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EVALUATION OF PEST MANAGEMENT PROGRAMS FOR COTTON, PEANUTS AND TOBACCO IN THE UNITED STATES

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This EPA report has been reviewed by the Office of Pesticide Programs and approved for publication. Approval does not signify that the contents necessarily reflect the views and policies of the Environmental Protection Agency, or does mention of trade names or commercial products constitute endorsement or recommendation for use.

PREFACE

This report describes the results of an "Evaluation of Pest Management Programs on Cotton, Peanuts and Tobacco in the United States" performed for the Council on Environmental Quality and the U.S. Environmental Protection Agency, Office of Pesticide Programs, under Contract No. EQ4ACØ36, RvR Consultants Project No. 66.

The project has been directed by Dr. R. von Rümker, Managing Partner, RvR Consultants, who also served as principal investigator. Co-principal investigators were Dr. G. A. Carlson, North Carolina State University; Dr. R. D. Lacewell, Texas A & M University; Dr. R. B. Norgaard, University of California; and Dr. D. W. Parvin, Jr., Mississippi State University. Dr. V. Ulrich, West Virginia University, assisted in finalizing this report. Ms. Freda Horay, RvR Partner, served as project associate. The field work was performed during the period July to September, 1974.

Dr. Warren R. Muir was project officer for the Council on Environmental Quality, and Mr. Charles D. Reese and Mr. Jeff Kempter represented the Office of Pesticide Programs, U.S. Environmental Protection Agency.

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28 October 1975

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This study received much support, assistance and encouragement from many scientists and others knowledgeable in the subject area, including Dr. P. L. Adkisson, Dr. F. S. Arant, Dr. J. R. Brazzel, Dr. L. A. Falcon, Dr. J. M. Good, Dr. F. A. Harris, Dr. J. B. Kendrick, Jr., Dr. F. G. Maxwell, Dr. L. D. Newsom, Dr. R. F. Smith, and Dr. R. V. Sturgeon, Jr. In addition, a number of persons were particularly helpful to the regional studies and in reviewing the regional report drafts, as recognized in the regional reports.

Draft final reports on the study were reviewed, in whole or in part, by Dr. W. R. Muir, Mr. C. D. Reese, Mr. J. Kempter, Dr. V. Ulrich, Dr. F. G. Maxwell, Dr. D. Pimentel, Dr. J. M. Good, Dr. V. W. Davis, and Dr. J. R. Brazzel. Many constructive comments that were very helpful in the finalization of this report were received from these reviewers.

The authors express their sincere gratitude for all of these contributions.

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INTRODUCTION

Much has been written and said about integrated pest management (IPM) in recent years, and several definitions have been offered by a number of authors and speakers including Geier (1966); Smith and Reynolds (1966); Smith and van den Bosch (1967); Stern et al. (1959); Kennedy (1968) Falcon (1972); and Rabb (1972). The Council on Environmental Quality (1972) defines integrated pest management as follows:

> "Integrated pest management is an approach that employs a combination of techniques to control the wide variety of potential pests that may threaten crops. It involves maximum reliance on natural pest population controls, along with a combination of techniques that may contribute to suppression--cultural methods, pest-specific diseases, resistant crop varieties, sterile insects, attractants, augmentation of parasites or predators, or chemical pesticides as needed. A pest management system is not simply biological control or the use of any single technique. Rather, it is an integrated and comprehensive approach to the use of various control methods that takes into account the role of all kinds of pests in their environment, possible interrelationships among the pests, and other factors."

For purposes of this study, pest management programs have been defined as those programs that contain at least the following three elements:

(1) Diagnosis of the pest problem by scouting, also referred to as "field checking", pest trapping and/or other methods;

(2) Determination if and when intervention, i.e., pest suppression, is required, mostly based on damage thresholds;

(3) Suppression of the pest(s) by the most appropriate tool(s) available.

The determination if and when intervention (pest suppression) is required is usually based on so-called "economic damage threshold" infestation levels. Up to the present, the most frequently used method of intervention (pest suppression or control) has been the use of chemical pesticides.

Unilateral reliance on chemical pesticides has resulted in economically as well as ecologically disastrous failures in a number of agro-ecosystems (Adkisson, 1971; Smith, 1962; Smith and Reynolds, 1972). On a number of crops, including cotton, deciduous fruits, vegetables, and others, insect and/or mite pests have become increasingly more difficult to control with chemical pesticides due to the development of resistance, destruction of beneficial predators and parasites, rapid resurgence of target pests, and build-up of previously unimportant species to economically damaging proportions. There have also been reports of development of resistance to chemical fungicides in plant-pathogenic fungi. In crops where chemical herbicides have been used for a number of years, weed populations are gradually changing; more difficult-to-control weeds are becoming more prevalent as those species that are easily controlled recede.

A variety of alternative pest control or suppression methods have been developed (Council on Environmental Quality, 1972). Integrated pest management endeavors to combine several pest suppression techniques, including the judicious use of chemical pesticides.

OBJECTIVES

This study was undertaken for the purpose of evaluating pest management programs on cotton, peanuts and tobacco in the United States. Specific objectives were as follows:

- Identify users and locations of major representative pest management programs;
- For these programs, assess (by years)
  - (a) biological effectiveness, including economic threshold levels and factors such as crop yield,

(b) types and amounts of costs associated with the establishment and operation of the program,

(c) environmental impact,

Compare the factors set forth above (a, b, c) with comparable farming operations not under pest management;

-- Assess the overall feasibility of pest management for cotton, peanuts and tobacco and specify constraints which may exist for the expansion of these programs;

-- Analyze the extent to which the findings of this study may be applicable to other crops.

Due to the sponsors' information needs and timing requirements, the field phase of this study had to be conducted on a tight time schedule (three months), at a time when many scientists connected with pest management programs are either in the field, on vacation, or busy with the resumption of classes (July through September, 1974).

STUDY APPROACH AND METHODS

To accomplish the objectives set forth above within the time frame stipulated, RvR Consultants engaged as co-investigators four agricultural economists, each of whom had previous experience in dealing with problems of crop protection and pest management. Each of them collected data and information and prepared a report in accordance with the overall project objectives for pest management programs in specific regions as follows:

D. W. Parvin, Jr.	Cotton programs in Louisiana, Mississippi, and Alabama
G. A. Carlson	Cotton programs in North Carolina and Arkansas, tobacco programs in North Carolina
R. D. Lacewell	Cotton programs in Texas, peanut programs in Texas and Oklahoma
R. B. Norgaard	Cotton programs in California and Arizona

This project team met with the project manager, R. von Rümker, at Dallas, Texas on July 10, 1974. This meeting was also attended

by the CEQ project officer, W. R. Muir, and by C. D. Reese, EPA project officer. The objectives of the study, the proposed organization of reports, availability and acquisition of data, coordination with other organizations, and many other working details were thoroughly discussed.

The U.S. Department of Agriculture's Cooperative Extension Service (CES) and Animal & Plant Health Inspection Service (APHIS) jointly sponsored and partially funded pilot pest management projects in the United States, beginning in 1971. That year, two pilot projects were established to control insects on tobacco in North Carolina and on cotton in Arizona, respectively. (Both of these projects are included in this evaluation.) Subsequently, this USDA/State program has been expanded rapidly; it included 39 projects in 29 states on 19 major crops in 1973 (Good, 1973).

The USDA Cooperative Extension Service was advised of this study at the time it was initiated by W. R. Muir, Council on Environmental Quality. Additional contacts concerning data acquisition, progress of the study and related matters were maintained by a personal meeting between W. R. Muir, R. C. Scott and others on July 25, 1974, and in subsequent contacts by telephone, by correspondence, and in person between R. von Rümker, R. C. Scott and J. M. Good. USDA/APHIS (J. R. Brazzel) was kept abreast of the study by R. von Rümker.

