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Control of Cotton Root Rot by Sweetclover in Rotation

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Preface

It has been shown frequently that the plowing under of legumes increases both the nitrogen content and the organic matter of the soil.

Experiences of some farmers, soil-fertility demonstrations and preliminary experiments have indicated that losses from root rot may be reduced following rotation of cotton with certain legume crops.

The use of replicated plots in a 5-year study (1943-47) at the Blackland Experiment Station (Substation No. 5) at Temple has proved the value of sweetclover in the control of cotton root rot and in the increase of cotton yields.

Sweetclovers best adapted to growing conditions in the central Blacklands of Texas (the Temple area) are indica *(Melilotus indica)* and hubam *(Melilotus alba* var. *annua)*. Both were used in the rotation experiments reported in this bulletin as winter and winter-summer crops.

Rotation with hubam that is grown to maturity at least once every third or fourth year was found to offer the best means yet known for the control of cotton root rot in the central Blacklands. In addition to a larger yield of cotton through disease control and increased soil fertility, the hubam crop provides additional farm income when used as pasture for livestock or when harvested as hay or seed.

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Control of Cotton Root Rot by Sweetclover in Rotation

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Cotton root rot has persisted as one of the most baffling problems in Texas agriculture. It has been the object of much research in the last half century, particularly in regard to studies of the causal organism (*Phymatotrichum omnivorum* (Shear) Duggar), resistant crops and crop rotation. Root-rot-resistant varieties of cotton have not been found. Consequently, rotation with immune plants such as corn, oats, sorghums or grasses have in the past constituted the most frequent recommendations for partial control of this disease. The sclerotia (Figure 1) of the causal fungus—small seed-like resting bodies that remain alive for many years—have been found from six inches to eight feet in the soil (20). Since these seed-like bodies keep the disease active from year to year, methods have been sought for producing cotton even in the presence of the fungus.

A step in this direction was the development of rotations with resistant crops. These practices were suggested for root-rot control as early as 1888 by Pammel (18) and a survey of the literature on this subject has been made by Rea (19). Another attack on the root-rot problem involved the use of organic manures. This method of control was also suggested by Pammel in the following statement written over 60 years ago: "Near Brenham, on Post Oak land, a field was found, two acres of which received a heavy dressing of stable manure two years previous. Here very little dead cotton was found. The soil adjoining this patch was identically the same, so far as one could tell from a superficial examination, yet nearly one-third of the cotton was dead. Mr. Peters pointed out to me a similar case near Calvert." More recently, King and Loomis (12) have found soil amendments of barnyard and green manures to give excellent control of root rot under irrigated experimental conditions in Arizona. The addition of organic material was found by Jordan *et al.* (7) to increase the effectiveness of deep-tillage practices for cotton root-rot control. In other experiments, Jordan, Nelson and Adams (9) showed that smaller percentages of cotton died from root rot where sorghum residues were turned under than in plots of continuous cotton. Experiments by Scofield (21), and Taubenhaus

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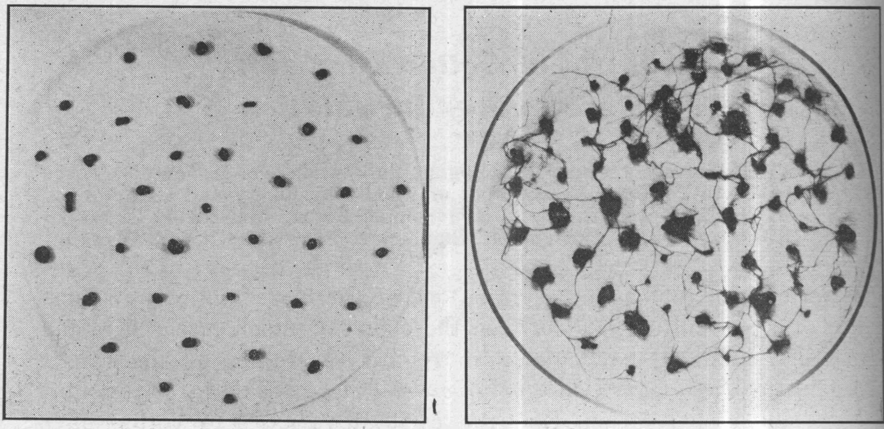

