	5,226
Dec. 19	255	373	670	1,393	2,090
			Austrian winter peas		
Sept. 30	4,728	5,909	6,996	9,436	7,515
Oct. 26	2,846	4,265	5,948	8,724	7,116
Nov. 23	978	1,545	2,372	4,548	4,745
Dec. 19	319	426	761	1,756	2,446

* Harvested March 19, 1929.

The results in Table 15 show that monantha vetch produced more green matter than either hairy vetch or Austrian winter peas on all cuttings up to April 2 except on December plantings. Austrian winter peas produced the highest yield on all cuttings after April 2 except on the November 23 planting. The results of this experiment show that monantha vetch and Austrian winter peas made sufficient growth to turn under by March 22 while hairy vetch made slightly more than half as much growth by that time.

Many kinds of winter legumes were planted in rows three feet apart for harvesting in the spring of 1925, 1926, 1927, 1928, and 1929. A part of each experimental area where the stand was practically perfect was cut close to the ground at various harvest dates each spring and the forage immediately weighed and again weighed after thorough air drying for a number of weeks.

Table 16 records the acre yields at the stage of late full bloom from annual plantings made near October 1 and from those made near November 1.

TABLE 16.—Average Yields in Entire Season of Winter Legumes Planted in Rows October 1 and November 1.

Kind	Number of years averaged		Pounds per acre			
			Planting date			
	Planting date		Oct. 1		Nov. 1	
	Oct. 1	Nov. 1	Green	Dry	Green	Dry
Monantha vetch	5	5	16,701	4,378	8,168	2,536
Woolly-pod vetch	5	5	11,664	3,419	12,220	3,082
Oregon vetch	5	5	11,424	3,003	10,416	3,179
Austrian winter peas	5	5	11,758	3,317	8,392	2,418
Hairy vetch	5	5	11,264	3,271	9,560	2,476
Crimson clover	4	5	10,760	3,090	6,200	2,551
Hungarian vetch	5	4	10,612	2,560	8,070	2,182
Tangier peas	3	4	22,826	4,165	10,790	3,666
Scotch vetch	2	2	7,445	3,930	11,169	3,293
Subterranean clover	3	2	8,009	3,805	4,880	2,656
Purple vetch	3	3	7,815	3,022	7,573	2,293
Canada field peas		3			6,200	2,744
Narrow-leaved vetch, Southern	2	5	9,080	2,240	6,192	1,467
Red clover, first year		1			3,220	1,033

Monantha vetch ranked first for the entire season in average dry weight of the October and November plantings, with woolly-pod vetch second and Oregon vetch third. Next came Austrian winter peas, hairy vetch, and crimson clover, all with practically identical average yields of air-dry material.

Austrian winter peas when allowed to stand until late bloom stage were sometimes reduced in relative rank by the attacks of plant lice. This injury was especially severe following the mild winter of 1926-1927 and again in 1929 when additional injury to this legume was caused by diseases that resulted in a blackening of the leaves and the stems.

Tangier peas ranked at or near the top in years of mild winters but were completely killed in two out of five years. Likewise frequent winter killing subtracted from the apparent productiveness of subterranean clover, purple vetch, and Canada field peas.

Earliness as well as total yield is important, especially when winter legumes are to be used for soil improvement. Therefore, in Table 17 these plants grown in rows three feet apart may be compared on the basis of the yields made by each on or just before April 1.

Among the legumes grown in rows in all five years woolly-pod vetch led in yield produced by April 1 with 1,352 pounds as the average weight of air-dry matter per acre. It was followed by Austrian winter peas with an average of 1,284 pounds and by monantha vetch with 1,179 pounds of air-dry material. The average of October and November plantings was 1,023 for Oregon vetch, 931 for hairy vetch, 818 for crimson clover, 805 for Hungarian vetch, and only 331 pounds for the southern strain of narrow-leaved vetch.