Several USDA agencies including CES, APHIS, the Economic Research Service and the Agricultural Research Service, as well as the two sponsoring agencies, the Council on Environmental Quality and the U.S. Environmental Protection Agency, provided project members with various reports and documents containing information on cotton, peanut, tobacco, and other pest management programs, and other helpful material. Much additional information was obtained by G. A. Carlson, R. D. Lacewell, R. B. Norgaard, D. W. Parvin, Jr., and R. von Rümker in the field, primarily from personnel directly involved with the cotton, peanut and tobacco pest management programs studied.

As the regional reports reflect, there was considerable variation between states in regard to the quality and quantity of data available on their respective pest management programs. In general, this investigation received outstanding support in most states covered, especially in Texas, Mississippi, Alabama, Louisiana, and Arkansas.

Drafts of the cotton reports by Carlson, Lacewell, Norgaard, and Parvin were received by RvR Consultants in early September of 1974, and drafts of the peanut report by Lacewell and the tobacco report by Carlson were received by mid-October, 1974. RvR Consultants then prepared analyses and overviews of the cotton, peanut, and tobacco programs studied, and summary evaluations. The cotton draft report was submitted to the sponsoring agencies in September of 1974, and the draft report on peanuts and tobacco in October of 1974. Both report drafts were then reviewed in whole or in part by a number of scientists knowledgeable in the subject matter, including Dr. W. R. Muir and Ms. M. Suter of the Council on Environmental Quality, Mr. C. D. Reese and Mr. J. Kempter of the U.S Environmental Protection Agency; Dr. J. M. Good, Dr. J. R. Brazzel, Dr. V. W. Davis and others, U.S. Department of Agriculture; Dr. D. Pimentel, Cornell University; Dr. F. G. Maxwell, Mississippi State University; Dr. R. F. Smith, University of California; Dr. G. A. Carlson, North Carolina State University; Dr. D. W. Parvin, Jr., Mississippi State University, Dr. R. D. Lacewell, Texas A & M University; and Dr. R. B. Norgaard, University of California.

Dr. V. Ulrich, West Virginia University, assisted in the editing of major parts of the report. In addition, each of the regional reports (Appendices A through F) was reviewed by several persons familiar with the individual programs studied, as recognized in each report by the respective authors. Many helpful comments and suggestions were received from these reviewers and utilized in the preparation of this final report.

In the early phases of this study, the terms "pest management" and "integrated pest management (IPM)" were used more or less interchangeably in the project's vocabulary. However, one of the

findings of the study was that most of the pest management programs evaluated were not genuinely integrated in the strict sense of the word. Therefore, the term "pest management programs" was subsequently applied, especially in the titles and main body of the report.

The results of this study are presented in this report at three levels of detail and resolution:

(1) Findings and conclusions are highlighted in the sections Summary (p. 7-12)
Conclusions and Recommendations (p. 12-16)

(2) A comprehensive overview, analysis and evaluation of the regional reports follows next, organized as follows:

Development of Pest Management Programs Environmental Impact Feasibility Constraints on Expansion Applicability of Findings to other Crops	Combined for all crops studied p. 17-46
Trends in Crop Production and Pesticide Use Users, Locations and Characteristics of the Programs Studied Program Costs Program Effectiveness Yield Pesticide Use Production Costs Growers' Profits	By crops: Cotton, p. 47-75 Peanuts, p. 76-92 Tobacco, p. 93-104

(3) The regional reports, Appendices A through F, are the data base of this study; they contain a large

volume of detailed information on the pest management programs studied, assembled by the regional investigators in accordance with the study objectives. Access to the data in the appendices is facilitated by many cross-references throughout the body of the report.

SUMMARY

In this study, 19 cotton pest management programs, 3 peanut pest management programs and 3 tobacco pest management programs were evaluated in regard to the users, locations and characteristics of each program, program costs, program effects on crop yield, pesticide use, production costs and growers' profits. The environmental impact and the biological and economic feasibility of each program were studied, and constraints on the expansion of pest management programs and the applicability of the findings of this study to other crops were assessed. In accordance with the sponsors' timing requirements, most of the data and information presented in this report were collected during the period July through September, 1974. The findings, conclusions and recommendations presented are based largely on the state of affairs as of the fall of 1974.

Key parameters of the programs studied and of their costs and effects are summarized in the following paragraphs. More specific, quantitative data on the 25 pest management programs are summarized in Table 3, p. 52 to 56 for the 19 cotton programs; in Table 7, p. 81 for the 3 peanut programs; and in Table 9, p. 98 for the tobacco programs. Detailed descriptions and evaluations of each program are presented in the regional reports, Appendices A through F.

Program Characteristics

The 19 cotton pest management programs ranged in size from 1,422 acres in one county to 204,000 acres in 23 counties and included programs started between 1949 and 1973. The 3 peanut pest management programs studied comprised 394, 1,315 and 6,558 acres,

respectively, and were initiated in 1971 or 1973. For the North Carolina tobacco pest management program, operations were evaluated for the 3-year period 1971 to 1973; the program comprised 8,032 acres in 5 counties in 1971 and expanded to 11,350 acres in 10 counties by 1973.

Program Costs

Operating cost and, to the extent available, implementation cost data were collected for all programs studied. In the cotton pest management programs, annual operating costs reported on a per acre basis ranged from $1.30 to about $5.50/acre (exclusive of costs of insecticides and application). Annual operating costs reported on an "entire program" basis ranged from $20,303 to $911,568. The annual operating costs of the peanut pest management programs evaluated ranged from $7,882 to $40,133 per program, or $1.20 to $53.16/acre. In the North Carolina tobacco pest management programs, annual operating costs ranged from $14.91 to $17.80 per acre.

Program Effectiveness

An overview of the effectiveness of the programs studied in terms of crop yield, insecticide use, production costs and growers' profits is presented in Table 1. In terms of all 25 programs evaluated (19 cotton, 3 peanut and 3 tobacco programs), program effects were as follows.

Crop yield: Adequate yield data were available for 18 programs, and in 13 (72%) of these, pest management program participants experienced increases in yield (quantity and/or quality). There were no changes in yield in 5 programs, and none of the programs studied reported yield decreases.

Insecticide Use: In 18 (86%) of 21 programs for which insecticide use data were available, insecticide inputs decreased, while they increased in 3 programs.

Production Costs: Adequate production cost data were available for 20 programs, and in 17 (85%) of these, production costs of program participants decreased, while there was an increase

Table 1 : Benefits of Pest Management Programs on Cotton, Peanuts and Tobacco

		Cotton	Peanuts	Tobacco	All Crops
# Programs Evaluated		19	3	3	25
Yield	Increased	11	2*	0	13
	Decreased	0	0	0	0
	No Change	2	0	3	5
	No Data	6	1	0	7
Insecticide Use	Increased	3	0	0	3
	Decreased	14	1	3	18
	No Change	0	0	0	0
	No Data	2	2	0	4
Production Costs	Increased	3	0	0	3
	Decreased	13	1	3**	17
	No Change	0	0	0	0
	No Data	3	2	0	5
Profit	Increased	15	2	3**	20
	Decreased	1	0	0	1
	No Change	0	0	0	0
	No Data	3	1	0	4

* Increase in Quantity and/or Quality

** Disregarding Scouting Costs

in production costs due to the pest management program in 3 of the cotton programs.