Figure 1. Sclerotia (resting bodies) of the cotton root-rot fungus, about one-half natural size. On left, sclerotia as they are found in the soil; on right, germinating sclerotia with thread-like mycelium. These seed-like bodies remain alive in the soil for many years.

and Killough (24), however, showed little effect from manure. It is of interest to note that Collins *et al.* (6) found higher contents of organic carbon and total nitrogen and wider carbon-nitrogen ratios in areas of non-infested Texas Blackland soil than in spots where the disease occurred.

The most recent development in the control of cotton root rot involves the use of legumes. One of the first reports of this method was made by Rogers (20) in a 2-year rotation experiment conducted at the Blackland Experiment Station (Substation No. 5) in 1940 and 1941. Rogers found that plots of cotton following hubam (*Melilotus alba* var. *annua*) had much less root rot than comparable plots where cotton had been grown for several years, and the yields of cotton were about twice as large. Some of the sweetclover in this experiment was cut for hay and some was harvested for seed. The crop residues were then plowed in late summer. As pointed out by Rogers, hubam may be severely attacked by the root-rot fungus when the plants are allowed to stand in the field until late summer for seed. Even though the hubam was attacked, there was a marked reduction in root rot in the succeeding crop of cotton.[3]

[3]These experiments have been continued separate from the experiments reported herein and the data on root-rot incidence and cotton yields have been assembled by Superintendent J. R. Johnston for the years 1941-47. Although only a few (2 or 4) replications were used these data may be significant. At least they show the same general trend as the results from a larger number of replications reported in this bulletin. The average for the 7 years shows a yield of 390 pounds of seed cotton per acre from the continuous cotton plots, 475 pounds from the cotton-corn rotation, 627 pounds after hubam for hay and 737 pounds after hubam for seed. The number of plants killed by root rot in August in these same treatments on a 7-year average was 28, 19, 5 and 3 percent, respectively.

Figure 2. Fall-planted sweetclover showing desired amount of growth at time of plowing under for green manure in late winter or early spring.

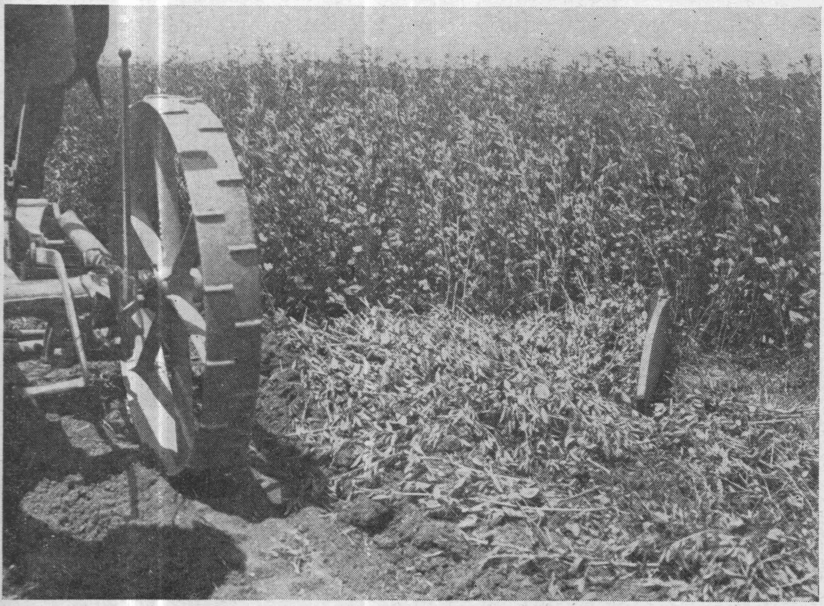

Figure 3. Fall-planted hubam showing height and dense stand at time of cutting for hay in early summer.