Table 17 shows that Tangier peas, among the kinds which were occasionally winter killed, led the list in yields when it survived, producing an average of 1,556 pounds of air-dry matter per acre.

TABLE 17.—Average Early Yields (by or just before April 1) of Winter Legumes Planted in Three-Foot Rows October 1 and November 1.

Kind	Number of years averaged		Pounds per acre			
	Planting date		Planting date			
			Oct. 1		Nov. 1	
	Oct. 1	Nov. 1	Green	Dry	Green	Dry
Woolly-pod vetch	5	5	9,280	1,864	5,215	840
Austrian winter peas	5	5	9,136	1,714	4,888	854
Monantha vetch	4	5	10,270	1,753	3,715	605
Oregon vetch	5	5	7,440	1,306	3,528	742
Hairy vetch	5	5	6,546	1,336	3,142	567
Crimson clover	4	5	6,520	1,086	3,460	551
Hungarian vetch	5	4	6,027	1,081	3,045	530
Tangier peas	3	4	13,987	2,281	7,125	831
Purple vetch	3	3	7,387	1,490	4,080	891
Canada field peas	2	3	2,960	839	3,333	863
Narrow-leaved vetch, Southern	5	4	2,416	461	869	200

Relative Earliness of Winter Legumes.—Earliness is a desirable characteristic in any winter legume whether it is grown for soil improvement or pasturage. Some measure of the relative earliness of different species is indicated by the dates at which they bloom. The most definite date in the blooming period, and probably the most significant as a measure of relative earliness, is the date when blooming *begins*. Hence, for each of the crop years 1925 to 1929 inclusive, systematic records have been made, showing the dates of earliest blooming for each of the best known winter legumes and for a number of rarely-grown kinds. These dates have been recorded for plants from plantings made at least four times a year, namely, near the first of October, November, December, and the latter part of February.

For reasons of space, the only data summarized in Table 18 are those relative to the initial blooming dates of vetches, peas, vetchlings, and crimson clover, and for only the annual November planting of each. The species are placed in the table in order of earliness.

TABLE 18.—Relative Earliness of Winter Legumes by Initial Blooming Dates, from Plantings Made near November 1.

Kind	Initial bloom dates		Days earlier than hairy vetch	
	Av. '26, '27, '29	Av. '27, '28, '29	Av. '26, '27, '29	Av. '27, '28, '29
Scotch vetch	Mar. 24	———	28	—
Narrow-leaved vetch, southern	Apr. 1	Apr. 2	20	20
Bitter vetch	———	Apr. 4		18
Monantha vetch	Apr. 4	Apr. 5	17	17
Crimson clover	Apr. 8	Apr. 12	13	10
Woolly-pod vetch, commercial	Apr. 13	Apr. 14	8	8
Tangier peas	Apr. 16	———	5	—
Oregon vetch	———	Apr. 18		4
Hairy vetch	Apr. 21	Apr. 22	—	—
Austrian winter peas	———	Apr. 25	Later	–3
Purple vetch	May 8	———	–17 (Later)	

As compared with the initial blooming date of hairy vetch, Scotch vetch was earlier by 28 days, the acclimatized strain of narrow-leaved vetch by 20 days, bitter vetch by 18 days, monantha vetch by 17 days, crimson clover by 10 to 13 days, the commercial strain of woolly-pod vetch by 8 days, Tangier peas by 5 days, and Oregon vetch by 4 days. Austrian winter peas were 3 days later than hairy vetch and purple vetch was 17 days later than hairy vetch. In general the order of earliness from the other three plantings was the same as for that made in November.

NITROGEN CONTENT OF WINTER LEGUMES

Per Cent of Nitrogen in Green Matter.—More than a hundred cuttings of hairy vetch, monantha vetch, and Austrian winter peas were made at various stages of growth to determine the amount of green matter per acre. Samples were taken from these cuttings and analyses made in the laboratory to determine the per cent of nitrogen in the green matter of each of the three legumes. Data showing the average per cent of nitrogen are presented in Table 19.