Profit: Participating growers' profits increased in 20 (95%) of 21 programs with adequate data; there was a slight (6.0%) decrease in 1 cotton pest management program in 1973, the base year for Table 1. This decrease (in the Frio County, Texas program) was due to locally adverse weather conditions which forced a delay of harvest in some fields and required a more intensive boll weevil diapause control program than would normally have been required. The program increased participants' profits in 3 out of 4 years since its inception in 1971.

Environmental Impact

To evaluate the environmental impact of the pest management programs studied turned out to be very difficult. There are no adequate, quantitative base line data available on the effects of "conventional" pesticide use on environmental quality and consequently, there is no basis for comparing the environmental effects of pest management programs to farming operations not under pest management. In many of the USDA/State-supported programs, environmental samples including soil, rodents, forage, fish, water, sediments, toads, and birds were collected and sent to a U.S. Department of Agriculture Laboratory for analysis. However, after storing these samples for several years, the Department decided not to analyze them.

In 18 of 21 programs for which insecticide use data are available, program participants used smaller quantities of chemical insecticides than non-participants, an indirect indication of positive program effects. In a number of programs, the safety and health of field scouts were monitored. No adverse effects on scout health were noted in any of the programs.

Feasibility

All 19 cotton pest management programs studied were found to be biologically and economically feasible, and generally successful in accomplishing their objectives. Among the 3 peanut programs

evaluated, only 1 had more than 1 year's operating experience, and this program appeared to be feasible. The biological and economic effectiveness of the remaining 2 programs for which only the start-up year's experiences were available for evaluation remains to be established firmly, but in both cases, prospects appear promising.

On tobacco in North Carolina, management of insect pests only does not appear to be economically feasible or attractive to growers, based on 3-year experiences (1971-1973). In response to these findings, the program objectives were greatly changed and expanded in 1974.

Constraints on Expansion

Several actual and potential constraints on the further expansion of pest management programs or, in positive terms, opportunities for improvement became apparent in the course of this study. These are highlighted briefly in the following section ("Conclusions and recommendations") and discussed in greater detail in the section on "Constraints on expansion" (p. 32 to 42). Regional findings in this regard are included in the regional reports, Appendices A through E (specifically, see pp. B-54 ff., C-39 ff., D-190 ff., F-33 ff.).

Applicability of Findings to Other Crops

The results of this study show that the biological as well as the economic elements of different pest management programs vary considerably between crops, and even between programs for the same crop in different geographical areas. In addition, the biological and economic effectiveness of any given program is subject to year-to-year variations due to changes in weather conditions, pest infestation levels, and other seasonal factors.

On the other hand, certain observations recurred in most of the programs studied and are therefore probably applicable to other crops as well. These are discussed briefly in the section on "Conclusions and recommendations", and in greater detail in the section on "Applicability of findings to other crops"

(p. 43 to 46). Regional findings in this regard are found on pp. C-52 ff., D-196 ff, and E-57 ff.

CONCLUSIONS AND RECOMMENDATIONS

Expansion Potential

There are several potential routes of expansion for pest management, including the following:

- -- Increase acreage under pest management;
- -- Increase variety of pest suppression tools and methods;
- -- Include pests other than insects (and mites);
- -- Expand pest management into crop management;
- -- Combine crop and pest management on a multi-crop, area-wide basis.

When the programs studied are compared against these potentials, it appears that while much progress has been made, there is much room for further progress and expansion. For instance, in most of the programs, i.e., in 14 of 19 cotton programs, in 2 of 3 peanut programs, and in all tobacco programs, insect suppression was the main or the only program objective, and the use of chemical insecticides "as needed" (as determined primarily by scouting) was the main pest management tool. Thus, these programs are not really integrated pest management, but "prescription insecticide" programs. Only 5 of the 19 cotton programs, and 1 of the 3 peanut programs had broader crop production improvement objectives. Very few programs included management of pests other than insects and mites (weeds, nematodes, plant diseases, etc.) among their objectives.

Recommendation:

Promote the expansion of pest management programs and practices towards more comprehensive objectives, and greater diversification and integration of management strategies and tools.

Research and Education

Lack of basic research does not currently appear to be a constraint on the further expansion of pest management programs on cotton, peanuts, or tobacco. However, much of the available research know-how is available primarily in isolated, compartmentalized form, and is often put together only in the farmer's field. At the farm level, pest and crop management are complex problems, while at public institutions, agricultural research and teaching are traditionally discipline -oriented and -organized. Better and more effective cooperation between all disciplines involved in crop protection and crop production, including economics, is an urgent prerequisite to the further successful development of pest management, plant health, and integrated crop production programs for cotton, peanuts, and tobacco, as well as for other crops. This need is equally apparent in the research area and in the education and training of pest and crop management scientists, administrators, and practitioners.

Recommendation:
Promote more effective cooperation between all disciplines involved in pest management and crop production in research as well as in education and training of pest management and crop production specialists.

Pest Management Delivery Systems

Pest management is a technology that has been and is being developed largely in the public sector, primarily by federal and state research and extension personnel, for implementation in the private sector, i.e., by many individual farmers. Other technologies developed in the public sector are also used mainly in the public sector, such as, for instance, space technology, military technology, etc. The delivery of pest management technology to users thus represents a somewhat unique problem. To the extent that pest management services and chemical pesticides are interchangeable, they compete for the same clients and dollars. Chemical pesticides are vigorously marketed, while pest management is

not. Successful implementation and expansion of pest management, especially of comprehensive, genuinely integrated plant health improvement and crop production programs, requires one-on-one contact between technology users and deliverers. In some of the programs studied, this problem was recognized, and an effort was made to strengthen and expand already existing pest management delivery systems; the use of private pest management consultants in the California cotton program is a case in point.

Recommendation:
The question of the structure and nature (public, private, optimal mix) of pest management delivery systems and related problems at the interface between the publicly developed pest management technology and its private users requires attention. Publicly funded or supported pest management programs should include definitive plans and provisions for delivery of pest management technology and services to users on an ongoing self-sustaining basis.

Information Needs

In most of the pest management programs studied, program design and execution did not include provision for adequate evaluation of the program's economic and ecological effectiveness. Data on program effects on crop yields, production costs and growers' profits are essential to "selling" pest management to growers. Likewise, adequate information on the benefits (or lack thereof) of these programs to society (tax payers) is needed to justify expenditures of additional public funds for pest management research, development and implementation.

Recommendation:
Publicly funded or supported pest management programs should include provision (and funds) for evaluation of their economic and ecological effectiveness.

Federal Support

Among the 19 cotton pest management programs studied in this project, 2 were initiated in 1949 and 1950, respectively, 9 between 1964 and 1971, and 8 in 1972 or later. Federal support for pest management programs from the USDA/State cooperative program first became available in 1971/1972. A comparison of the rates of progress in different programs before and after that time indicates that the infusion of the federal support and funds resulted in expansion and improvement of existing programs and stimulated the establishment of many new programs, including the 3 peanut pest management programs studied and the North Carolina tobacco pest management program. The USDA/State program has also promoted the expansion of pest management objectives and strategies along the lines suggested above under "Expansion Potential" (p. 12).

Likewise, the multi-agency research project entitled "Integrated pest management/the principles, strategies, and tactics of pest population regulation and control in major crop ecosystems", popularly known as the "Huffaker Project", funded jointly by the National Science Foundation, the U.S. Environmental Protection Agency and the U.S. Department of Agriculture, has stimulated a great deal of research and development activity in many areas related to pest management.

For a more comprehensive discussion of the role of government support from a regional standpoint, the reader is referred to pp. D-191 to D-194.

Recommendation:

Continue to provide federal support for pest management research, development, and implementation.