During the past five years 1943-47, three progress reports have been issued by the Texas Station on the value of sweetclover crops in reducing the losses from cotton root rot. The first of these by Hill, Lyle and Johnston (10) showed the results with cotton in a 2-year rotation with hubam which was harvested as hay (Figure 3) or for seed. The second by Lyle and Hill (15) gave results of experiments with hubam and annual yellow-blossom sweetclover (*Melilotus indica,* commonly called indica) as winter cover crops only. These two reports involved data taken during the first 2 years of the study reported in this bulletin. Brooks (4) issued a report in 1947 of similar studies at Substation No. 16, Iowa Park.

Following suggestions from the Extension Service and the Soil Conservation Service, Texas farmers in areas where cotton root rot is prevalent have used legume crops for several years to improve cotton yields and lessen the damage from root rot. The experience of farmers in the Blackland area has tended in most instances to substantiate these recommendations. Additional information on the effect of a legume crop on root-rot control is provided by Barker and Blank (2). In their survey of cotton fields in the Pecos Valley of Texas and New Mexico, it was noted that alfalfa was commonly used in rotation with cotton and that losses from root rot were slight, particularly during the first 3 or 4 years following the plowing under of alfalfa.

Two theories have been mentioned as the possible explanation of the effectiveness of legume crops in cotton root-rot control. The effects of additional nitrogen in the soil offer one possible answer since nitrogen or ammonium fertilizers have shown beneficial effects against the disease in several instances (1, 3, 6, 7, 8, 9, 23). The other theory is that changes in the microfloral populations of the soil are responsible for the control of the disease through antibiotic effects of other soil organisms on *Phymatotrichum omnivorum*. According to King (14): "The root rot fungus does not thrive in the presence of great activity on the part of saprophytic organisms, and the cotton plants frequently escape infection." King and Loomis (11) had reported earlier that apparently healthy cotton plants in manured plots were occasionally found to have infected roots and they suggested that "the plants may be better equipped to avoid or withstand the disease under the modified soil conditions." Mitchell, Hooton and Clark (17), and Clark (5) have shown that both the mycelium and sclerotia of *P. omnivorum* are destroyed in non-sterile soils with added organic matter. Increases in the populations of such soil organisms as bacteria, actinomyces and certain fungi have been noted by King, Hope and Eaton (13), and by Mitchell, Adams and Thom (16) in soils which had received organic materials.

Experimental Procedure

Three acres of fairly level and uniform land of Houston Black clay soil were set aside in 1942 at the Blackland Experiment Station for these cotton root-rot control experiments. The experimental area was in cotton the previous year and in miscellaneous non-legume crops prior to that time. Crop rotations with hubam and indica were started. The plots were 18 feet wide and 138 feet long, with a 6-foot interval between plots kept clean. The cotton was in 3-foot rows and data were taken from 132 feet of the four center rows. There were four treatments in each of six randomized blocks. These treatments were continuous cotton, cotton each year following hubam green manure (winter cover), cotton each year following indica (winter cover), and 2-year rotations of cotton with hubam (grown to maturity for seed). Record of the cotton plants killed by root rot was taken at least twice each year, early in August and September. The taproots and large lateral roots of the non-wilted cotton plants in the various plots were examined in 1946 for signs of root-rot infection.

Hubam was tested as a winter cover crop and also in a 2-year rotation with cotton. Indica was used as a winter green manure crop. It is better adapted to warm winter climates and makes more winter growth than hubam in locations where it survives. The vicinity of Temple is about the northern limit for fall planting of indica.

This study was conducted as originally designed for 2 years. It was then desired to alter the design slightly and to obtain information concerning the residual effect of the hubam on root rot. The hubam planted for green manure was allowed to mature in 1945. This area in 1946 provided information for 1 year in cotton after hubam, and in 1947 for 2 years in cotton after hubam. By allowing the hubam to mature for harvest, information was made available for studying the amount of root rot in cotton 1, 2 and 3 years after a crop of hubam was harvested for seed (Table 4).

The sweetclover seed were inoculated and planted each year in the fall (early October). Hubam and indica were drilled at the rate of about 10-15 pounds per acre. The top growth of the sweetclovers was sampled just before bedding under about March 15 when used as green manure, and just before seed harvest when the hubam was grown to maturity. The plots with hubam grown for seed were flat broken after seed harvest, and then bedded and rebedded before planting cotton the next year.

