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SOYBEANS

ALABAMA AGRICULTURAL EXPERIMENT STATION AUBURN UNIVERSITY
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FOREWORD

This publication was developed to provide an update of the many aspects of soybean research underway at the Alabama Agricultural Experiment Station. Although results of individual soybean projects have been reported in various Experiment Station publications, not since Bulletin 415 was published in 1971 has a single publication summarized all phases of soybean research underway. Some of the studies reported date back several years, but the findings are such that they are still applicable today. Thus, these reports were included to make the publication representative of Auburn's soybean research program. We trust this information will be useful to soybean growers and to Alabama's total soybean industry.

Preparation of this comprehensive report was truly a team effort, with 34 individuals representing four subject matter areas and the outlying units of the Alabama Agricultural Experiment Station (AAES), the Alabama Cooperative Extension Service (ACES), and Agricultural Research Service, U.S. Department of Agriculture (USDA). The contributors are:

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INTRODUCTION

Status of Alabama's Soybean Industry

J.L. Stallings

Acreage of soybeans has dramatically increased in Alabama in the last 20 years after being a relatively minor crop in earlier years. The increase started slowly after 1960, then increased generally at an increasing rate until peak acreage was reached in 1979, figure 1.

Along with this increased acreage has come a shift in location of soybean production, figure 2. In 1959, which was before the start of the general increase, soybean acreage in Alabama was concentrated mostly in Baldwin County in the Gulf Coast Region, with only scattered acreage in the rest of the State. By 1969, however, while the Gulf Coast Region was still important, new acreage concentrations were starting to develop in the Black Belt and Limestone Valley regions. These regions continued to increase acreage during the next 10 years, but by 1979, the peak acreage year, important new production regions had developed in the Wiregrass, Sand Mountain, Upper Coastal Plains, and Lower Coastal Plains regions.

The dramatic increase in acreage of soybeans in the last 20 years probably resulted from a variety of reasons, including increasing prices and value, profitability relative to alternative enterprises, increasing use with wheat in double cropping, and adaptability of soybeans to a wider range of soil

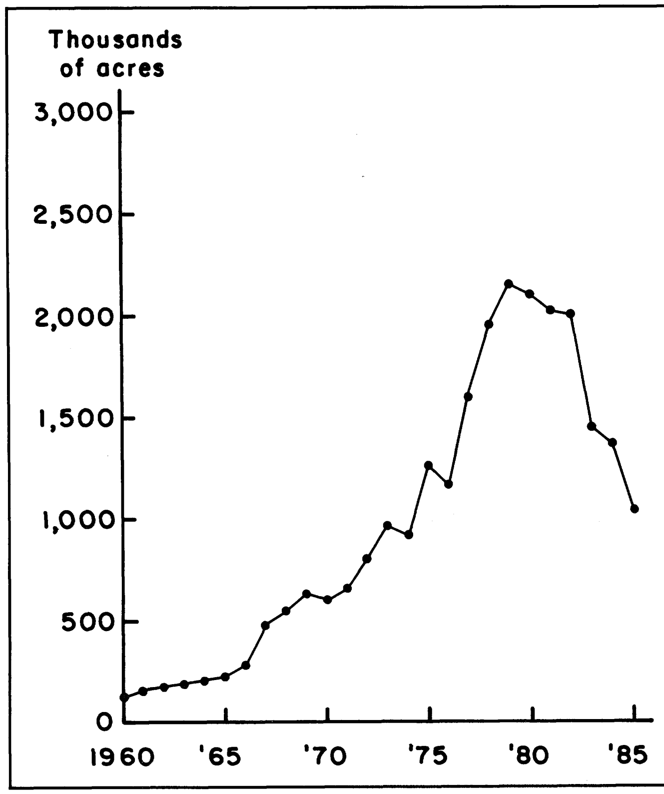


FIG. 1. Harvested acres of soybeans in Alabama, 1960-85.

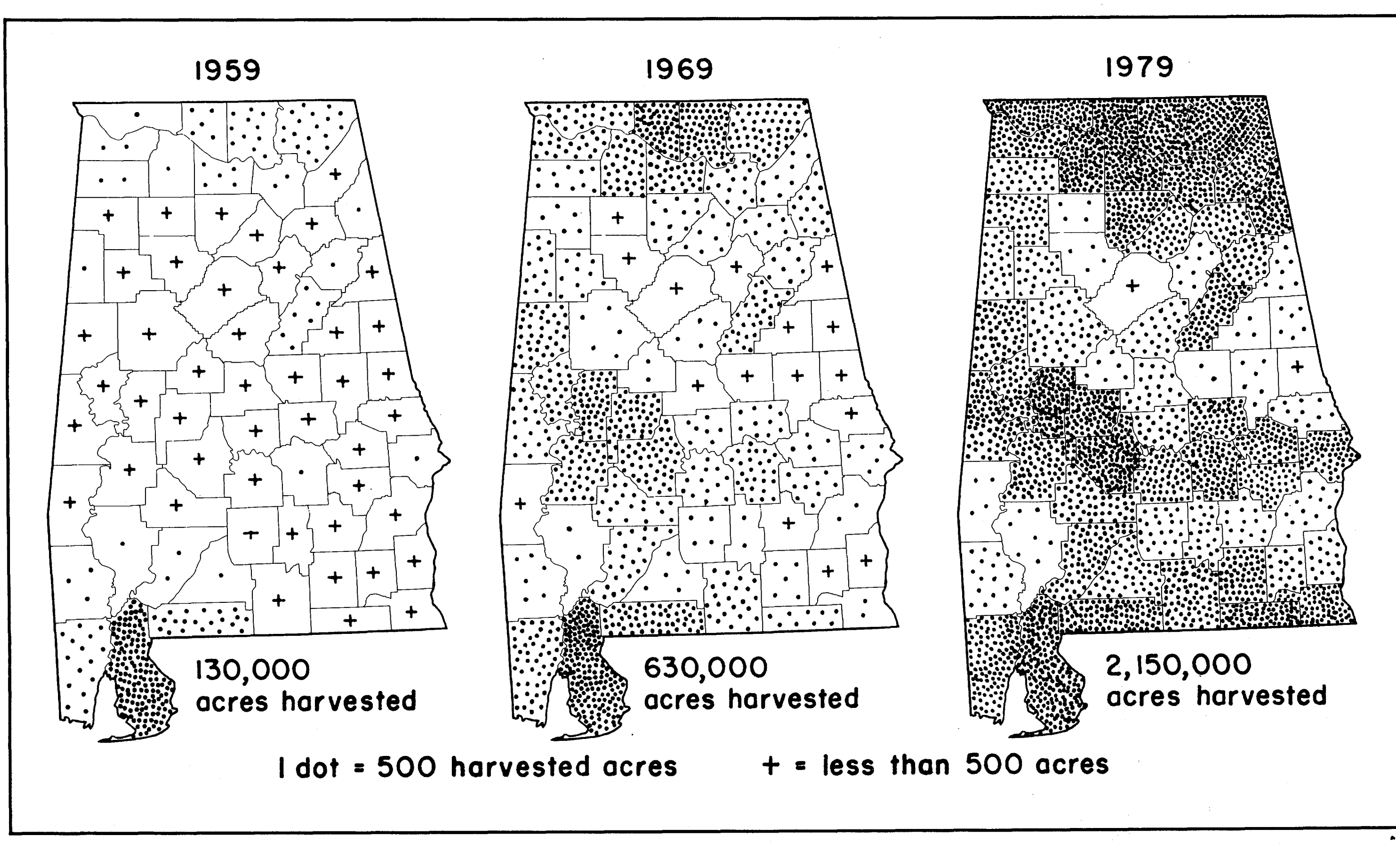


FIG. 2. Harvested acres of soybeans in Alabama, by counties, 1959, 1969, and 1979.

types than for some other row crops. However, the trend in average yields in Alabama has remained approximately level to slightly downward in recent years, a phenomenon of increasing concern. There are needs and opportunities for dramatic breakthroughs in soybean yields.

International Trade in Soybeans

J.L. Stallings

International trade is the dominant economic factor in the U.S. soybean economy. Between 50 and 60 percent of all U.S. soybeans have been exported in recent years. This means that more than 1 of every 2 acres of U.S. soybeans is dependent upon export markets. Because of the fungible nature of every bushel of soybeans (i.e.—1 bushel of soybeans is approximately equal to every other bushel), the same is true of Alabama, regardless of the bushels actually exported from the State. Over the last 5 years, the United States has exported an average of 55.3 percent of total soybean production. Thus, Alabama's export share is that proportion of the State output. The value of Alabama's export share increased to a high of 203.6 million dollars in 1979-80.

WHOLE SOYBEAN PRODUCTION AND TRADE

The United States is by far the most important producer of soybeans in the world, accounting for an average of 63.9 percent (nearly two-thirds) of world production in the 5 years from 1977 to 1981. Only three other countries, individually, averaged over 1 percent or more of world production during these years: Brazil, with 16.3 percent; the Peoples Republic of China, 9.5 percent; and Argentina, 4.0 percent.

Given the already large U.S. share of world exports, the prospects for increasing the United States' sale of whole beans by obtaining a bigger share of the existing market would seem to be somewhat limited. More promising is the potential for sales to an expanding total market. Such expansion may occur with or without U.S. encouragement as countries become more affluent and develop livestock feeding industries. There may be somewhat greater potential for expansion of the world market share in exports of soybean meal and soybean oil, where the United States does not now control as large a proportion of the market.

There is also the question of whether exports of whole beans should be expanded at the expense of exports of meal and oil. Conventional economic and political wisdom would hold that, from the United States' perspective, the more of the manufacturing process that can be done in the United States using domestic labor, the better. The process of converting beans to meal and oil before export presumably would result in more employment in the United States and the export of a higher value product per unit of weight.

SOYBEAN CAKE AND MEAL PRODUCTION AND TRADE

Soybean meal production does not necessarily take place in the countries where the soybeans are produced. For instance, while the four largest producers of soybeans accounted for an average of 93.7 percent of world production during 1977-81, these countries accounted for only 66.8 percent of meal production. Many important users of soybean meal prefer to import whole beans and produce their own meal and oil. Some of these countries in turn export meal and, especially, oil in competition with the United States. Notable among these are the countries of the European Economic Community (EEC).

While the United States dominated world production of soybean meal with an average of 40.7 percent during 1977-81, the domination was not nearly as great as with soybean production (63.9 percent) and whole soybean exports (81.7 percent). Brazil is the only other important producer of both soybeans and soybean meal competing with the United States in the export of soybean meal.

The United States is the world's largest producer of soybeans and soybean meal, but it is not the dominant exporter of meal. Over the period 1977-81, Brazil averaged slightly more meal exports than the United States, with 36.8 percent of the world total. One of the reasons for Brazil's leadership in meal exports is that the United States utilized domestically an average of 72.2 percent of its total meal supply for these years. U.S. meal exports, therefore, are more of a residual market after domestic needs are met than is the case in Brazil.

This condition applies to Alabama as well. With its large poultry industry, Alabama uses virtually all soybean meal produced within the State. During this same period, Brazil used domestically only 25.6 percent of its production of meal, leaving a larger absolute amount for export.

While the EEC produces much of the meal it uses from imports of whole beans, it is also the world's principal importer of soybean meal. The EEC accounted for 52.7 percent of all world imports of soybean meal during 1977-81. The Communist bloc countries of Europe have also become important importers as they have increasingly developed more livestock feeding, accounting for 22.7 percent of meal imports during 1977-81. European countries together account for about three-fourths of the world's meal imports.

As with world imports, the EEC and the Communist countries of Europe (including Yugoslavia) took the largest amounts of U.S. exports of soybean meal, 49.8 and 20.2 percent, respectively, during 1977-81. When all of Europe is included, about three-fourths of U.S. trade in soybean meal is accounted for. Only Canada, Japan, and Mexico are other important customers for U.S. soybean meal.

SOYBEAN OIL PRODUCTION AND TRADE

As with world meal production, the United States and Brazil dominated world soybean oil production (41.5 and 16.7 percent, respectively, during 1977-81). Only these two countries produced enough oil from their own beans to have a significant amount to export. Most other important producers of oil, excepting the Peoples Republic of China, produce it from imported beans.

Relatively few countries of the world export important amounts of soybean oil, but a great many import at least some. While importers of oil are many of the same countries that export whole beans and meal, the important importers of oil comprise a different set of customers than for beans and meal.

Important exporters of oil are the United States, Brazil, and Argentina, as with beans and meal. However, some of the European countries that import whole beans and do their own crushing to obtain the meal have a surplus of oil for export. Among these are the Netherlands, Spain, West Germany, France, Belgium, and Luxemburg.

India has consistently accounted for a large percentage of the world's imports of soybean oil to meet the needs of its large population. Unlike the Peoples Republic of China, which produces most of what it uses, India consistently does not produce enough edible oils for its domestic needs and should be a good customer for edible oils for many years. Over the past 5 years, the United States has contributed an average of 41.9 percent of India's imports of soybean oil.

A large number of countries import important amounts of soybean oil, but none is as important as India. However, over 37 percent of the soybean oil imported is accounted for by countries other than the top 10. Much of this total is to third world countries, especially in Africa, which is exported under the PL 480 (Food for Peace Program) program as a form of foreign aid. While none of these countries beyond the top 10 is a significant importer individually, together they are a substantial outlet for sales of soybean oil. A current problem hindering their growth is the large third-world debt which limits their purchasing power in the world market since most of their hard currency must go to service their debts.

U.S. exports of soybean oil have generally followed the same pattern as the more important importers of the world, with a few exceptions. India was the most important customer for soybean oil during 1977-81, averaging 25.2 percent of U.S. exports, while Pakistan was second with 14 percent. The United States has supplied over 62 percent of Pakistan's total imports over the last 5 years.

After India and Pakistan, a large number of countries take an important share of U.S. exports of oil, but no other country dominates. There is also an important amount of exports beyond the top 10 accounting for over 26 percent of U.S. exports. Most of this is in shipments under PL 480 as a form of foreign aid, and represents a small amount to each of a large number of countries.

Alabama's Soybean Marketing System

James R. Hurst

Alabama's soybean marketing system consists of some 75 country elevators, two processing plants, and one export elevator located throughout the major producing areas of the State, table 1. Most country elevators which buy soybeans and grain from local producers for shipment to export markets or to domestic processors are owned by or deal exclusively with one of the major cooperatives or private export firms. Almost all Alabama-produced soybeans are shipped by country elevators either to domestic processing plants in Decatur and Guntersville or to Mobile for export. Alabama has few terminals or sub-terminal elevators because shipping directly to processors or exporters is more economical than is transfer through terminal elevators. Also, increased farm storage and development of highways have caused more soybeans to move directly from farms to processors and exporters. Such direct shipments result in improved prices to farmers.

The State had approximately 75 million bushels of grain and soybean storage capacity in 1979, 2.9 times the 1969 capacity. On-farm storage accounted for 35 million bushels and commercial storage (including soybean processing plants and export elevators) for 40 million bushels in 1979.

The effective handling capacity of the commerical marketing system is about 160 million bushels annually. The system is adequate to handle the annual volume but is congested during harvest season, when a majority of the soybean crop is marketed.

Most soybean producers have an adequate number of alternative marketing facilities within reasonable trucking distance to assure receiving a competitive price.

Geographical price differentials within Alabama over the period 1977 to 1981 ranged from about 10¢ to 50¢. Cash soybean prices at country elevators were generally higher in the southern part of the State in the fall and winter months and higher in the northern part during the summer months just before harvest. With the decreasing export demand in the 1980's, geographical price differentials are becoming less significant.

Locational price differences can be explained largely by the fact that export demand peaks during the fall and winter, while domestic processor demand peaks in summer. When prices at more distant terminal markets are high enough to more than offset the additional transportation costs, producers may find it profitable to sell at the more distant markets.

Producers who market their soybeans uniformly throughout a marketing year may find it profitable to make some sales to distant markets based on current market differentials. However, when adjusted for transportation costs, geographical price differentials are not as significant as seasonal price differentials. This leads to the conclusion that where to sell has not offered as much opportunity for increasing profit as when to sell in recent years.

TABLE 1. ELEVATORS SERVING ALABAMA SOYBEAN PRODUCERS, 1984

Firm	Phone number	Storage capacity	Firm	Phone number	Storage capacity
		Bu.			*Bu.*
Gold Kist, Inc., Summerdale	989-6257	318,000	Section Gin & Grain, Section	228-4238	125,000
L. Irwin & Son, Foley	943-8067	115,000	Scott Brothers Grain Elev., Detroit	273-7161	90,000
Louis Dreyfus Corp. Robertsdale	947-5002	150,000	Lauderdale County Coop., Florence	764-8441	272,000
E.G. Manci, Loxley	964-5031	40,000	Lawrence Co. Exchange, Inc., Moulton	974-9213	100,000
W.J. Nelson Co., Fairhope	928-8225	16,000	Wheeler Grain Co., Hillsboro	637-2772	400,000
Fitzpatrick Grain, Fitzpatrick	738-4747	92,000	Gold Kist Soy Elev., Athens	232-8776	80,000
Quality Seed & Fertilizer, Fitzpatrick	277-5400	100,000	Limestone Farmers' Coop., Athens	232-5500	150,000
Lapeyrouse Grain Corp., Greenville	382-6631	160,000	Wheeler Grainery, Athens	729-1772	400,000
Cherokee Farmers Coop., Centre	927-3135	30,000	Central Ala. Grain Elev., Hurtsboro	485-3203	290,000
Cherokee Milling, Centre	927-5192	30,000	J.D. Ray Co., Tuskegee	727-1260	50,000
Farmer's Grain-Leesburg, Inc., Leesburg	526-8118	70,000	Gold Kist Grain, Huntsville	539-0425	51,000
Central Grain & Feed Supply, Maplesville	366-2672	52,000	Madison County Coop., Meridianville	828-0744	47,000
Colbert Farmers Co-op, Tuscumbia	383-6462	95,000	Demopolis Grain Corp. (Lapeyrouse),		
Colbert Farmers Co-op, Leighton	446-8170	70,000	Demopolis	289-1440	380,000
Farmer Home Gin Co., Leighton	446-8330	32,000	Fincher Farm Supply, Inc., Hackleburg	935-3137	45,000
Darby Grain Elevator, Inc., Evergreen	578-1420	250,000	McRae Brothers, Hamilton	921-2639	150,000
Anderson's Grain, Andalusia	223-6541	100,000	Cargill, Inc., Guntersville	582-5719	575,000
Zorn Brothers, Inc., Florala	858-3297	155,000	Central Soya of Ala., Inc., Guntersville	582-3223	240,000
Brantley Gin Co., Brantley	527-3208	30,000	Continental Grain-Processing Div.,		
Gold Kist, Inc., Browns	628-6240	250,000	Guntersville	582-5664	3,200,000
R.W. Kirk and Son, Orrville	996-8301	280,000	Great Combine, Guntersville	582-6206	110,000
Selma Grain Corp., Selma	874-6676	302,000	Ala. State Docks Public Grain Elev., Mobile	690-6063	3,200,000
M.B. Bell, Jr., Grain Co., Sylvania	638-3666	120,000	Lapeyrouse Grain Corp., Mobile	476-3592	1,000,000
DeKalb Farmers Coop., Inc., Rainsville	683-2569	170,000	Lapeyrouse Grain of St. Elmo, St. Elmo	957-2177	45,000
Great Combine, Inc., Crossville	528-7165	75,000	Farmers Coop Market, Frisco City	267-3175	15,000
Seed Processors, Inc., Wetumpka	567-4710	88,000	Lapeyrouse Grain Corp. of Ala., Claiborne	258-2494	427,000
Atmore Truckers Assoc., Inc., Atmore	368-2191	32,000	Montgomery Grain Corp. (Lapeyrouse),		
Frank Currie Gin Co., McCullough	577-6411	30,000	Montgomery	263-5541	594,000
Escambia Farm & Seed Co., Inc., Atmore	368-1340	300,000	AFC Marketing Ser., Inc., Decatur	353-2961	375,000
Lapeyrouse Grain Corp., Atmore	368-4539	85,000	Bunge Grain, Inc., Decatur	350-4550	7,500,000
Fayette Grain & Feed Co., Fayette	932-6732	47,000	Uniontown Grain Elev., Uniontown	628-6726	250,000
Farmer's Supply & Mkt. Assn., Russellville	332-3273	64,000	Lapeyrouse Grain, Aliceville	455-2271	312,000
Brooks Grain Co., Inc., Samson	898-7194	250,000	Tom Soya Grain, Aliceville	373-8761	140,000
Geneva Grain Co., Inc., Geneva	684-2188	468,000	Pike Farmers Coop., Troy	566-1834	45,000
Harrell Milling Co., Inc., Hartford	588-2261	400,000	Central Ala. Grain, Inc., Hurtsboro	485-3203	292,000
Hartford Farm Coop., Inc., Hartford	588-2992	135,000	Chattahoochee Valley Grain, Phenix City	298-1498	426,000
AFC Marketing Ser., Demopolis	289-1100	1,000,000	Gold Kist, Inc., Pell City	884-2415	42,000
Columbia Grain (Lapeyrouse), Columbia	696-4414	579,000	Talladega Coop Grain Elev., Talladega	362-2716	80,000
I.E. Airheart & Sons, Scottsboro	574-2011	171,000	Tuscaloosa Grain Corp. (Lapeyrouse),		
Jackson Farmers Co-op, Scottsboro	574-1688	85,000	Northport	345-3727	572,000
Jackson Farmers Co-op, Stevenson	437-8829	11,000	Gold Kist, Inc., Jasper	387-1436	165,000
Pisgah Gin Co., Pisgah	451-3255	25,000	Gold Kist Elev., Camden	682-4632	183,000

VARIETY DEVELOPMENT

Evaluation and Improvement of Soybean Varieties

David B. Weaver, G.V. Granade, R. Rodriguez-Kabana, and B.H. Cosper

Varietal selection is an integral part of any soybean management program. Not only do soybean varieties differ in yield potential, but frequently these differences occur because of other important agronomic and pest resistance characteristics. A variety that may be best at one location may respond poorly at another because of differences in rainfall, soil fertility, pest population, and a host of other variables that shape the environment in which the plants are growing. Varietal selection is complicated even further by the number of varieties available for production in Alabama. In 1971 there were only 15 varieties available for production. In contrast, the 1983 Experiment Station variety tests included 103 varieties.

VARIETY DEVELOPMENT

In 1981, a soybean breeding project was initiated to develop improved soybean varieties especially adapted to Alabama growing conditions. The primary objective is to develop varieties with higher yield potential that are better able to resist attack by some of Alabama's major pests, including soybean cyst nematodes, root-knot nematodes, and stem canker.

Over 4,000 experimental lines have been evaluated so far. Several of these have shown good agronomic potential and will be yield tested at several locations across Alabama. Other experimental lines are currently in various stages of development. Experimental lines are being grown year-round—at the Plant Breeding Unit in Tallassee during the summer and in winter nurseries in Belize, Central America, and in the greenhouse at Auburn during the winter.

CURRENT VARIETIES

Seed yields for selected varieties are summarized for the years 1981-83 for five soybean production areas in Alabama, table 2. Analysis of variety tests conducted since 1976 revealed that variety recommendations are best made on the basis of five major areas: the Baldwin-Mobile county (Gulf Coast) area, the Black Belt area, and the remainder of the State divided into north, central, and south areas. Three years is considered to be the minimum time necessary for testing and comparing varieties, because some years may favor certain varieties while the same variety may do poorly in other years. Some newer varieties (released since 1980) are probably suitable for production in one or more areas but have not had sufficient testing time to be included in the comparisons.

Some of the new public varieties, Foster, Kirby, Johnston, and Jeff, have been compared to older, more established varieties, tables 3 and 4. These new public varieties have not been sufficiently tested in Alabama variety tests to appear on the recommended list, and seed of some of these varieties may still be limited. Also reported in the tables are reactions to a number of pests that are frequently a problem in Alabama. For many varieties, large differences in reaction to these pests are much more important than small differences in yield. Jeff, for example, yielded about 3 bushels per acre less than Tracy-M or Centennial over a 3-year period at the Tennessee Valley Substation, table 3. However, Centennial and Tracy-M are susceptible to race 4 of the soybean cyst nematode and would be expected to yield poorly in fields infested with this pest. Jeff is resistant and should perform normally under race 4 cyst nematode infested conditions. Special pest problems that have recently been evaluated in Alabama Agricultural Experiment Station trials are covered in the following paragraphs.

TABLE 2. PERFORMANCE OF SELECTED SOYBEAN VARIETIES, 1981-83

Variety	Seed yield per acre						
	North Alabama		Central Alabama	South Alabama		Black Belt	Gulf Coast
	Early planted	Late planted		Early planted	Late planted		
	Bu.	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*
Early							
Bedford	36.3	34.3				13.4	46.4
Deltapine 105	42.6	39.5	25.8	40.9	29.7	24.3	
Essex	34.8	38.9					
Forrest	38.8	38.7	24.8	34.2	24.9	15.3	35.2
Medium							
Centennial	32.6	33.6	24.1	41.1	30.0	17.1	40.6
Coker 156	36.5	37.3	24.5	45.2	19.1	22.6	42.8
Davis	33.5	35.8	24.9	44.7	33.6	24.9	43.8
Tracy-M	34.4	34.7	24.8	37.5	25.3	20.9	41.2
Late							
Braxton	33.5	35.2	25.6	46.3	33.4	27.1	46.1
Cobb				48.7	39.9	18.4	42.9
Foster			21.2	45.5		13.0	41.8
GaSoy 17			23.8	47.3	34.4	18.1	46.1
Hartz 7126			26.9	40.4		15.4	
Ransom			23.1	43.1	30.5	21.0	43.7
Wright			24.4	45.0	32.5	23.0	46.0
L.S.D. (.05)	6.2	4.2	8.1	9.9	7.5	5.3	9.8

TABLE 3. MATURITY GROUP VI COOPERATIVE UNIFORM SOYBEAN TEST, TENNESSEE VALLEY SUBSTATION, 1981-83

Variety	Yield/acre	M.i.[1]	M.a.	SCN-3	SCN-4	S.C.
	Bu.					
Centennial	36.4	R[2]	S	R	S	MR
Tracy-M	36.4	S	S	S	S	R
Jeff	33.0	R	S	R	R	S

[1]M.i. = *Meloidogyne incognita* (cotton root-knot nematode); M.a. = *M. arenaria* (peanut root-knot nematode); SCN = soybean cyst nematode (race 3 and 4); S.C. = stem canker.
[2]R = resistant, MR = moderately resistant, and S = susceptible.

TABLE 4. MATURITY GROUP VIII COOPERATIVE UNIFORM SOYBEAN TEST, GULF COAST SUBSTATION AND TALLASSEE, 1981-83

Variety	Yield/acre	M.i.[1]	M.a.	SCN-3	SCN-4	S.C.
	Bu.					
Hutton	31.6	R[2]	S	S	S	S
Cobb	33.9	R	S	S	S	MR
Foster	33.6	R	S	R	S	MR
Kirby	33.4	R	R	R	S	MR
Johnston	34.9	S	S	S	S	MR

[1]M.i. = *Meloidogyne incognita* (cotton root-knot nematode); M.a. = *M. arenaria* (peanut root-knot nematode); SCN = soybean cyst nematode (race 3 and 4); S.C. = stem canker.
[2]R = resistant, MR = moderately resistant, and S = susceptible.

Root-knot nematodes. Several root-knot resistant or root-knot susceptible varieties were compared for yield performance on a field in Baldwin County, Alabama, that was severely infested with the cotton root-knot nematode, table 5. Two tests were conducted—one during 1982 and 1983 and one during 1983 only. Varieties that are susceptible to the cotton root-knot nematode were included in the tests for comparison purposes. Results confirm that nematode resistance is highly specific. Coker 317 has good resistance to soybean cyst nematode, but this resistance did not prevent damage by the cotton root-knot nematode. Under high levels of root-knot nematode infestation, such as those occurring in this field, even root-knot resistant varieties offer little protection. With the Environmental Protection Agency's recent elimination of EDB, an effective and economical soil fumigant, nematode resistant varieties will be a key control practice for many growers. Based on results of these tests, Kirby and Foster (new releases by the USDA and University of Florida) offer the best chance for success in soybean fields infested with the root-knot nematode. Braxton also offers some resistance in a variety with slightly earlier maturity. These tests were conducted under extreme conditions and yield losses will probably not be so severe under more normal infestation levels.

TABLE 5. SEED YIELDS OF SOYBEAN VARIETIES GROWN WITHOUT CONTROL FOR ROOT-KNOT NEMATODES, BALDWIN COUNTY, ALABAMA

Cultivar	Yield/acre
	Bu.
Test 1 (1982-83)	
Foster	21.1
Coker 317[1]	9.9
Ransom[1]	10.5
RA 701	14.1
Braxton	15.4
GK 49	10.3
A 7372	11.2
Test 2 (1983 only)	
Kirby	35.4
Foster	26.1
Coker 317[1]	19.0
Braxton	21.4
Ransom[1]	14.5
Johnston[1]	8.5
Cobb	8.5

[1]Susceptible to root-knot nematode. All other varieties are resistant.