Publicly funded or supported pest management programs at the farm level should include provision for monitoring program effectiveness and biological and economic feasibility, and definitive plans for transfer to self-sustaining status (or discontinuation if not feasible) at the

earliest possible time.

New programs should be established and funded with a view to further expanding pest management towards its full potentials.

DEVELOPMENT OF PEST MANAGEMENT PROGRAMS IN THE U.S.

The first cotton insect pest control or suppression program meeting the criteria for pest management programs set forth above (p. 1) was initiated in the state of Arkansas in the late 1940's. The development and operation of the Arkansas program are described in detail by Carlson and Grube, p. B-2-3, B-8 ff.

Additional pest management programs were started soon thereafter in other cotton growing states. These included "supervised pest control" programs by private pest management consultants in California (as relayed by Norgaard, p. C-6 ff.); "spray cooperatives" and pest management programs initiated as commercial operations in North Carolina in 1967/1968 (Carlson and Grube, p. B-13 ff. and B-42 ff.); several programs in Texas, primarily involving diapause boll weevil (Anthonomus grandis) control (reported by Lacewell and Casey, p. D-6 ff., D-23 ff., D-45 ff., and D-56 ff.); and a private grower cooperative program aimed at control of the pink bollworm (Pectinophora gossypiella) and the cotton leaf perforator (Bucculatrix thurberiella) in the Safford Valley, Graham County, Arizona (Norgaard, p. C-42 ff.)

All of these programs implemented technology developed over the years in the research programs of the U.S. Department of Agriculture and the land-grant universities and state agricultural experiment stations.

Application of pest management strategies on cotton (and other crops) received substantial additional support and expanded at an accelerated rate following several milestone events in the early 1970's, including the following.

To promote implementation of pest management, the U.S. Department of Agriculture initiated (in 1971) two "pilot pest management projects", i.e., one on cotton in Arizona and one on tobacco in North Carolina, at a funding level of $200,000. The program was expanded in 1972 to 22 projects on 10 crops in 21 states, funded at $1.2 million. In 1973, the program was increased again to 39 projects on 19 crops in 29 states, funded at $2.2 million (Good, 1975).

In 1972, a multi-agency research project entitled "Integrated Pest Management/The Principles, Strategies and Tactics of Pest Population Regulation and Control in Major Crop Ecosystems", popularly known as the "Huffaker Project", was initiated. This bold and imaginative project, managed by C. B. Huffaker and R. F. Smith, University of California, involves 19 universities, several agencies of the U.S. Department of Agriculture, several state agencies, and certain private institutions. The program includes a cotton subproject in which the University of Arkansas, the University of California, Mississippi State University, Texas A & M University, and the U.S. Department of Agriculture cooperate.

The overall project is funded jointly by the National Science Foundation, the U.S. Department of Agriculture, and the U.S. Environmental Protection Agency. From its inception through February 28, 1976, the project received $8,267,900 from the National Science Foundation and the U.S. Environmental Protection Agency, and $1,556,100 from the U.S. Department of Agriculture. An additional $3,112,200 are to be provided by the National Science Foundation and the U.S. Environmental Protection Agency for the last two years of the project, to February 28, 1978. These grants, totalling about $13 million, represent about one-half of the full level of financial effort going into the project. Internal support provided by each of the participating institutions in the form of academic and staff salaries, facilities and (in some instances) a portion of the overhead comprises an amount estimated to be equal to that received from the agencies formally funding the project (Huffaker, 1975).

These two large nationwide programs stimulated a great deal of activity directly or indirectly connected with pest management in federal and state agencies and laboratories, universities, state agricultural experiment stations, extension services, et. Pest management conferences and workshops were held throughout the country, and symposia and paper reading sessions dealing with pest management became a standard component of most or all meetings of scientific societies interested in crops and pests. These activi-

ties have produced much new knowledge, and a large number of scientific and popular publications, reviews and unpublished reports dealing primarily with the entomological aspects of pest management. By comparison, relatively little attention seems to have been devoted thus far to problems such as truly interdisciplinary pest and crop management, economics, and how to translate research findings into self-sustaining agronomic practices at the grower level.

The Federal government, through its Legislative as well as its Executive branches, encouraged further research and implementation of pest management. The President's message of February 8, 1972 to the Congress outlining his environmental program includes the following statement on integrated pest management:

> "Chemical pesticides are a familiar example of a technological innovation which has provided important benefits to man but which has also produced unintended and unanticipated harm. New technologies of integrated pest management must be developed so that agricultural and forest productivity can be maintained together with, rather than at the expense of, environmental quality. Integrated pest management means judicious use of selective chemical pesticides in combination with nonchemical agents and methods. It seeks to maximize reliance on such natural pest population controls as predators, sterilization, and pest diseases. The following actions are being taken:
>
> --I have directed the Department of Agriculture, the National Science Foundation, and the Environmental Protection Agency to launch a large-scale integrated pest management research and development program. This program will be conducted by a number of our leading universities.
>
> --I have directed the Department of Agriculture to increase field testing of promising new methods of pest detection and control. Also, other existing Federal pesticide application programs will be examined for the purpose of incorporating new pest management techniques.
>
> --I have directed the Departments of Agriculture and of Health, Education, and Welfare to encourage the development of training and certification programs at appropriate academic institutions in order to provide the large number of crop protection specialists that will be needed as integrated

pest management becomes more fully utilized.

--I have authorized the Department of Agriculture to expand its crop field scout demonstration program to cover nearly four million acres under agricultural production by the upcoming growing season.

Through this program many unnecessary pesticide applications can be eliminated, since the scouts will be used to determine when pesticide applications are actually needed."

The "Federal Environmental Pesticide Control Act of 1972", an Act to amend the Federal Insecticide, Fungicide and Rodenticide Act (Public Law 92-516, 92nd Congress, H.R.10729, October 21, 1972) mandates the following in Section 20 (a):

"The Administrator (of the U.S. Environmental Protection Agency) shall undertake research, including research by grant or contract with other Federal agencies, universities, or others as may be necessary to carry out the purposes of this Act, and he shall give priority to research to develop biologically integrated alternatives for pest control".

These Presidential and Congressional mandates were implemented by policy statements, guidelines, and actions of the Executive Branch, especially the Council on Environmental Quality, the U.S. Environmental Protection Agency, and the U.S. Department of Agriculture. As an example, the Secretary of Agriculture's memorandum No. 1799 of February 1, 1973 stated:

"Non-chemical methods of pest control, biological or cultural, will be used and recommended whenever such methods are economically feasible and effective for control or elimination of pests. When non-chemical methods are not tenable, integrated control systems utilizing both chemical and non-chemical techniques will be used and recommended in the interest of maximum effectiveness and safety".

In November of 1972, the Council on Environmental Quality issued a publication entitled "Integrated Pest Management" in which the need for this approach to crop protection and the current state

of the art set forth in a well written and concise form. This publication includes brief outlines of the current state of development of chemical and nonchemical pest management methods.

These Federal initiatives have stimulated and accelerated research activities in the sciences underlying pest management, especially entomology, and efforts to implement pest management technology in field programs. However, research activities and new knowledge will not affect agricultural production, environmental quality, or societal well-being unless and until they are widely accepted and practiced at the grower level. The present study is part of an effort to evaluate the biological and economic feasibility of pest management on selected crops, and the process of transfer of this technology to growers.