The Roldo Rowden cottonseed was Kemgas delinted, treated with New Improved Ceresan, and planted with a hill-drop tractor planter about the middle of April.

Results

A temperature of 17° F. on December 15, 1943, plus about five additional days of freezing weather totally killed the indica but caused only about 5 percent loss in the hubam. After replanting the indica, another freeze (January 9-15) killed about 50 percent of the top growth with scarcely any further damage to the hubam.

The amount of legume growth turned under before the planting of cotton is shown by the dry weights of samples cut from each plot (Table 1). Although the winter cover was small (from 48 to 450 pounds dry weight per acre) in each case, the indica gave more winter growth than the hubam except where the former was frozen out. The hubam made rapid growth in the spring (Figure 2) and by seed harvest time had developed a top growth of from 6,400 to 9,400 pounds dry weight per acre (Figure 6). Although the legume crops aided in delaying or preventing root rot in the cotton which followed, they were not resistant to the disease themselves. Root rot does not occur in the winter but it may develop on hubam grown for seed. The disease, moreover, does not appear on hubam until the seed crop is nearly ready for harvest and therefore causes no economic loss.

The effect of legumes in rotation on the amount of root rot or delay in dying of cotton is shown in Table 2 together with the yields of seed cotton from these plots. The winter legume green manure (Figure 2) reduced the kill from root rot from 34 to 17 percent (August data) and increased the yield of cotton about 25 percent (Figure 5). The 2-year rotation of hubam was far more effective than the winter green manures in its action to reduce root rot and increase the yield of cotton (Figures 4 and 6). Four years' results, 1944-47, show that the disease was reduced from 29 to 5 percent with a yield increase of about 56 percent (Tables 2 and 3). The effect of hubam in rotation was studied further (Table 3), and will be described later.

The difference between August and September records for root-rot kill proved that the legumes delayed the incidence of the disease. Later observations showed that although the disease did spread, it did not attack as large a number of plants in the rotation plots as it did in the checks. There was partial control as well as delay of the disease, particularly with the 2-year rotation. There was practically no difference in effect between the two legumes used as winter green manure crops. The yield of cotton was related inversely to the amount of root-rot kill; the less root rot the more cotton produced. The August record of root rot was more nearly a correct measure of the loss in yield than the September record.

Table 1. Dry weight of sweetclover (tops) when plowed under and yield of hubam seed in 2-year rotation

Rotation	Location acre and plot	Dry weight, pounds per acre				Yield of seed, pounds per acre				
		1943	1944	1945	1946	1943	1944	1945	1946	1947
Hubam as green manure (winter cover)	E7–5	549	348	48						
	E7–8	589	339	48						
	F7–1	311	149	48						
	F7–9	318	626	48						
	G7–5	516	253	48						
	G7–8	288	354	48						
Average		427	345	48						
Indica as green manure (winter cover)	E7–1	585	179	290	322					
	E7–7	508	185	145	290					
	F7–4	375	163	290	209					
	F7–10	502	158	97	354					
	G7–2	362	132	145	322					
	G7–6	381	124	242	258					
Average		452	157	202	292					
Hubam as a seed crop in a 2-year rotation	E7–4, 3*	5920	9502	8809	2320	1452	1636	1452	213	568
	E7–6, 9	8440	10293	8518	2620	1815	1694	1016	227	805
	F7–5, 2	7135	8652	7889	2180	1936	1752	968	227	610
	F7–8, 6	5920	9716	7986	2660	1573	1844	1065	257	610
	G7–1, 4	4980	8200	6292	2240	1694	1452	678	281	422
	G7–9, 10	6102	10502	8470	2500	1573	2120	1258	294	647
Average		6416	9478	8023	2420	1674	1750	1073	250	610

*Plots E7–4, E7–6, F7–5, F7–8, G7–1, and G7–9 were in hubam during even years; E7–3, E7–9, F7–2, F7–6, G7–4, and G7–10 were in hubam during odd years.