TABLE 19.—Per Cent of Nitrogen in Green Matter of Hairy Vetch, Monantha Vetch, and Austrian Winter Peas.*

Variety	Number samples	Per cent nitrogen
Hairy vetch	168	1.00
Monantha vetch	161	0.76
Austrian winter peas	180	0.79

*Some of the samples analyzed were supplied by the agricultural department of the Central of Georgia railroad.

Based on the average per cent of nitrogen for each of the three legumes shown in Table 19, it is safe to recommend that hairy vetch be turned under when it has made sufficient growth to cut 5,000 pounds of green matter per acre and that monantha vetch and Austrian winter peas be turned under when they will cut 6,000 pounds of green matter per acre. Stated in terms of green matter per hundred square feet, it is recommended that hairy vetch be turned when it will cut 12 pounds of green material and monantha vetch and Austrian winter peas when they will cut 14 pounds per hundred square feet. If the three legumes are allowed to make the growth outlined above, about 45 pounds of nitrogen per acre will be added to the soil.

THE PRODUCTION AND HARVESTING OF WINTER LEGUME SEED

Regular Variety Test.—During the past five years, 1925 to 1929 inclusive, variety tests of vetches and winter peas were conducted. The most promising varieties were included in these tests. One-half of the area devoted to each variety was cut for hay and the other half harvested for seed. Of the varieties tested, monantha vetch, Austrian winter peas, and Tangier peas were the only varieties that showed any promise as seed producers for this section. The average yields of seed for five years of the three leading varieties were as follows: Monantha vetch 139 pounds, Austrian winter peas 216 pounds, and Tangier peas 225 pounds per acre. Seed from the variety test was not harvested in 1928 because of excessive rainfall at harvest time. A good crop of seed was produced and if harvested would probably have increased the average yields of monantha vetch and Austrian winter peas. Tangier peas were killed by cold in 1928; hence the average yield of this variety would not have been affected. Although Tangier peas have produced some good crops of seed, this variety is not winter hardy, having been killed by cold in January 1928 and in December 1929.

General Field Planting.—General field plantings of about five acres of monantha vetch and Austrian winter peas were made in 1928 and 1929 for seed production. The seed crop from these plantings was grown and harvested under average farm conditions. Excessive rainfall delayed harvesting in 1928, but approximately 400 pounds of seed per acre were harvested.

Harvesting methods were studied in connection with this general field planting. The most satisfactory method used was to allow the plants to become dry, rake with a hay rake without mowing, and thresh in the field. Threshing was done with a grain thresher from which one concave was removed. The speed of the machine was reduced to prevent splitting the seed.

Spring Planting.—Another experiment was started in 1928 to study the effects of spring planting, with different fertilizer treatments, on the yields of seed of monantha vetch and Austrian winter peas. Plantings were made about February 15. All plots in this experiment received a uniform application of 600 pounds of basic slag per acre. One plot planted to each legume was treated with 5 tons of manure per acre and another received 200 pounds of nitrate of soda per acre. The yields of seed produced in 1928 and 1929 from spring plantings for seed production were lower than the yields from fall plantings.

COLD, INSECT, AND DISEASE INJURY TO WINTER LEGUMES

Winter Injury.—Detailed notes were made of the effects produced on each of a large number of winter legumes by the coldest weather of each of the past six winters, 1924-25 through 1929-30.

The severity and date of the coldest weather, according to the readings of the Weather Bureau thermometers in a standard weather shelter at Auburn, in each of these years is shown in Table 20.

TABLE 20.—Minimum Official Temperatures at Auburn.