ENVIRONMENTAL EFFECTS OF PEST MANAGEMENT PROGRAMS

Of all criteria by which the effectiveness of pest management programs may be measured, their environmental impact is most difficult to evaluate. Very little information is available documenting cause/effect-type relationships between the orderly use (as opposed to accidents, spills, gross misuse, etc.) of specific pesticides on specific crops and environmental quality. Pesticide residues have been found analytically in human tissues, as well as in numerous environmental samples, including soil, air, water, sediment, wildlife, fish, lower aquatic organisms, domestic animals, plants, and other materials collected in various pesticide monitoring programs. However, in most instances, the significance of these residues and their effects (if any) on the organisms or media in which they are present is not clear. In the absence of adequate, quantitative baseline data on the effects of "conventional" pesticide use on environmental quality, it is very difficult to assess the environmental effects of pest management programs as compared to farming operations relying primarily on chemical pesticides for pest control.

Human Health Effects

There are numerous instances, many well documented, in which pesticides, including those used on cotton, tobacco and/or peanuts, have resulted in human illness and deaths. Victims include pesticide applicators, other persons directly working with pesticides, farm workers, as well as persons not directly involved in pesticide operations, especially children. While a detailed study of human health effects was not included in the scope of this study, it should be mentioned that pest management programs will have beneficial effects in this field in several ways, including the following.

(1) The results of this study indicate that adoption of pest management principles and practices will in many instances result in a decrease in the quantities of pesticides used. This in itself should decrease the exposure of pesticide workers, other farm workers, and bystanders to toxic pesticides and thus the incidence of poisoning cases.

(2) Several pest management programs include grower education, encourage more judicious use of pesticides, and promote greater awareness of the hazards associated with pesticide use, including hazards to human health. Better training of persons handling pesticides should help to reduce the pesticide accident rate.

(3) In a number of the programs studied, program participants are transferring the responsibility for insect suppression measures, including insecticide applications, to the pest management organization. (This is the case in the North Carolina "spray cooperatives" and in some of the commercial operations in that state; and in some of the California and Arizona programs.) As more pest management programs develop into area-wide crop protection or crop management schemes, pesticides will increasingly be applied over larger

areas by professional applicators, instead of by individual growers to their own fields. This will reduce the number of individuals exposed to pesticide concentrates and spray mixtures and should thus be another factor reducing pesticide accidents.

The report by Norgaard (p. C-33 ff.) includes statistics on occupational diseases attributed to pesticides by industry groups and specific pesticides (Table C-11), and by types of pesticides and cotton growing counties in California (Table C-12) for 1971. However, these data do not differentiate between "convential" pesticide use practices and pest management programs and therefore do not provide direct answers to the questions addressed in this chapter. As Norgaard (p. C-36) points out, pest management involves frequent entry of fields by persons employed to check population densities of pests and beneficial organisms. This increases the potential for exposure to pesticide residues and poisonings for this group. However, field checkers are generally informed as to possible harmful effects of pesticides, when fields have been treated, and on the protective procedures that may be required. As a result, no field-checker poisonings have been experienced in California.

The North Carolina tobacco pest management program included a human health effects element (Carlson, 1975). In 1973, blood cholinesterase levels of field personnel in 2 counties were monitored. All determinations fell within normal ranges. (Depression of blood cholinesterase indicates exposure to organophosphate or carbamate insecticides.)

Scout health and safety were also monitored in the Texas pest management programs. Scouts received pre-employment physical examinations, and a medical history was obtained. Blood cholinesterase determinations were run biweekly, and urine samples were analyzed for paranitrophenol levels, indicative of exposure to parathion or methyl parathion. In the Rio Grande Valley program, monitoring data showed that there was organophosphate exposure of the scouts as a group, but there were no clinically significant

deviations from normal values in any one individual. No adverse health effects were experienced by scouts involved in any of the other Texas pest management programs either, and it was concluded that there were no significant pesticide-related effects on any scout in the program (Lacewell, 1975).

Environmental Effects

None of the pest management programs reviewed in this study included effective plans or designs for measurement of environmental impact. In some of the USDA/State cooperative programs, environmental samples including soil, rodents, forage, water, sediment, fish, toads, and birds were collected and sent to a USDA laboratory for analysis. However, after storing these samples for several years, the Department decided not to analyze them (Reeves, 1975).

In spite of the dearth of specific data referred to above, it is generally assumed that pesticides have a deleterious effect on the environment outside the target area. In addition, adverse effects of pesticides on the target agro-eco systems in which they have been used have been documented in a number of instances; some of these are reported in the publications cited above in the introduction. Thus, the assumption that decreased use of pesticides will be beneficial to environmental quality is held widely. Based on this assumption, all of the authors of the regional reports (Appendices A through F) used the effect of pest management programs on pesticide inputs as one measure of their environmental impact, rating reductions in the quantities of pesticides used by pest management program participants as a positive indicator of beneficial effects on environmental quality.

Cotton: As the data summarized in Tables 1 and 3 show, 14 of 19 cotton pest management programs resulted in a decrease in the quantity of insecticides used. There was an increase in insecticide use in 3 programs. The remaining 2 programs lack adequate data on insecticide use.

Norgaard's report on the California cotton pest management

programs (Appendix C) is the only regional report that includes data on bee, fish and wildlife losses due to pesticides. Fish and wildlife losses attributed to pesticides in the San Joaquin Valley from 1965 to 1969 are summarized in Table 13, page C-37. However, many other crops are produced in the Valley, and it is impossible to attribute all of the reported wildlife losses to the use of insecticides on cotton. Furthermore, there are no quantitative comparisons between pest management program participants' and non-participants' cotton insect control practices for the years in question, nor data on the effects of specific pesticide use practices on wildlife. Thus, while the fish and wildlife loss data are interesting, they make no direct contribution to an assessment of the environmental impact of pest management programs in the area. The same comments in priciple apply to the reports on the adverse effects of pesticides on bees. The bee, fish and wildlife loss data simply document that these undesirable "side-effects" from the use of pesticides did occur, the expectation being that a reduction in the volume of use of toxic insecticides on cotton would most likely reduce such losses.

Peanuts: In general, peanuts receive relatively heavy pesticide inputs in the United States. The per-acre use of insecticides on peanuts increased slightly from 1966 to 1971, but the use of herbicides on peanuts increased by about 50%, and the use of fungicides almost quadrupled.

Adequate pesticide use data are available for only one of the three peanut programs studied. In Frio County, Texas, the adoption of pest management procedures decreased the quantities of insecticides used. The results of field plot trials in Oklahoma (Lacewell and Casey, p. E-46 ff.) suggest that in that area, the use of pesticides on peanuts may be suboptimal, and that increased inputs of pesticides, especially insecticides and/or nematicides, may increase peanut yields and growers' net returns. Thus, it is possible that more intensive peanut pest monitoring, and a better understanding of the combined effects of all production inputs on peanut

yields and profits will result in increased pesticide use in that area. If increased pesticide use is equated with adverse effects on environmental quality, negative environmental impacts might be anticipated. However, there is no evidence that the present (or an increased) use of pesticides on peanuts is (or will be) detrimental to environmental quality.

Tobacco: As summarized in Table 9 , p. 98 and documented in detail by Carlson and Cooper (p. F-31 ff.) the North Carolina tobacco pest management program resulted in reduced use of insecticides in each of the 3 years studied. In addition, Carlson and Cooper reported the abundance of several species of beneficial insects, including stiltbugs and Campoletis (p. F-9, Table 2.3), and tiger beetles (p. F-30, Table 3.7). These were sampled in different years inside and outside of the pest management area. There were some numerical differences in the populations of these beneficial insects, but they were statistically insignificant due to large variances.

Data on residues of insecticides in sample areas are included in North Carolina's tobacco pest management program report for 1973. Only traces of currently used chemical pesticides were detected in crops sampled since 1971, indicating that presently used pesticides, at presently practiced use patterns, do not create environmental residue problems, with the exception of methomyl. Residues of this insecticide were found from pesticide useage at a time preceding the pest management program.