TABLE 6. STEM CANKER AND IRON CHLOROSIS RATINGS FOR SELECTED SOYBEAN VARIETIES

Variety	Stem canker rating[1]	Iron chlorosis rating
Bay	1.0	2
Bedford	3.0	2
Deltapine 105	2.7	2
Deltapine 345	2.5	1
Essex	M	2
Forrest	2.7	3
Agratech 67	2.3	2
Centennial	1.3	3
Coker 156	2.0	2
Davis	1.1	2
Jeff	3.0	2
Lee 74	2.7	2
Tracy-M	1.0	2
Agripro AP 70	2.3	2
Braxton	1.0	1
Coker 237	3.3	1
Duocrop	2.7	2
GaSoy 17	2.0	2
Govan	2.3	2
Ransom	2.3	2
Wilstar 790	3.3	2
Wright	2.0	3
Cobb	2.3	2
Coker 488	2.0	2
Foster	2.0	3
Hutton	4.0	1
Kirby	2.7	3

[1]Stem canker and iron chlorosis are rated on a scale of 1 to 5, with 1 = best and 5 = worst. A rating of M = mature.

Stem canker. Much attention has been paid to varietal response to infection by stem canker *(Diaporthe phaseolorum* var. *caulivora)*, first diagnosed in Alabama in 1977. Initial observations and research quickly discovered that a few varieties were extremely and uniformly susceptible to stem canker, and two or three varieties were resistant. The majority of varieties lie somewhere between these two extremes.

Average disease ratings from several experiments for many adapted varieties are presented in table 6. Any variety with a rating of 4 or higher is considered to be extremely susceptible and unsuited for planting under any circumstances. Varieties with a rating of 2 to 3 are considered to be somewhat susceptible. Those few varieties with a rating less than 2 are considered to be resistant, but it would be inadvisable to plant only those varieties in view of the other pests that may be present. Tracy-M and Braxton, for example, have no resistance to the soybean cyst nematode.

Other characteristics. Also included in table 6 is an iron chlorosis susceptibility rating. Iron chlorosis is caused by the unavailability of iron in certain high pH soils, and some varieties are better able to extract iron at low soil levels than others. This condition is usually not apparent except during periods of dry weather, but can cause significant yield loss.

See color plate numbers 1 and 2, page 24.

CULTURAL PRACTICES

Effect of In-row Chisel at Planting on Yield and Growth of Full-season Soybeans

D.L. Thurlow, C.B. Elkins, and A.E. Hiltbold

Sandy surface soils, such as those in the Coastal Plains of Alabama, are highly susceptible to traffic and tillage compactions. Wheel traffic of tractors and combines often compacts the plow layers, and disks and plows can create severe compaction at the bottom of the tillage zone, which is referred to as a disk, plow, or tillage pan. These compacted layers often prevent proper root development and prevent roots from reaching available moisture in the subsoil horizons. Tillage pans are present in almost all soils, but they do not restrict root development in all soils.

During 1974 and 1975, a study was conducted at the Wiregrass Substation to determine the effects of in-row subsoiling, conventional tilled soil, and planting date on growth and yields of Forrest, McNair 600, and Bragg soybean varieties. The conventional treatment seedbed was prepared by turning soil 9 inches, disking, and rotary tilling (prior to planting). The chisel treatment was prepared with a 2-inch subsoil shank run to a depth of 14 inches and the soil bedded over the chisel opening.

There was a yield increase to chiseling under the row with all varieties at both planting dates in 1974. However, yields were not different due to chiseling in 1975. There was a planting date interaction on yield of McNair 600 and Bragg in 1974 in that McNair 600 produced a higher yield for May 11 planting but was lower in yield than Bragg for the May 30 planting, table 7. All varieties responded with increased plant height at both planting dates and in both years where the subsoil chisel was used.

TABLE 7. EFFECT OF PLANTING DATE AND IN-ROW CHISELING ON SOYBEAN YIELD AND PLANT HEIGHT, WIREGRASS SUBSTATION, 1974-75

Soil preparation	Variety	Yield/acre 1974	Yield/acre 1975	Yield/acre Av.	Plant height 1974	Plant height 1975	Plant height Av.
		Bu.	*Bu.*	*Bu.*	*In.*	*In.*	*In.*
Early Planting Date[1]							
Chisel	Forrest	45	27	36	28	24	26
Chisel	McNair 600	47	34	41	30	25	28
Chisel	Bragg	45	29	37	33	29	31
	Av.			38			28
Conventional	Forrest	30	25	28	23	21	22
Conventional	McNair 600	36	36	36	21	24	23
Conventional	Bragg	33	27	30	27	28	28
	Av.		31			24	
Late Planting Date							
Chisel	McNair 600	44	31	38	30	37	34
Chisel	Bragg	54	27	41	35	31	33
	Av.			40			34
Conventional	McNair 600	33	30	32	25	23	24
Conventional	Bragg	39	25	32	31	26	29
	Av.			32			27

[1]Planting dates were May 10 and May 30 for 1974 and May 22 and June 3 for 1975.

From 1977 through 1981, research was done at nine locations in Alabama to determine if disrupting the tillage pans with an in-row subsoiler at planting, in both conventional and no-tillage cropping systems, would improve soybean plant growth and yields.

The conventional tillage treatment consisted of either chiseling or turning soils 8-10 inches deep and then disking, rotary tilling, or using a combination seedbed conditioner to prepare a seedbed. The no-tillage treatment was planted into a killed stand of small grain or old crop residue with only a double disk opener planter. The in-row subsoil treatments were planted with a Brown Harden Super Seeder®. Subsoil depth was 12-14 inches.

Essex soybeans were planted in the three northern Alabama locations and Ransom soybeans were planted in the six southern Alabama locations. All plantings were made for full season production using a 36-inch row width. The yield and growth of soybeans are reported as relative yield and plant height in relation to the conventional tillage treatment, tables 8 and 9.

TABLE 8. RELATIVE PLANT HEIGHT OF SOYBEANS AS AFFECTED BY PREPLANT SOIL PREPARATION AND IN-ROW SUBSOILING ON SEVEN SOILS IN ALABAMA[1]

Tillage treatment	Relative plant height by location: Tennessee Valley Substation (1978-79)	Sand Mountain Substation (1977-78)	Tallassee (1977-81)	Prattville Experiment Field (1977-81)	Monroeville Experiment Field (1977&79)	Wiregrass Substation (1978)	Gulf Coast Substation (1978)
Conventional tillage..........	100	100	100	100	100	100	100
Conventional tillage plus in-row subsoiling......	100	101	107	100	102	125	103
No-tillage..................	97	101	82	71	87	71	76
No-tillage plus in-row subsoiling..........	102	109	107	94	100	118	94
Av. plant height for conventional tillage, inches............	26	25	31	31	33	23	37

[1]Soil types: Tennessee Valley Substation, Decatur clay; Sand Mountain Substation, Hartsells fine sandy loam; Tallassee, Cahaba fine sandy loam; Prattville Field, Lucedale fine sandy loam; Monroeville Field, Lucedale fine sandy loam; Gulf Coast Substation, Malbis fine sandy loam; Wiregrass Substation, Dothan fine sandy loam.

TABLE 9. RELATIVE YIELD OF SOYBEANS AS AFFECTED BY PREPLANT SOIL PREPARATION AND IN-ROW SUBSOILING ON EIGHT SOILS IN ALABAMA

Tillage treatment	Tennessee Valley Substation (1978-79)	Sand Mountain Substation (1977-79)	Upper Coastal Plain Substation (1978-79)	Tallassee (1980-81)	Prattville Experiment Field (1978-81)	Monroeville Experiment Field (1977-79)	Wiregrass Substation (1978-80)	Gulf Coast Substation (1978-79)
Conventional tillage	100	100	100	100	100	100	100	100
Conventional tillage plus in-row subsoiling	113	92	106	115	105	99	156	98
No-tillage	114	71	87	84	66	85	85	79
No-tillage plus in-row subsoiling	116	87	91	100	104	105	152	100
Av. yield for conventional tillage, bushels per acre	37.4	33.9	28.8	28.4	19.5	37.1	15.6	33.9

When compared to the conventional tillage treatment, no-tillage without subsoiling resulted in reduced soybean yields and plant growth on all Coastal Plains and River Terrace soils. The use of the in-row subsoiler with the conventional tillage system at planting increased yields over the conventional tillage system at Tallassee and the Wiregrass Substation. The Tallassee soil had a strong plow pan and the Wiregrass soil developed a compact layer in the lower plow layer during the herbicide incorporation with rotary tiller and disk.

Yields of soybeans under the no-tillage system with the in-row subsoiler were equal to those grown on the conventional system with and without the in-row subsoiler except at the Sand Mountain Substation. There the highest yields were from conventional tillage. The most noticeable effect of tillage treatments on vegetative growth was reduced plant height in the no-tillage treatment at Tallassee, Prattville Field, Monroeville Field, Wiregrass Substation, and Gulf Coast Substation. At the Tennessee Valley Substation, all plots produced good growth and yield with all tillage systems.

The results of these studies suggest that for full season soybeans, yields from no-tillage systems may be comparable to or higher than yields from conventional tillage systems provided an in-row subsoiler is used on Coastal Plains and River Terrace soils.

See color plate number 3.

Tillage Systems for Full-season and Double-cropped Soybeans

J.T. Touchton, D.L. Thurlow, C.B. Elkins, and G.V. Granade

During the past few years, many tillage studies have been conducted in Alabama and the Southeast. The conclusion to be drawn from these studies is that the most economical tillage system will vary among soils, years, row widths, cropping systems, and varieties. Because of the many factors that can affect yield responses to tillage, it is impossible to prescribe a single optimum tillage system.

FULL-SEASON SOYBEANS AND TILLAGE

From 1977 through 1981, studies were conducted at eight locations in Alabama to compare the effects of conventional tillage, no tillage, and no tillage with in-row subsoiling on yield of full-season soybeans. No-tillage was planting into a killed stand of small grain (or old crop residue) with a double-disk opener planter. The in-row subsoiling was with a Brown Harden Super Seeder® to a depth of 12-14 inches. Essex variety was planted in the northern half of the State and Ransom in the southern half. All plantings were made for full-season production using a 36-inch row width.

No-tillage without subsoiling resulted in lower soybean yields and less plant growth on all Coastal Plains and River Terrace soils, table 10. Yields under no-tillage with the in-row subsoiler were equal to the conventional system, except at the Sand Mountain Substation where the highest yield was with conventional tillage. The most visible effect of tillage treatments was shorter plants in the no-tillage treatment at several sites. At the Tennessee Valley Substation, all tillage treatments produced equally good yields.

In summary, yields of full-season soybeans under no-tillage were equal to or higher than yields under conventional tillage **provided** an in-row subsoiler was used on Coastal Plains and River Terrace soils.

DOUBLE-CROPPED SOYBEANS AND TILLAGE

From 1981 through 1983, two studies were conducted at five locations to compare the effects of tillage systems on yields of double-cropped wheat and soybeans. One study consisted of tillage prior to planting wheat (wheat tillage) and the other consisted of tillage prior to planting soybeans (soybean tillage).

Wheat Tillage

The tillage systems for wheat consisted of no-till, disk, chisel plow-disk, chisel plow-drag, turn-disk, and turn-drag. At Brewton, Monroeville, and Prattville fields, a drag bar was used for the drag treatment, but a roterra was used at the other locations. After wheat harvest, no-till soybeans were planted without a subsoiler on one-half of the plots and with an in-row subsoiler on the other half. The soybean variety was either Bragg or Braxton.

For both wheat and soybeans there were no yield differences among the deep tillage treatments (chisel-disk, chisel-drag, turn-disk, and turn-drag). Because of this, they will be collectively referred to as "deep tillage."

Wheat yields were highly dependent on tillage, table 11. No-till produced considerably lower wheat yields than deep tillage at all locations. Disk tillage resulted in lower yields than deep tillage at Wiregrass Substation, Brewton Field, and Prattville Field.

TABLE 10. RELATIVE YIELD AND PLANT HEIGHT OF SOYBEANS AS AFFECTED BY PREPLANT SOIL PREPARATION AND IN-ROW SUBSOILING[1]

Tillage treatment	Relative yield and plant height by location[2]															
	Tennessee Valley Substation (1978-79)		Sand Mountain Substation (1977-79)		Upper Coastal Plain Substation (1978-79)		Plant Breeding Unit (1977-81) (1980-81)		Prattville Experiment Field (1978-81)		Monroeville Experiment Field (1977-79)		Wiregrass Substation (1978-80)		Gulf Coast Substation (1978-79)	
	Yield	*Ht.*	*Yield*	*Ht.*	*Yield*	*Ht.*	*Yield*	*Ht.*	*Yield*	*Ht.*	*Yield*	*Ht.*	*Yield*	*Ht.*	*Yield*	*Ht.*
Conventional tillage	100	100	100	100	100	N/A[3]	100	100	100	100	100	100	100	100	100	100
No-tillage	114	97	71	101	87	N/A	84	82	66	71	85	87	85	71	79	76
No-tillage plus in-row subsoiling	116	102	87	109	91	N/A	100	102	104	94	105	100	152	118	100	94
Yield (bu./acre) and plant height (in.) for conventional tillage	37.4	26	33.9	25	28.8	N/A	28.4	31	19.5	31	37.1	33	15.6	23	33.9	37

[1]Soil types: Tennessee Valley Substation, Decatur clay; Sand Mountain Substation, Hartsells fine sandy loam; Upper Coastal Plain Substation, Savannah fine sandy loam; Prattville, Lucedale fine sandy loam; Monroeville, Lucedale fine sandy loam; Gulf Coast Substation, Malbis fine sandy loam; Wiregrass Substation, Dothan fine sandy loam; Tallassee, Cahaba fine sandy loam.
[2]Relative yields (Yield) and relative plant heights (Ht.) were calculated by dividing yield and plant height of "conventional tillage" into yield and plant height of each tillage treatment.
[3]N/A—plant height not available at this substation.

TABLE 11. WHEAT GRAIN YIELD AS AFFECTED BY TILLAGE PRIOR TO PLANTING WHEAT

Location[1]	Soil	Variety	Wheat yield/acre by tillage		
			No-till	Disk	Deep[2]
			Bu.	*Bu.*	*Bu.*
Wiregrass Substation	Dothan fsl	Coker 747	34	41	50
Brewton Experiment Field	Benndale sl	Coker 747	20	25	35
Monroeville Experiment Field	Lucedale scl	Coker 747	44	52	54
Prattville Experiment Field	Bama sl	Coker 747	29	40	48
Black Belt Substation	Sumpter c	McNair 1003	32	40	39
Gulf Coast Substation	Malbis fsl	Coker 762	49	55	55

[1]Yields are averaged over 3 years (1981-83), except Gulf Coast Substation data are for only 2 years (1982 & 1983).
[2]Deep tillage is an average of four tillage systems: chisel-disk, chisel-drag, turn-disk, and turn-drag.

In-row subsoiling of soybeans ahead of wheat did not affect wheat yields during the first 2 years of the test. In the third year, however, wheat following subsoiled soybeans outyielded other tillage treatments at the Wiregrass Substation, Gulf Coast Substation, and Monroeville Field, table 12. This result illustrates the need for occasional deep tillage on some soils.

Soybean yields were not particularly affected by the tillage system used for wheat, table 13. However, the need for subsoiling soybeans was sometimes highly dependent on the previous wheat tillage.

On the soils at the Monroeville Field, Black Belt Substation, and Gulf Coast Substation, soybean yields were not affected by wheat tillage nor by subsoiling of soybeans. The most economical tillage system for these soils probably would be to disk prior to wheat and no-till soybeans without in-row subsoiling. Row widths, however, might make a difference.

TABLE 12. WHEAT YIELDS IN 1983 AS AFFECTED BY PLANTING METHODS FOR SOYBEANS AND TILLAGE PRIOR TO SOYBEANS

Location	Subsoiled soybeans	Wheat yield/acre, by tillage		
		No-till	Disk	Deep
		Bu.	*Bu.*	*Bu.*
Wiregrass Substation	No	21	32	46
	Yes	30	46	52
Monroeville Field	No	41	44	46
	Yes	45	47	51
Gulf Coast Substation	No	49	48	53
	Yes	51	59	59

Wide-row plantings of soybeans (30 to 36 inches) would probably need to be subsoiled because subsoiling generally results in larger plants. Large plants are required to close the canopy in wide rows but not in narrow rows.

On the soils at the Wiregrass Substation and the Brewton Experiment Field, in-row subsoiling of soybeans resulted in higher yields unless the soil had been deep tilled for wheat. If wheat is no-tilled or if the soil is disked for wheat, in-row subsoiling is needed for soybeans, even if planted in narrow

TABLE 13. YIELD OF NO-TILLAGE SOYBEANS AS AFFECTED BY TILLAGE PRIOR TO PLANTING WHEAT AND IN-ROW SUBSOILING FOR SOYBEANS

Location[1]	Subsoiling soybeans	Soybean yield/acre, by wheat tillage		
		No-till	Disk	Deep[2]
		Bu.	*Bu.*	*Bu.*
Wiregrass Substation	No	40	41	44
	Yes	43	45	44
Brewton Experiment Field	No	30	36	44
	Yes	46	49	49
Monroeville Experiment Field	No	35	36	36
	Yes	37	37	37
Prattville Experiment Field	No	28	25	28
	Yes	31	29	31
Black Belt Substation	No	35	30	32
Gulf Coast Substation	No	49	47	51
	Yes	52	49	50

[1]Data include 1 year at Black Belt Substation, 2 years at Gulf Coast Substation, and 3 years at other locations.
[2]Deep tillage is average of four tillage systems: chisel-drag, chisel-disk, turn-drag, and turn-disk.

TABLE 14. YIELD OF DOUBLE-CROPPED SOYBEANS AS AFFECTED BY TILLAGE PRIOR TO PLANTING SOYBEANS

Tillage	Soybean yield/acre, by location[1]					
	Wiregrass Substation	Brewton Experiment Field	Monroeville Experiment Field	Prattville Experiment Field	Black Belt Substation	Gulf Coast Substation
	Bu.	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*
No-till	39	24	18	29	16	48
No-till[2]	43	39	22	29	22	44
Disk	40	22	23	29	28	46
Deep	42	32	24	29	27	51
FLSD (0.10)	2	4	3	NS	4	5

[1]Yields are averaged over 2 years at the Black Belt and Gulf Coast substations and 3 years at other locations. Deep tillage yields are averages of four systems: chisel-disk, chisel-drag, turn-disk, and turn-drag.
[2]Planted with an in-row subsoiler.

rows. If the soil is deep tilled for wheat, however, there is no need for in-row subsoiling. The most economical tillage system would appear to be deep tillage for wheat and no-till for soybeans—with soybeans planted in narrow rows.

On the soil at the Prattville Experiment Field, soybean yields were not affected by tillage for wheat, but there was a consistent yield increase (3 to 4 bushels per acre) with in-row subsoiling. Since deep tillage resulted in consistently higher wheat yields, the most economical tillage system for this soil would be deep tillage for wheat and in-row subsoiling for soybeans.

Soybean Tillage

This study was conducted at the same locations as the wheat tillage study. Tillage treatments prior to planting soybeans were no-till, no-till plus in-row subsoiling, disk, chisel plow-disk, chisel plow-drag, turn-disk, and turn-drag. The soil was disked each year prior to planting wheat.

Soybean yields for all deep tillage systems were the same, so yields for all deep tillages are averaged. However, yield differences were found among the other tillage systems, table 14, except at the Prattville Experiment Field. Wheat yields were not affected by tillage for soybeans, so the spring tillage system can be selected based on what is best for soybeans.

TABLE 15. SOYBEAN YIELDS IN 1983 AS AFFECTED BY TILLAGE AND IN-ROW SUBSOILING ON A NORFOLK FSL

Variety	Yield/acre, by tillage		
	Conventional	No-till subsoil	No-till
	Bu.	*Bu.*	*Bu.*
Maturity Group V			
Bay	23	19	20
Bedford	27	23	22
Coker 355	28	26	21
Forrest	32	26	16
Maturity Group VI			
Centennial	35	33	29
Coker 156	37	33	29
Davis	35	33	27
Tracy-M	24	23	20
Maturity Group VII			
Braxton	35	36	37
Coker 237	35	37	34
Ransom	35	36	31
Wright	33	35	32
Maturity Group VIII			
Cobb	30	35	36
Coker 338	27	31	29
Coker 488	35	36	35
Hutton	21	27	27

On soils at the Prattville Experiment Field and the Gulf Coast Substation, no-till without subsoiling would be most economical. On soils at the Wiregrass Substation and Brewton Experiment Field, no-till with in-row subsoiling would be most economical. Disk tillage would be best for the Black Belt Substation soil and either disk tillage or no-till with in-row subsoiling would be best on soil at the Monroeville Experiment Field.

VARIETY-TILLAGE TEST

When comparing data on tillage systems, responses to tillage can be affected by variables that cannot be included or controlled. An example is variety responses. In most tests conducted on tillage systems, a single variety has been used. In a recent tillage-variety experiment at the E.V. Smith Research Center, yields of different varieties of soybeans were affected differently by the different tillage systems, table 15. For example, Forrest yielded best under conventional tillage and did poorly under no-till culture unless it was in-row subsoiled; Braxton yielded the same under all tillage systems; Hutton yielded best under no-till culture and in-row subsoiling did not matter.

Results of this 1-year variety-tillage experiment illustrate the difficulty of making tillage recommendations. The data are interpreted as meaning that a specific tillage system will not always result in higher yields than some other system.

See color plate number 4.

Crop Rotations

J.T. Touchton, D.L. Thurlow, and J.T. Cope, Jr.

For many years, rotations involving legumes were standard practice in most agricultural systems. During the past few decades, however, there has been a movement toward continuous cropping or monoculture, with commercial fertilizers, insecticides, fungicides, and herbicides substituted for the beneficial effects of crop rotation. However, long-term continuous cropping can result in problems that cannot be economically solved with commercial products, and crop rotations are needed for economical yields.

Currently, the primary interest in soybean-grain crop rotations is to control nematodes and stem canker in soybeans.

TABLE 16. CORN GRAIN YIELDS AS AFFECTED BY PREVIOUS CROPS AND APPLIED NITROGEN

Previous crop	Yield/acre, by N rate/acre			
	None	60 lb.	120 lb.	240 lb.
	Bu.	*Bu.*	*Bu.*	*Bu.*
Black Belt Substation, 1981-82				
Soybeans.....	70	102	134	152
Sorghum.....	26	71	122	135
Sand Mountain Substation, 1981-82				
Soybeans.....	24	92	113	111
Sorghum.....	14	81	100	110
Tennessee Valley Substation, 1981-82				
Soybeans.....	89	112	121	120
Sorghum.....	44	93	118	123

TABLE 17. YIELDS OF CORN, WHEAT, AND SOYBEANS FROM THREE-CROP AND TWO-CROP ROTATIONS AT SIX ALABAMA LOCATIONS, 1968-78

Cropping sequence	Brewton Experiment Field	Monroeville Experiment Field	Prattville Experiment Field	Wiregrass Substation	Sand Mountain Substation	Tennessee Valley Substation
	Bu.	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*
3-crop rotation						
Corn....................	97	89	77	100	131	103
Wheat..................	24	26	39	40	46	45
Soybeans................	39	39	39	32	38	29
2-crop rotation						
Corn....................	93	83	78	86	119	109
Soybeans................	34	34	36	30	40	41

Crop rotations are probably valid methods of controlling these pests, but an added benefit is that grain crop rotations with soybeans will also increase the profitability of grain crop production.

In 1980, studies were established at the Sand Mountain, Black Belt, and Tennessee Valley substations to determine the effect of soybean crops on yield and nitrogen fertilizer requirements of corn that follows in the rotation. Corn was planted behind either soybeans or grain sorghum. The soybeans, but not grain sorghum, would provide N and a rotational effect on corn. Various N rates were applied to the grain sorghum and to the corn.

Corn yields from these rotations are listed in table 16. When comparing corn yield responses to N rates, it is obvious, especially at the low N rates, that soybeans were supplying 30 to 60 pounds of N per acre to corn.

Lowering N fertilizer requirements was not the only benefit of rotating corn with soybeans. In two of the six tests (Black Belt Substation, 1981, and Sand Mountain Substation, 1982) there was also a rotational effect. For example, corn yields in both of these years leveled off at the 120-pound-per-acre N rate regardless of the previous crop, but corn yields following soybeans averaged 22 bushels per acre higher than when following grain sorghum. Similar rotational effects were obtained by following soybeans with grain sorghum.

Two- vs. Three-crop Rotations

Long-term rotation studies have been conducted at several locations since 1929. From 1968 to 1978, these studies were in two-crop and three-crop rotation comparisons. The two-crop rotation was corn-soybeans, and the three-crop rotation was corn-wheat-soybeans. Yield differences between the two rotations varied among locations, table 17. At three of the six locations (Brewton Experiment Field, Monroeville Experiment Field, and Wiregrass Substation), the corn-wheat-soybean rotation resulted in 7- and 5-bushel-per-acre higher corn and soybean yields, respectively, than the soybean-corn rotation. At the Prattville Experiment Field, the three-crop rotation increased soybean yields by 3 bushels per acre per year. At the Sand Mountain Substation, the three-crop rotation decreased soybean yields by 2 bushels per acre per year, but it increased corn yields by 12 bushels; in addition, wheat yields averaged 46 bushels per acre. Only at the Tennessee Valley Substation was the economical advantage of a three- vs. a two-crop rotation questionable. At that location, the 7-year average wheat yield was good (45 bushels per acre), but the wheat resulted in a 5-bushel-per-acre-per-year corn yield reduction and a 12-bushel-per-acre-per-year soybean yield reduction.

See color plate number 5.

Soybean Row Spacing

D.L. Thurlow

Soybeans grown in Alabama prior to 1965 were planted in 38- to 42-inch rows with the same equipment used for cotton and corn. A survey conducted by the National Soybean Crop Improvement Council indicated that 27 percent of the 1969 soybean crop in Alabama was planted in rows closer than 33 inches and 8 percent in rows closer than 26 inches.

Most research on row spacing in the Southeast prior to 1960 had not shown any advantage to narrow rows. This was due to the soybean varieties then available, and to the fact that most research was conducted with planting dates that favored maximum vegetation growth. However, many soybean fields planted in wide rows and double cropped after small grain fail to develop a closed soybean canopy.

To study the effect of row spacing on plant growth and seed yield, field tests were conducted at three Alabama locations with full season varieties from maturity groups VI, VII, and VIII for northern, central, and southern locations, respec-

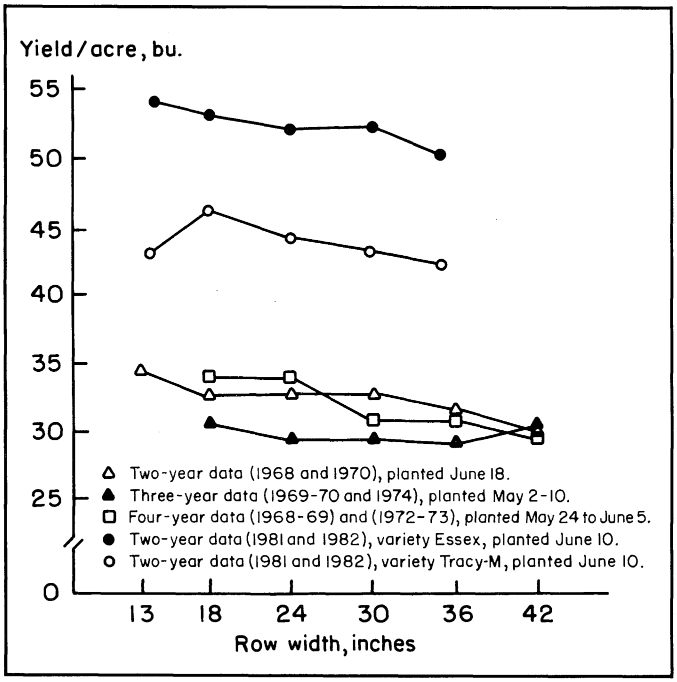


FIG. 3. Soybean yields as affected by row spacing and planting date, Tennessee Valley Substation.

tively: Tennessee Valley Substation, 1968 to 1970, 1972 to 1973, and 1981 to 1982, figure 3; Black Belt Substation, 1968 to 1970, figure 4; and Gulf Coast Substation, 1968 to 1970, figure 5. These tests included row widths of 7 to 42 inches in 1968, 13 to 42 inches from 1968 to 1973, and 14 to 35 inches from 1981 to 1982. All row width tests at each location in 1968 and 1969 were planted to the same seeding rate, 1 bushel per acre, which was approximately 10 plants per foot of row in 36-inch row spacing. Later tests were conducted with more than one seeding rate, and yields are reported as average of all seeding rates for each row spacing used. The tests in north Alabama, figure 3, during 1982 and 1983 were conducted using the short, early variety Essex and taller, full season Tracy-M. The planting dates at each location were selected so they either favored maximum potential growth of the soybean plant (early plantings) or were delayed by 3-4 weeks so that the soybean plants were limited in growth because shorter days induced early flowering.