Winter of	Lowest reading		Next lowest reading	
	F.	Date	F.	Date
1924-25	22	Dec. 26	24	Nov. 25
1925-26	9	Dec. 28	21	Jan. 14
1926-27	11	Jan. 16	24	Dec. 16
1927-28	8	Jan. 2	13	Dec. 9
1928-29	24	Dec. 9	27	Jan. 12
1929-30	16	Jan. 19	18	Dec. 3
do.			19	Dec. 20

Records were made of the effects of these and other temperatures nearly as low on the seedlings of a long list of species, each grown from plantings made near the first day of October, November, and December, respectively. In Table 21 only the effects on the plantings of early October and November are summarized, since the direct cold injury to the December planting was sometimes complicated with fatalities due to the lifting or heaving of the soil. Not every species was subjected to all the cold periods mentioned above.

The species that escaped with no material injury to the seedlings of the plantings made in the early days of October and November were: hairy, woolly-pod and Hungarian vetches, the Southern strain of narrow-leaved vetch (*Vicia angustifolia*), and Austrian winter peas. It now seems safe to class the above mentioned kinds as *winter hardy,* at least as far north as Auburn, Alabama, (latitude 32½ and with an altitude of about 750 feet) when the seeds are planted not later than the first week in November.

The list below embraces the *nearly hardy* kinds under the conditions of these experiments. These species were severely injured or killed only by the repeated severe freezes of January 1-6, 1928, with a minimum of 8°F. in the Auburn weather shelter. They were: Oregon vetch, crimson clover, "white blooming crimson clover", red clover, alsike clover, white clover, black medic, Tifton bur clover, Hubam, and yellow biennial melilotus. The kinds just mentioned proved winter hardy against a minimum of 9°F. on December 28, 1925, and of 11°F. on January 16, 1927; hence may be regarded as winter hardy at Auburn except in unusually severe winters. Biennial white melilotus (sweet clover) seems also to belong in this class.

The following plants proved tenderer than those mentioned above: monantha, bitter, and Scotch vetches, lentil, Tangier peas, sweet peas, and the northern strain of narrow-leaved vetch. These were materially injured at Auburn by a minimum temperature of 9°F. or 11°F., or by both, and were sometimes notably injured by slightly higher temperatures.

The kinds that were materially damaged (killed or severely injured) by the rather moderate cold of December 1929 (minima 18°F. and 19°F., with a thin coat of ice for one day over all foliage) were the following: monantha, purple and Scotch vetches, only the northern strain of narrow-leaved vetch, Tangier peas, Canada field peas, lentil, horsebean, sweet peas, hairy Peruvian alfalfa, California bur clover, and Fenugreek.

The most tender toward cold of any of the winter legumes tested during the past six years were the following: horsebean, Canada field peas, purple vetch, Scotch vetch, sickle vetch, Lathyrus clymenum, Italian melilotus, early yellow annual melilotus, Egyptian or Alexandrian clover, early grass pea (*Lathyrus sativus*), late grass pea, chick pea (*Cicer arietenum*), *Medicago*

TABLE 21.—**Effects of minimum Winter Temperatures (Fahrenheit) on Winter Legumes.**

Kind	Killed by F.	Severely injured by F.	Appreciably injured by F.	Escaped material injury by F.
Vetch group *(Vicia, Pisum,* and *Lathyrus)*				
Monantha vetch *(V. monantha)*	8	9	11	24
do.	19	18		
Oregon vetch *(V. sativa)*		8		9
do.				11
Purple vetch *(V. atropurpurea)*	8		11	22
do.	18			
Bitter vetch *(V. ervilia)*		8	11	24
Narrow-leaved vetch, northern *(V. angustifolia)*	8		9	24
do. do.	19		18	
Scotch vetch *(V. sativa, var.)*	8	9	11	22
do.	19			
Taingier peas *(L. tingitanus)*	8	9	11	24
do.	19	18		
Canada field peas *(P. arvense)*	8	9	22	24
do.	18			
Pearl vetch	8		11	9
Sickle vetch *(V. sicula)*	9			
Lentil *(Ervum lens)*	8	11		24
do.	9	19	18	
Horsebean *(V. faba)*	8	11	24	
do.	9			
do.	18			
Sweet peas, Spencer mixed *(L. ordoratus)*	8	9	11	24
do.	18			
Grass pea, Late white *(L. sativus)*	8	11		24
do.	9			
Grass pea, Early white	8	11		
do.		24		

TABLE 21.—Effects of Minimum Winter Temperatures (Fahrenheit) on Winter Legumes (Cont'd.).