In summary, no data are available which would permit a rigorous evaluation of the environmental impact of the pest management programs studied in comparison to comparable fields, farms or areas not under pest management. An indirect indication of possible positive program effects is a reduction in the use of chemical pesticides in most of the programs.

FEASIBILITY OF THE PEST MANAGEMENT PROGRAMS STUDIED

Cotton: The feasibility of each of the cotton pest management programs evaluated in this study was carefully assessed. Details are documented and discussed by Parvin for Louisiana, Mississippi and Alabama in Appendix A, by Carlson and Grube for North Carolina and Arkansas in Appendix B, by Norgaard for California and Arizona in Appendix C, and by Lacewell and Casey for Texas in Appendix D.

Without exception, these investigators report that each program evaluated is feasible. As summarized in Table 1 , p. 9 and, in greater detail, in Table 3, p. 52-56 , cotton yields increased in 11 of 13 programs for which yield data are available, insecticide use decreased in 14 of 17 programs with adequate insecticide use data, cotton production costs decreased in 13 of 16 programs, and growers' profits increased in 15 of 16 programs.

Present and future benefits of pest management programs to cotton producers, to environmental quality, and to society have been well documented for several programs, notably those in Texas. In several instances, it appears that the pest management approach was not only feasible, but was actually a practical, economic necessity. This is the case, for example, in the diapause boll weevil control programs in Texas, and in the programs in the Rio Grande Valley of Texas and in Graham County in Arizona.

Peanuts: The feasibility of the 3 peanut pest management programs studied has been evaluated by Lacewell and Casey (pp. E-16, E-34, E-53). Adequate information and experience are currently available only for the Frio County, Texas program. For this program, there appears to be a cost effectiveness of $8-16 returned per dollar of program cost. In addition to these monetary gains, the program contributed to a downward trend in the quantity of insecticides used. Current producer costs for the program are $1.00/acre. Participating producers have indicated that they would be willing to pay $2.00/acre or more to continue the program.

These factors indicate that the program is attractive to growers, and that it is effective in accomplishing its principal objective, management of the burrowing bug (Pangaeus bilineatus). The program appears to be feasible both biologically and economically.

The remaining 2 programs, both supported by USDA grant funds (Comanche County, Texas and Oklahoma), were implemented only in 1973. Both programs experienced various start-up difficulties, including late availability of funds, inadequate time and funds for program planning and preparation, and late start of field operations relative to the vegetation period of peanuts. In both programs, actual costs per program acres were excessive. As of the fall of 1974, data and operating experiences available were insufficient for a realistic assessment of the economic feasibility of these programs.

Both of these programs address not only insect problems, but include consideration of plant diseases, nematodes, weeds, soil fertility, and plant health. It is not clear how much such an integrated pest management/plant health service would be worth to peanut growers, but some indications in this regard may be gleaned from the Oklahoma program. This program has several interesting features. It provides not only pest management advice to participating growers, but includes field demonstration tests in which different peanut management practices and production inputs are evaluated comparatively. Novel monitoring techniques such as infrared photography and remote sensing are being evaluated. A mobile diagnostic laboratory of the type successfully used in Virginia for many years is employed in the program. Thus, it appears that this program involves an interdisciplinary effort to develop a complete, efficient peanut production system, focusing on plant health improvement, rather than only on the management of one or a few specific pests.

Plans for 1974 for the Oklahoma program included making suggestions to participating growers based on populations of harmful

(and beneficial) insects, weeds, nematodes, and diseases, to be monitored by plant health teams weekly from June through August, and bi-weekly in September and October. Growers will also receive advice on soil fertility and irrigation. Each grower will receive a "field report" following each visit by the plant health team. The field report will be supplemented by the services of the mobile plant health diagnostic laboratory which is staffed with a technician and a field plant health supervisor. Participating growers are paying a fee of $8/acre for this service for the first 50 acres, $7/acre for the next 25 acres, and $6/acre for the balance of acres in the program. Plans for 1975 envisioned expansion of this approach to additional crops.

The biological and economic effectiveness of this comprehensive, innovative approach that incorporates interdisciplinary inputs and several different techniques (field monitoring, field test plots, mobile diagnostic laboratory, with remote sensing perhaps to be added) remains to be established. However, the large differences in peanut yields and in gross and net returns obtained in the 1973 Hughes County field demonstration plots indicate that there is considerable room for improvement of peanut production in Oklahoma. The potential net profit improvements indicated are of the order of $160-240/acre. Potential profit increases of this magnitude could well support the cost of an effective, comprehensive plant health improvement service.

Peanut programs based on integrated management of pest complexes as well as production practices have been operated successfully for many years in Eastern peanut growing areas including Virginia and Georgia. These programs were initiated long before the term "integrated pest management" became popular. In Georgia, for instance, this approach quadrupled peanut yields in 20 years (Good, 1974a). Due to limitations in available time and funds, it was not possible to include an evaluation of these older programs in the present study.

Tobacco: The gross return of tobacco in North Carolina is about $2,000/acre. The North Carolina tobacco pest management program, by its published objectives and activities from 1971-1973, was not an integrated pest, but an insect management program. Program objectives did not include management of tobacco diseases, nematodes, or weeds, nor soil fertility or general plant health considerations. According to the information analyzed by Carlson and Cooper (p. F-27 to F-29), the estimated costs for insecticides and application on all North Carolina tobacco farms in 1971 was $11.28/acre. Pest management program participants may have realized cost savings from reduced use of insecticides ranging from $2.51 to $5.55/acre, averaging $4.26/acre for the 3 year period 1971-1973. The latter figure amounts to 0.2% of the farm value of one acre of tobacco, while the total average cost for insect control for all North Carolina tobacco growers, $11.28/acre, amounts to 0.56% of the farm value of the crop per acre. Thus, tobacco insect control is not a major tobacco production cost item.

As summarized in Table 9 , p. 98 , the total cost of insect management (including scouting, extension service and professional support, overhead, and cost of insecticides and application) for program participants ranged from $23.53/acre in 1972 to $23.68 per acre in 1971 and 1973. The cost of insect management per acre of tobacco in the program was more than twice as high as the estimated cost of insecticides plus application on all North Carolina farms. The per-acre costs of scouting (scout salaries and travel) alone, disregarding all other program expense elements, were higher than the savings in insecticides and application costs. (Program participants realized a small actual increase in profits only because they did not make any contributions to the costs of the program.)

For these reasons, it does not appear that a pest management program limited to the management of insect pests on tobacco is economically feasible in North Carolina.

As Carlson and Cooper point out in the concluding remarks of

their detailed study (p. F-35), yield and quality improvements were not part of the North Carolina tobacco pest management program up to 1973. Due to the high value of the tobacco crop, small improvements in yield quantity or quality will justify considerable expenditures of management resources. Thus, while tobacco insect management may not be economically feasible by itself, it may well be viable as one component in an interdisciplinary tobacco pest management/plant health improvement program. This was recognized by USDA and North Carolina program managers and consequently, the program was restructured, and a new 3-year program began in crop year 1974. The new thrust will provide for integrated management of pest problems caused by insects, weeds, diseases, and nematodes, and for sucker control. It is known that the principal losses of tobacco are caused by diseases and nematodes, and individualized recommendations for management of these pests will more likely be economically attractive to tobacco growers. For example, a large percentage of the tobacco acreage is treated with expensive soil fumigants for the control of soil-borne disease organisms and nematodes. These treatments cost $20 to $60 per acre; and substantial savings to growers could probably be realized by more precise application based on needs and use of less expensive chemicals, depending on the pests present (Good, 1974a).