Soybean yields in north Alabama tests were not affected by row spacing during the 3 years plantings were made in early May, figure 3. However, when plantings were made in late May and early June, yield was increased as the row spacing was narrowed, figure 3. The highest soybean yields were obtained at 18- to 24-inch spacing. The greatest increase in yields due to row spacing was for the late June planting, figure 3, with the highest yield from 13-inch spacing.

In 1981 and 1982, Essex and Tracy-M cultivars were used to study the effect of row spacing on short and tall soybean varieties, figure 3. The shorter cultivar, Essex, produced the highest yield with little lodging. However, much of the lower yield of Tracy-M as compared to Essex was due to lodging. Lodging of Tracy-M increased when plant population was increased, but despite lodging problems the highest yield was obtained from the highest plant population, three plants per square foot of area.

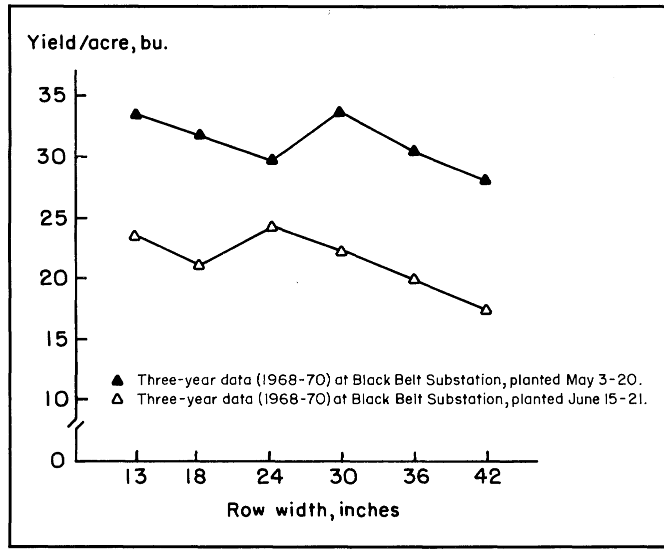


FIG. 4. Soybean yields as affected by row spacing and planting date, Black Belt Substation.

In central Alabama on a Eutaw clay soil at the Black Belt Substation, Bragg soybean yields were higher for row width narrower than 42 inches for 2 of the 4 years for plantings in mid-May and 2 of the 3 years for late June plantings, figure 4.

In southern Alabama on a Malbis fine sandy loam soil at the Gulf Coast Substation, the effect of row spacing for early and late plantings shows that a delayed planting yield loss in conventional row widths of 36 inches can be overcome by narrowing row width to 13 to 18 inches, figure 5. In late May and early June plantings, yields were increased by narrow row spacing only 50 percent of the time, figure 5. However, when plantings were made in late June, soybean yields were in-

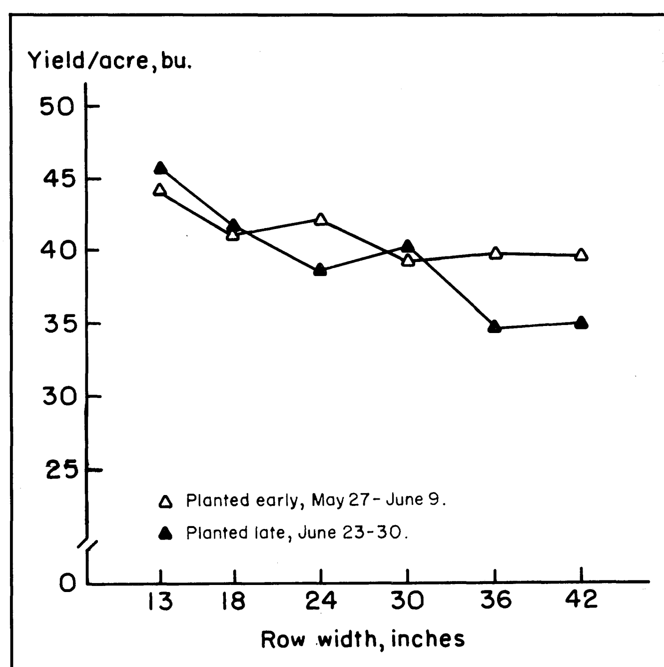


FIG. 5. Soybean yields as affected by row spacing and planting date, 3-year average, Gulf Coast Substation.

creased all 4 years with 13-inch row spacings versus 36- to 42-inch spacing, figure 5.

Soybean row spacing research in the Southeast does not show much advantage for narrow row spacing over the conventional row width of 36-40 inches for early plantings. Since there was not a decrease in yield by planting early in narrow rows and with the increased advantage in yield from narrow rows versus wide row spacing for late planted soybeans, it would be a good production practice to narrow row spacings provided other cultural practices such as weed and insect control are not hindered.

See color plate number 6.

Planting Date Effect on Soybean Growth and Yield

D.L. Thurlow

Planting date is one of the most important management practices in soybean production. Soybean varieties differ in growth habit, flowering date, and maturity. Much of this variability in growth is due to sensitivity to day length. Because every soybean variety has a different day length response, getting maximum growth and yield requires that time of planting be based on calendar date and soil temperature for each location. In north Alabama, soil temperature and climatic conditions are generally favorable for planting soybeans in early May when the day length is such that the full season varieties will grow and produce adequate plant height before flowering. In central and southern Alabama, however, the soil temperature and other climatic conditions are generally favorable for planting soybeans 4 to 6 weeks before the day lengths reach the stage that will allow full season varieties to make sufficient plant growth for maximum yields. The large acreage produced by most farmers has forced them to utilize more and more of this available planting period without realizing the effect it may have on the final growth and yield of soybeans.

The Maturity Group VII varieties, which are considered full season and best adapted for central Alabama, flower before adequate growth is made if grown with day lengths of less than 14.5 hours. At the Black Belt Substation, the long days of June and early July (greater than 15 hours) prevent flowering of Maturity Group VII and VIII varieties. The shorter days of late July and August will cause these varieties to stop vegetative growth and initiate flowering and pod development. If these varieties are planted in mid- to late June, adequate plant growth will not be obtained and yields will be lowered.

To better evaluate this effect of early and late planting on growth and bean yield of soybeans in Alabama, studies were conducted with single cropped soybeans for several years at the Brewton and Prattville experiment fields and the Black Belt and Sand Mountain substations. Planting dates and varieties used are listed in tables 18-24. The soybeans were grown with conventional tillage management practices using row widths of 36 inches and seeding rates of 12 seed per foot of row.

TABLE 18. PLANT HEIGHT OF SOYBEAN VARIETIES AS AFFECTED BY PLANTING DATE DURING 1974-78 WHEN GROWN AT BLACK BELT SUBSTATION

Maturity group and variety	Plant height, by planting date				
	Apr. 15[1]	Apr. 26[2]	May 16	June 3[3]	June 22
	In.	*In.*	*In.*	*In.*	*In.*
Group V					
Essex	16	19	20	23	22
Group VI					
Davis	28	32	32	32	28
Group VII					
Bragg	26	32	37	36	31
Group VIII					
Hutton	25	30	35	33	28
Mean	24	28	31	31	27

[1]No planting 1978.
[2]No planting 1977.
[3]No planting 1974.

TABLE 19. PLANT HEIGHT OF DIFFERENT SOYBEAN VARIETIES PLANTED AT VARIOUS DATES, BREWTON EXPERIMENT FIELD, 1981-82

Maturity group and variety	Plant height, by planting date						
	Apr. 14	Apr. 28	May 12	May 26	June 8	June 23	Av.
	In.	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*
Group VI							
Coker 156	23	26	29	28	29	22	26
Davis	30	29	34	36	32	28	31
Group VII							
Braxton	30	30	36	36	36	28	32
Ransom	23	22	31	33	35	26	28
Group VIII							
Foster	30	30	36	36	35	29	33
Hutton	26	27	33	33	34	28	31
Mean	26	27	33	34	33	27	

Data on the effect of planting date on plant height at the Black Belt Substation and Brewton Experiment Field show that the maximum growth was different for each variety, tables 18 and 19. Bragg and Hutton produced maximum plant height and seed yield with the mid-May planting. The plant height of Davis was similar from late April through early June plantings. A very early variety, Essex, showed little effect of planting date on plant height. However, maximum yields for Essex were obtained for mid-May planting.

TABLE 20. YIELD OF DIFFERENT SOYBEAN VARIETIES PLANTED AT VARIOUS DATES, BREWTON EXPERIMENT FIELD, 1981-82

Maturity group and variety	Yield/acre[1], by planting date					
	Apr. 14	Apr. 28	May 12	May 26	June 8	June 23
	Bu.	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*
Group VI						
Coker 156	48	54	52	48	37	23
Davis	49	52	50	51	39	34
Average	48	53	51	50	38	29
Group VII						
Braxton	44	48	51	53	44	33
Ransom	41	45	50	56	44	31
Average	42	47	51	54	44	32
Group VIII						
Foster	48	50	50	56	41	31
Hutton	47	47	46	49	40	24
Average	48	49	48	53	40	27

[1]Computed on basis of 13 percent moisture.

A similar study at the Brewton Field using two varieties each from maturity groups VI, VII, and VIII indicated maximum plant height was obtained for plantings from early May to early June, table 19. The least effect of planting date on plant height was again with varieties from Maturity Group VI.

TABLE 21. YIELD OF DIFFERENT SOYBEAN VARIETIES PLANTED AT VARIOUS DATES, BLACK BELT SUBSTATION, 1970-78

Maturity group and variety	Average yield[1]/acre, by planting date				
	Apr. 14	Apr. 17	May 14	June 6	June 28
	Bu.	*Bu.*	*Bu.*	*Bu.*	*Bu.*
4-year average (1970-73)					
Group V					
Dare	36.6	35.2	35.2	30.2	18.7
Group VI					
Davis	36.5	39.7	37.1	32.2	24.8
Group VII					
Bragg	29.7	30.6	32.3	28.5	24.0
Group VIII					
Hampton 266	23.1	22.0	22.6	24.4	21.4
Average	31.5	31.9	31.8	28.9	22.2
5-year average (1974-78)					
Group V					
Essex	21.2	23.9	32.0	26.2	22.3
Group VI					
Davis	35.7	33.8	34.3	29.4	26.8
Group VII					
Bragg	27.1	29.5	31.8	29.2	26.0
Group VIII					
Hutton	27.2	28.2	32.8	28.5	25.6
Average	27.8	28.9	32.7	28.3	25.1

[1]All yields reported as 13 percent moisture.

TABLE 22. LONG-TIME YIELDS OF SOYBEANS AS AFFECTED BY PLANTING DATES AT SAND MOUNTAIN SUBSTATION, CROSSVILLE, ALABAMA

Maturity group and variety	No. of varieties[2]	14-year[1] average yield/acre, by planting date		
		May 5	May 25	June 20
		Bu.	*Bu.*	*Bu.*
Group V (early)	1-5	38.0	33.2 (-.23)[3]	29.7 (-.13)[3]
Group VI (full stage)	3-7	36.0	33.1 (-.15)	29.4 (-.14)
Group VII (late)	1-2	36.9	34.5 (-.11)	30.7 (-.15)
Group VIII (very late)	1-2	36.0	32.5 (-.17)	30.6 (-.07)
Average	6-14	36.8	33.3 (-.17)	30.1 (-.12)

[1]14-year average includes 1967-71 and 1973-81 yields.
[2]Number of varieties in each maturity group used each year to compute average yield for each planting date.
[3]Average yield loss (bushels per acre per day) from previous planting date.

The effect of planting date on yield of full-season soybeans, tables 20 and 21, followed closely with early plant growth (height from tables 18 and 19) unless late season moisture was limiting. The late May plantings at the Brewton Field, table 20, gave the highest average yield for all Group VII and VIII varieties for the 2 years, 54 and 53 bushels per acre, respectively. Late April and early May planting yields were lower, but not as low as early June plantings which dropped to 44 and 40 bushels and late June plantings, which were 32 and 27 bushels per acre. The varieties Coker 156 and Davis produced maximum yields in the late April plantings, with only slightly lower yield for May plantings. Similarly at the Black Belt Substation, the highest average yield across all maturity groups was the mid-May plantings when Essex was the Group V entry during 1974-78. However, when Dare was the Group V entry during 1970-73, the average yields for early plantings were similar. This interaction of the maturity Group V and VI varieties Dare and Davis, table 21, with planting date was similar to Coker 156 and Davis at the Brewton Field. The data from the Black Belt Substation and Brewton Field, tables 20 and 21, indicate that early varieties (Coker 156 and Davis) are best when planted early (mid-April through mid-May) in central and southern Alabama. However, this may not be true of all varieties of these maturity groups as is indicated by the effect of planting date on yield of Essex, table 21.

Summary data from date of planting variety tests from 1967 through 1981 show yield losses when planting was delayed from optimum dates of May 5, May 15, and late May in northern, central, and southern Alabama locations, respectively, tables 22, 23, and 24.

The yields of Group V varieties in north Alabama, table 23, were reduced the greatest (0.23 bushel per day) when planting was delayed from May 5 to May 25, with a further reduction of 0.13 bushel per day when delayed to June 20. The Group VIII varieties made lowest yield from early plantings, but yield was the least affected by delayed planting, with only a reduction of 0.12 bushel per acre per day when planting was delayed from May 5 to June 20.

In central Alabama at two locations, there was an interaction with planting date and maturity groups, table 23. On a Lucedale fine sandy loam soil at the Prattville Field, the very early varieties of Maturity Group V had a 10-year average of greater than 33 bushels per acre when planted in early May. The yields of these varieties decreased by 0.16 bushel per acre per day when plantings were delayed to the middle of June.

TABLE 23. LONG-TIME YIELDS OF SOYBEANS AS AFFECTED BY PLANTING DATES AT TWO CENTRAL ALABAMA LOCATIONS

Maturity group	No. of varieties[3]	Yield/acre, by location and planting date: Prattville Field, 10-yr. av.[1]		Black Belt Substation, 14-yr. av.[2]		
		May 15	June 19	May 22	June 5	June 26
		Bu.	*Bu.*	*Bu.*	*Bu.*	*Bu.*
Group V (very early)	1-4	33.3	27.8 (-.16)[4]	30.8	25.4 (-.39)[4]	17.0 (-.40)[4]
Group VI (early)	4-7	31.4	27.5 (-.11)	34.0	28.0 (-.43)	20.3 (-.38)
Group VII (full season)	2-5	29.3	28.5 (-.02)	31.8	28.1 (-.26)	20.4 (-.23)
Group VIII (late)	2-4	29.4	29.7 (+.01)	28.2	25.5 (-.19)	20.7 (-.23)
Average	9-17	30.7	28.1 (-.07)	31.2	26.5 (-.34)	19.6 (-.33)

[1]Ten-year average (1970-79).
[2]Fourteen-year averages (1967-68 and 1970-81).
[3]Number of varieties in each maturity group used each year to compute yields for each planting date.
[4]Average yield loss (bushels per acre per day) from previous planting date.

TABLE 24. LONG-TIME YIELDS OF SOYBEANS AS AFFECTED BY PLANTING DATE AT BREWTON FIELD, BREWTON, ALABAMA

Maturity group	No. of varieties[2]	Ten-year[1] average yield/ acre, by planting date	
		May 29	June 26
		Bu.	*Bu.*
Group V (very early)	1-4	33.8	25.0 (-.31)[3]
Group VI (early)	4-7	35.9	28.7 (-.26)
Group VII (full season)	3-6	39.4	30.3 (-.33)
Group VIII (full season)	2-5	40.6	32.8 (-.28)
Average	10-19	37.4	29.2 (-.31)

[1]Ten-year average (1971-79 and 1981).
[2]Number of varieties from each maturity group used each year to compute average yields for each planting date.
[3]Average yield loss (bushels per acre per day) from previous planting date.

TABLE 25. EFFECT OF THREE PLANTING DEPTHS ON AVERAGE PERCENTAGE EMERGENCE OF SOYBEAN SEEDLINGS FROM FIVE DIFFERENT PLANTINGS ON THREE DIFFERENT SOILS.

No.[1] of entries	Range of germination		Field emergence by planting depth		
	Standard test	Vigor test	5/8 in.	1 1/4 in.	1 7/8 in.
	Pct.	*Pct.*	*Pct.*	*Pct.*	*Pct.*
2	92-94	82-86	72	82	69
5	87-91	68-77	65	77	65
2	82-86	64-76	64	72	62
2	80-81	53-58	61	70	63
2	76-78	58-62	60	71	57
2	71-75	47-53	53	70	55
1	68	50	50	64	50

[1]Sixteen lots of seed of varying laboratory germinations determined by Alabama State Department of Agriculture Seed Laboratory.
[2]Percent of 100 seeds that had emerged by 14-21 days after planting. These figures are average field emergence of five test locations.

The full and late season varieties were the lowest yielding at the early plantings, but their yields did not change with delayed plantings. The Prattville Field location usually has good distribution of rainfall during the growing season until the period from mid-August to mid-September. This period is usually short on rainfall, resulting in lower yields for late maturing soybean varieties that are usually starting to fill the pods during this period. Without this moisture stress period, the full season varieties would be expected to react similar to results in southern Alabama, table 24, where moisture is usually not as limiting for yield.

The highest yielding varieties from the Black Belt Substation on Sumter and Vaiden clay soils over a 14-year period were the early Group VI varieties, table 23. At this location, delayed planting of Group V or VI varieties from mid-May to late June decreased soybean yields by approximately 0.4 bushel per acre per day. For the same period, the full and late season varieties yields were decreased 0.3 and 0.2 bushel per acre per day, respectively.

In south Alabama at the Brewton Field on a Lucedale fine sandy loam there was an average yield loss of 0.3 bushel per acre per day when planting was delayed from late May to late June. The highest yielding varieties for the late May planting were those in maturity Group VIII. However, the greatest yield loss due to delayed planting was Group VII varieties, which had a 0.33 bushel per acre per day loss in yield.

See color plate numbers 7 and 8.

Effect of Depth of Planting on Stand of Soybeans

D.L. Thurlow, C.C. King, Jr., and J.A. Pitts

The optimum stand for maximum seed yield of soybeans ranges from two to four seeds per square foot of area. The best seeding rate for a given location will depend on the variety used and time of planting. Soil texture, moisture, and condition of the seedbed are other factors that affect stand. Without proper seed and soil contact so that moisture can be transferred into the seed to assure rapid germination, soybean stands are certain to be poor.

Soil moisture at planting time and rain within 2 weeks after planting may affect stand, as was the case in 1977 and 1978 when extremely low rainfall was recorded during May. Field emergence of only 67 percent was obtained for the 48 varieties and lines planted at 13 Experiment Station locations around the State in 1977. To get the desired stand of 6 to 11 plants per foot of row in 36-inch rows at 67 percent emergence would require planting 10 to 16 seed per foot of row. In 36-inch rows, this translates into 50 to 80 pounds of medium size seed per acre. Increasing field emergence to 80 percent could reduce seed requirements and cost by 20 percent.

Planting soybean seed at the correct depth can help overcome some of the stand problems resulting from adverse soil and environmental conditions.

To determine the effect of planting depth on field emergence and final stand of soybeans, field tests were conducted in northern, central, and southern Alabama in 1977 and 1978. In 1977, 16 seed lots varying in germination from 68 to 94 percent were planted; in 1978, two seed lots of Bragg soybeans (83 and 93 percent germination) were used on the same three soils. One hundred seeds were planted in 12-foot rows using three planting depths. Planting dates were May 9 and June 21, 1977, and June 10, 1978, at the Tennessee Valley Substation, June 1 and 7, 1977, and June 1 and 13 and July 6, 1978, at the E.V. Smith Research Center, and July 12, 1977, and July 21, 1978, at the Gulf Coast Substation.

Soil moisture was good at all locations at time of planting, but tillage done to freshen the seedbed caused loss of moisture at all locations each year. Moisture was found to be particularly critical at the shallow planting depth each year but adequate for emergence at deeper depths. When rainfall occurred within 2 to 4 days after planting, crusting of soil lowered emergence from the deepest planting depth of 1⅞ or 2¼ inches.

The average field emergence in 1977 was greater than 80 percent when high vigor seed were planted at 1¼-inch depth, but near 70 percent emergence when planted either shallower or deeper, table 25. These data also show that field emergence decreased as lower quality seed were used.

Despite drought conditions in 1978, seedling emergence from the 1½-inch planting depth ranged from 79 to 95 percent for seed lots of 83 and 93 percent germination, table 26. Emergence from the deepest depth, 2¼ inches, and

TABLE 26. EFFECT OF THREE PLANTING DEPTHS ON PERCENTAGE EMERGENCE OF SOYBEAN SEEDLINGS, TWO SEED LOTS, FIVE PLANTINGS

Location and date of planting	Seed lot[1]	Emergence by planting date		
		3/4 in.	1 1/2 in.	2 1/4 in.
		Pct.	*Pct.*	*Pct.*
Tennessee Valley Substation				
June 10	A	81	88	83
	B	58	80	74
E.V. Smith Research Center				
June 1	A	93	83	69
	B	80	80	49
June 13	A	87	95	49
	B	86	94	53
July 6	A	90	95	60
	B	74	88	66
Gulf Coast Substation				
July 30	A	60	87	74
	B	72	79	65

[1]Lot A had 93 percent germination and lot B had 83 percent germination in laboratory tests.

shallow depth was similar but generally lower than from the 1½-inch depth at the Tennessee Valley and Gulf Coast substations. However, at the E.V. Smith Research Center emergence from the 2¼-inch depth was poorer than from the ¾-inch depth. Poorer emergence from the ¾-inch depth in 1978 was due to lack of rainfall for 15 and 8 days after planting, respectively, at the Gulf Coast and Tennessee Valley substations.

Planting conditions for the June 1 and 13 plantings at the E.V. Smith Research Center in 1978 were excellent as rain occurred 1 day after planting. Where soil moisture was good (June 1 and 13, 1978, plantings at the E.V. Smith Research Center and July 27, 1977, planting at the Gulf Coast Substation), there was no difference in emergence from shallow (⅝- or ¾-inch) and middle (1¼- to 1½-inch) planting depth. However, the emergence at the deeper planting depth of 1⅞ and 2¼ inches was poor at these locations due to crusting of surface soil.

At all locations and for both years, the intermediate planting depths (1¼ or 1½ inches) produced stands which were equal to or better than stands obtained from the shallow (⅝- or ¾-inch) or deep (1⅞- or 2½-inch) planting depths. The shallow planting depth resulted in stands equal to the intermediate planting depth only when the soil moisture was excellent at planting or rains came soon thereafter. The deeper planting depth resulted in poorer stands than did the intermediate planting depth in practically every case. Thus, it appears that the most reliable planting depth for soybeans is 1¼ to 1½ inches. Additionally, when using seed with high vigor and germination, correct planting depth would mean that fewer seed per acre would be required to obtain comparable stands.

Soil Fertility Requirements for Soybeans

Clyde E. Evans, C.H. Burmester, Fred Adams, J.T. Cope, Jr., and John Odom

The principal soil fertility factors to be considered in growing soybeans are liming and phosphorus (P) and potassium (K) fertilization. The requirements for these are readily determined by soil testing.

Soil samples tested from soybean fields during the 3 years 1982-84 showed 32 percent of them required lime. About 60 percent of the fields needed phosphorus and potassium and about 40 percent needed no fertilizer.

PHOSPHORUS AND POTASSIUM

During 1977-82, experiments were conducted at six locations to evaluate soil-test fertilizer recommendations for phosphorus and potassium. Objectives of these experiments were to:

1. Evaluate P and K recommendations based on current soil test ratings.
2. Compare annual applications of P and K with biennial applications.
3. Compare broadcast versus row applications of fertilizers at double or triple the recommended rates of P and K.

The cropping system was a soybean-corn rotation. All except one location had soils "medium" or "high" in P and K. Yields given in table 27 (averages of all years except the severe drought years) show that good yields of soybeans were made without fertilizer applications at all locations even on soils testing "medium." Fertilizer rates had no effect on yields.

A series of experiments with potassium fertilizer was conducted at several substations or experiment fields during 1979-82. On three sites quite low in soil-test K, good responses to fertilizer K were realized, table 28. Three other locations were "medium" in soil test K, and these showed only small increases from K fertilizer. Maximum yield was achieved with either 30 or 60 pounds per acre of fertilizer K_2O. For a soil that tests "low," the soil testing lab recommends 80 pounds per acre of K_2O and for a soil that tests "medium," 40 pounds per acre.

Long-term soil fertility experiments with N, P, and K at six locations in Alabama included soybeans in recent years. The check (zero) treatment for P_2O_5 has not received P fertilizer since 1957 and the check treatment for K_2O has not received K fertilizer since 1929. One treatment received 30 pounds N per acre.

There was no increase in soybean yields from nitrogen fertilizer. Five of the locations were "low" in P with soil fertility indexes of 60 or 70 and one location was "high" in P. One of the soils testing "low" responded to 60 pounds P_2O_5 per acre, three responded to either 20 or 40 pounds P_2O_5, and P fertilizer did not increase yields at the other, table 29. Soybean yields were not affected by P fertilizer on the soil testing "high."

Soil-test K was "medium" at all locations except for the Prattville Experiment Field where it was high in 1980-82. Five of the soils responded to either 20 or 40 pounds K_2O per acre, but there was no response from K fertilizer at the Prattville Experiment Field.

The data presented in tables 27-29 make it clear that soil-test fertilizer recommendations based on soil-test values are more than adequate to give maximum soybean yields. For phosphorus, it appears that a soil-fertility index of about 60 or 70 is the dividing line between yield response or no response

TABLE 27. YIELD OF SOYBEANS AS AFFECTED BY SOIL TEST LEVEL AND P OR K FERTILIZER, 1977-82

Location	P rating and index	Per acre yield: Without P	Per acre yield: With P	K rating and index	Per acre yield: Without K	Per acre yield: With K
		Bu.	*Bu.*		*Bu.*	*Bu.*
Gulf Coast Substation	H110	39	38	M 80	38	38
Monroeville Experiment Field	H130	33	32	H 90	33	32
Brewton Experiment Field....	H 140	36	38	M 80	36	38
Sand Mountain Substation	M 90	40	40	M 80	40	40
Black Belt Substation.........	L 60	39	40	VH 160	40	40
Tennessee Valley Substation ..	M 90	28	29	H 100	29	29

TABLE 28. EFFECT OF POTASSIUM FERTILIZER ON SOYBEAN YIELDS, 1979-82

Lb. K_2O/ acre	Per acre yield by location: Sand Mountain Substation	Brewton Experiment Field	Wiregrass Substation	Monroeville Experiment Field	Prattville Experiment Field	Tennessee Valley Substation
	Bu.	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*
0.....................	18	16	29	23	24	45
30.....................	39	37	32	37	29	49
60.....................	48	38	33	39	29	50
120.....................	47	38	31	41	28	50
Soil test K for no K treatment						
Rating/index	L 30	L 60	M 80	L 60	M 70	M 70

TABLE 29. EFFECT OF P AND K ON SOYBEAN YIELDS AT SIX LOCATIONS, 3-YEAR AVERAGE

Fertilizer rate, lb./acre	Yield per acre: Sand Mountain Substation	Brewton Experiment Field	Prattville Experiment Field	Monroeville Experiment Field	Upper Coastal Plain Substation	Tennessee Valley Substation
	Bu.	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*
			PHOSPHORUS			
P_2O_5						
0..................	28	32	32	23	32	48
20..................	33	36	32	27	37	48
40..................	38	38	31	27	38	48
60..................	37	41	32	27	39	48
100..................	37	40	31	29	37	48
Soil test P	L 70	L 70	H 170	L 70	L 70	L 70
			POTASSIUM			
K_2O						
0..................	31	33	32	24	34	46
20..................	34	36	31	25	35	47
40..................	37	40	31	27	35	48
60..................	38	41	32	27	37	50
80..................	40	37	33	28	38	51
100..................	37	40	31	29	37	48
Soil test K	M 70	M 80	H 90	M 70	M 80	M 80

to P fertilizer. There may or may not be a response to fertilizer P at "medium" P (Index 80-100). For potassium, soils with a "medium" K fertility (Index 70-80) showed a yield response to 20 to 40 pounds per acre of K_2O. Thus, the recommended rate of 40 pounds per acre of K_2O for a "medium" soil-test is adequate to give maximum economic yields of soybeans. For a "low" soil-test K (Index 10-60), soybeans responded to 30 or 60 pounds K_2O per acre. Therefore, the recommended rate of 80 pounds K_2O for a "low" soil-test K is adequate.

LIMING

A total of 53 lime experiments with soybeans on farmers' fields was harvested during the years 1975-80. Twenty-one of these were located on Highland Rim soils, 14 on Tennessee Valley soils, and 18 on Appalachian Plateau soils. The greatest yield responses to liming in individual tests were 9 bushels per acre on Highland Rim soils, 22 bushels on Tennessee Valley soils, and 12 bushels on Appalachian Plateau soils.

The soil pH below which a yield response to liming is expected is called the "critical" pH. There are always some exceptions, of course, and there is considerable variation in the data. The critical pH for liming Highland Rim soils for soybeans appears to be about 5.2.

The critical pH for liming Tennessee Valley and Appalachian Plateau soils for soybeans appears to be about 5.4.