Table 2. Root rot and yield of cotton in rotations with indica and hubam

Rotation	Location acre and plot	Percent of plants killed by root rot						Yield, seed cotton, pounds per acre		
		1943		1944		1945				
		Aug. 2	Sept. 7	Aug. 2	Sept. 1	Aug. 1	Sept. 3	1943	1944	1945
Continuous cotton (check)	E7–2	34	98	5	8	28	58	522	504	371
	E7–10	13	26	23	27	46	81	962	457	280
	F7–3	50	95	5	5	26	71	371	425	366
	F7–7	74	96	7	8	46	83	275	412	319
	G7–3	52	99	28	32	43	86	344	404	176
	G7–7	31	71	47	60	60	86	605	237	250
Average		42	81	19	23	42	78	513	406	294
Indica as green manure (winter) followed by cotton (1 year rotation)	E7–1	8	74	3	4	11	41	742	547	613
	E7–7	41	88	22	28	46	57	578	440	280
	F7–4	35	89	1	3	4	19	468	492	624
	F7–10	23	77	9	16	18	48	660	371	476
	G7–2	16	80	9	13	14	71	688	503	437
	G7–6	25	69	21	26	47	71	715	363	286
Average		25	80	11	15	22	51	642	453	453
Difference from check		–17	–1	–8	–8	–20	–27	+25%	+12%	+54%
Hubam as green manure (winter) followed by cotton (1 year rotation)	E7–5	20	70	5	9	16	35	742	463	566
	E7–8	11	83	4	7	19	51	550	499	335
	F7–1	17	67	21	33	20	68	990	550	330
	F7–9	28	95	2	4	14	28	550	502	547
	G7–5	33	80	8	9	41	80	701	429	292
	G7–8	12	82	9	12	5	8	550	400	544
Average		20	80	8	12	19	45	680	474	436

Difference from check		—22	—1	—11	—11	—23	—33	+33%	+17%	+48%
Hubam for seed, 1 year; cotton next year (2 year rotation)	E7–4, 3*	**	**	17	25	12	25	**	430	646
	E7–6, 9	....	....	4	6	14	28	....	496	542
	F7–5, 2	....	....	7	12	7	16	....	446	490
	F7–8, 6	....	....	7	9	5	10	....	468	688
	G7–1, 4	....	....	4	7	1	7	....	489	707
	G7–9, 10	....	....	5	8	1	5	....	564	490
Average	....	....	....	7	11	7	15	....	482	594
Difference from check	....	....	....	—12	—2	—36	—63	....	+19%	+102%

*Plots E7–4, E7–6, F7–5, F7–8, G7–1, and G7–9 were in cotton during 1943 and 1945; E7–3, E7–9, F7–2, F7–6, G7–4, and G7–10 were in cotton during 1944.

**First year of test, in hubam, no 2-year rotation results.

Table 3. Root rot and yield of cotton after hubam

Location acre and plot	1946			1947	
	Percent root rot		Seed cotton pounds per acre	Percent root rot Aug. 1*	Seed cotton pounds per acre
	Aug. 1	Sept. 1			
	Continuous cotton (check)			Continuous cotton (check)	
E7–2	15	63	187	4	685
E7–10	45	79	165	14	421
F7–3	28	68	190	3	536
F7–7	42	80	138	3	347
G7–3	34	75	151	9	490
G7–7	67	89	58	7	433
Average....	39	76	148	7	485
	2 years in cotton after 1 year hubam†			3 years in cotton after 1 year hubam	
E7–4	22	43	275	1	564
E7–6	38	72	154	3	531
F7–5	26	57	162	6	487
F7–8	20	56	305	5	509
G7–1	16	54	278	2	663
G7–9	8	22	316	tr.T	583
Average....	22	49	248	3	556
	1 year in cotton after 1 year hubam			2 years in cotton after 1 year hubam‡	
E7–3	7	11	289	1	690
E7–9	7	16	553	1	633
F7–2	11	20	308	4	699
F7–6	5	16	358	2	589
G7–4	8	21	371	9	514
G7–10	2	2	390	tr.	540
Average....	7	14	378	3	611
	Cotton after hubam (winter)			Hubam this year	
E7–1	12	27	368	....	....
E7–7	7	13	443	....	....
F7–4	11	23	346	....	....
F7–10	11	26	330	....	....
G7–2	12	30	324	....	....
G7–6	30	68	226	....	....
Average....	14	31	340		