Kind	Killed by F.	Severely injured by F.	Appreciably injured by F.	Escaped material injury by F.
Clovers *(Trifolium sp.)*				
Crimson clover		8		9
Subterranean clover	8		24	9
do.			18	11
Hop clover *(T. aureum)* (Cultivated)	8			9
do. (In old sod)				8
Medics *(Medicago sp.)*				
Alfalfa, common			8	
Alfalfa, hairy Peruvian		18	9	
Black medic *(M. lupulina)*		8		11
Bur clover, southern *(M. arabica)*	8		9	11
Bur clover, early southern	8		9	
Tifton bur clover *(M. rigidula)*		8		9
California bur clover *(M. hispida)*	8	11		24
do.	19	18		
Snail clover *(M. scutellata)*	9	22		
Button clover *(M. orbicularis)*			9	
Spineless bur clover *(M. apiculata)*			11	
M. hispida lappacea	9		22	
M. echinus	9			

hispida lappacea, Medicago echinus, snail clover, *and Lupinus manus.*

Variable Response of the Same Species to Low Temperatures.—It is not correct to assume that one species will always be killed by a definite minimum temperature. Other conditions not fully understood sometimes modify the severity of the injury. For example, monantha, purple and Scotch vetches, and Tangier peas withstood a minimum of 11°F. on January 16, 1927; yet these same species were among those completely killed by the much more moderate cold of December 1929. In the latter period the lowest temperatures reached in the cold periods near the first of December and again just before Christmas were 18°F. and 19°F., respectively.

Plausible explanations of the more disastrous effects of these last mentioned temperatures are to be found in: (1) the continued repetition of below-freezing morning temperatures for six successive days just before Christmas and (2) in the maintenance of a thin coating of ice over all foliage for about 24 hours on December 22, 1929, this glaze being maintained while the thermometer hovered around the freezing point throughout the day.

The following example shows that even during the same period of cold a single species may suffer various degrees of injury on different fields of the same farm. Monantha vetch, planted in rows three feet apart near the first of October and also near the first of November, was killed to the last plant by the December 1929 freezes, in the South Annex field at Auburn. But this cold weather killed completely only a small percentage of monantha plants sown broadcast in October of the same year on another Auburn field. In still other parts of the station farm monantha vetch plants of about the same age suffered intermediate degrees of injury. The stand that survived the two cold periods which occurred in December 1929 varied on this one farm from 0 to about 90 per cent in various fields having about the same slope or exposure. Possible accessory causes seem to lie in the unlike amounts of disease noted in the several fields and in the relative fertility of the various soils. Damping off had been especially severe in the South Annex field, but no special complaint of it was made as affecting serious losses in the other fields although it was prevalent.

The red root rot disease described in later paragraphs was shown by repeated examinations and counts to be extremely prevalent on monantha vetch in the field where complete winter killing occurred. It was also quite general in the field where the next largest amount of winter injury was found and was least prevalent in the fields where the least amount of cold injury was noted. In one field about 90 per cent of a stand survived the winter of 1929-1930. Moreover, soil conditions other than the presence of disease organisms seemed to influence the severity of winter injury.

Relative Susceptibility to Insect Injury and Disease.—Plant lice or aphids have been found on all vetches tested. The extent of their injury has been very unlike on different species. The kinds most severely damaged by aphids have been monantha vetch, bitter vetch, and Austrian winter peas. Occasionally the growth of monantha vetch and Austrian winter peas has been stopped and the plants practically killed by plant lice. This injury has usually become severe only after April 1 when considerable growth has already been made. Thus the fertilizer value of these legumes for plowing under early has not been greatly diminished, although there has resulted a notable reduction for the entire growing season in the potential production of nitrogen, organic matter, and forage.