The current lime recommendation for soybeans calls for liming Tennessee Valley soils when pH is below 5.6 and liming other soils when they are below pH 5.8. This provides a margin of safety in that lime is recommended before the soil becomes acid enough to reduce yields.

MICRONUTRIENTS

Although the seven micronutrients are as important in plant nutrition as the primary and secondary nutrients, they are needed in much smaller quantities and most Alabama soils contain adequate amounts for soybeans. In some cases, however, molybdenum (Mo) and manganese (Mn) are deficient for soybeans in Alabama. Molybdenum deficiency is rare and occurs only on very acid soils. Liming to the proper soil pH range corrects the deficiency without the use of Mo fertilizer. Use of Mo fertilizer will also correct the deficiency, but will not correct other problems associated with very low pH.

Manganese is high in almost all Alabama soils. However, soybeans grown on sandy soils with intermittent high water tables, high organic content, and near-neutral pH may show Mn deficiency. This condition has been observed only in the extreme southwestern area of the State and is likely to occur in low, poorly drained spots of fields. Where this occurs, 10 pounds per acre of Mn each year in a fertilizer will correct the problem. It can also be applied as a foliar application. Symptoms for cyst nematode damage are similar to those for Mn deficiency on soybeans.

Some legumes require a higher level of soil boron (B) than most other crops for maximum seed yields. To determine if soybeans was among the group of legumes requiring higher-than-normal boron, several experiments have been conducted on coarse-textured soils where boron deficiency is most likely to occur.

Since lime applications are known to reduce the availability of soil B to plants, experiments included both limed and unlimed plots. Boron fertilizer failed to affect soybean yields any year at any test site, suggesting that boron deficiency is unlikely to be a problem for soybean production in Alabama.

See color plate numbers 9 and 10.

Soybean Inoculation and Nitrogen Fixation

A.E. Hiltbold and D.L. Thurlow

As a member of the plant family of legumes, soybeans utilize atmospheric nitrogen to produce high yields without the necessity of applying commercial nitrogen. By a process called nitrogen fixation, root bacteria (rhizobia) that grow in soybean roots are able to convert atmospheric nitrogen into organic forms that are utilized by the plant to produce protein. In Alabama, soybeans obtain about three-fourths of their total nitrogen from the atmosphere and about one-fourth from the soil, table 30.

Soybeans grown on Alabama soils obtain only about 65 pounds of nitrogen per acre from soil organic matter, crop residues, and carryover fertilizer. This soil-derived nitrogen accounts for production of only 14 to 15 bushels per acre of soybeans. Plant nitrogen derived from the atmosphere, however, amounts to about 190 pounds per acre. This, along with soil nitrogen, is adequate for the crop to produce an average of 53 bushels per acre, table 30.

TABLE 30. YIELD AND NITROGEN FIXATION BY LEE SOYBEANS IN 1984

Location	Soybean yield/ acre	Atmospheric N_2 fixed	
		Total N/ acre	Pct. of plant N
	Bu.	*Lb.*	*Pct.*
Gulf Coast Substation	55	202	75
Brewton Field	57	182	70
Black Belt Substation 1	43	186	76
Black Belt Substation 2	42	112	66
Prattville Field	44	180	80
Plant Breeding Unit	59	173	67
E.V. Smith Research Center	61	213	80
Sand Mountain Substation	58	221	75
Tennessee Valley Substation	55	218	79
AVERAGE	53	188	74

EFFECTIVENESS OF INOCULANTS

Not all rhizobia are alike. Those that form nodules on clover, for example, do not nodulate peanut or soybean. Soybeans are nodulated only by the rhizobia *Rhizobium japonicum*, which is not native to the United States. This means that soils planted to soybeans for the first time are not likely to contain *R. japonicum* although they may have rhizobia for other legumes. First plantings require application of *R. ja-*

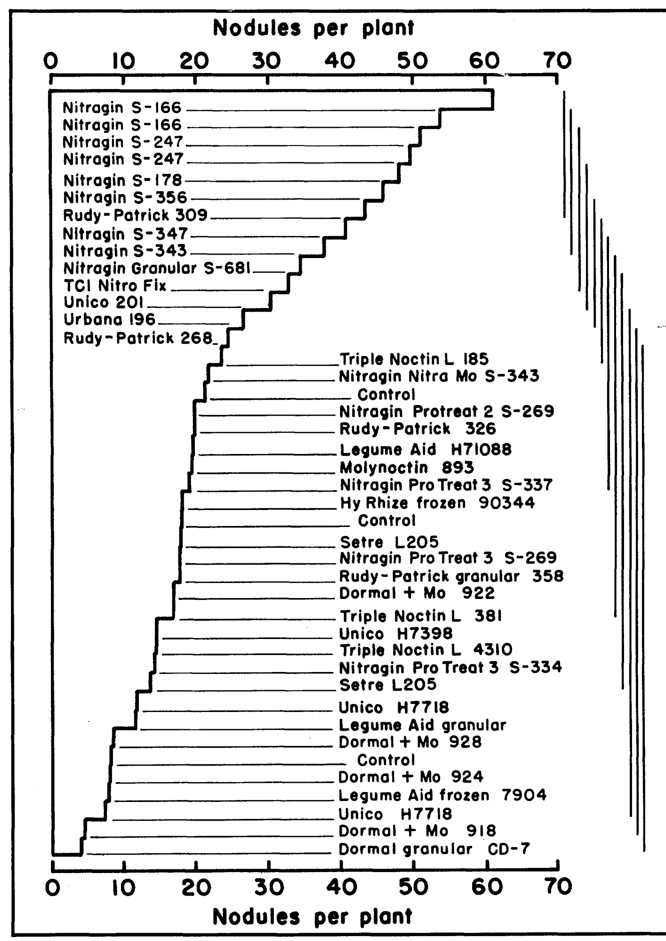


FIG. 6. Number of nodules per plant at bloom time in 1979 after application of commercial soybean inoculants at planting. Products within a vertical line do not differ (95 percent confidence level).

ponicum with the seed to ensure nodulation and avoid nitrogen deficiency and low yield.

The inoculant industry cultures rhizobia and markets a variety of products for application on the seed or into the furrow with the seed at planting. Powdered peat is the conventional carrier for bacteria, but clay, vermiculite, and oil carriers are also used for application on soybean seed. Granular peat or corn cob carriers are used for in-furrow application. Frozen, concentrated cultures are available that may be diluted and sprayed in the furrow at planting. Some inoculants have seed-treatment chemicals such as fungicide or molybdate salts mixed with the bacteria or packaged separately for application with bacteria.

Soybean inoculants offered for sale in Alabama during 1975-79 were evaluated for effectiveness. The number of viable rhizobia in each inoculant was determined by bacterial plate count and by nodulation of soybeans in the plant dilution technique. Inoculants were also compared in greenhouse pot experiments and in field experiments where each inoculant was applied according to the manufacturer's instructions. Experiment sites with essentially no *R. japonicum* in the soil were selected to make the nodulation and yield of soybeans dependent on the applied inoculants. Results showed a wide range of effectiveness among commercial inoculants. Some products contained more than a billion rhizobia per gram of inoculant, while others contained a thousand or less per gram when purchased. When applied as recommended to soybeans in the field, some inoculants produced abundant nodules, while other inoculants produced none, figure 6. Those that provided one hundred thousand to one million *R. japonicum* cells per seed produced superior nodulation, while those that supplied one thousand or less per seed were useless. Similarly, inoculants that produced abundant nodulation increased soybean grain yields, while yield was poor with those providing few rhizobia and no nodulation.

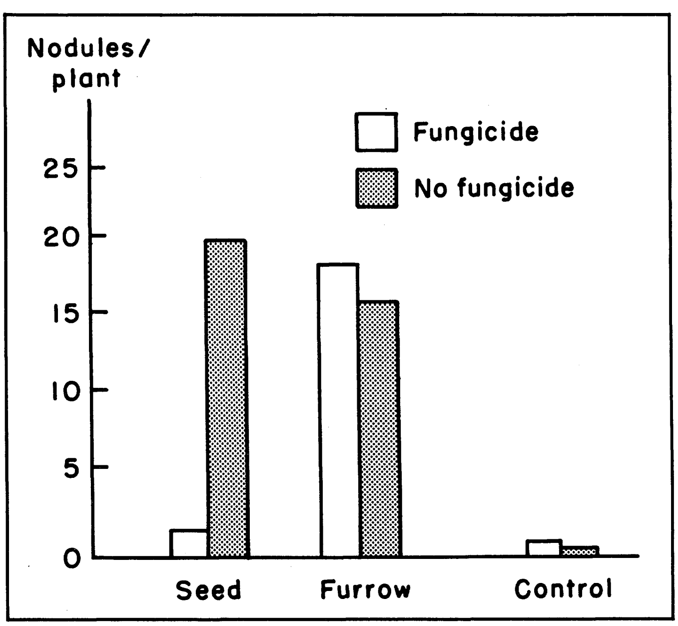


FIG. 7. Number of nodules per plant at bloom stage after application of inoculant on the seed or into the furrow with seed treated or not treated with captan fungicide.

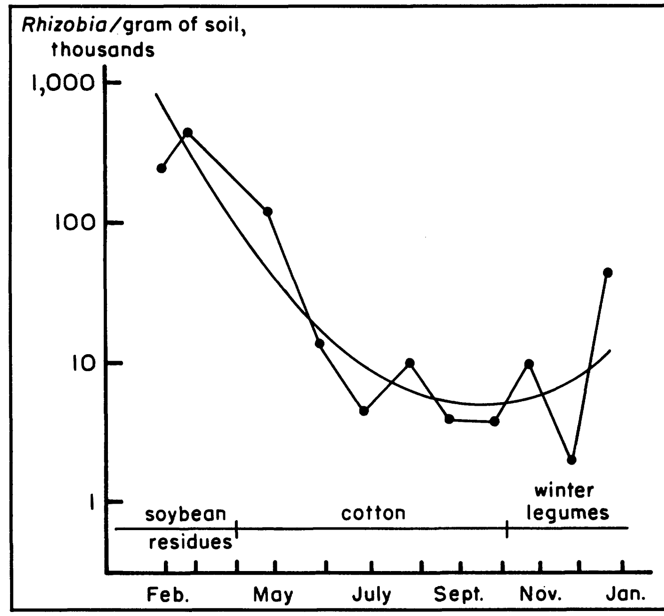
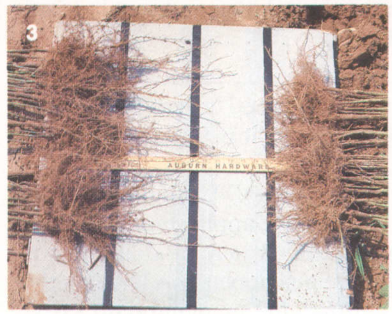


FIG. 8. Numbers of *Rhizobium japonicum* in soil following the soybean crop and during the growth of cotton and winter legumes, 1980-82.

Some products performed poorly despite apparently adequate viability of the inoculant. This was the case where fungicide was added to the seed with the inoculant at planting. Captan and other fungicides for seedling disease control are not compatible with *R. japonicum* when both are placed on the seed. Research at the Wiregrass Substation in 1980 determined the effectiveness of inoculant applied on the seed compared to in-furrow application somewhat separated from the seed. Powdered peat with sticker was used for the seed-applied rhizobia, while a granular inoculant was applied in the furrow. Another variable was application of captan to the seed at the recommended rate for seedling disease control. Soybean plants were dug at bloom stage and their nodulation determined. Where captan was applied on the seed with rhizobia, the inoculant failed, figure 7. Separating the bacteria from the fungicide-treated seed, however, as with the granular in-furrow inoculant, avoided toxicity to the rhizobia and resulted in good nodulation.

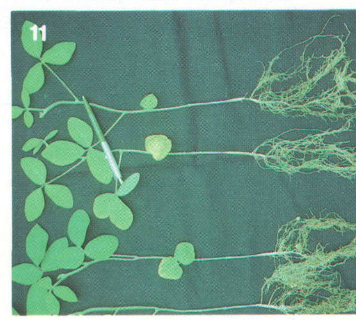
When soils are planted to soybeans for the first time, early and effective inoculation can be obtained with either seed- or soil-applied inoculant supplying one hundred thousand or more *R. japonicum* cells per seed. An evaluation of 118 commercial inoculants showed that peat-based inoculants were the most viable and effective. Clay- and oil-based products performed poorly; the latter contained fungicide and/or molybdate. If seed quality or planting condition dictate the use of fungicide, then a granular inoculant has distinct advantage over a seed-applied inoculant. However, granular inoculants are more expensive and require application equipment on the planter. Soils that have previously produced good crops of soybeans will have established populations of *R. japonicum* throughout the root zone so that fungicide toxicity to seed-applied rhizobia is of no concern. Response to any inoculant is unlikely under these conditions.

Soybean rhizobia survive in soil following the soybean crop, but their populations decrease. In a soybean-cotton-

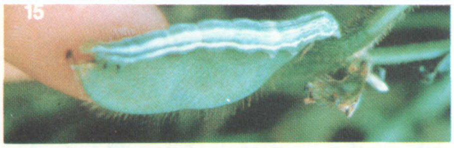


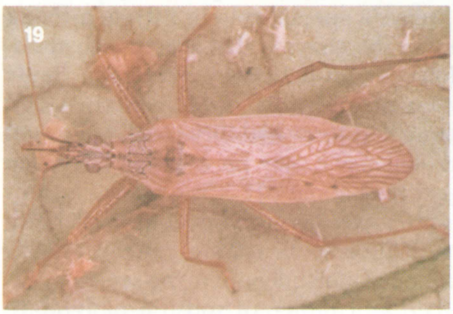
(1) Four-row varietal plots at the Plant Breeding Unit, Tallassee, are a part of the extensive variety development program underway. (2) USDA uniform and preliminary tests screen large numbers of experimental varieties for their potential value. (3) Deeper rooting of plants at left is the result of in-row subsoiling as compared to conventional tillage. (4) Turn-disk preparation for wheat ahead of no-till soybeans was one of the tillage systems tried for double-crop production of soybeans. (5) Rotating soybeans with grain crops not only helps control nematodes and stem canker in soybeans, but it also increases profitability of grain production. (6) Row widths of 42 inches

(left) and 14 inches (right) were compared in this Tennessee Valley Substation planting, as well as at locations in other Alabama regions. (7) Effect of planting date on growth of Braxton soybeans, a Group VII variety, at Tennessee Valley Substation. (8) Effect of planting date on growth of Hutton soybeans, a Group VIII variety, at Tennessee Valley Substation. (9) Effect of low phosphorus on soybeans is evident in the plot in foreground. (10) Plants in foreground show symptoms of potassium deficiency. (11) Soybean plants with root nod-

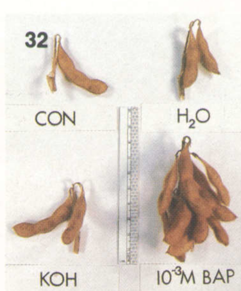


ules at 3 weeks after planting. (12) Growth of sicklepod and cocklebur was suppressed by 12-inch rows (shown) and 6-inch rows, as compared with 18- and 36-inch rows. (13) Chlorimurm (a part of the herbicide Canopy) applied preemergence at 1 ounce active ingredient per acre provided excellent control of sicklepod at the Black Belt Substation (14) Controlled droplet applicator delivers low volume (1 quart to 10 gallons per acre) and produces spray particles in the 200-micron range.





(15) The soybean looper, *Pseudoplusia includens,* is a voracious soybean foliage feeder (photo courtesy J. French). (16) The velvetbean caterpillar, *Anticarsia gemmatalis,* is a serious soybean pest in the southern region of Alabama (photo courtesy J. French). (17) The threecornered alfalfa hopper, *Spissistilus festinus,* helps spread soybean diseases and also slows sugar flow from leaf petioles to developing seed (photo courtesy J. French). (18) Leaf petiole girdled by threecornered alfalfa hoppers. (19) Nabids are abundant natural enemies of many soybean insect pests. (20) The green lynx spider, an effective predator, is one of many species of spiders that contribute to pest regulation in Alabama soybean fields. (21) Tachinid flies are effective parasitoids of most major lepidopterous pests in the soybean ecosystem. (22) *Nomuraea rileyi,* a fungal pathogen of nearly all lepidopterous larvae attacking soybeans, causes high levels of mortality in some years, particularly late in the growing season. (23) *Erynia (Entomophthora) gammae* is a fungal parasite which at times causes dramatic levels of mortality in populations of the soybean looper. (24) Symptoms of stem canker on soybean leaf. (25) Severe stem canker lesion on soybean stem.



(26) Response of varieties growing on nematode infested soil. (27) Nematode damage to soybeans in a Baldwin County field infested with cyst and root-knot nematodes. (28) Variety comparisons in nematode infested field on same farm as field shown in 27. (29) Terminal raceme of a field-grown Braxton soybean plant with developing flowers produced at approximately 18 nodes. Pod development is occurring at basal nodes, whereas open flowers are still present at the raceme tip. (30) Terminal raceme from a field-grown Bragg soybean plant with one developing pod remaining at a basal node and open flowers present at the tip. Many flowers have abscised from intervening nodes. (31) Terminal raceme from a field-grown Bragg soybean plant in which all flowers or pods have abscised at all nodes. (32) Terminal racemes from field-grown Bragg soybean plants at harvest. Racemes were treated during flowering as follows: CON (untreated), H_2O (sprayed with water), KOH (sprayed with a potassium hydroxide solution), BAP (sprayed with a solution of 6-benzylaminopurine, a plant growth regulator). Note the large numbers of pods on the BAP-treated racemes compared to other treatments.

corn rotation experiment at Auburn, one million or more *R. japonicum* cells per gram of soil were found during the winter after the soybean crop, figure 8. Populations decreased sharply into the following season under cotton. In the cropping sequence of soybeans-cotton-corn, the number of *R. japonicum* in the soil declined each year until soybeans were replanted in the rotation. The die-off of *R. japonicum* was most extreme in strongly acidic soil, compared to soil maintained at favorable pH with liming. In soil at pH 5 or below, populations of *R. japonicum* essentially disappeared in the year after soybeans. Therefore, strongly acidic soils need (1) liming to correct the acidity limitation of both soybean host and rhizobia, and (2) application of an effective inoculant with the seed. Other situations where seed inoculation may be advantageous include fields that have not been planted to soybeans within 5 years or where previous inoculations failed. Recent evidence in Alabama and elsewhere suggests soybean yields may respond to application of superior strains of *R. japonicum,* even in soils well supplied with soybean rhizobia.

EFFECT OF N FERTILIZER

Nitrogen in the form of ammonium and nitrate (normal fertilizer forms) is readily used by legume plants, but these chemically combined sources of nitrogen interfere with nodule development and nitrogen-fixing activity of existing nodules. This may occur in soils well supplied with decomposable organic matter or with fertilizer nitrogen carryover from a prior crop. An experiment in central Alabama showed as little as 40 pounds per acre of fertilizer nitrogen applied at planting reduced nodulation of soybeans at bloom stage, table 31. Furthermore, fertilizer nitrogen did not increase yield over that obtained with seed inoculation alone. This is the usual result; fertilizer nitrogen can be utilized by soybeans, but nitrogen fixation is reduced by an equivalent amount. Where soybeans are well inoculated, fertilizer nitrogen is unnecessary and costly. On the other hand, where soybeans are poorly inoculated, it may be possible to avoid crop failure with applied nitrogen. The extent to which soybean yield can be salvaged decreases with advancing stage of development. Inoculation failure is shown by lack of root nodules, pale green foliage, and slow growth. Fertilizer nitrogen applied prebloom may substitute partially for lack of fixation. However, an effectively fixing soybean crop derives 150 to 200 pounds of nitrogen per acre from the atmosphere, equivalent to a fertilizer application of 300 to 400 pounds per acre.

TABLE 31. EFFECTS OF SEED INOCULATION AND FERTILIZER NITROGEN ON NODULATION AND YIELD OF SOYBEANS, 1975

Treatment	Nodules per plant at bloom stage	Soybean yield/acre
	No.	*Bu.*
None	2.9 c	25.2 b[1]
Seed inoculation	25.7 a	31.3 a
Seed inoculation plus 40 lb./acre N	10.3 b	29.6 a

[1]Values bearing the same letter within a column do not differ (95% confidence level, Duncan's multiple range test).

EFFECT OF MOLYBDENUM

Molybdenum, a nutrient element required by plants in only trace amounts, plays a special role in nitrogen-fixing plants as a constituent of the enzyme that reacts with atmospheric nitrogen. Molybdenum deficiency, therefore, limits the nitrogen nutrition of soybeans. Soils contain small amounts of molybdenum and its availability is related to soil acidity. Molybdenum deficiency may be encountered when soils become more acid than about pH 5.5. Conversely, liming strongly acidic soils increases molybdenum availability and avoids deficiency. Where soybeans are planted in soils below pH 5.5, application of molybdenum to the seed may increase yields. As little as 1 ounce of sodium molybdate (Na_2MoO_4) dissolved in a small amount of water to moisten a bushel of seed at planting time will supply this nutrient element. This practice has not been found to interfere with seed-applied rhizobia. However, molybdenum is not a satisfactory substitute for lime on strongly acid soils. In many instances, infertility of strongly acid soils is not corrected by adding molybdenum. In these situations, liming improves yield by reducing toxic aluminum, increasing calcium levels, and improving molybdenum availability.

See color plate number 11.

PEST CONTROL

Soybean Weed Control

R. Harold Walker, James R. Harris, and Ted Whitwell

Weeds continue to be a major pest problem for Alabama soybean producers. The complexity of the problem is compounded by the variety and nature of the weeds in soybean fields. Many annual weeds and grasses, and a few persistent perennials such as johnsongrass and nutsedges, are severe problems.

The complexity of the problem is further dramatized by changes that take place in the soybean-field ecosystem. These changes were slow when hand-hoeing and cultivation removed weeds mechanically. However, the introduction and use of herbicides accelerated changes in the ecosystem. When a field is consistently treated with the same or similar herbicides for a number of years, some obvious and predictable changes occur. Annual weeds best controlled by these herbicide(s) begin to lose their dominance in the weed population and begin to disappear. Taking their place will be annual and/or perennial species that are less susceptible to herbicides in general.

Today, weed species that are most troublesome in Alabama soybean fields include sicklepod, annual morningglories, cocklebur, and johnsongrass. Other species that pose similar concerns include Florida beggarweed, bristly starbur, Texas panicum, pigweeds, nutsedges, and prickly sida. Consequently, research efforts are directed toward these problems.

CULTURAL AND MECHANICAL METHODS

Competitive Capacity of Soybeans

One of the least appreciated aspects of the soybean plant is its capacity to smother weeds that emerge during the first few weeks after soybean planting. If weeds are effectively controlled the first 4 to 6 weeks after soybean planting, the soybean canopy will effectively suppress weeds during the remainder of the growing season. Cooperative research between the Alabama and Georgia Experiment Stations shows soybeans maintained free of sicklepod for 4 weeks after emergence produced yields equal to those kept free of sicklepod all season, table 32. In three of the five trials, only 2 weeks of weed-free maintenance was required to produce yields equal to season-long maintenance.

TABLE 32. EFFECT OF SICKLEPOD-FREE PERIOD ON SOYBEAN YIELD

Free of sicklepod[1]	Soybean yield/acre[2]				
	1980, Headland	1981 Headland	1981 Plains	1982 Headland	1982 Plains
	Bu.	*Bu.*	*Bu.*	*Bu.*	*Bu.*
None	27b	29c	10c	24b	33b
2 weeks	33a	45b	44b	28a	56a
4 weeks	34a	51a	49a	28a	57a
All season	37a	51a	50a	28a	55a

[1]Indicates number of weeks after planting that soybeans were kept free of weeds and then allowed to reinfest naturally.
[2]Means within columns followed by the same letter are not statistically different. Data are summed over three row spacings, 8, 16, and 32 inches.

Soybean row spacing influences the time required for weed-free maintenance. The sooner the soybean canopy shades the ground, the shorter time required for weed control inputs. In research at the Wiregrass Substation, soybeans were planted in rows spaced 6, 12, 18, and 36 inches and the same number of sicklepod or cocklebur plants were allowed to grow with the soybeans for 17 weeks. Data taken at 17 weeks show that as row spacing became narrower, weight of sicklepod and cocklebur decreased, indicating more competition from the soybeans, table 33. Both sicklepod and cocklebur produced about as much weight in the non-irrigated treatments as they did in the irrigated, indicating their capacity to effectively compete for water.

TABLE 33. EFFECT OF SOYBEAN ROW SPACING ON SICKLEPOD AND COCKLEBUR FRESH WEIGHT, WIREGRASS SUBSTATION

Row spacing, inches	Fresh weight/acre			
	Non-irrigated Sicklepod	Non-irrigated Cocklebur	Irrigated Sicklepod	Irrigated Cocklebur
	Lb.	*Lb.*	*Lb.*	*Lb.*
6	1,850	4,610	830	2,940
12	4,175	7,370	2,760	9,765
18	4,650	12,520	6,500	13,290
36	5,150	13,649	8,930	14,700

Mechanical Control

Some weeds, such as bristly starbur, were adequately controlled with cultivation in research at the Wiregrass Substation. Treflan® does not control this weed, but Treflan plus one cultivation provided bristly starbur control and soybean yields equal to the best preemergence applied herbicide (metribuzin). Early planting allowed soybeans to gain a competitive advantage over the bristly starbur and thus cultivation was adequate.

Tillage, Herbicides, and Crop Rotation

Tillage, weed control, and crop rotation are important factors in any soybean production system. Integrating these components into a system in order to identify the value of each was the objective of other research. Comparisons included conventional tillage versus no-till; "standard" versus "intense" weed control inputs; and continuous soybeans versus soybean/corn rotation. Sicklepod was the weed studied in this research. Sicklepod control, sicklepod seed in the soil, and crop yield were measured along with calculating net returns to land and management. Several trends are apparent from data in tables 34 and 35: (1) No-till, although planted approximately 1 month later, compared favorably with conventional tillage for sicklepod control, soybean yield, and net returns; (2) "intense" weed control provided

TABLE 34. SICKLEPOD CONTROL AND SOYBEAN YIELD IN RESPONSE TO WEED MANAGEMENT SYSTEMS, TALLASSEE, ALABAMA

Treatment[2]	Results, by years[1]							
	1979		1980		1981		1982	
	Sicklepod control	Soybean yield/acre	Sicklepod control	Soybean yield/acre	Sicklepod control	Soybean yield/acre	Sicklepod control	Soybean yield/acre
	Pct.	*Bu.*	*Pct.*	*Bu.*	*Pct.*	*Bu.*	*Pct.*	*Bu.*
Tilled								
1. Continuous soybeans, "standard" weed control	96 b	35 a	52 b	11 bc	77 b	23 d	60 c	10 c
2. Continuous soybeans[3], "intense" weed control	98 a	24 cd	98 a	16 ab	98 a	28 abc	97 a	29 a
3. Soybean/corn rotation, "standard" weed control	97 ab	32 ab	40 b	—	79 b	30 ab	66 c	—
4. Soybean/corn rotation[3], "intense" weed control	98 a	24 cd	93 a	—	98 a	32 a	92 ab	—
No-till								
5. Continuous soybeans, "standard" weed control	98 a	24 a-d	86 a	11 bc	72 b	21 d	86 b	28 a
6. Continuous soybeans[3], "intense" weed control	86 b	23 d	99 a	14 abc	94 a	25 bcd	97 a	28 a
7. Soybean/corn rotation, "standard" weed control	98 a	25 bcd	85 a	—	79 b	26 bcd	83 b	—
8. Soybean/corn rotation[3], "intense" weed control	—	25 bcd	92 a	—	94a	26 bcd	88 ab	—

[1]Mean values with the same letter are not statistically different.
[2]Corn was planted in 1980 and 1982 in the rotation.
[3]Soybean yields were reduced as a result of injury from postemergence-directed herbicides during 1979.

TABLE 35. NET RETURNS TO LAND AND MANAGEMENT FROM SOYBEANS AS A RESULT OF WEED MANAGEMENT SYSTEMS, TALLASSEE, ALABAMA

Treatment[2]	Net return/acre[1]			
	1979	1980	1981	1982
	Dol.	*Dol.*	*Dol.*	*Dol.*
Tilled				
1. Continuous soybeans, "standard" weed control	72a	-64a	6bc	-71c
2. Continuous soybeans, "intense" weed control	-26efg	-62a	1c	5b
3. Soybean/corn rotation[2], "standard" weed control	55ab	—	46a	—
4. Soybean/corn rotation, "intense" weed control	-30fg	—	21abc	—
No-till				
5. Continuous soybeans, "standard" weed control	45abc	-53a	6bc	49a
6. Continuous soybeans[3] "intense" weed control	-6def	-45a	15bc	30ab
7. Soybean/corn rotation, "standard" weed control	23bcd	—	34ab	—
8. Soybean/corn rotation, "intense" weed control	13cde	—	21abc	—

[1]Mean values with the same letter are not statistically different.
[2]Corn was planted in 1980 and 1982 in the rotation.
[3]Soybean yields were reduced as a result of injury from postemergence-directed herbicides during 1979.

reduced sicklepod seed in the soil 40 to 50 percent, but net returns to land and management were frequently unacceptable; (3) "standard" weed control provided fair sicklepod control, reasonable soybean yields, and more acceptable net returns, although sicklepod seed in the soil increased about 10 percent; and (4) the soybean/corn rotation began to show a positive trend in the third year.