In summary, all cotton pest management programs studied in this project were found to be feasible and generally successful in accomplishing their objectives, with differences in objectives between projects and areas.

Of the 3 peanut programs studied, only one (Frio County, Texas) had more than one year's operating experience. This program appears to be feasible. Both of the Oklahoma programs were initiated only in 1973 and therefore had only one year's operating experience at the time when the field phase of the present study was conducted (early fall of 1974). The biological and economic effectiveness of these programs

remains to be established firmly, but prospects appear very promising.

On tobacco in North Carolina, management of insect pests only does not appear to be economically feasible or attractive to growers, and in response to these findings, program objectives were greatly changed and expanded in 1974.

CONSTRAINTS ON EXPANSION OF PEST MANAGEMENT PROGRAMS

Review of the pest management programs studied in this project, including the regional investigators' projections, indicates that these programs could expand in several different ways, i.e.:

- -- cover more acres;
- -- use greater variety of insect suppression tools and techniques;
- -- include pests other than insects (and mites);
- -- include crop (not just pest) management;
- -- include crop and pest management on a multi-crop, area-wide basis.

Evaluating the pest management programs studied, especially those on cotton, against these potentials, it appears that most of them are, at this stage, still primarily "prescription insecticide" schemes. Some cotton programs have expanded prescription insecticide use almost to an area-wide basis. The use of insect suppression tools other than insecticides is minimal compared to the use of insecticides. On cotton, there does not appear to be any expansion toward the management of pests other than insects (and mites). Some cotton programs are developing into crop/insect management schemes.

This analysis should not detract from the success and viability of the pest management approach on cotton; it simply indicates that there is much room for expansion, and that the development

thus far has largely been in the area where the immediate needs were the greatest. The USDS/State-supported programs have been instrumental in stimulating the expansion of pest management. In particular, the USDA/State program has brought substantial additional cotton acreage under pest management. It has reinvigorated some of the older programs that were showing signs of sagging, and has given much added impetus to the adoption of the crop development/plant measurement approach and thus to the expansion of pest management in the direction of total crop management. The "Huffaker program" has added substantially to the research base for these efforts in the fields on which it focuses, i.e., the principles, strategies and tactics of the population regulation and control of pests, primarily foliar insects, on cotton and several other crops (alfalfa, citrus, pines, pome and stone fruits, and soybeans). Both of these programs (USDA/State and "Huffaker"), of course, benefit from, and build further on the vast base of research and technology developed over many years by the U.S. Department of Agriculture, public and private universities, State Agricultural Experiment Stations and Extension Services, private industry, and others.

The data presented in this study and in other reports show that pest management programs have produced many benefits to agriculture as well as to society at large. However, in view of the magnitude of the effort, the amounts of public funds (both Federal and State) that have been invested, and the favorable results at hand, the question arises: If pest management is so advantageous to all, why is it not adopted more rapidly?

Integrated pest management is a new technology that might be compared to the development of a new product or technology in an industrial setting in terms of the phases involved in such a process, including research, development, pilot marketing, and full commercial production, marketing and use.

In the research phase, candidate new products (or technologies) are invented and tested, and their suitability for their intended

purpose is determined. A crucial step in the development phase of a new product, after its basic effectiveness has been established, is the determination of its economic feasibility, including obtaining answers to questions such as:

-- How much does it cost?
-- What will it do for users?
-- How much is it worth to users?
-- How much will users pay?
-- How does it compare to present products or practices?

In the commercial world, it would not be possible to successfully introduce and market a new product without solid answers to these questions.

Even after a product proceeds from research and development to commercial production, marketing and use, there is an ongoing need for research support. Continued research is required for product improvement, and to adapt the product or technology to changing user needs. Development or technical service personnel assist users in obtaining optimal benefits from the product, handle problems of unsatisfactory performance and/or other user complaints, provide communication between research and users, and promote new and expanded uses. Very often, a new product is first manufactured and marketed on a limited, or pilot scale to verify or correct the economic, functional and operational forecasts made earlier.

Finally, full commercial production, marketing and use present the acid test on the validity of all previous forecasts and expectations. The well-known case of Ford's Edsel, among others, documents that massive product failures are still possible at this late stage.

Comparing pest management as a new technology to the development of a new product or technology in a commercial environment provides a frame of reference helpful to the identification of certain strengths and weaknesses.

Research

Considerable research has been conducted in the past on the pests including insects, nematodes, diseases, weeds, etc., of cotton, peanuts, tobacco, and many other crops, as well as on many other facets of the production of these crops. However, up to the present, such research appears to have been conducted largely on a disciplinary basis, without effective interdisciplinary cooperation, leaving it up to the grower to put it all together, and to work out as best he (or she) can unforeseen interactions between the different pieces of technology that were developed in isolation.

Cotton: As pointed out above, a broad base of research know-how on cotton insects and other pests has been developed in the United States over many years. Among the commodities studied in this project, cotton is the only one included in the "Huffaker Project". By its very title and its stated objectives, this program is a research and method development effort. It strives to be multi-disciplinary, but seems to be heavily tilted toward entomology. Furthermore, while inputs from economists were planned, it seems that in actual fact, economists have had only limited influence on, and participation in program planning, design, and execution. This deficiency may become serious in areas where Huffaker project activities progress from research into the development and implementation phases of pest management.

Peanuts: The peanut pest management programs studied utilize and implement research results developed in the states concerned and elsewhere and rely on ongoing research support and backup. The Oklahoma program shows that field observations often raise questions that can be resolved successfully only by continued research participation and support. Lacewell and Casey emphasize that both of the Texas peanut pest management programs also rely heavily on, and receive, strong research backup.

Thus, lack of research data does not appear to be a major constraint on expansion of peanut pest management programs, but

ongoing research support is clearly an important requirement.

Tobacco: Rabb et al. (1974) have pointed out and documented that a substantial pool of research knowledge exists in regard to tobacco production and, in particular, in regard to the insects and diseases affecting tobacco. These authors make the following observation regarding utilization of this research know-how:

> "The integration of pest control actions into the tobacco production system has been a slow step-by-step process taking many years. Most of the inputs by pathologists and entomologists have been made separately, and each group has developed and implemented its own 'action' program."

Rabb et al. (1974) cite several examples of tobacco production improvements made unilaterally by one discipline, without cooperation with other disciplines in the research (or development) phase. For instance, it was found that the introduction of nematode-resistant tobacco varieties aggravated damage by the tobacco hornworm, *Manduca sexta*. Other examples include the role of insects in the transmission of tobacco diseases; the increased susceptibility of plants to disease because of insect damage; and the influence of the use of maleic hydrazide, a chemical employed most frequently for chemical sucker control on tobacco, in reducing overwintering populations of the tobacco hornworm.

It appears that sufficient basic knowledge on tobacco pests exists to support pest management programs on tobacco. However, more effective cooperation between all scientific disciplines involved in tobacco pest management and production would seem to be required in the further development of integrated pest and crop management systems for tobacco.

Development

The USDA/State-supported "pilot program for integrated pest management", by its title and objectives, would correspond to the development and pilot marketing phase in the life of a new

commercial product. This comparison suggests several opportunities for improvement.

Economic and ecological evaluation: As pointed out above, studies on economic effectiveness and feasibility are an essential step in the development phase of a new product or technology. In this regard, most of the pest management programs evaluated in this study leave much to be desired. It appears that in most or all of these programs, economists were not involved in program planning and design and, to the extent that they participated at all, had mostly inadequate data to evaluate ex post facto.

Scott (1974) and other leaders of the USDA/State cooperative pest management program have emphasized that "Extension pest management programs are designed to teach farmers to adopt integrated biological, cultural, and chemical technology to control agricultural pests", and that "these programs have both economic and environmental objectives -- to help maximize incomes of producers and reduce potential adverse environmental effects of pesticides".