Table 3. Root rot and yield of cotton after hubam—Continued

Location acre and plot	1946 Percent root rot Aug. 1	1946 Percent root rot Sept. 1	1946 Seed cotton pounds per acre	1947 Percent root rot Aug. 1*	1947 Seed cotton pounds per acre
	Hubam for seed this year			1 year cotton after 1 year hubam	
E7–5	....	....	....	0	677
E7–8	....	....	....	0	503
F7–1	....	....	....	tr.	652
F7–9	....	....	....	0	641
G7–5	....	....	....	tr.	556
G7–8	....	....	....	0	666
Average....	....	....	....	tr.	616

*Owing to the dry season in 1947, root rot developed but little after August 1 and no readings were taken in September of that year.
†1 year in hubam for seed, 1944.
‡2 years in hubam for seed, 1943 and 1945.
TTrace—less than 1 percent.

There was a great variation in results, both in replications of the same treatments and in different years. This is a characteristic of the disease more than with most other plant pathological problems.

Residual Effects of Sweetclover

It was decided in the fall of 1945 to use the winter green manure plots to determine the lasting effects of a mature hubam crop on root-rot occurrence and on the yield of cotton. This would indicate how often the hubam would need to be grown in a given area to give the most economical control of root rot. The 1945 cotton plots in the 2-year rotation were planted to cotton again in 1946 to give results on the second year of cotton after hubam. These plots would be third-year and fourth-year cotton in 1947 and 1948, respectively. The plots planted to hubam in the fall of 1946 were allowed to mature for seed in 1947.

As may be seen in Table 4, there were marked increases in yields of seed cotton in the second year after hubam, both in 1946 and 1947. The 1947 data also show an increase for the third year after hubam, although the difference in this case was not as great as in the case of the first and second years after the mature hubam.

Root-rot Infection of Non-wilted Plants

All cotton plants in the two border rows in each plot which seemed to be healthy from above-ground appearance were pulled in September 1946 and the roots examined for infection by the cotton-root-rot fungus. This examination was made following a rain which loosened the soil to that the cotton roots could be easily removed. It was expected that many living cotton plants would be found in the 2-year hubam rotations which had been attacked by the fungus and had recovered through the maintenance of one or more healthy lateral roots. This was not found to be the case. Although a large percentage of the plants in the check plots had roots that showed varying amounts of infection on the root system, those in the 2-year hubam rotations showed much less infection. It was noticed that long lateral roots often became infected by the root-rot fungus when they entered the fallow areas between the plots.

Discussion

The average yield of cotton following the various rotation and green-manure treatments for each of the 5 years of experimental work is given in Table 4 which summarizes the data in Tables 2 and 3. As may be seen in this table, all of the treatments resulted in increases in the average yield of the six plots in all years. These differences were not statistically significant in 1943 and 1944, however, the treated plots had a higher yield than the continuous cotton. During the years, 1945-47, on the other hand, nearly all of the treatments were significantly different from the checks. The significant differences occurred mainly between the continuous cotton and the treatments as a whole. There were no marked differences between the various sweetclover treatments. A tendency can be seen for the effectiveness of the mature-hubam treatment to diminish in successive years, and eventually the cotton in the 1-year hubam plots probably would have yields and root-rot losses comparable

Table 4. Summary of average yields of cotton following the various treatments for the 5-year period. Seed cotton, pounds per acre

Treatment	1943	1944	1945	1946	1947
Continuous cotton (check)	513	406	294	148	484
1st year after hubam for seed	.....	482	594	378	616
2nd year after hubam for seed	.....	.....	.....	248	611
3rd year after hubam for seed	.....	.....	.....	.....	556
Winter hubam (green manure)	680	474	436	339	.....
Winter indica (green manure)	642	453	453	.....	.....

with the continuous cotton plots. For best results, therefore, it would appear desirable to grow a crop of mature hubam in the rotation every 2 or 3 years.