CHEMICAL METHODS

Johnsongrass and Annual Grasses

Several of the new herbicides that can be applied over the top proved to be effective for johnsongrass control in soybeans. They performed well at low rates when applied following Treflan preplant, or at higher rates when Treflan was not applied preplant. Smaller grass was generally easier to control, particularly with Verdict® and Fusilade®. This also indicates that not all grass species are equally susceptible to each of the herbicides. Other susceptible grasses include Texas panicum, goosegrass, broadleaf signalgrass, and bermudagrass. There also is evidence that tank-mixing these new postemergence grass herbicides with other herbicides, such as Basagran®, Blazer®, and Dyanap®, will reduce grass control. At the Wiregrass Substation, mixing Tackle® (same as Blazer) and Whip® reduced crabgrass control as compared to Whip alone, and the same type antagonism occurred with Assure® plus Tackle.

Sicklepod

This weed continues to be one of the most troublesome in soybean production in Alabama and other Southern States. Lexone®/Sencor® still provide the most effective preemergence control, but preemergence Lasso®, Dual®, and Vernam® also suppress sicklepod. Postemergence treatment with Lorox®, 2,4-DB, Lexone/Sencor, and Toxaphene®, along with appropriate cultural practices, provided effective sicklepod control in research at two locations, table 36.

Consistent control of sicklepod and better soybean yields were evident with the more intensive control systems (treatments 3, 4, 9, 10, and 11) for both row spacings. With excellent growing conditions in 1979, however, less weed control inputs (numbers 1, 2, 7, and 8) provided good results, indicating the increased competitiveness of the soybeans.

Where growing conditions were poor in 1978 and 1980, the less intensive control systems tended to give better performance when used with the 10-inch row spacing (treatments 1 and 2 versus 7 and 8). The narrow rows better compensated for the poorer soybean growth. Likewise, where no sicklepod control was applied (treatment 6 versus 13) soy-

TABLE 36. INFLUENCE OF ROW SPACING AND HERBICIDES ON SICKLEPOD CONTROL IN SOYBEANS

Control systems-treatment number and lb. active/acre	Planting dates[1]	Tennessee Valley Substation 1978 Sicklepod control	1978 Soybean yield	1979 Sicklepod control	1979 Soybean yield	1980 Sicklepod control	1980 Soybean yield	Gulf Coast Sub., 1980 Sicklepod control	Gulf Coast Sub., 1980 Soybean yield
		Pct.	Bu.	Pct.	Bu.	Pct.	Bu.	Pct.	Bu.
30-inch rows									
1. Tolban + Sencor-PPI (3/4 + 3/8)	May	23	30	66	66	3	16	—	—
	June/July	—	—	30	24	59	7	48	23
2. Lasso + Sencor-PRE (2½ + 3/8)	May	15	30	95	64	0	16	—	—
	June/July	—	—	20	25	82	12	56	24
3. Lasso + Sencor-PRE cultivate; Lorox + Butyrac 200-PDS (2½ + 3/8; 1/2 + 1/4)	May	98	42	100	62	93	28	—	—
	June/July	—	—	87	32	100	13	97	34
4. Tolban + Vernam-PPI cultivate; Sencor PDS (1/2 + 2½; 3/8).........	May	—	—	98	62	89	31	—	—
	June/July	—	—	95	19[2]	95	13	95	32
5. Hand hoed check..................	May	100	29	98	65	92	23	—	—
	June/July	—	—	60	27	90	11	98	34
6. Non-treated check.................	May	0	25	0	56	3	10	—	—
	June/July	—	—	0	17	0	3	0	17
10-inch rows									
7. Tolban + Sencor-PPI (3/4 + 3/8)	May	92	37	80	59	18	21	—	—
	June/July	—	—	70	29	81	11	59	29
8. Lasso + Sencor-PRE (2½ + 3/8)	May	96	33	100	60	12	24	—	—
	June/July	—	—	56	30	98	11	64	28
9. Lasso + Sencor-PRE; Toxaphene POT (2½ + 3/8; 3; 3)................	May	—	—	100	62	92	31	—	—
	June/July	—	—	100	31	100	10	97	39
10. Tolban-PPI; Toxaphene-POT (3/4; 3; 3)..........................	May	—	—	—	—	62	25	—	—
	June/July	—	—	—	—	96	9	90	32
11. Lasso-PRE; Toxaphene-POT (3; 3; 3)	May	—	—	—	—	64	23	—	—
	June/July	—	—	—	—	100	7	94	32
12. Hand hoed check..................	May	98	35	91	56	98	33	—	—
	June/July	—	—	100	28	96	6	98	35
13. Non-treated check.................	May	38	33	41	64	8	16	—	—
	June/July	—	—	0	26	9	5	0	25

[1]Essex soybeans planted first week of May and Lee 74 planted last week in June at Tennessee Valley Substation. Ransom soybeans planted first week in July at Gulf Coast Substation. Soybean seeding rate was same for both row spacings, 130,000 plants per acre.
[2]Low yield due to injury from Sencor post-directed.

TABLE 37. INFLUENCE OF SELECTED SICKLEPOD CONTROL SYSTEMS ON NET RETURNS TO LAND AND MANAGEMENT

Control systems-treatment number and lb. active/acre	Planting dates	Net returns to land and management/acre: Tennessee Valley Sub. 1979	Tennessee Valley Sub. 1980	Gulf Coast Sub., 1980
		Dol.	*Dol.*	*Dol.*
30-inch rows				
1. Tolban + Sencor-PPI (3/4 + 3/8)................	May	345	13	—
	June/July	65	-59	62
2. Lasso + Sencor-PRE (2½ + 3/8)................	May	326	7	—
	June/July	70	-26	65
3. Lasso + Sencor-PRE culti-vate; Lorox + 2,4-DB-PDS	May	306	86	—
	June/July	105	-27	129
4. Tolban + Vernam-PPI culti-vate; Sencor-PDS (1/2 + 2½; 3/8)......................	May	306	105	—
	June/July	14	-22	114
6. Non-treated check	May	28	-17	—
	June/July	30	-70	35
10-inch rows				
7. Tolban + Sencor-PPI (3/4 + 3/8)................	May	253	36	—
	June/July	69	-27	80
8. Lasso + Sencor-PRE (2½ + 3/8)................	May	228	65	—
	June/July	76	-26	68
9. Lasso + Sencor-PRE Toxa-phene-POT (2½ + 3/8; 3;3)	May	256	95	—
	June/July	74	-50	128
13. Non-treated check	May	294	15	—
	June/July	55	-69	55

beans in 10-inch rows yielded more. Where plots were hand hoed (5 versus 12), 10-inch rows influenced yield less.

Net returns to land and management calculated for some of the sicklepod control systems for 1979 and 1980, table 37, reflect the same trends as soybean yields given in table 36.

There is a need to replace Toxaphene with another herbicide that can be applied postemergence over the top of soybeans for sicklepod control. Classic® and Scepter® show good potential.

Annual Morningglories

It is common to find morningglories and sicklepod in the same field. Morningglory control with existing preemergence herbicides is generally poor, although suppression does occur with Vernam, Dyanap, and occasionally with Treflan and Surflan®. Conversely, some postemergence herbicides have provided acceptable control. Blazer applied postemergence over the top has been the most consistent. Lorox + 2,4-DB applied postemergence directed has been an effective treatment.

With sicklepod and morningglories in the same field, the narrower row patterns (18-inch and twin 9-inch) generally produced higher yields than 36-inch rows with all levels of weed control, table 38. Also, Surflan + Lexone applied pre-

TABLE 38. SICKLEPOD AND MORNINGGLORY CONTROL AS AFFECTED BY ROW PATTERNS, HERBICIDES, AND CULTIVATION, GULF COAST SUBSTATION

Treatment	Row pattern	Control				Soybean yield/acre
		Morningglory		Sicklepod		
		Early	Late	Early	Late	
		Pct.	*Pct.*	*Pct.*	*Pct.*	*Bu.*
Hoed check	36 in.	100	95	99	95	55
	18 in.	99	95	100	95	59
	Twin 9-in.	100	88	100	94	62
1 cultivation	36-in.	50	25	70	45	44
	18-in.	33	9	67	24	45
	Twin 9-in.	36	13	56	20	49
Surflan + Lexone	36-in.	25	8	45	15	40
	18-in.	38	24	81	51	50
	Twin 9-in.	24	15	60	24	54
Surflan + Lexone + 1 cultivation	36-in.	58	45	89	63	50
	18-in.	50	38	92	74	58
	Twin 9-in.	56	36	82	42	58
Surflan + Lexone; Toxaphene; and Toxaphene + Blazer	36-in.	96	88	99	95	55
	18-in.	99	95	99	95	58
	Twin 9-in.	98	94	99	95	67

emergence and Toxaphene + Blazer applied postemergence over the top provided highest weed control and soybean yields. Classic and Scepter show good potential for control of this weed complex.

Cocklebur

Common cocklebur is the most competitive weed species in soybeans. In 4 years of research at the Black Belt Substation, Basagran, Dyanap, and 2,4-DB were applied in various combinations both with and without cultivation. One, two, and three cultivations were also included without herbicides. Basagran and Dyanap were applied postemergence over the top and 2,4-DB was directed underneath the soybean canopy.

One to three cultivations alone failed to provide adequate cocklebur control, tables 39 and 40, or soybean yields, table 41. Two or three cultivations were no better than one, for this heavy clay soil.

One cultivation plus herbicide(s) or herbicides alone provided good to excellent early and late season cocklebur control, tables 39 and 40. However, little or no differences in soy-

TABLE 39. EARLY SEASON COMMON COCKLEBUR CONTROL AS AFFECTED BY CULTIVATION AND/OR HERBICIDES

Control[1] system	Rate/acre	Early cocklebur control				
		1979	1980	1981	1982	4-yr. av.
	Pints	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
1. Basagran; 1 cultivation	1½	80	85	85	92	86
2. Basagran; Basagran	1½; 1½	89	84	98	91	91
3. Dyanap; 1 cultivation	4	85	80	71	93	82
4. Dyanap; Dyanap	4; 4	76	66	73	86	75
5. Basagran; 1 cultivation + 2,4-DB	1½, 0.8	88	88	95	92	91
6. Basagran; 2,4-DB; 2,4-DB	1½; 0.8; 0.8	89	69	86	80	86
7. Dyanap; 1 cultivation + 2,4-DB	6; 0.8	83	85	81	89	85
8. Dyanap; 2,4-DB; 2,4-DB	6; 0.8; 0.8	78	60	80	79	74
9. Dyanap; Basagran	6; 1½	76	66	97	85	81
10. Basagran; Dyanap	1½; 6	89	80	94	90	88
11. Dyanap; 1 cultivation; Basagran	6; 1½	81	87	98	87	88
12. Basagran; 1 cultivation; Dyanap	1½; 6	73	90	96	94	88
13. 1 cultivation	—	53	54	45	71	56
14. 2 cultivations	—	53	64	35	82	59
15. 3 cultivations	—	44	69	48	87	62
16. Hoed check	—	100	100	99	92	98

[1]The first cultivation and application of Basagran and Dyanap were applied 22 days after planting. The second cultivation, the second application of Basagran and Dyanap, and the first postemergence directed application of 2,4-DB were applied 38 days after planting. The third cultivation and the second application of 2,4-DB were applied 59 days after planting.

TABLE 40. LATE SEASON COMMON COCKLEBUR CONTROL AS AFFECTED BY CULTIVATION AND/OR HERBICIDES

Control[1] system	Rate/acre	Late cocklebur control				
		1979	1980	1981	1982	4-yr. av.
	Pints	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
1. Basagran; 1 cultivation	1½	61	73	79	82	74
2. Basagran; Basagran	1½; 1½	98	85	99	86	92
3. Dyanap; 1 cultivation	4	66	70	68	85	72
4. Dyanap; Dyanap	4; 4	91	65	73	85	79
5. Basagran; 1 cultivation + 2,4-DB	1½, 0.8	97	85	93	88	91
6. Basagran; 2,4-DB; 2,4-DB	1½; 0.8; 0.8	97	75	86	85	86
7. Dyanap; 1 cultivation + 2,4-DB	6; 0.8	95	76	83	73	82
8. Dyanap; 2,4-DB; 2,4-DB	6; 0.8; 0.8	97	60	82	64	76
9. Dyanap; Basagran	6; 1½	94	59	99	76	82
10. Basagran; Dyanap	1½, 6	94	81	96	76	87
11. Dyanap; 1 cultivation; Basagran	6; 1½	95	91	99	87	93
12. Basagran; 1 cultivation; Dyanap	1½; 6	90	90	99	89	92
13. 1 cultivation	—	35	38	45	38	39
14. 2 cultivations	—	66	54	45	46	53
15. 3 cultivations	—	65	56	66	63	63
16. Hoed check	—	100	100	98	93	98

[1]The first cultivation and application of Basagran and Dyanap were applied 22 days after planting. The second cultivation, the second application of Basagran and Dyanap, and the first postemergence directed application of 2,4-DB were applied 38 days after planting. The third cultivation and the second application of 2,4-DB were applied 59 days after planting.

TABLE 41. SOYBEAN YIELD AS AFFECTED BY CULTIVATION AND/OR HERBICIDES FOR COMMON COCKLEBUR CONTROL

Control[1] system	Rate/acre	Soybean yield/acre				
		1979	1980	1981	1982	4-yr. av.
	Pints	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*
1. Basagran; 1 cultivation	1½	33	6	27	37	26
2. Basagran; Basagran	1½; 1½	36	8	30	37	28
3. Dyanap; 1 cultivation	4	35	5	24	37	25
4. Dyanap; Dyanap	4; 4	35	6	20	28	22
5. Basagran; 1 cultivation + 2,4-DB	1½; 0.8	37	7	29	38	28
6. Basagran; 2,4-DB; 2,4-DB	1½; 0.8; 0.8	36	8	27	38	27
7. Dyanap; 1 cultivation + 2,4-DB	6; 0.8	36	7	26	32	25
8. Dyanap; 2,4-DB; 2,4-DB	6; 0.8; 0.8	36	8	19	31	24
9. Dyanap; Basagran	6; 1½	33	7	31	34	26
10. Basagran; Dyanap	1½; 6	38	5	30	27	25
11. Dyanap; 1 cultivation; Basagran	6; 1½	36	8	31	32	27
12. Basagran; 1 cultivation; Dyanap	1½; 6	34	6	31	30	25
13. 1 cultivation	—	27	8	14	32	20
14. 2 cultivations	—	33	7	13	30	21
15. 3 cultivations	—	30	5	14	32	20
16. Hoed check	—	39	8	33	38	30

[1]The first cultivation and application of Basagran and Dyanap were applied 22 days after planting. The second cultivation, the second application of Basagran and Dyanap, and the first postemergence directed application of 2,4-DB were applied 38 days after planting. The third cultivation and the second application of 2,4-DB were applied 59 days after planting.

bean yields were evident for treatments producing cocklebur control ranging from 72 to 93 percent for the 4-year period, table 41.

Choosing the "best" system becomes a bit more involved when yield differences are few. If only cost is considered, then Dyanap at 4 pints per acre plus one cultivation was the least expensive treatment at approximately $10 per acre ($5 for chemical, $2 for application, and $3 for one cultivation). This treatment was categorized as providing good early season and fair late season cocklebur control, table 42. Since late season cocklebur control averaged 72 percent, it is logical to assume that cocklebur seed were returned to the soil. What effect these additional weed seeds will have on future cocklebur problems is not known.

TABLE 42. EARLY AND LATE SEASON COMMON COCKLEBUR CONTROL AVERAGED OVER FOUR YEARS AND CATEGORIZED INTO CONTROL GROUPS

COCKLEBUR CONTROL, EARLY	COCKLEBUR CONTROL, LATE
Excellent (90's percent)	**Excellent (90's percent)**
Basagran; 1 cultivation + 2,4-DB	Basagran; 1 cultivation + 2,4-DB
Basagran; Basagran	Basagran; Basagran
Hoed check	Basagran; 1 cultivation; Dyanap
Good (80's percent)	Dyanap; 1 cultivation; Basagran
Dyanap; Basagran	Hoed check
Dyanap; 1 cultivation	**Good (80's percent)**
Dyanap; 1 cultivation + 2,4-DB	Dyanap, Basagran
Basagran; 1 cultivation	Dyanap; 1 cultivation + 2,4-DB
Basagran; 2,4-DB; 2,4-DB	Basagran; 2,4-DB; 2,4-DB
Basagran; Dyanap	Basagran; Dyanap
Dyanap; 1 cultivation; Basagran	**Fair (70's percent)**
Basagran; 1 cultivation; Dyanap	Dyanap; 1 cultivation
Fair (70's percent)	Basagran; 1 cultivation
Dyanap; 2,4-DB; 2,4-DB	Dyanap; 2,4-DB; 2,4-DB
Dyanap; Dyanap	Dyanap; Dyanap
Poor (65 percent)	**Poor (65 percent)**
1. Cultivation	1. Cultivation
2. Cultivation	2. Cultivation
3. Cultivation	3. Cultivation

The most expensive treatment was two applications of Basagran at 1½ pints per acre per application ($28.50 for chemical and $4 for application). However, late season cocklebur control averaged 92 percent for the 4-year period. One would assume that few cocklebur seeds were returned to the soil and if this continued for a few years, cocklebur infestation would probably decline. Since this was not measured, it is difficult to assess the value of the added chemical expense. Perhaps one compromise is the treatment that contained Basagran at 1½ pints per acre applied postemergence over the top plus one cultivation and 2,4-DB directed underneath the soybean canopy during the cultivation process. This treatment cost approximately $19 per acre, but it produced excellent cocklebur control for all years and had soybean yields equal to the hoed check.

Both Classic and Scepter have provided excellent control of cocklebur, sicklepod, and annual morningglories.

HERBICIDE APPLICATION

Controlled Droplet Applicator Vs. Conventional Nozzles

There have been reports that the use of the controlled droplet application (CDA) system for herbicide and other pesticide application will allow rate reductions. However, data have been insufficient to adequately prove or disprove these claims.

Research to investigate the effectiveness of the CDA and soybean oil carrier as compared to conventional hydraulic boom (CHB) application of herbicides and soybean oil for weed control in soybeans was begun in 1983 at the Black Belt Substation, E.V. Smith Research Center, Prattville Experiment Field, and Tennessee Valley Substation. Five methods of application were evaluated:

(1) ***Conventional:*** CHB equipped with 11002 flat fan tips, water used as a carrier at 16 gallons per acre.

(2) ***Low volume conventional:*** CHB equipped with 800067 (730039 at Tennessee Valley); water plus soybean oil concentrate (1 quart/per acre) used as carrier in a total volume of 4 gallons per acre.

(3) ***Low volume conventional:*** Same as method 2 except soybean oil concentrate increased to 2 quarts per acre.

(4) ***Controlled droplet applicator:*** CDA operated at 1,650 revolutions per minute (RPM) equipped with 4916/20 orifices (RPM at Tennessee Valley was 3,700). Water plus soybean oil concentrate (1 quart per acre) used as carrier in a total volume of 2 gallons per acre.

(5) ***Controlled droplet applicator:*** Same as method 4 except soybean oil concentrate increased to 2 quarts per acre.

All plots received Lasso 4E + Lexone 75 df applied preemergence (PRE) and Basagran 4 + Blazer 2L applied postemergence over the top (POT) at normal (X) and half normal (1/2 X) rates. This provided for four rate combinations: (1) X PRE + X POT; (2) 1/2 X PRE + X POT; (3) X PRE + 1/2 X POT; (4) 1/2 X PRE + 1/2 X POT.

Data collection for each location was percent weed control by species, soybean injury, fresh weight of weeds, and soybean yields for both cultivated and uncultivated rows. Several conclusions can be made:

1. Low volume (2 to 5 gallons per acre) herbicide application is viable. Additional refinement is, however, needed.
2. The more costly CDA applicator is no better than low volume conventional application.
3. Few weed control advantages have been shown for using soybean oil as the herbicide carrier versus water. Conversely, mixing problems have been encountered with oils and herbicides that are not oil soluble (dry and water soluble formulations).
4. Where a surfactant and/or adjuvant is needed, soybean oil has worked as well as petroleum base oils.
5. The full rate of herbicides is not always needed. However, when and how much to reduce rates must be decided by each individual producer. Variables such as weed density, soil types, weed species susceptibility, stage of growth, and weather conditions must be included in the decision process. Herbicide label directions must also be considered for product guarantees to be valid.

See color plate numbers 12, 13, and 14.

Management of Soybean Insects

T.P. Mack and C.B. Backman

Insects attacking soybeans have generally increased in economic importance as the acreage of soybeans has increased in Alabama. Insects reduce yields by eating foliage, damaging pods and/or seeds, boring or girdling plant parts, transmitting diseases, and reducing the soybean plant's ability to fix nitrogen. Soybeans are attacked by more than 100 species of arthropod pests worldwide, 17 of which are pests of soybean in Alabama, table 43. Many of these are capable of becoming economically important pests if populations of their natural control agents are disrupted by unnecessary pesticide applications.

TABLE 43. INSECTS OF ECONOMIC IMPORTANCE ON ALABAMA SOYBEANS

Scientific name	Common name	Pest status[1]
Heliothis virescens (Fabricius)	Tobacco budworm	rare
Heliothis zea (Boddie)	Podworm	often
Spodoptera exigua Hubner	Beet armyworm	rare
Spodoptera frugiperda (J.E. Smith)	Fall armyworm	rare
Spodoptera ornithogalli (Guenee)	Yellowstriped armyworm	rare
Feltia subterranea (Fabricius)	Granulate cutworm	rare
Plathypena scabra (Fabricius)	Green cloverworm	rare
Anticarsia gemmatalis Hubner	Velvetbean caterpillar	often
Pseudoplusia includens (Walker)	Soybean looper	annual
Trichoplusia ni (Hubner)	Cabbage looper	rare
Elasmopalpus lignosellus (Zeller)	Lesser cornstalk borer	occasional[2]
Spissistilus festinus (Say)	Threecornered alfalfa hopper	often
Nezara viridula Linnaeus	Southern green stinkbug	occasional
Acrosternum hilare (Say)	Green stinkbug	occasional
Euschistus servus (Say)	Brown stinkbug	occasional
Epilachna varivestis Mulsant	Mexican bean beetle	rare
Cerotoma trifurcata (Forster)	Bean leaf beetle	occasional

[1]Refers to how often the insect requires a pest management action to prevent economic damage.
[2]True status of this pest in Alabama is uncertain due to lack of good data.

DISTRIBUTION OF SOYBEAN INSECT PESTS IN ALABAMA

The abundance and damage potential of most soybean insect pests varies with location in Alabama. In a recent U.S. Department of Agriculture sponsored meeting with Alabama soybean researchers, three distinct soybean insect regions were identified, figure 9. The top six soybean insect pests were then ranked according to the amount of economic losses they cause annually, table 44. Podworms, which feed directly on developing soybean pods, ranked as the most important statewide. Soybean loopers, which are foliar feeders, were considered in the central region to be as damaging as podworms, and overall were ranked as the second most important soybean insect pest in the state. Threecornered alfalfa hoppers were ranked as the fourth most damaging soybean insect pest statewide. However, new information on these stem, branch, and leaf petiole girdling insects indicates they may rank third or even second among the most damaging insect pests. Velvetbean caterpillars ranked fifth in statewide importance, but second in importance in the southern region. These foliar feeding insects are probably the **most** important soybean insect for the Alabama counties that border Florida. Researchers in Florida rate the velvetbean caterpillar as the number one soybean insect pest in that state.

TABLE 44. ECONOMIC RANKING OF SOYBEAN INSECT PESTS IN ALABAMA[1]

Insect	Ranking			
	Northern	Central	Southern	State
Podworm	1[2]	1	1	1
Soybean looper	2	1	3	2
Green stinkbug	3	3	2	3
Threecornered alfalfa hopper	x[3]	2[3]	3[3]	4[3]
Velvetbean caterpillar	x	3	2	5
Lesser cornstalk borer	x	x	4	6

[1]From a 1983 USDA sponsored survey.
[2]Numbers indicate rank, with a rank of "1" being highest. An "x" indicates that a pest is not an important soybean insect pest in that region.
[3]New information indicates that threecornered alfalfa hoppers are a more serious soybean insect pest than this table indicates.

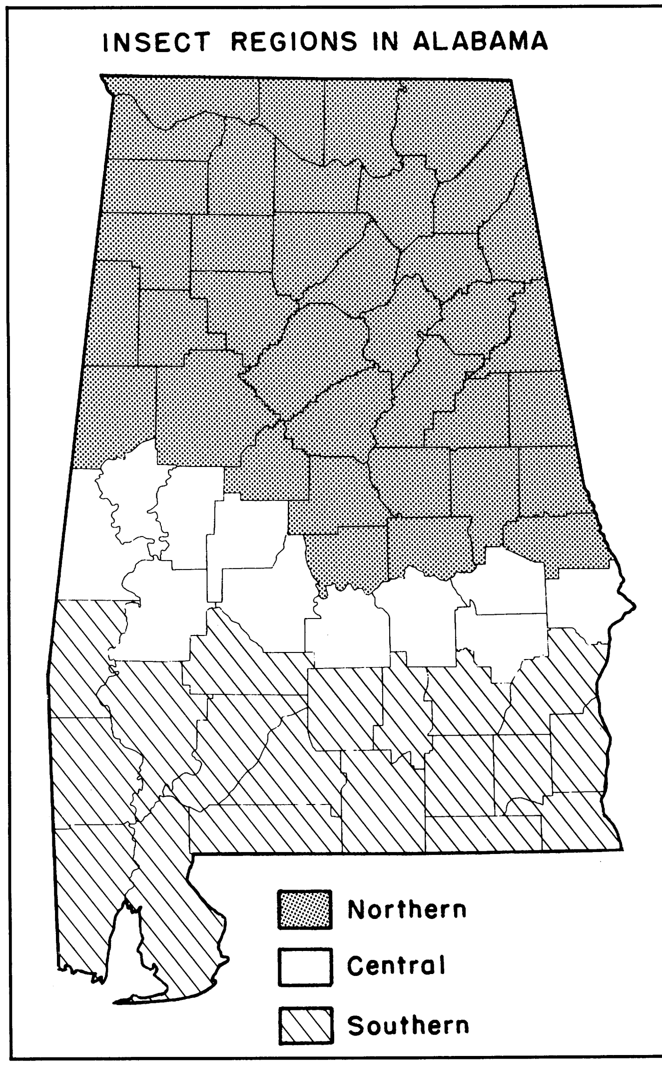


FIG. 9. Northern, central, and southern Alabama insect regions as determined in a 1983 USDA survey.

MANAGEMENT OF SOYBEAN INSECTS

Pest management is the utilization of all available techniques to manage pest populations and avoid adverse ecological and social consequences. This technique is an effective method of reducing insects losses in soybeans, but is employed in less than 40 percent of all of the soybeans grown in

TABLE 45. SOYBEAN PEST MANAGEMENT PRACTICES FOR FOLIAR FEEDING INSECTS AND THEIR USAGE IN ALABAMA[1]

Pest	Practice	Percent of planted acres			
		Northern	Central	Southern	State
Corn earworm	early planting	1	1	2	1
Foliar and podfeeders	scouting	35	35	35	35
Velvetbean caterpillar	early planting	0	2	4	2

[1]From 1983 USDA sponsored survey.

Alabama, table 45. A cornerstone of pest management is the concept of an economic injury level—the population level of a pest that can be tolerated without significant economic loss. Since pest management practices (e.g. pesticides, biological control, etc.) are used only when the cost of control is less than or equal to the crop loss from the pest, unnecessary pesticide applications are prevented. This can save substantial sums of money. For example, a cotton insect pest management program in Texas increased **grower net profits** by more than 50 percent in a 2-year study. Soybean pest management systems in other states have saved growers money, so insect pest management in Alabama should too.

Two major insects are being intensively studied in Alabama pest management research: the threecornered alfalfa hopper and the soybean looper. The threecornered alfalfa hopper is a small, green treehopper that feeds on alfalfa, tomatoes, wheat, barley, oats, clover, cowpeas, soybeans, sunflower, johnsongrass, bermudagrass, cocklebur, and vetch. It feeds by using its piercing-sucking mouthparts to puncture stems, branches, or leaf petioles. Small hopper nymphs feed randomly, while larger nymphs make a continuous series of punctures around the circumference of a stem. This characteristic damage is called a girdle. Early season girdling of main stems causes lodging, breakage, and plant mortality. A large nymph can completely girdle a main stem in less than 24 hours. Threecornered alfalfa hopper damage can affect seedling soybean plant growth in many ways, figure 10. For example, this pest aids in the transmission of at least two soybean diseases, stem blight *(Diaporthe phaseolorum)* and sclerotial blight *(Sclerotium rolfsii)*, by injuring the plant and thus providing a favorable avenue of entrance for the fungi. Stem canker *(Diaporthe phaseolorum* var. *caulivora)* infection may also be increased by threecornered alfalfa hopper injury. Stem canker is extremely closely related to stem blight, the incidence of which has been shown to increase with threecornered alfalfa hopper damage. The disease augmentation effect of threecornered alfalfa hopper feeding means that a much lower population can cause economic damage because of the combined injury and disease effects.