Hairy and woolly-pod vetches have been seriously injured by anthracnose and another disease (*Ascochyta*), both affecting the stems and leaves. The stems, especially near the ground, turn black, and shrivel, and many of the branches die. The foliage becomes discolored and often drops.

Austrian winter peas, and Canada field peas have sometimes lost a considerable percentage of their leaflets by such blackening. Narrow-leaved vetch has sometimes been seriously injured by the diseases mentioned above.

Hungarian vetch has been more free from these, as well as from other diseases mentioned later, than has any other of the many vetches tested.

The damping-off fungi have sometimes killed a considerable percentage of the seedlings of vetches and other legumes when continuous wet weather has followed closely after germination. Especially notable have been its winter injuries to bitter, monantha, and hairy vetches, and to Austrian winter peas.

Monantha and bitter vetches have been extensively attacked and seriously injured by a disease that exhibits symptoms not found on other vetches. This disease, here tentatively designated as red root rot, is characterized by bright red spots and streaks or patches on the whitened underground part of the stem, on the roots, and even on the germinating seeds of monantha and bitter vetches. Later the reddened area sometimes encircles the root or lower stem, thus causing the death or extreme dwarfing of the plant. Unthrifty plants sometimes show reddening and other unhealthy symptoms on at least a part of the foliage. Doctor J. L. Seal, pathologist of the Alabama Experiment Station, has found bacteria and in other cases fungi associated with these red spots on the underground part of the plant but has not yet made positive identification of this disease.

The red spots on the seedlings are usually first observable at or just below the point of attachment of the old seed, as well as on the germinated seed itself just below the seedcoat. These facts suggest that the organism is probably carried by the seed.

Moreover, our observations seem to indicate that this disease becomes more prevalent after vetch has been grown for several years in the same field. This suggests the probable advisability of rotating soil-improving crops as well as practicing rotation for the main crops. This course seems entirely feasible in view of the fact that crimson clover and Hungarian vetch among the well tested legumes have for the past six years proved resistant to the diseases that have at times been extremely injurious to Austrian winter peas and hairy vetch growing in adjacent rows.

SUMMARY

Experiments with legumes were among the first studies undertaken by the Alabama Experiment Station. The results of this earlier work emphasized the need of phosphorus and the inoculation of legumes by the proper bacteria.

This bulletin records results of experiments with legumes by the Alabama Experiment Station from 1896 through 1929.

The yield of corn was maintained by legumes on land cropped continuously to corn during a 34-year period. Corn yields declined more than 50 per cent on land cropped continuously to corn, without legumes, during a 34-year period, 1896 to 1929. Yields of cotton and corn in a three year rotation with legumes were four times as great as those in the same rotation without legumes.

When applied alone in a three year rotation phosphate and potash did not increase the yield of corn and increased the average yield of seed cotton only 19 pounds per acre, but when they were applied in the rotation with legumes the yields were increased by 293 pounds of seed cotton and 11 bushels of corn per acre.

Cotton following vetch produced 1,231 pounds of seed cotton per acre as compared with 1,222 pounds per acre and 1,471 pounds per acre on adjacent plots which were treated with 325 pounds of nitrate of soda per acre and 5 tons of manure per acre, respectively.

Corn following legumes turned under March 25, April 5, and April 15 produced greater average yields over a 5-year period than corn on corresponding plots which received 200, 300, and 400 pounds of nitrate of soda per acre. Cotton following vetch turned March 25 produced a greater average yield than that following vetch turned April 5 or April 15.

The residue from vetch turned in 1925, 1926, and 1927 produced more corn in 1928 than either 200 or 300 pounds of nitrate of soda per acre. The residue from vetch and annual yellow melilotus turned under in 1925, 1926, and 1927 resulted in an average increase of 224 pounds of seed cotton per acre in 1928. Vetch turned under in 1925, 1926, and 1927 resulted in an increase of 13.1 bushels of corn per acre in 1929.