In comparison with other recommendations for the control of cotton root rot, the sweetclover-rotation method offers the best control measure yet devised for holding the disease in check (Figures 4, 5 and 6) and at the same time increasing the yield of cotton. Aside from root-rot control, the maintenance of soil fertility through the beneficial fixation of nitrogen by the legume and the addition of organic material to the soil are in keeping with the best agronomic practices.

Although early flat-breaking alone may result in considerable control of cotton root rot (7, 22), this cultural practice is not always effective (7). Sweetclover residues plowed under in late summer or early fall give a higher degree of root-rot control as well as increased yields, when compared with early plowing. The apparent decrease in activity of the root-rot fungus on cotton in the 2-year hubam rotations may indicate an additional effect of the decomposed hubam residue in the soil. Examination of the data shows a correlation between the yield of cotton and the percentage of living plants at the time of the first count of dead cotton. This would indicate a direct effect of root-rot control on yield increases in the cotton in addition to the increased soil fertility provided by the legume.

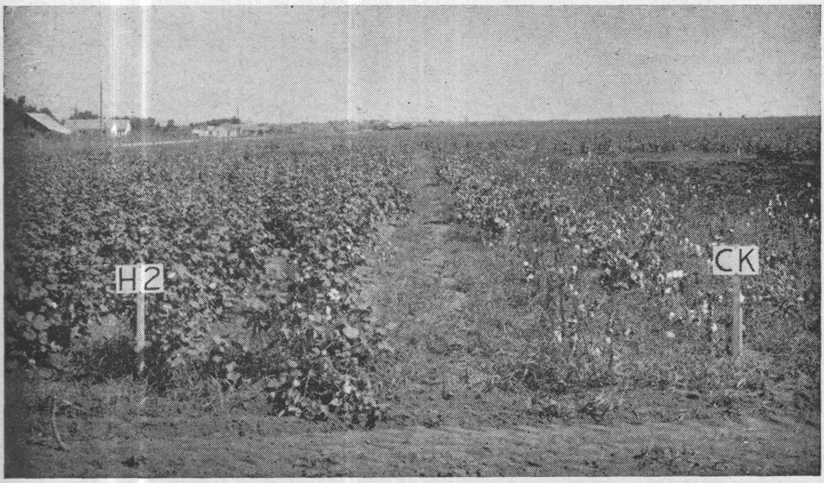

Figure 4. Experimental plots showing excellent control of cotton root rot where hubam was grown to maturity the preceding year (H2 on left, 1st-year cotton after hubam for seed). The check plot on the right (CK) shows a high percentage of root rot.