Threecornered alfalfa hopper feeding shifts from the base of the main stem to the upper part of the main stem,

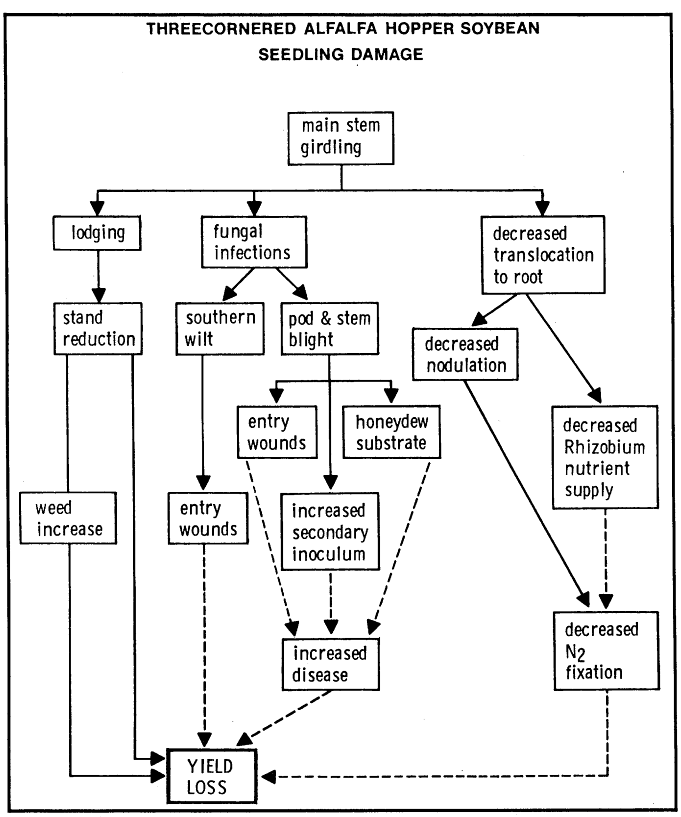


FIG. 10. Ways in which threecornered alfalfa hopper damage affects soybean seedlings. (Drawing by P. Mitchell.)

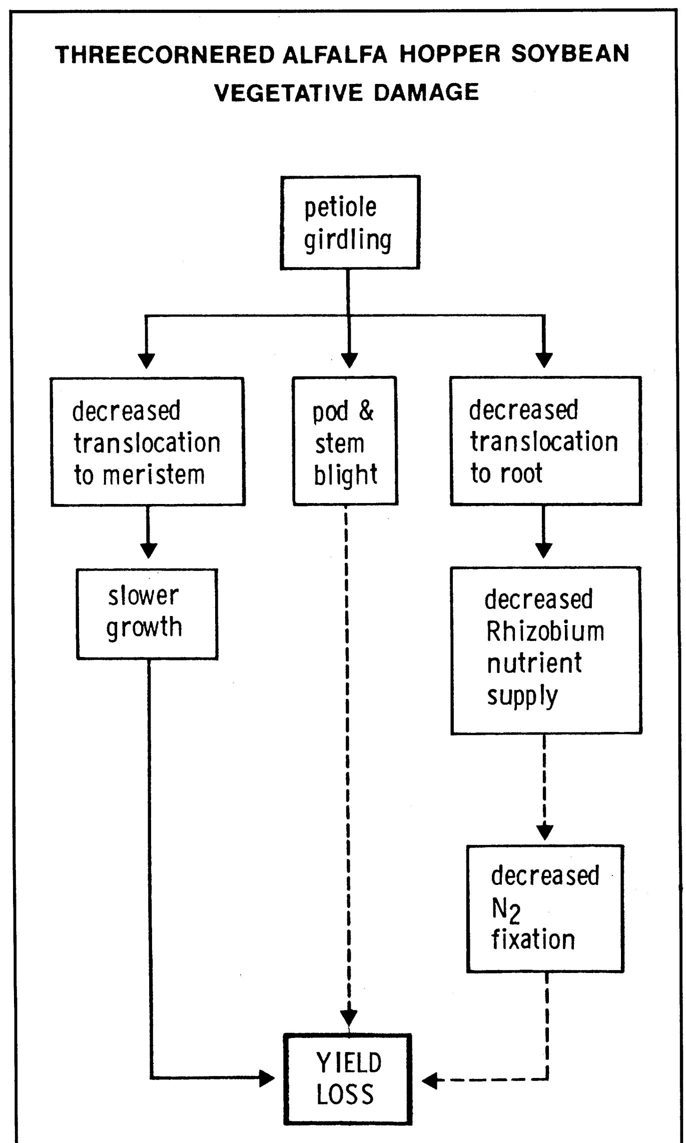


FIG. 11. Types of soybean vegetative damage done by threecornered alfalfa hopper. (Drawing by P. Mitchell.)

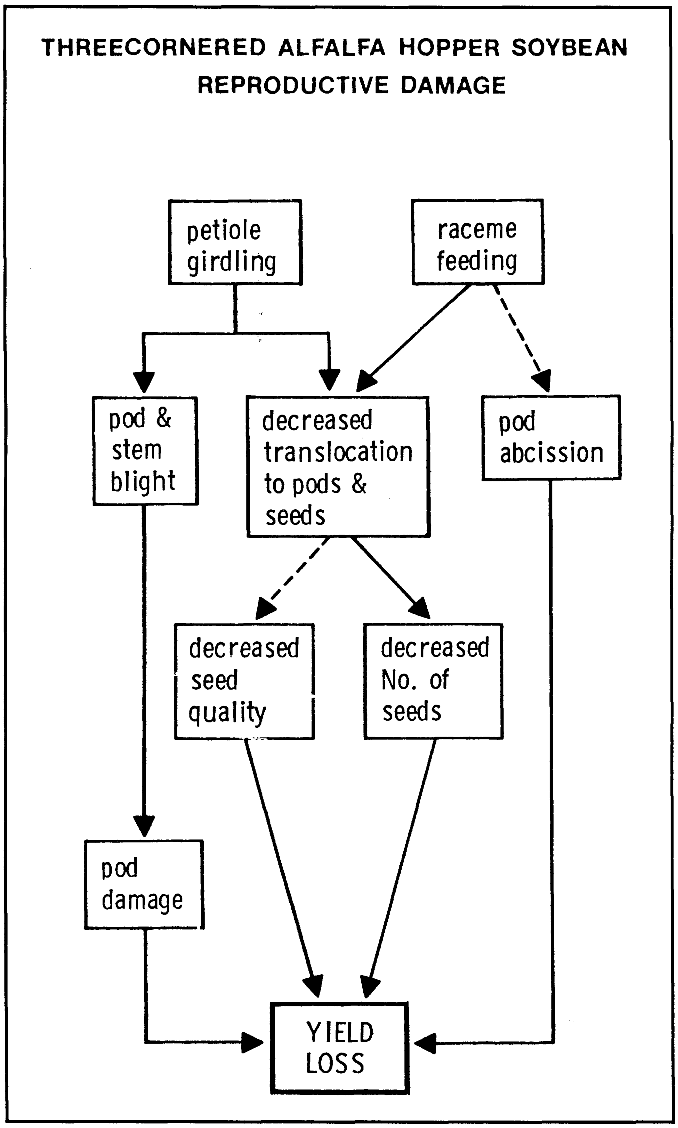


FIG. 12. Types of reproductive damage done to soybean by threecornered alfalfa hopper. (Drawing by P. Mitchell.)

branches, and leaf petioles as a soybean plant increases in height and the main stem hardens. This vegetative feeding, figure 11, reduces yields by decreasing the flow of sugars produced in the leaves to the roots and to the growing tip of the plant. However, the most serious damage occurs when a plant is blossoming and actively producing seeds. Threecornered alfalfa hoppers girdle leaf petioles at this time. A single petiole can be girdled many times.

This "late season" damage has been considered unimportant until very recently. Results from a 2-year study indicate that threecornered alfalfa hopper feeding can reduce soybean stem, pod, and seed dry weights. Yield losses from 16 hoppers per row-foot were 48 percent in 1982 and 45 percent in 1983. Petiole girdling probably physically reduced the flow of sugars to the pods, figure 12. In a number of studies the flow of sugars from a leaf to a seed has been drastically reduced by physically girdling the petiole. Threecornered alfalfa hopper girdling might be viewed as a "kink" in the leaf petiole "pipeline" to the pods and seeds.

Two other reasons make threecornered alfalfa hopper research especially important for Alabama. First, the threecornered alfalfa hopper overwinters on pine trees, which means that Alabama can support a larger overwintering population than some other states, and second, the abundance of threecornered alfalfa hoppers has increased in conservation tillage regimes. Therefore, as conservation tillage use for soybeans increases in Alabama, yield losses from hopper feeding and diseases augmented by the threecornered alfalfa hoppers may proportionally increase.

Threecornered Alfalfa Hopper Control

Management of threecornered alfalfa hopper populations is being viewed in the context of total pest management. Thus, any control measure used on threecornered alfalfa hoppers must impact minimally on other organisms in the ecosystem. For this reason, host plant resistance is being examined. Some of the current Group VI and VII soybean varieties were evaluated for their resistance to threecornered alfalfa hopper injury in a large plot field study. Tracy-M and Davis had lower threecornered alfalfa hopper populations than did Braxton, Bragg, Coker 237, Wright, or GA Soy 17. Fifty-six experimental genotypes were also screened for resistance to threecornered alfalfa hoppers. A number of the genotypes had lower nymphal populations than some of the standard varieties.

Chemical control of threecornered alfalfa hoppers has been examined in a number of studies. Lannate®, Ammo®, Ambush®, Sevin®, Cymbush®, and Orthene® all reduced threecornered alfalfa hopper populations 3 days postspray in a small plot test conducted at Selma, table 46. A large plot test indicated that Lannate (0.2 pound active per acre) was the most effective insecticide tested because it reduced the threecornered alfalfa hopper population without drastically reducing big-eyed bug or nabid populations. Big-eyed bugs and nabids are extremely important insect natural enemies in soybeans. A nabid, for example, is capable of killing more than 40 small podworms per day. Podworms are most injurious to soybeans at early podfill. If an insecticide spray for threecornered alfalfa hoppers is applied just prior to the immigration of podworm adults, then a podworm outbreak could be generated by the destruction of natural enemies

TABLE 46. MEAN NUMBER OF LARGE THREECORNERED ALFALFA HOPPERS ON SOYBEANS AT SELMA, 1982[1]

Treatment, pounds active/acre	Large threecornered alfalfa hoppers/ 6 row ft.			
	Prespray	Postspray		
		1 day	3 days	7 days
	No.	*No.*	*No.*	*No.*
Scout 3E, 0.13	5.88 ab	0.75 ab	0.25 b	0 c
S3206 2.3, E 0.1	2.5 b	.38 b	.38 b	0.13 c
Orthene 75 WP, 0.66	5.00 ab	1.13 ab	.75 b	1.00 bc
Ammo 2.5E, 0.04	4.25 ab	.63 ab	.13 b	0 c
Cymbush 3E, 0.06	4.13 ab	2.00 ab	1.00 b	.63 c
Pounce 3.2E, 0.10	3.88 ab	2.13 ab	.88 b	1.13 abc
Ambush 2E, 0.10	3.38 ab	.63 ab	1.13 b	.75 c
Sevin 4XLR 1.0	7.13 a	2.13 ab	.25 b	0 c
Lannate 1.8E 0.45	3.5 ab	.25 b	.13 b	.25 c
Super-tin 4L	2.5 b	2.50 ab	3.63 a	3.25 a
Control	1.75 b	3.13 a	3.63 a	3.13 ab

[1]Four replicates (4 rows x 40 feet) were used in the study. Means followed by the same letter are not significantly different at the 5 % level according to a DMRT.

such as nabids and big-eyed bugs. Thus, it is important to conserve natural enemies of insect pests.

Soybean Looper Control

The soybean looper is often a late season pest of soybeans in the Southeast and is capable of causing severe damage to soybeans. It is a foliar feeding insect that reduces soybean yields by eating leaves needed to produce the sugars used by the plant to grow viable seeds. Soybean looper larval population outbreaks are usually rapid, going from less than one larva per shake-cloth to more than 30 in less than 7 days. It is a migratory insect that overwinters in Florida. The soybean looper is routinely exposed to as many as 100 insecticide applications per year in Florida because of loopers attacking chrysanthemums. Circumstantial evidence indicates that these applications contributed to the current Lannate resistance found in some looper populations. If this is true, resistance to the new pyrethroids, such as Ambush, Pounce, and Ammo, may rapidly occur.

A study was begun to examine the egg laying rate of adult female soybean loopers over a range of temperatures. This information was needed because, assuming that a large population of looper larvae originated from a large number of eggs, the number of eggs laid could be used to estimate larval populations. The total number of soybean looper eggs varied with temperature, figure 13, with most eggs being laid at 78°F. Soybean loopers laid eggs at their fastest rate from 78 to 85°F. Therefore, a large number of loopers could be deposited in a short time if temperatures ranged from 78 to 85°F at night when loopers lay eggs. This would be especially true if warm night temperatures coincided with a large number of immigrating adults. These results suggest that an estimate of the adult looper population size coupled with temperature may prove helpful in forecasting looper outbreaks, and thus give soybean growers a warning before economic losses occur.

In chemical control studies, Ambush was the most effective compound against soybean loopers. It was more effective than Ammo or Cymbush in reducing small and medium sized loopers in 1982-85 field tests. Ambush, as well as Lannate-Ambush (0.225 + 0.05 pound active per acre) and Lorsban-Ambush (0.5 + 0.05 pound active per acre) mixtures, effectively reduced looper populations in 1983.

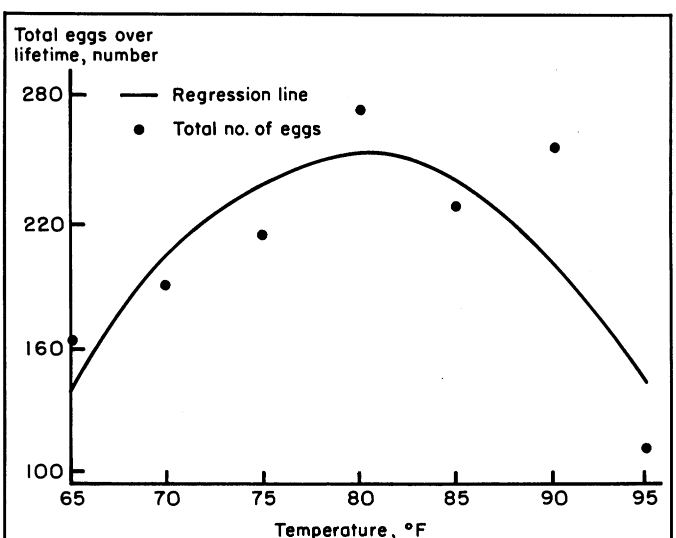


FIG. 13. Effect of temperature on total number of eggs laid by soybean looper over a lifetime.

See color plate numbers 15, 16, 17, 18, and 19.

Biological Control of Soybean Insect Pests

J.D. Harper

A wide spectrum of parasites, predators, and pathogens affects populations of insect pests of soybeans. While the extent of pest control by these natural enemies is hard to quantify, it is clear that they contribute significantly to the maintenance of pest populations below economically damaging levels in most fields in most years. Occasionally, unusual weather conditions, high immigration rates of pest species into fields, or other factors result in an imbalance between the natural enemies and pest species. Under these conditions, the pests are able to cause economic damage to the soybean crop. All too often, the factor which causes this imbalance is the misuse of pesticides.

Every soybean field has its own complex of predaceous insects and spiders. The most common of these are big-eyed bugs, damsel bugs, minute pirate bugs, spined soldier bugs (predaceous stink bugs), ground beetles, earwigs, and several species of spiders. While the extent of pest control by each of these predators is hard to quantify, predators contribute significantly to the maintenance of pest populations below economic injury levels.

Parasites, principally small to minute wasps and tachinid flies which resemble rather hairy or spiny houseflies, also aid in maintaining pest populations below economic injury levels. Parasites lay their eggs in or on the eggs or larvae of pest species and develop in the living hosts. When the parasites' larval development is complete, they emerge from their hosts, generally killing the hosts in the process.

Most pest insects in soybeans also suffer from one or more diseases. These are caused by viruses, protozoa, fungi, and bacteria. Nematodes parasitize pest species, causing disease-like symptoms as well. At times, mass die-offs of pests occur as these pathogens spread through pest populations. Particularly well known to growers are the fungi *Nomuraea rileyi* and *Entomophthora gammae*. *Nomuraea* is most frequently seen in late season. It infests most species of lepidopterous caterpillars which feed on soybean. It causes the familiar white cadavers which are seen sticking to leaves and stalks of soybean plants. *Entomophthora gammae* infects soybean and cabbage loopers, causing the caterpillars to hang from leaves as shriveled yellow or brown larvae. *Entomophthora gammae* is generally important in late August and September. Nuclear polyhedrosis viruses also infect the soybean podworm in Alabama, and others are known from the velvetbean caterpillar and soybean looper, as well as from less frequent pests such as the various armyworms and the cabbage looper.

Natural enemies are generally utilized in one of three ways—through conservation, augmentation, or introduction. Conservation involves management practices which have minimal impact on beneficial organisms. Augmentation of natural enemies implies release of parasites or pathogens to increase the levels of beneficials which cannot multiply fast enough to control increasing pest populations. Introduction is the practice of releasing natural enemies into a field where they do not already occur.

SURVEY FOR NATURAL ENEMIES

For several seasons, collections of lepidopterous caterpillars have been made at several locations through the central and southern regions of Alabama. Many species of parasites, predators, and pathogens have been recorded in these surveys to determine what natural enemies are present. Five species of parasitic wasps and five species of flies make up the majority of parasites associated with larvae of green cloverworm, soybean podworm, soybean looper, and velvetbean caterpillar. Most of these parasites are not host specific, but attack two or more of these pests. Parasitism rates are usually from 5 to 20 percent, but in some fields in late summer, parasitism of the soybean looper reached 75-80 percent. All disease agents mentioned previously have been found in the Alabama surveys. Rates of infection have varied with host species, location in the State, and time of year, and have ranged from less than 5 to greater than 95 percent.

MICROBIAL PESTICIDES

Products based on the bacterium *Bacillus thuringiensis* are ideally suited to soybean pest management programs because of their selectivity. They kill only their target pests and do not harm beneficials. Results of several studies on the use of *B. thuringiensis* as a selective microbial insecticide for green cloverworm, soybean looper, velvetbean caterpillar, and soybean podworm show it is (1) highly effective against both green cloverworm and velvetbean caterpillar at low rates, tables 47, 48, and 49, (2) effective against soybean looper at higher rates, table 49, and (3) not effective against podworms at the dosages tested, table 49. The improved commercial formulations of this bacterium used today are more concentrated and more easily handled than similar products available a decade ago.

TABLE 47. CONTROL OF VELVETBEAN CATERPILLAR WITH DIFFERENT RATES OF DIPEL (ACTIVE INGREDIENT = *BACILLUS THURINGIENSIS*) FOLLOWING AUGUST 27 AND SEPTEMBER 10, 1980, APPLICATIONS ON REPLICATED FIELD PLOTS, GULF COAST SUBSTATION

Treatment, active/acre	Medium + large larvae/3 ft. of row			Yield/acre
	9/9	9/16	9/23	
	No.	*No.*	*No.*	*Bu.*
Dipel, 0.25 lb.	3.8a[1]	0.5a	7.3a	33.1a
Dipel, 0.50 lb.	2.3a	1.0a	6.3a	29.4a
Dipel, 0.75 lb.	1.5a	1.8a	6.0a	31.4a
Lannate, 0.45 lb.	4.5a	3.8a	1.8a	30.3a
Untreated.	13.5b	58.3b	18.9b	19.0b

[1]Means in the same column followed by the same letter do not differ significantly at the 0.05 level of probability (Duncan's new multiple range test).

A second microbially derived pesticide currently under investigation is Thuringiensin, a toxin produced by certain varieties of *B. thuringiensis*. Laboratory research to date has demonstrated that this material is capable of killing soybean podworms at very low dosages. Use of these materials illustrates the introduction type of approach to biological control. Neither material occurs naturally in the field nor multiplies under field conditions.

TABLE 48. VELVETBEAN CATERPILLAR CONTROL WITH THURICIDE (ACTIVE INGREDIENT = *BACILLUS THURINGIENSIS*) APPLIED OCTOBER 3, BLACK BELT SUBSTATION, 1979

Treatment, active/acre	Medium and large larvae at days post-treatment	
	2	5
	No.	*No.*
Thuricide HP, 0.5 lb.	55.0a[1]	9.7a
Thuricide HP, 0.5 lb. + Gustol, 1.0 lb.[2]	61.0a	9.0a
Untreated	87.7a	63.7b

[1]Means in the same column followed by the same letter do not differ significantly at the 0.5 level of probability (Duncan's new multiple range test).
[2]Gustol is a commercial feeding stimulant.

ROLE AND DYNAMICS OF INSECT PATHOGENS

Nomuraea rileyi has been tested for its insecticidal properties through introductions as a sprayed preparation of fungal spores. Results suggest that this method of utilization will not provide adequate control of the lepidopterous pest complex with the strain chosen for use. A second set of experiments was conducted to try to augment the natural population of *Nomuraea* which normally infects a low level of host larvae in early summer, creating inocula for a growing level of infection through the summer. Heavy incidence normally occurs in late summer, often too late to be of economic help to the grower. A test of the theory that an early application of infectious fungal spores might initiate an earlier buildup suggests that this management approach warrants further testing. Identification of the optimal strain of *Nomuraea* appears critical to the future success of this project. The incidence of the fungus, *Entomophthora gammae*, in soybean loopers has been monitored for several years. Findings make it obvious that under the right conditions, this fungus can decimate looper populations. Evidence indicates that *E. gammae* develops best at low night temperatures of 68-72°F and during periods when relative humidity remains above 95 percent for several hours. These conditions occur nightly during mid- to late summer in most central Alabama soybeans. These factors alone, however, do not provide all the conditions necessary for a fungal outbreak in host populations.

FOREIGN EXPLORATION FOR AN INTRODUCTION OF EXOTIC NATURAL ENEMIES

A final avenue of research on biological control has been the exploration for natural enemies which occur in other countries but not in the Southeastern United States. These natural enemies are imported and held in Federal quarantine facilities until they are determined to be safe for release in

TABLE 49. EFFECT OF DIPEL AGAINST GREEN CLOVERWORM, SOYBEAN LOOPER, AND SOYBEAN PODWORM, MATERIALS APPLIED 8/19 AND AGAIN 8/31, TALLASSEE, ALABAMA, 1982

Treatment, active ingredient/acre	Mean no. of larvae/3 feet of row							
	Green cloverworm		Medium + large soybean loopers				Podworms	
	8/24	8/27	8/24	8/27	9/3	9/7	8/24	8/27
	No.	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*
Dipel, 0.50 lb.	0.8	1.2	7.5	18.3	6.4	5.4	15.0	15.0
Dipel, 0.75 lb.	0	.2	2.3	7.0	4.4	2.2	27.5	10.0
Lannate, 0.45 lb.	.2	.2	5.0	6.7	5.5	4.8	2.5	5.0
Untreated	6.2	4.5	10.6	19.7	9.8	12.2	22.5	20.0

this country. Several parasites have been collected in Ecuador, one of which has now been established in Florida and may eventually be released in Alabama. Still being examined as potential release agents are several pathogens collected in Ecuador, as well as pathogens collected by other scientists in Argentina, Brazil, and Central America.

See color plate numbers 20, 21, 22, and 23.

Interrelationships of Soybean Cultivars and Environment to Disease Development and Fungicide Performance

Paul A. Backman and Mark A. Crawford

The most frequently observed foliage, stem, or pod pathogens on soybeans grown in the Southeast are *Septoria glycines* (cause of brown spot), *Cercospora sojina* (cause of frogeye leafspot), *Peronospora manshurica* (cause of downy mildew), *Diaporthe phaseolorum* var. *sojae* (cause of pod and stem blight), *D. phaseolorum* var. *caulivora* (cause of stem canker), and *Colletotrichum dematium* (cause of anthracnose). Several other fungal diseases and some bacterial and viral diseases affect soybeans in the area, but they are erratic in occurrence and distribution. Loss estimates for all soybean diseases vary greatly, due to the subjective bases employed in assessment and wide differences in disease severity.

Development of appropriate fungicidal treatments for the control of soybean diseases requires the following information: what fungi cause significant yield and seed quality losses; what environmental conditions predispose plants to infection; and what fungicides will control the damaging pathogens?

Thirty-three tests were conducted statewide in Alabama to determine the response of various soybean cultivars to fungicides. As the soybeans approached early pod set (R_3), fungicides were applied, followed by a second application 14-18 days later (R_5, early pod-fill). R-ratings refer to the reproductive stages of the soybean plant. All fungicides were applied with a high-clearance ground sprayer operating at 90 p.s.i. and delivering 25 g.p.a. through hollow-cone type nozzles. Three nozzles were positioned over the row, i.e. one above the top and one on each side. All tests were arranged in randomized complete block or split-plot designs with five to eight replications. Only the results from the untreated control plots and plots treated with Benlate® 50 WP (8 ounces per acre per application) will be presented. These results are related to prevailing weather conditions during the bloom to pod-fill periods as recorded by nearby stations operated by the U.S. National Weather Service.

Two tests were conducted to determine the principal pathogens of soybeans and their relative pathogenic potentials. Cultivars evaluated were Forrest, Davis, Bragg, and Hutton, representing maturity groupings V, VI, VII, and VIII, respectively. For Alabama conditions, maturity groups V and VI are considered early-maturing, and groups VII and VIII late-maturing cultivars. Differences in severity of the various diseases were achieved through differential susceptibilities of the cultivars, and by treatment of the cultivars with fungicides. Cultivars were planted at different times to coordinate bloom occurrence (R_1) on the same date (± 2 days) for each cultivar. This allowed cultivars from different maturity groupings to be evaluated following treatment with fungicides under the same environmental conditions, and at the same developmental stage. Fungicides used were Benlate 50 WP (0.5 pound per acre at each application), Du-Ter 47 WP® (fentin hydroxide, 0.5 pound per acre per application), and Mertect 340 F® thiabendazole, 42.3% flowable (6 fluid ounces per acre at each application). Fungicides were applied as described for the statewide tests to four-row split plots with cultivars the whole plot. Treatment x cultivar combinations were replicated eight times at each of the two locations.

Samples for foliar disease estimation were obtained as follows: (1) approximately 15 trifoliolate leaves, including petioles, were picked about one-third of the way down the plant at intervals throughout the length of the two middle rows of each plot; and (2) at harvest, combine trash was randomly bagged from each plot to include representative samples of stems and pods.

Bases for the severity ratings of the various diseases and damage were:

(1) Brown spot, frogeye leafspot, and downy mildew—lesion frequency on trifoliolate samples.
(2) Anthracnose and pod and stem blight—severity on dried stem samples after harvest.
(3) Senescence—relative state of decline when control plots were 50 percent defoliated (on 1-5 scale, where 1 = full green and 5 = dead).

Severity of each of the diseases present was recorded for each cultivar x treatment and related to environmental conditions occurring during the spray period. Disease ratings were made on a 1-5 rating scheme where 1 = no symptoms, 2 = scattered infection, 3 = moderate infection (most leaves, stems, or pods multiply infected), and 4 and 5 = increasingly severe levels of infection. Ratings were estimated to the one-tenth unit. In trials involving several cultivars sprayed during the bloom to pod-fill periods (coordinated bloom studies), foliar disease ratings were made as each cultivar approached senescence, and reflected the performance of the fungicide at a similar physiological state (pre-senescence) for each cultivar. However, it should be noted that early-maturing cultivars reached senescence sooner after treatment than did the late-maturing cultivars.

Yields for both statewide and coordinated bloom tests were obtained by harvesting the center two rows of the four-row plots. The ends of the plots were trimmed off before harvest to eliminate any edge effect. The yields reported reflect actual seed yields after harvesting with a two-row combine.

On a multi-year, multi-location basis, soybean yield responses to two fungicides were erratic, varying from actual losses to 40 percent increases. When the 33 tests were evaluated for response to benomyl, it was clear that the largest increase occurred in tests conducted in wet locations with 5 or more days of rainfall in the 3 weeks immediately after bloom initiation. Any day with >2.0 mm of rain was considered "wet." Yields of both early and late maturing cultivars were increased (4.5-5.6 bushels per acre) by benomyl in "wet" environments, but were not increased in "dry" environments.

Soybean cultivars from the coordinated bloom test at the Black Belt Substation predominantly were infected with brown spot and anthracnose. Levels of anthracnose were similar for all cultivars. Yield differences between fungicide treatments were related to control of these two pathogens. The yield of cultivar Forrest plants, however, was severely reduced by drought. Benlate was effective against both brown spot and anthracnose, while Du-Ter 47 WP was effective primarily against anthracnose and Mertect 340 F was not effective against either organism.