Kudzu turned under in 1919 increased the average yield of two crops of sorghum hay by 2,536 pounds per acre, four crops

of corn by 19.3 bushels per acre, and seven crops of oats by 7.9 bushels per acre.

Applications of superphosphate in rotations at Andalusia, Hackleburg, Prattville, and Sylacauga resulted in increases of 2,000 to 8,000 pounds of green material per acre in the yields of winter legumes.

Lime applied in rotations increased the yields of green material of winter legumes 7,356 pounds per acre at Andalusia, 3,863 pounds at Hackleburg, and 6,142 pounds at Prattville.

Six tons of manure per acre applied in connection with superphosphate and lime in rotations, increased the yields of green material of winter legumes by 3,500 pounds to 9,000 pounds per acre at Andalusia, Hackleburg, and Sylacauga.

Applications of ground limestone and basic slag produced approximately the same yields of vetch, but ground limestone produced more than twice as much annual yellow melilotus as basic slag. Annual yellow melilotus failed on Norfolk soil without lime. Lime in a three-year rotation increased the yields of summer legumes 34 per cent on Decatur soil, 59 per cent on Ruston soil, 67 per cent on Greenville soil, and 68 per cent on Cecil soil.

Hairy vetch, monantha vetch, and Austrian winter peas produced larger yields when planted in drills 12 inches apart than when seeded broadcast. Light rates of seeding of monantha vetch and Austrian winter peas when planted September 30 produced more green matter than heavy rates of seeding planted October 26. Plantings of nine winter legumes made in drills near October 1 averaged 25 per cent more air-dry material than plantings made November 1.

Monantha vetch and Austrian winter peas produced sufficient green material to turn under by March 22; by this date hairy vetch had produced approximately half as much growth.

Monantha vetch ranked first among many winter legumes in total yield of dry material produced from plantings made about October 1 and November 1 in drills three feet apart. Next followed in order, for the five year period, woolly-pod vetch, Oregon vetch, and Austrian winter peas. Harvests made April 1 of many winter legumes show that woolly-pod vetch, Austrian winter peas, monantha vetch, Oregon vetch, and hairy vetch, in the order named, produced the largest yield of dry material from early October and November plantings.

The relative earliness of various winter legumes, based on the beginning of blooming, was found to be as follows: Scotch vetch, the southern strain of narrow-leaved vetch, bitter vetch, monantha vtech, crimson clover, wooly-pod vetch, Tangier peas, Oregon vetch, hairy vetch, Austrian winter peas, and purple vetch.

Results of more than 100 analyses show that the green tops of hairy vetch contain 1.00 per cent nitrogen, monantha vetch 0.76 per cent, and Austrian winter peas 0.79 per cent.

Based on the nitrogen content of the three legumes studied, it is recommended that hairy vetch be turned when the green tops from 100 square feet weigh 12 pounds, and that Austrian winter peas and monantha vetch be allowed to attain a growth of 14 pounds.

Monantha vetch, Austrian winter peas, and Tangier peas produced the largest yields of seed in the variety test of winter legumes but have not been consistent seed producers.

Among the drilled winter legumes that proved hardy at Auburn against all low temperatures of the past six years were hairy, Hungarian, and woolly-pod vetches, Austrian winter peas, and the southern strain of narrow-leaved vetch. Killed or severely injured only once, with a minimum temperature of 8°F., were Oregon vetch; crimson, red, Alsike, and white clovers; black medic; Tifton bur clover; and hubam and yellow biennial melilotus. The same minimum temperatures that in some winters killed or severely injured a given winter legume brought little or no injury to the same species in other winters.

Austrian winter peas and monantha and bitter vetches proved most susceptible at Auburn to injury by aphids.

Stem and leaf diseases repeatedly damaged Austrian winter peas, hairy vetch, and woolly-pod vetch. Hungarian vetch and crimson clover were among the legumes that escaped injury by these diseases.