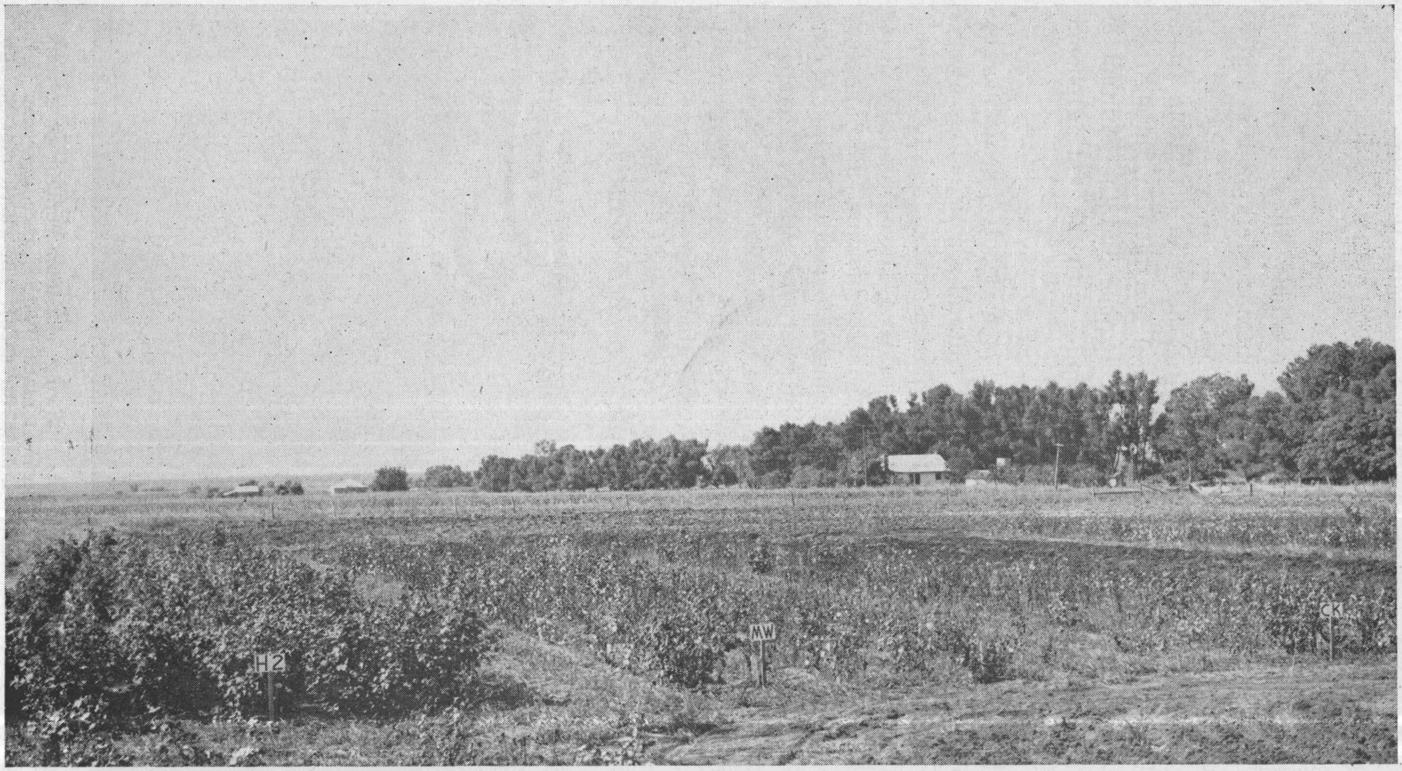

Figure 5. Good control of cotton root rot was obtained in the 2-year hubam-cotton rotation (H2) on left. More root rot occurred in the center plot (winter indica, MW) and in the check plot (CK) on the right. The yield of cotton was higher in the center plot than in the check plot due to delay in appearance of root rot following winter cover crops. The pictures in Figures 4, 5 and 6 were taken in September 1945.

Figure 6. Heavy loss from root rot is shown in the check cotton plot (left center, CK), while the plot on the right in which hubam was harvested for seed the previous year is practically free from dead cotton (H2). The hubam residue after harvest for seed and ready to be turned under for experimental root-rot control may be seen on the extreme left.

Acknowledgment

Special acknowledgment is made to R. C. Henderson for his assistance in collecting field data, and to Dr. J. R. Johnston, present superintendent of Substation No. 5, for consummation of these studies.

Summary

This bulletin presents the results of a 5-year study at the Blackland Experiment Station on the effectiveness of winter and winter-summer crops of *Melilotus indica* (referred to as indica) and *Melilotus alba* var. *annua* (hubam) in rotation with cotton for the control of root rot.

When sweetclovers were used as green-manure crops (plowed under in early spring) and followed by cotton the same year, cotton root rot was delayed and decreased and increases in yield were found in most cases.

Delay and marked reduction in cotton root rot and the highest yields of cotton were found in the plots in which hubam had been grown to maturity the previous year. Outstanding yield increases in cotton were obtained during the first 2 years following the rotation with mature hubam and there was also an apparent increase in the third-year cotton after hubam.

The degree of root-rot control, as shown by the increased yield of cotton in plots following mature hubam the previous year, is proportional to the reduction in number of cotton plants killed early in the season by root rot. Late-season root rot has less effect on yield.

The beneficial effects of the hubam in rotation appeared to diminish with successive plantings of cotton, making the plowing under of the mature hubam crop necessary about every third or fourth year for best results.

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