In coordinated bloom studies at Tallassee, Alabama, anthracnose and frogeye leafspot most frequently were observed at severe levels. Even though relative disease severities (anthracnose-frogeye) were similar to the severities of the brownspot-anthracnose complex observed at the Black Belt Substation, yield responses to fungicide treatments were only 50-60 percent of those observed in the early study. Plants of cultivar Davis were resistant to *C. sojina* (cause of frogeye), but still responded at 70-80 percent of the increased yield of cultivars with both frogeye and anthracnose. Mertect was again ineffective against anthracnose at this location. Yield improvements following thiabendazole treatment must therefore be related to control of frogeye.

In both coordinated bloom studies, neither downy mildew nor pod and stem blight responded to fungicidal treatment. Downy mildew developed before treatment, and did not seem to increase after bloom. Pod and stem blight appeared to develop well after pod fill and thus could not affect yield. No stem canker was observed. Observations on these diseases, therefore, are not reported here.

Delayed senescence was found to be a good indicator for reduction in total disease. In both coordinated bloom tests, delay in the onset of senescence was typically related to increased yield and disease control.

These data indicate that for significant yield increases to occur in response to benomyl, soybeans must be under periods of recurrent rainfall from bloom to pod-fill. These "wet" periods would correspond to infection periods for the principal foliar pathogens. Untreated controls in the 21 "wet" tests had much higher levels of disease than did the untreated controls in the "dry" tests. The 5 wet-dry scheme, as described, appeared to be a good predictor for the efficacy of Benlate. As modified for the two-spray program recommended in Alabama, farmers are advised to make the first application of 8 ounces per acre benomyl 50 WP at R_3 if 2-3 wet days have occurred since bloom. If these wet conditions have not been met by 1 week after R_3, the application is omitted. A second application of Benlate at the same rate is made only if 2 additional wet days occur during the 10-day period following the first application. Use of this prediction system would have eliminated at least one-third of the benomyl applications made in the 33-test study. Of the results recorded, only 2 of the 12 dry tests treated with benomyl had yields at least 6 percent greater than the nontreated control. Of the six lowest-yielding wet tests treated with benomyl, all had yield improvements of 6-10 percent over the control; the other 15 wet tests yielded considerably higher. A complete treatment of the "common sense" system for timing of fungicide applications to soybeans can be found in the following section.

Reports that late-maturing cultivars sprayed with fungicides do not respond with yield increases as great as early-maturing cultivars are partially confirmed. However, it was noted that early-maturing cultivars usually proceed from bloom to pod-fill during the wetter late July through August period. The lower yield response of later cultivars to fungicides may merely be a reflection of few infection periods occurring during September, rather than disease tolerance.

Coordinated bloom studies allowed evaluation of the damage potential of each of several soybean diseases. Levels of disease achieved through fungicidal application and cultivar resistance served as the basis for damage determinations. Yields from each cultivar served as the integrating factor for total disease damage, and reflected the cumulative disease load. Data from the Black Belt Substation revealed brown spot to be as damaging to yield as anthracnose. This can be deduced by comparing the yield responses of Hutton (low brown spot) and Davis (high brown spot) to Benlate treatment, when each had about equal levels of anthracnose (frogeye levels were negligible). The Davis soybeans responded with a 31 percent yield increase; yield of Hutton increased 8.2 percent. Only Hutton soybeans showed increased yields after treatment with Du-Ter, primarily because this fungicide was very active against anthracnose but poor against brown spot. Since Hutton had high levels only of anthracnose, treatment with Du-Ter was effective.

Yields from the Tallassee tests indicate that anthracnose affected yield more than did frogeye leafspot. This is apparent when comparing yield response of Davis (very little frogeye) to benomyl, with that of Forrest, Bragg, and Hutton cultivars (high levels of frogeye). Only low levels of brown spot were found in this test. Yield increased primarily in response to anthracnose control rather than to the control of frogeye leafspot.

Comparisons of yields from the Black Belt Substation test with those from the Tallassee test indicate that the greater percentage yield increases following fungicide treatment at the Black Belt were due to high levels of brown spot on the cultivars that exhibited highest yield responses.

Results of these tests indicate that, in order of damage potential, anthracnose is slightly more damaging than brown spot, and frogeye is least damaging. In these tests, the foliar fungi *C. sojina*, *S. glycines*, and *C. truncatum* all apparently invaded between bloom and pod-fill. Pod and stem blight develops much later, probably in late pod-fill, with little yield loss. Yield reductions from these organisms were probably due to reduced photosynthetic capability because of premature senescence, resulting in smaller seed. Hormone-like activity has been ascribed to Benlate in previous studies. However, these data indicated no kinetin-like activity when Benlate was applied to soybeans.

In the 33 statewide tests reported, anthracnose was dominant in every test, with recorded yield increases from controlling the disease. Brown spot occurred more sporadically, but yields were also improved where it was controlled. Benlate gave superior control of both pathogens, while Du-Ter was effective against anthracnose. Mertect at the rates employed was ineffective against these pathogens, but showed good activity against frogeye leafspot. Results of the Alabama tests indicate that using foliar fungicides only when wet conditions favor disease development should prevent many unnecessary applications and improve the economic return of fungicides when used in soybeans.

A Common Sense Timing System for the Application of Foliar Fungicides

Paul A. Backman, Mark A. Crawford, and Mack Hammond

As early as 1977, research in Alabama indicated fungicides applied to control leaf and stem diseases in soybeans were not beneficial during dry periods. The northern portion of the State is much drier than the Gulf region during the summer months, and less frequent periods of rainfall in that region reduce severity of soybean diseases. This weather pattern was taken into consideration in designing a cost-effective system for the application of fungicides to soybeans.

Tests were conducted throughout the northern region of Alabama to evaluate a system for the timing of fungicide applications based on local (on-farm) weather conditions. This timing system was compared to the standard program (sprays, regardless of weather, at early pod set and 14 to 18 days later) and to unsprayed soybeans. Beginning at early bloom (first bloom), any day with 1/10 in. of rain or extended periods of fog and dew was considered wet. When 3 to 4 wet days had been recorded, an application of Benlate at 8 ounces per acre was made using a high clearance sprayer. This application usually occurred during early pod set, but occasionally was made during bloom. The second application was made 14-20 days after the first, if 3 to 4 more wet days occurred when the count was begun 10 days after the first application. During periods of especially wet weather, the interval was shortened to as little as 10 days to compensate for frequent disease infection periods and washing-off of the fungicide. All spray trials were replicated six times and results are reported as treatment means.

Data from the meteorological timing system indicated several advantages over the standard spray program. The number of fungicide applications was reduced an average of 40 percent, while the frequency of nonprofitable fungicide applications was reduced to zero for the meteorological system from 60 percent for the standard program. However, disease control was slightly inferior to the standard program. The economic data indicated that not only was the number of locations with non-economic return on fungicide investment reduced where the meteorological timing system was used, but all locations gave a positive dollar return above cost. The ratio of increased crop value to cost of control was very positive for the meteorological program ($3.03 per $1.00), but only marginally beneficial for the standard program ($1.19 per $1.00).

These data indicate that foliar diseases can cause substantial losses in soybeans but, in the drier regions of Alabama, control measures cannot be utilized routinely at standardized times with the expectation of reasonable return on investment. The meteorological timing system described for application of benomyl, based on the probability of damaging levels of disease developing, reduced total pesticide application by 35 percent, yet gave a greater dollar return per acre in all six experiments.

A portion of the success of this experiment can be related to the systemic nature of benomyl, which allows for removal of established infections. Further, actual weather rather than predicted weather was utilized. Should contact fungicides be employed (e.g. Bravo 500®), sprays would have to be applied before infection periods as protectants, and predicted weather would have to be utilized.

Aerial Applications of Fungicides to Soybeans

Paul A. Backman, B.H. Cosper, and Mark Crawford

Research relating to efficiency of application of aerially applied fungicides has been conducted in Alabama since 1978, with emphasis given to improving the delivery of fungicides to the crop surface. Fungicides applied to soybeans in a water carrier were compared to those in water plus spray oil,and water plus the viscoelastic agent Nalcotrol®. The percent of fungicide reaching the foliage was determined. Data gathered show that when small droplets were produced, the benefits of this tank additive were lost. The spray volume per acre in which fungicides should be delivered by airplanes was also evaluated. Results indicated that rates of delivery as low as 2.3 gallons per acre may effectively deliver the fungicide to the crop. Low volumes were particularly effective under conditions of high humidity (Marion, Alabama, test), but higher spray volumes generally improved deposition.

Reducing Losses from Soybean Stem Canker

Paul A. Backman, Mark A. Crawford, and Mack Hammond

Soybean stem canker, a disease caused by the fungus *Diaporthe phaseolorum* var. *caulivora*, has been found in soybeans grown from Canada to the Gulf of Mexico. However, until recently severe losses from this disease had not been observed in Alabama. In 1977, several thousand acres of soybeans in Montgomery County were infected with this fungus and severe crop losses occurred. During the 1980 and 1981 seasons, stem canker occurred throughout the Black Belt counties of central Alabama, as well as in several river bottom areas adjacent to this zone. During the 1982 season, stem canker was found in the Tennessee Valley and the mountain valleys of northeast Alabama.

Symptoms of the disease are small reddish-black lesions originating typically in the leaf axils, becoming black, sunken, and elongate on the stem. As the disease becomes severe, plants typically show chlorosis (yellowing) between leaf veins, followed by death of the interveinal tissue and chlorosis near the veins. In advanced stages of the disease, the plant dies, usually retaining the dead leaves. Whole fields have frequently been destroyed as a result of this disease.

Research from several regions of the country indicates that the stem canker fungus can be seed-borne, and that this is an important means of long distance movement for the infestation of new fields. A second means of spread is on equipment containing infested crop debris or soil. Once established, the fungus lives from year to year on crop debris. One or two infected plants in a field during the first year can lead to total devastation during the second year, if susceptible cultivars are grown.

Infection of the soybean plant seems to occur early in the growing season. Data from central Alabama indicate that soybeans planted after June 15 develop little or no stem canker symptoms, regardless of how susceptible the variety may be.

The disease cycle begins in the early spring with the development of the spores within the fungus fruiting body (perithecium), figure 14. These perithecia develop on plant debris from the previous crop. In about mid-April, the spores are mature and are exuded out of the perithecial neck, in a sticky mass. This spore mass is not easily wind-borne, but when it rains, the impacting rain droplets can be carried by wind for considerable distances. Spore formation and dispersal continue until early June, when the spore production of perithecia appears to reduce greatly. In years such as 1984, when spore development is delayed by unfavorable environment, infections still occur, but too late to cause disease.

Spores that are carried to young soybean plants apparently infect the leaves. Like almost all foliar pathogens, the stem canker fungus requires an extended period of free moisture for the infection process to occur. Usually this moisture would be provided by the rain that carried the spore to the soybean plant. Typically the young plant has not passed beyond the 5- or 6-leaf stage before almost all spore production steps have occurred. Reports in the literature indicate that if the first six leaves are removed anytime before bloom, the plants never develop canker. Further, fungicide sprays made during this early vegetative period can prevent disease development.

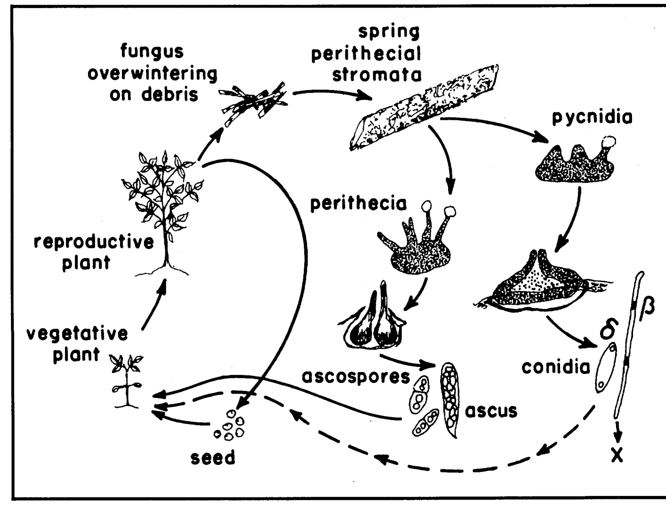


FIG. 14. Life cycle of *Diaporthe phaseolorum* f. sp. *caulivora* (cause of stem canker). Solid lines indicate known developmental pathways, while a broken line indicates one requiring verification; "X" indicates no apparent function.

Following infection, the fungus remains in the leaf tissue until about the bloom stage of soybean development. At this time it appears to grow into the stem producing the symptoms described earlier.

Research on fungicidal control of stem canker has continued since 1980. Data from a test conducted in 1983 evaluating Benlate® 50WP for control of stem canker under various application schedules indicate that only the spray program that included a treatment at the V_2 (2-leaf) stage reduced stem canker and increased yield. If a V_2 spray is used, subsequent fungicide applications enhance control, even when these later sprays do not themselves affect disease level. Evaluation of these data and data from other states indicates that fungicides must be applied during the vegetative growth stages, timed to coincide with spore release and infection, to be effective. Furthermore, these applications will show improved control if fungicides are also applied at later dates. Other points that are indicated include (1) highly susceptible and susceptible varieties (e.g. J-77-339, Hutton, and Bragg) require too many fungicide applications to economically control the disease; (2) for varieties showing some resistance (e.g. S-69-96 and Davis), fungicides show excellent yield improvements; (3) timing is critical, while application rates are less important; (4) banded applications over the top of young plants have been highly successful, and (5) Benlate gives good control, but other fungicides such as Bravo applied early can also control the disease.

See color plate numbers 24 and 25.

Nematode Problems in Soybeans

R. Rodriguez-Kabana, D.G. Robertson, C.F. Weaver, P.S. King, E.L. Snoddy, and D.B. Weaver

The soybean is a legume species with a wide range of susceptibility to plant parasitic nematodes. Virtually all major genera of plant nematodes successfully parasitize the crop. The root-knot nematodes *(Meloidogyne arenaria, M. incognita,* and *M. javanica)* and the cyst nematode *(Heterodera glycines)* cause the most economic damage. A complicating factor in nematode damage to soybeans is that there is great variation in ability to parasitize soybean within the same nematode species. Because of this, several races of cyst nematodes are recognized and it is known that there are races within each root-knot nematode species. Various other nematode species, such as lesion *(Pratylenchus),* stubby *(Paratrichodorus),* sting *(Belonolaimus),* spiral *(Helicotylenchus),* lance *(Hoplolaimus),* and reniform *(Rotylenchulus reniformis),* attack and cause injury to soybeans, generally to a lesser degree than the root-knot and cyst nematodes.

OCCURRENCE OF NEMATODES IN ALABAMA SOYBEAN FIELDS

All of the nematode species and genera mentioned have been recorded in Alabama soybean fields. However, of most frequent occurrence are the root-knot, the cyst, the lesion, and the stubby root nematodes. The species most frequently encountered in the State and also the most difficult to manage are the soybean cyst nematode and the root-knot nematodes. Survey results indicate that simultaneous occurrence of root-knot and cyst nematodes in Alabama soybean fields is on the increase. The magnitude of the nematode problem in Alabama is illustrated by results from a 1983 unbiased survey of soybean fields in the State. Of the total soybean acreage in the survey, 45.6 percent was infested to some level with cyst, root-knot, or combinations of cyst and root-knot nematodes: 12.4 percent of the acreage was heavily infested with the cyst nematode, 4.4 percent was severely infested with root-knot nematodes, and 4.0 percent had both cyst and root-knot nematodes. The degree of infestation by nematodes varied among regions of the state, figure 15. In Baldwin County, 90.2 percent of the 101 fields surveyed in November 1983 were heavily infested with cyst or root-knot nematodes and 33.6 percent had mixed populations of cyst and root-knot nematodes.

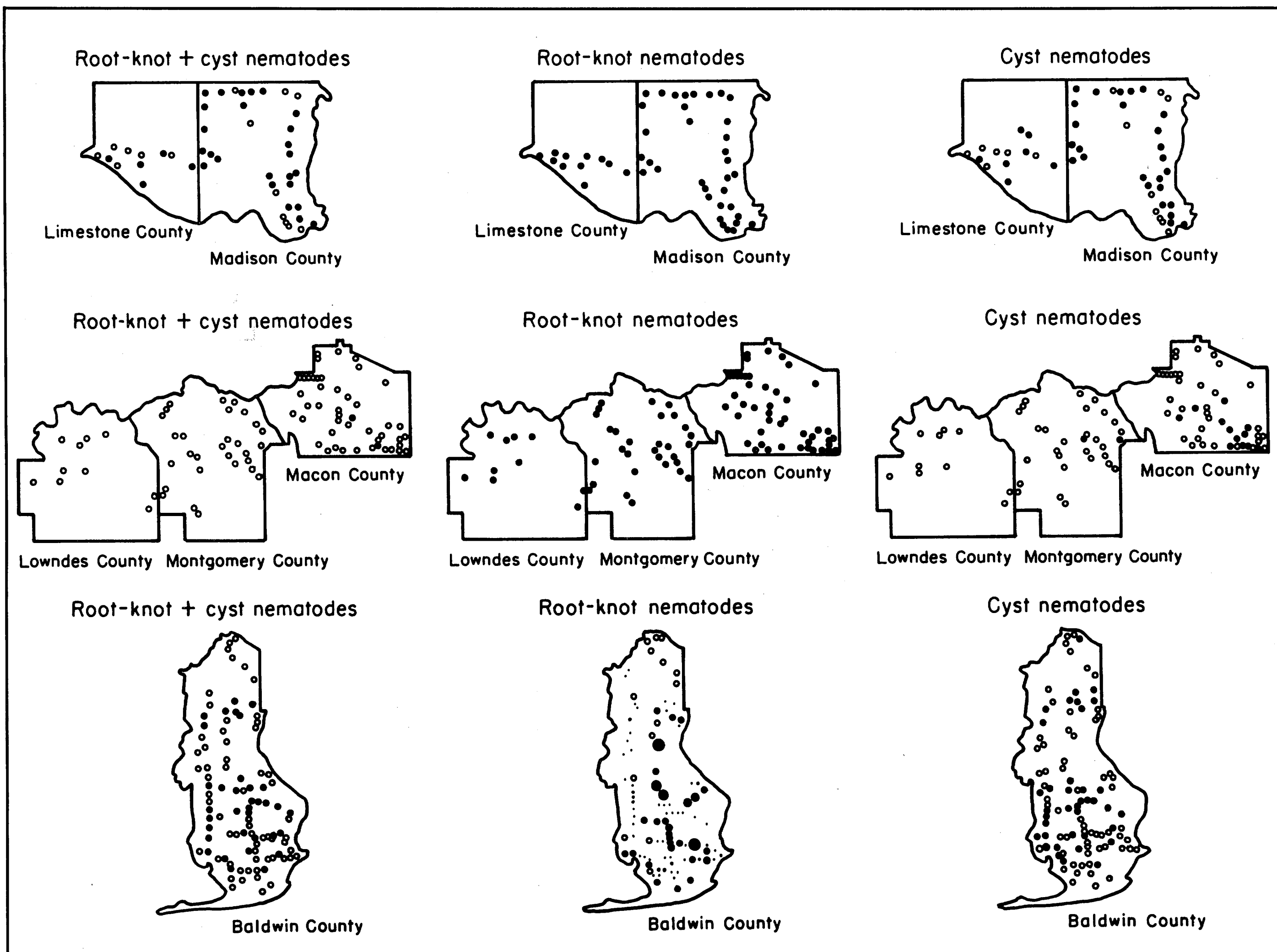


FIG. 15. Distribution of root-knot and cyst nematodes in soybean fields in representative counties in Alabama, from a survey conducted in November 1983. (Open dots mean no nematodes and black dots indicate the presence of nematodes; for root-knot nematodes in Baldwin County, the size of the black dot is directly related to the severity of infestation.)

YIELD LOSSES

Yield losses to plant parasitic nematodes depend on the nematode species and races present in a given field and the soybean variety planted in the field. Nematodes other than root-knot or cyst nematodes rarely cause yield losses greater than 10-15 percent in Alabama. However, losses sustained from attacks by root-knot or cyst nematodes can be as much as 70-80 percent. Research for several years has attempted to quantify precisely the relation between soybean yields and numbers of root-knot or cyst nematodes in soil. This work, for example, has indicated that losses for Ransom soybean to a species of root-knot nematodes *(M. arenaria)* are in the range of 4-10 pounds per acre per larva of the nematode found in 100 cubic centimeters of soil (nematode infestation is best estimated 4-6 weeks before harvest). Similar studies have been conducted for other soybean cultivars and for the cyst nematode and other root-knot nematodes. The results show substantial yield losses to these nematodes. The calculated soybean yield loss to the nematode for the State in 1983 was 11.72 million bushels.

METHODS OF CONTROL

Traditional methods of controlling plant parasitic nematodes rely on the development of resistant varieties, the use of effective nematicides, and rotation with non-host crops. Plant breeding efforts to develop resistant cultivars are discussed in another section of this publication. Currently, there are no commercially available soybean cultivars with combined resistance to all important root-knot nematodes and with resistance to the major races of the cyst nematode.

TABLE 50. YIELD RESPONSES OF SELECTED SOYBEAN VARIETIES TO APPLICATIONS OF EDB[1] IN A FIELD INFESTED WITH *MELOIDOGYNE INCOGNITA* AND *HETERODERA GLYCINES*, NEAR ELBERTA, ALABAMA, 1982

Variety	Yield per acre		Gain/acre	Yield increase
	No EDB	With EDB		
	Bu.	*Bu.*	*Bu.*	*Pct.*
Coker 317	1	33	32	2,825
Ransom	5	37	32	654
GK 49	6	28	22	394
Braxton	8	33	25	304
RA 701	8	30	22	280
A 7372	6	28	22	374
Foster	12	37	25	206

[1]EDB was applied as Soilbrom® 90 at planting time at a rate of 2 gallons per acre.

TABLE 51. YIELD RESPONSES OF SELECTED SOYBEAN VARIETIES TO APPLICATIONS OF EDB[1] IN A FIELD INFESTED WITH *MELOIDOGYNE INCOGNITA* AND *HETERODERA GLYCINES*, NEAR ELBERTA, ALABAMA, 1983

Variety	Yield per acre		Gain/acre	Yield increase
	No EDB	With EDB		
	Bu.	*Bu.*	*Bu.*	*Pct.*
Coker 317	19	50	31	162
Ransom	9	40	32	373
GK 49	14	41	27	187
Braxton	9	36	27	321
RA 701	21	46	25	115
Kirby	35	55	20	57
Foster	26	51	25	96

[1]EDB was applied as Soilbrom® 90 at planting time at a rate of 2 gallons per acre.

There are, however, soybean varieties (e.g. Kirby, Foster, LeFlore) that are capable of delivering relatively high yields in fields with extreme levels of infestation by both root-knot and cyst nematodes. Tables 50 and 51 illustrate the range of variability in yield performance of selected soybean cultivars in a field infested with root-knot *(M. incognita)* and cyst (race 3) nematodes. These results show that it is possible to develop soybean cultivars that can tolerate heavy nematode infestations and still deliver acceptable yields. However, all cultivars suffered substantial yield losses.

NEMATICIDES

The use of nematicides in soybeans received a great deal of attention in the research. Nematicides can be classified as either fumigants or nonfumigants. Fumigant nematicides are those that are injected into the soil where they vaporize and move through the soil. Fumigants are the oldest nematicides and among the most effective; however, two of the best performing of these, EDB and DBCP, are no longer available for use by farmers. A third fumigant, 1,3-dichloropropene (Te-

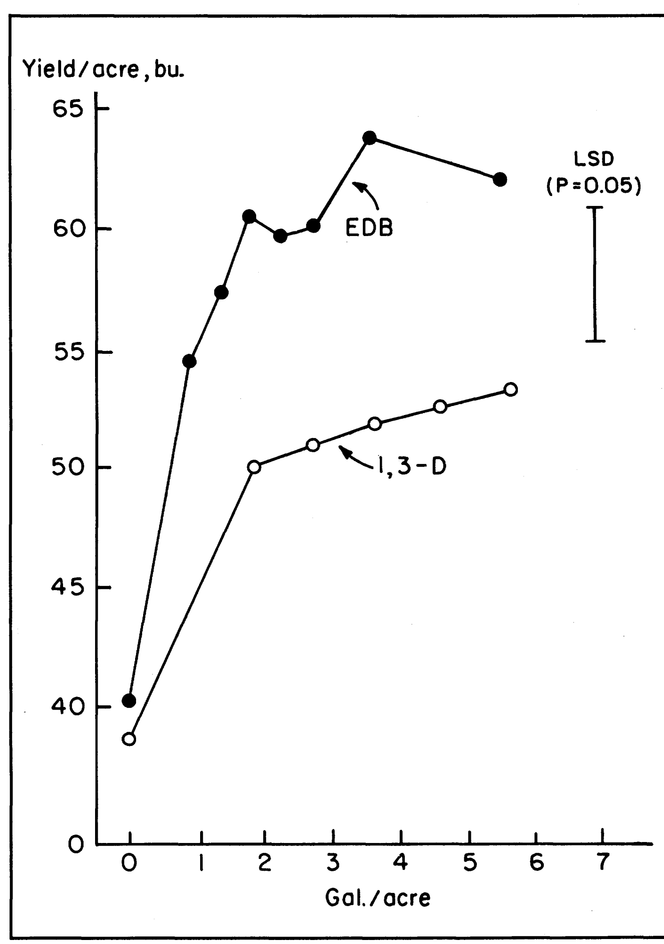


FIG. 16. Although Telone II is still available for use as a nematicide, high rates are required and it has not performed as well as EDB.

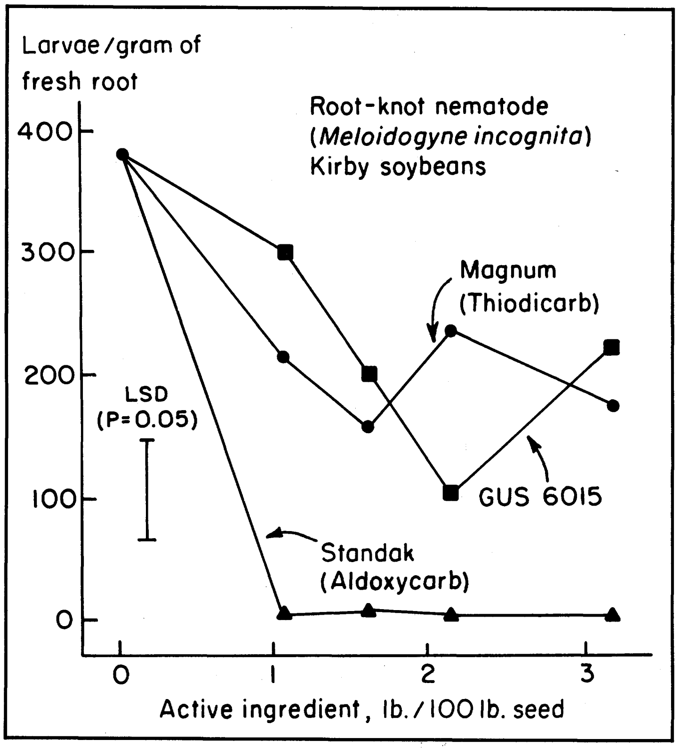


FIG. 17. Seed treatment with new systemic nematicides has shown great promise in greenhouse tests.

lone® II), is still available for use, but rates of 3-5 gallons per acre are required to obtain maximal yield response and has not performed as well as EDB in any of the trials, figure 16.

Non-fumigant nematicides (Furadan®, Nemacur®, Temik®) are most commonly used in granular formulations. In the Alabama research, they performed best when applied at planting time in narrow (4- to 8-inch) bands or in the furrow. Multi-year studies on the performance of these nematicides have shown that their use can result in significant yield increases, table 52; however, much of their performance depends on the level of nematode infestation and on the correct choice of cultivar.

A new area of nematicide research in soybeans currently

TABLE 52. COMPARATIVE EFFECT OF NEMATICIDES APPLIED TO SOYBEAN FIELDS INFESTED WITH SOYBEAN CYST AND ROOT-KNOT NEMATODES ON PRODUCTION

Treatment[1] and rate/acre	Per acre increase				
	1980	1981	1982	1983	4-year average
	Bu.	*Bu.*	*Bu.*	*Bu.*	*Bu.*
Nemacur® 15G (phenamiphos), 13 lb.	8	7	4	10	7
Temik® 15G (aldicarb), 13 lb.	7	6	8	11	8
Furadan 10G (carbofuran), 20 lb.	2	0	—	2	1
Soilbrom® 90 (EDB), 2 gal.	11	25	17	22	19

[1]Granular nematicides applied in 7- to 8-inch band and scratched in top 2 inches of soil. Fumigant injected 8 inches deep.

underway is the use of seed treatments. New systemic nematicides have been developed that can be used for seed treatments without injury to the resulting soybean plants. These treatments have shown great promise under greenhouse conditions for reducing root-knot and cyst nematodes, figure 17. Such a treatment has important advantages of reduced cost, safety, and delivery of an effective material where it is needed, around the developing seedling roots.

THE FUTURE

Nematode problems in soybeans in Alabama will continue to increase, especially from the soybean cyst nematode. These problems will have to be addressed within a pest management system. Cropping systems will have to be identified that are economical and will result in low populations of plant parasitic nematodes. Ongoing research in several areas of the State is seeking to identify cropping systems that will permit sustained soybean yields and keep nematode numbers low. Also, the information gathered from these studies is currently being integrated into computer management models to deliver the information directly to producers. Within the next 5 years there are likely to be many high yielding soybean varieties with increased levels of tolerance to nematodes that can be integrated within production systems to reduce the costs of production.

See color plate numbers 26, 27, and 28.

PHYSIOLOGICAL DEVELOPMENT

Flower and Pod Abscission of Soybean

Curt M. Peterson, Michael W. Folsom, Roland R. Dute, and Larry M. Dalrymple

There are many different factors limiting soybean yields in Alabama, including environmental and biological stresses. One major factor causing a decreased yield potential and contributing to a yield barrier is the abscission of large numbers of flowers and pods before seed maturity. Since the number of pods produced by a plant ultimately contributes to yield, substantial increases in productivity could be attained by reducing the number of flowers and pods lost, thereby increasing pod set. Although considerable research, both nationally and worldwide, has been performed in the last 30 years to determine the causes of abscission in soybean and other grain legumes, the primary factor(s) responsible for this problem are still unknown. Research has been in progress at Auburn since 1975 in an attempt to determine the extent and causes of abscission occurring in Maturity Group VII and VIII soybean cultivars grown in Alabama.

A diagrammatic representation of the typical growth habit of Bragg soybean plants at harvest is illustrated in figure 18. The plants used for this study were grown in nonirrigated field plots with 40-inch row spaces and about 8 seeds per foot of row at the Agronomy Farm at Auburn. Each main stem and all axillary branches consist of nodes and internodes. A node is a place on a stem where one leaf and one or more axillary branches or flowering racemes (flower clusters) may form. A typical plant produces an average of 19 mainstem nodes, 36 axillary branch nodes, and 10 subaxillary branch nodes for a total number of 65 vegetative nodes.

Flowers are borne on racemes which potentially can be produced at all nodes on the plant, figure 18. Frequently, two racemes are produced at higher mainstem nodes where axillary branches do not develop. In addition, a terminal raceme is produced at the tip of the mainstem and each axillary branch. Flowering proceeds rapidly so that within a few days flowers appear at most mainstem nodes and older nodes on axillary branches. The process then continues for a 4- to 6-week period with most flowers forming during a 2- to 3-week period. Pollination and fertilization (seed set) frequently occur 1 to 2 days before flowers open. Pods develop slowly for

TABLE 53. STAGES OF REPRODUCTIVE DEVELOPMENT FOR BRAGG SOYBEAN PLANTS GROWN IN FIELD PLOTS AT THE AGRONOMY FARM, AUBURN, ALABAMA, DURING SUMMER

Developmental stages	Reproductive characteristics
Abscised bud	Developing flower prior to complete expansion of petals; before pollination and fertilization.
Abscised flower	Open flower; pollination completed; fertilized ovules present.
Abscised immature pod	Flower having withered and/or discolored petals; zygotes to proembryos present in ovules; no visible elongation of the pistil into a pod.
Abscised pod	Visible elongation and/or enlargement of the pod; seeds at different stages of development.
Mature pod	The pod present on racemes at final harvest usually with one or more seeds present.

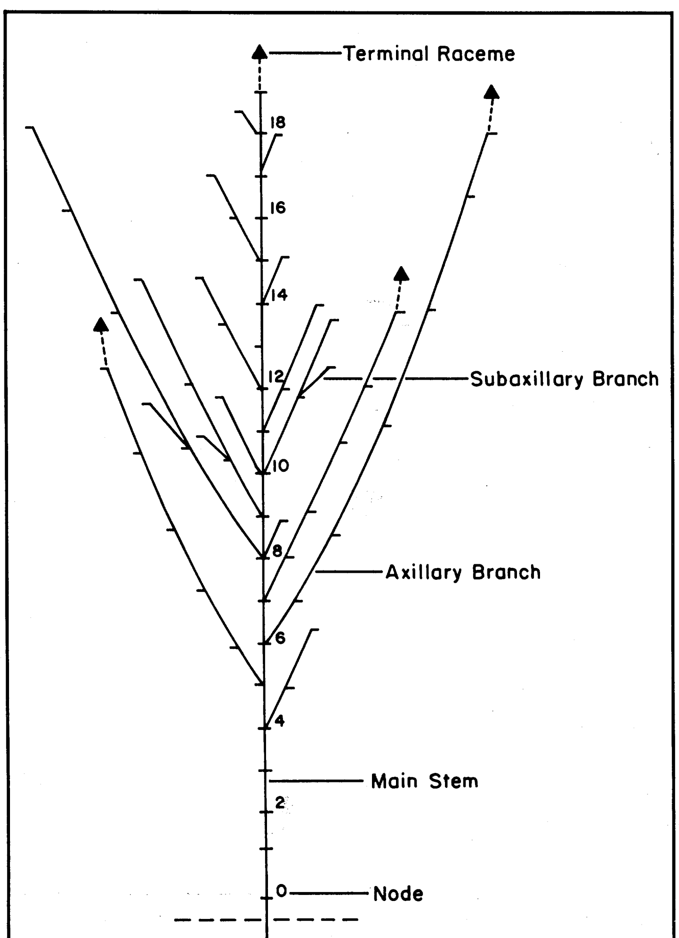


FIG. 18. Diagram of a typical field-grown soybean plant at harvest, having a determinate growth habit with many lateral or axillary branches.

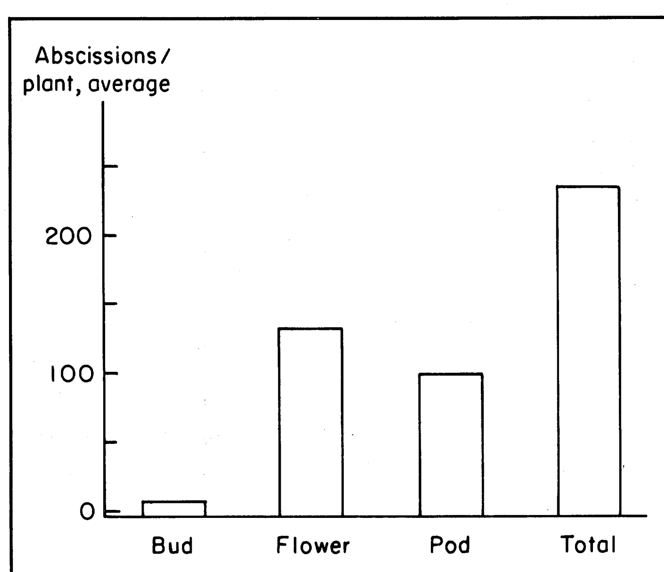


FIG. 19. The average number of bud, flower, and pod abscissions and total abscissions per plant for field-grown Bragg soybean plants.

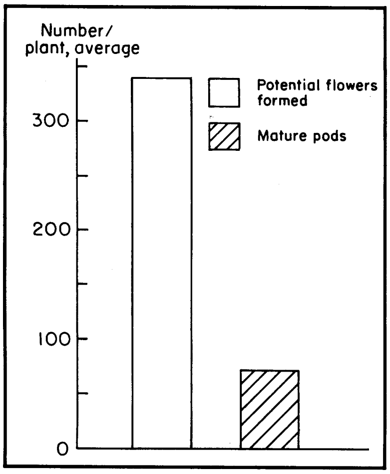


FIG. 20. The average number of potential flowers and mature pods formed on field-grown Bragg soybean plants.

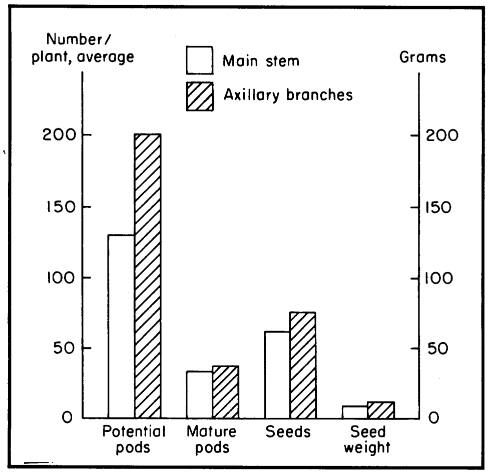


FIG. 21. The average number of potential pods, mature pods, seeds, and total seed weight produced on the main stem and axillary (lateral) branches of field-grown Bragg soybean plants.

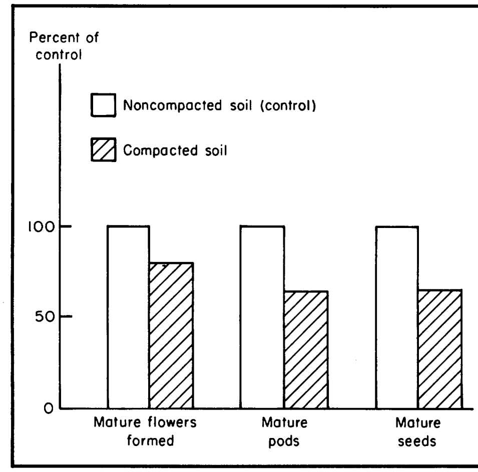


FIG. 22. The total number of flowers, pods, and seeds produced on Bragg soybean plants grown in noncompacted and compacted (hardpan present) soil.

the first few days following fertilization, rapid elongation begins on the fifth day, and full pod length is attained after about 15 to 20 days.

During a typical growing season, abscission was observed and recorded at several different stages of flower and pod development, table 53. Few of the abscissions were unopened flowers or buds, figure 19. Almost one-half of the potential pods abscised at flowering. In addition, a large number of pods at various stages of development abscised during pod enlargement and seed filling.

More than three-fourths of the flowers or pods formed on Bragg soybean plants abscised before seed maturity, figure 20. Although typical Bragg soybean plants growing under nonirrigated conditions produced an average of 341 total flowers during one growing season on all racemes, only an average of 72 mature pods were present on plants at final harvest.

Flowers or pods abscised from all racemes on both the mainstem and axillary branches. However, abscissions were disproportionately greater from racemes at lower mainstem nodes and on branches. Thus, the final number of seeds and seed weight produced on branches were similar to that observed on the mainstem, figure 21.

The extent of abscission during a growing season may be affected by environmental factors. One such factor is drought stress, which can be caused by a lack of rainfall or the presence of a hardpan of compacted soil. A hardpan limits the size of a root system by restricting root penetration into deeper soil layers where stored water reserves might be available. The resulting drought stress leads, in turn, to a decrease in total flower production per plant, and to an increase in flower and pod abscission, resulting in fewer seeds per plant, figure 22. However, drought stress is not the only factor which causes abscission, because even in a year with ample soil moisture during flowering, abscission still may exceed 70 percent in Bragg soybean.

A study of abscission from terminal racemes of Bragg soybean plants during one growing season showed that more than 75 percent of the abscissions occurred during a 14-day period when flowering reached its peak in mid-August, figure 23. Most abscissions were either open flowers or flowers having withered petals. This indicated that there is a critical period during early pod development when most abscissions occur. This period coincides with fertilization and early embryogenesis.

The number of nodes or sites on terminal racemes where individual flowers are attached varies with the cultivar and growing conditions. Flower development proceeds from the base to the tip of each raceme, figure 24, so that pods may be developing at basal nodes when buds or unopened flowers are present at the raceme tip. Occasionally, racemes may be ob-

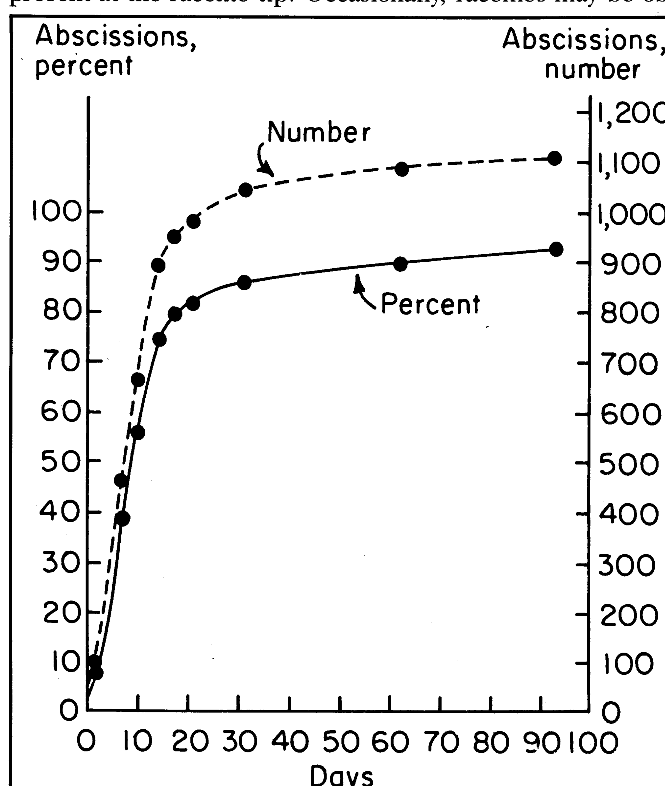


FIG. 23. The percent abscission (shedding) and number of abscissions observed on terminal racemes of field-grown Bragg soybean plants during the 1977 growing season.

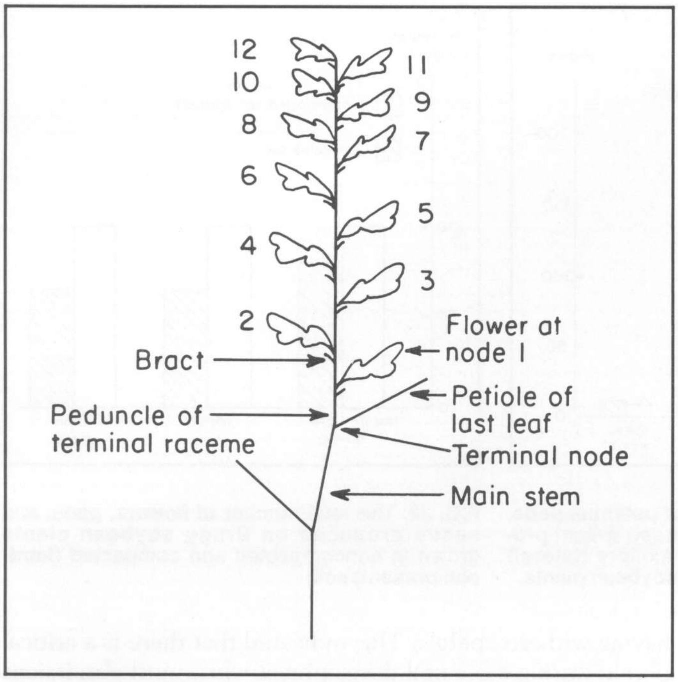


FIG. 24. Diagram of a terminal raceme (flower cluster) formed at the tip of the main stem of soybean plants having a determinate growth habit. Individual flowers are attached to the main stalk (peduncle) of the raceme at regular intervals (nodes). The oldest flower or pod is attached at node 1, with younger flowers or pods produced at remaining nodes.

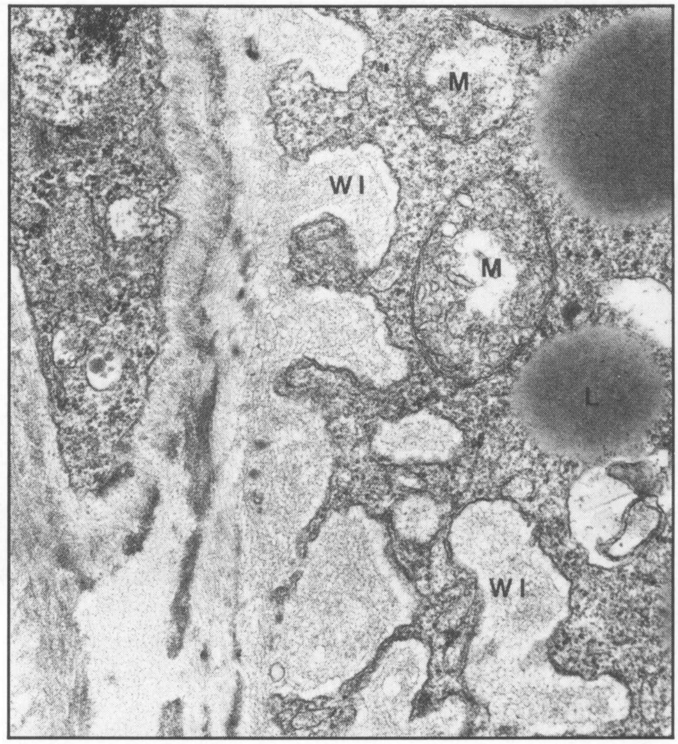


FIG. 26. Electron micrograph showing wall ingrowths (WI) extending into the cytoplasm of the central cell. Numerous subcellular organelles [e.g., mitochondria (M) and lipid bodies (L)] are closely associated with these wall ingrowths.

served where pods and flowers are forming at all nodes on a raceme and no abscissions are present, color plate no. 29. Usually, however, one or more pods are observed developing at the raceme base with many abscissions occurring at intervening nodes between these pods and buds or flowers at the tip, color plate no. 30. More abscissions occur from nodes at the tip of a raceme than from nodes at the base, and in some cases all flowers abscise from a raceme, color plate no. 31.

Histological observations of soybean flowers, made to determine stages of ovule (immature seed) development associated with abscission, revealed that large amounts of starch are deposited in the ovule, figure 25. The starch that accumulates in the central cell of the embryo sac within each ovule is formed in packets, and completely fills this cell prior

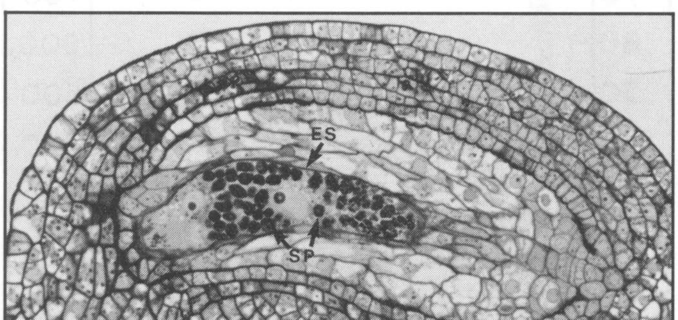


FIG. 25. Ovule (immature seed) from a soybean flower. The elongated structure in the center is an embryo sac (ES) within which the embryo will form following fertilization. Large numbers of starch packets (SP) are visible in the central cell of the embryo sac.

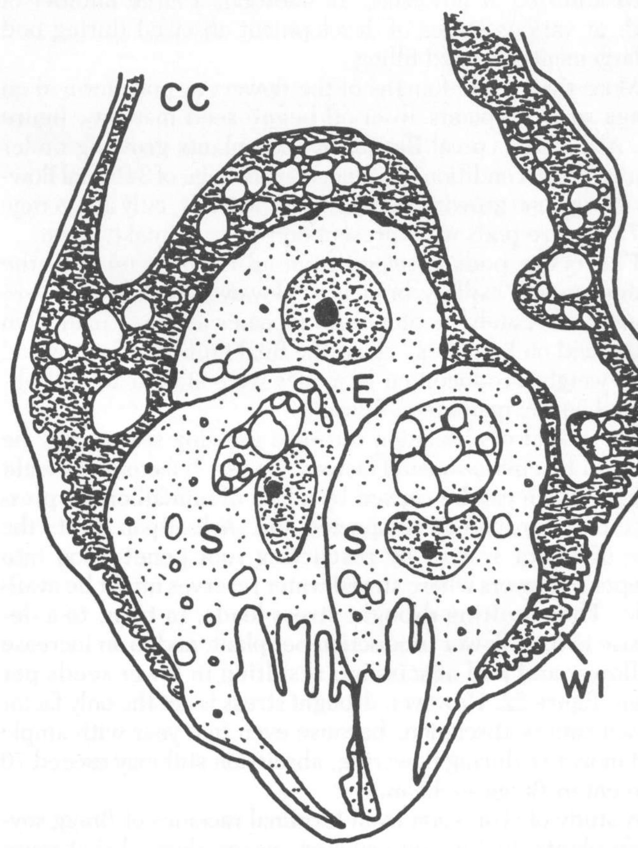


FIG. 27. Diagram of the micropylar end of an embryo sac from a soybean ovule showing the three cells of the egg apparatus [egg cell (E) and two synergids (S)] and numerous wall ingrowths (WI) extending along the lateral walls of the central cell (CC).

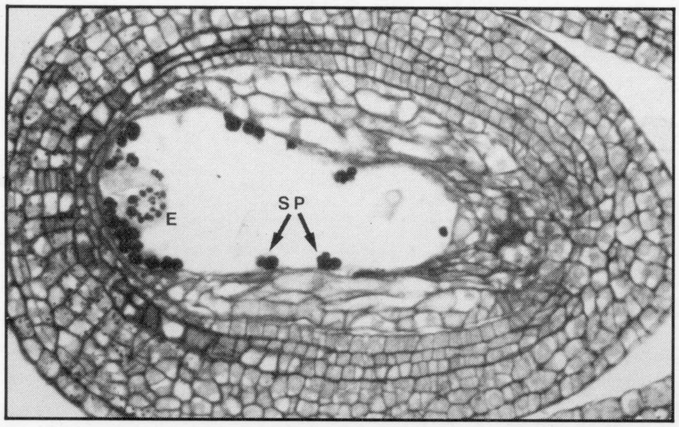


FIG. 28. Longitudinal section of a soybean ovule. A fertilized egg (E) is visible at the micropylar end of the embryo sac. Few starch packets (SP) remain in the large central cell of the embryo sac. (Compare to figure 25.)

to fertilization. Conspicuous wall ingrowths of the central cell are visible when sections of mature embryo sacs are viewed with an electron microscope, figure 26. These wall ingrowths are particularly prevalent at the end of the central cell adjacent to the three cells of the egg apparatus, figure 27. Although the precise function of these wall ingrowths has not been determined, in other cells they have been shown to increase short distance transfer of nutrients. Prior to fertilization, starch begins to disappear from the central cell. By the time the fertilized egg (zygote) has formed, many of the starch packets have disappeared, figure 28. During the proembryo stage (4 to 16 cells), starch completely disappears and endosperm nuclei are evident in the central cell, figure 29. Most of the embryo sacs in ovules from abscised flowers contain proembryos surrounded by free-nuclear endosperm (a nutritive tissue), illustrating that both pollination and fertilization had occurred.

The presence of proembryos in ovules of abscised flowers indicates that abscission is not due to inadequate pollination, lack of viable pollen, or failure of fertilization. The large accumulation of starch present in abscised flowers and their

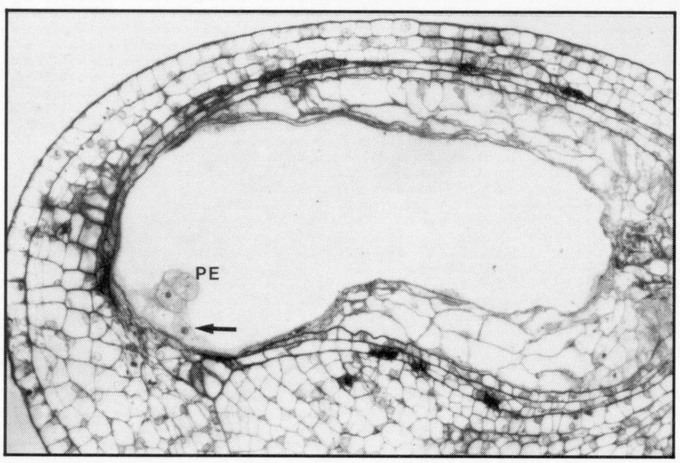


FIG. 29. Longitudinal section of a soybean ovule containing a proembryo (PE). Starch packets are completely absent in the central cell. An endosperm nucleus (arrow) is visible next to the proembryo.

TABLE 54. NUMBERS OF SEEDS PER RACEME AND PER POD AND AVERAGE SEED WEIGHT PER TERMINAL RACEME AND POD OF FIELD-GROWN BRAGG SOYBEAN PLANTS LEFT UNTREATED (CONTROL) OR SPRAYED WITH A 10^{-3} M BAP SOLUTION

Treatment	Seeds/ raceme	Seeds/ pod	Average seed weight	
			Per raceme	Per pod
	No.	*No.*	*Grams*	*Grams*
Control (no spray)	1.33	2.66	0.21	0.29
BAP	16.17	2.03	2.29	.21

ovules and embryo sacs suggests that neither is a lack of assimilates or fixed carbon ("nutrients") a major cause of abscission. However, abscission could be the result of some events that lead to a cessation of embryo and endosperm development.

Growth regulators have been widely implicated in the control of abscission of flowers and young fruits of many different species of plants. A cytokinin, 6-benzylaminopurine (BAP), is a case in point. BAP treatments were applied only to terminal racemes rather than whole plants to determine whether abscission on individual racemes could be affected. Experiments were performed over four different growing seasons on terminal racemes of field-grown Bragg, Braxton, Lee, and Tracy-M soybean plants. Depending on the stage of reproductive development, the concentration of BAP used, and the extent of water stress at the time of treatment, BAP can significantly increase pod set on terminal racemes. In one experiment, terminal racemes of Bragg soybean plants were sprayed to wetness with 10^{-3} M BAP every other day from R2 (one flower at every node on treated plants) until R5 (midpod fill). This BAP treatment resulted in a 2.5-fold increase in the total number of mature pods present on terminal racemes, color plate no. 32. More than a 12-fold increase in seeds was observed for the BAP versus the control treatment, table 54. While the number of seeds per raceme and average seed weight per raceme were substantially increased, the number of seeds per pod remained unaffected by the treatments. However, the average seed weight per pod was reduced 27 percent by the BAP treatment when compared to the control treatment. This reduction in seed weight was more than offset by the 12-fold increase in number of seeds.

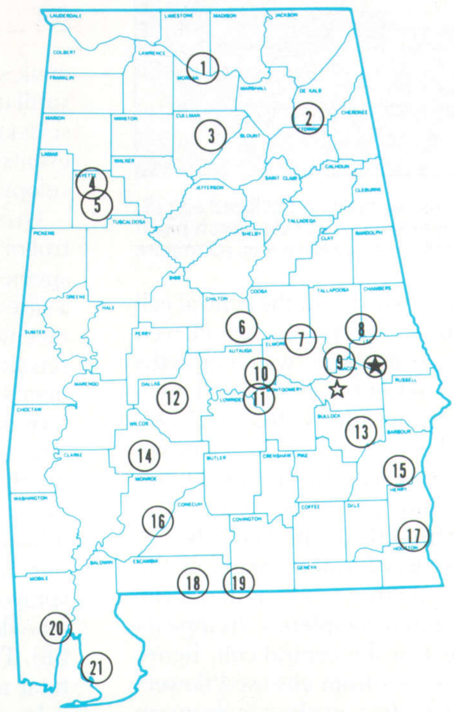
Although BAP can significantly decrease flower and pod shedding from terminal racemes of field-grown soybeans, it has a deleterious effect on leaf expansion. Young leaves that are exposed to the spray fail to expand normally and appear wrinkled. Other changes in shoot morphology also have been observed. Consequently, the promotive effect that BAP has on flower and pod retention is partially offset by the negative effects it has on shoot tip development including leaf expansion. This damage to the leaves becomes a major problem when entire plants are treated with BAP in an attempt to increase total pod and seed yield.

Attainment of any substantial increase in seed yields of soybeans in the future will depend in large measure on success in understanding the physiological and anatomical processes limiting yield.

See color plate numbers 29, 30, 31, and 32.

Alabama's Agricultural Experiment Station System
AUBURN UNIVERSITY

With an agricultural research unit in every major soil area, Auburn University serves the needs of field crop, livestock, forestry, and horticultural producers in each region in Alabama. Every citizen of the State has a stake in this research program, since any advantage from new and more economical ways of producing and handling farm products directly benefits the consuming public.



Research Unit Identification

★ Main Agricultural Experiment Station, Auburn.
☆ E. V. Smith Research Center, Shorter.

1. Tennessee Valley Substation, Belle Mina.
2. Sand Mountain Substation, Crossville.
3. North Alabama Horticulture Substation, Cullman.
4. Upper Coastal Plain Substation, Winfield.
5. Forestry Unit, Fayette County.
6. Chilton Area Horticulture Substation, Clanton.
7. Forestry Unit, Coosa County.
8. Piedmont Substation, Camp Hill.
9. Plant Breeding Unit, Tallassee.
10. Forestry Unit, Autauga County.
11. Prattville Experiment Field, Prattville.
12. Black Belt Substation, Marion Junction.
13. The Turnipseed-Ikenberry Place, Union Springs.
14. Lower Coastal Plain Substation, Camden.
15. Forestry Unit, Barbour County.
16. Monroeville Experiment Field, Monroeville.
17. Wiregrass Substation, Headland.
18. Brewton Experiment Field, Brewton.
19. Solon Dixon Forestry Education Center, Covington and Escambia counties.
20. Ornamental Horticulture Substation, Spring Hill.
21. Gulf Coast Substation, Fairhope.