In the light of these program objectives, it is surprising that the design and funding of the programs apparently did not provide for thorough, systematic evaluation of their economic and environmental effects. Economic benefits to be obtained from pest management programs will be far more persuasive to growers than other factors. If pilot pest management programs are intended to promote grower acceptance and implementation of integrated pest management, generation of adequate economic data would appear to be essential. If, in addition, these programs have environmental objectives, then they should also include provision for monitoring achievement of these objectives.

Information feedback: The information feedback loop in the USDA/State program appears to be rather long, slow, and inefficient. For instance, data necessary for an evaluation of the effectiveness of the 1972 program were not collected from State project leaders until late in 1973, and were not summarized and published until the latter part of the summer of 1974. An evaluation of the 1973 programs was not available in the fall of 1974. Results

of analyses of the environmental samples collected in 1972, were not available in the fall of 1974, and in the spring of 1975, it was announced that plans to analyze these samples had been abandoned. Some pest management workers contacted in this study in the early fall of 1974 were reluctant, unwilling or unable to provide information because they had not collected or analyzed their 1972 and/or 1973 data as yet.

In the commercial world, beginning a new year's cycle in the development of a seasonal product (such as pest management) without prior complete assessment and exploitation of the preceding year's experience would be considered inexcusable. By comparison, the present information handling practices in many of the programs studied in this project cause long delays in the application of field experience. More rapid and efficient collection and evaluation of field data and more rapid communication of the findings to all program participants and to other interested agencies and persons would appear to be highly desirable.

Pest Management Delivery Systems

Delivery of pest management technology to growers may be compared to the marketing of a new product. In the commercial environment, it would be very difficult, if not impossible for any new product, no matter how good, to gain wide acceptance and use without effective marketing. In the United States as well as in many other "free market" countries, marketing has traditionally been a function of private enterprise.

Chemical pesticides and pest management services, to the extent that they are interchangeable, compete for the same users and dollars. In the U.S., chemical pesticides are promoted and marketed vigorously. By comparison, pest management does not appear to be "sold" nationwide or regionally with any degree of vigor. It thus appears to be in the position of a new product without effective marketing.

Cotton: In the cotton pest management programs studied in this project, pest management is being delivered to growers through private pest management consultants or organizations in some cases (North Carolina, Arizona/Graham County, and California's private consultants), through the publicly funded Extension Service in others. The two systems are not mutually exclusive; most or all private consultants rely in varying degrees on the research, back-up, and support of Federal and State research and extension personnel. In some states, notably in California, the administrators of the USDA/State-supported cotton pest management program have endeavored to expand private pest management consulting. In other states, private pest management activities do not appear to be encouraged by the State program.

Peanuts: No private enterprise "marketing" or delivery of the pest management technology to users appears to be involved in any of the peanut pest management programs studied. In the case of the grower-initiated Frio County, Texas program, pest management is delivered to growers by State agricultural agencies. Research support is provided by the Texas Agricultural Experiment Station, and pest management monitoring and advisory services are delivered directly to peanut producers by or through the Texas Agricultural Extension Service. Program users pay for the costs of scouting, and the services of the State agencies are paid from State funds.

The other two programs studied did not appear to encourage private enterprise participation either. If the Oklahoma program accomplishes the ambitious objectives envisioned for 1974, 1975 and beyond without private enterprise participation, a considerable expansion of the role of State agencies, especially of the Extension Service, would seem to be required.

Tobacco: No elements of private enterprise delivery of pest management technology to growers appear to be involved in the North Carolina tobacco pest management program. Program participants receive the "product", pest management services and advice, directly or indirectly from State agencies, primarily the Extension Service.

Successful implementation of integrated pest management, especially of more comprehensive plant health improvement programs, requires one-on-one contact between pest management users and pest management deliverers. This requirement appears to be at odds with several basic principles that apply to all extension programs, but especially to developing pest management programs, as stated by Good (1974b) as follows:

-- Extension must not compete with the private sector.
-- Extension cannot provide specialized services to select individual or groups.
-- Extension must present alternative choices so that growers have sufficient knowledge to make enlightened decisions.

A study of the relative advantages and disadvantages of the delivery of pest management technology with or without private enterprise participation was not included in the scope of this study. However, the facts discussed above indicate that a better understanding of the optimal mix between public and private activity in the delivery of integrated pest management technology to users may be important to the further planning and implementation of public policies in this field.

Interdisciplinary Research, Education and Training of Personnel

Pest (not just insect) management and plant health improvement are complex problems that clearly require an interdisciplinary approach. Tackling crop production problems in an interdisciplinary manner is not the traditional approach within the U.S. Department of Agriculture, nor at U.S. universities and State Experiment Stations. Agriculture-oriented universities in the U.S. are traditionally discipline -oriented and -organized in research and education, and this seems to carry through to the Extension system. Effective cooperation between entomologists, plant pathologists, nematologists, weed scientists, plant physiologists, plant breeders, agronomists, engineers, chemists, and other disciplines involved in crop production appears to be feeble

or nonexistent in most academic institutions. Cooperation between the biological and physical disciplines and economists and sociologists likewise is vastly underdeveloped.

It appears that more effective cooperation between all disciplines involved in crop production is an urgent prerequisite to the further successful development of integrated pest management or plant health programs for cotton, peanuts and tobacco, as well as for other crops. Such interdisciplinary cooperation is essential for the efficient solution of research problems, as well as for the education and training of field personnel and growers.

Program Management

At this writing (1974/1975), overall responsibility for progress of the various federally supported pest management programs, and for optimal use of public funds appropriated for this purpose appears to be ill defined, and diffused throughout different Federal and State agencies. The question arises whether the interest of farmers as well as of society (and taxpayers) at large would not be better served by tighter management, i.e., if one agency would be given specific overall responsibility and authority for the further development and implementation of pest management programs.

This function would be comparable to that of a product manager in industrial settings. The product (or program) manager concept has been used extensively and successfully in other mission-oriented governmental activities such as, for instance, the space program and the military services. Management tools such as the "Program Evaluation and Review Technique" (PERT), critical path method, and/or others are often used with much success; they facilitate program coherence, communications, and timely completion of individual work elements.

None of these management methods appear to be in use in the USDA/State program, or between that program and the "Huffaker Project" and other pest management efforts. Very tight manage-

ment of the entire program may not be feasible or even desirable. However, there does appear to be a need for more effective guidance and support of individual program elements, including promotion of more effective coordination and cooperation between all elements necessary to the efficient further development of truly integrated, practical pest/crop management systems; improvement of information collection and handling procedures, and strengthening of a communications system through which information can and will flow swiftly in both directions, i.e., from research workers through extension and other advisory personnel to growers, and vice versa. Another function of such overall pest management program guidance would be to avoid unnecessary duplication of effort, to pinpoint and correct weaknesses, and to keep the overall program moving in the right direction.

In summary, much has been accomplished in the establishment and expansion of pest management programs on cotton, peanuts and tobacco, especially in the last 3 years (since 1972) through the USDA/State-supported program, but a great deal more remains to be done to develop this technology towards its full potential, and to make it permanently viable and self-sustaining. There are opportunities for improvement in the following areas, especially in publicly funded or supported programs:

- *Evaluation of the economic and ecological effests of pest management programs;*
- *Information feedback;*
- *Pest management delivery systems;*
- *Interdisciplinary research, education and training of personnel;*
- *Overall program guidance.*

Note: As emphasized above in the introductory sections of this report, the findings and conclusions presented are based on data and information collected in the field in the early fall of 1974.

APPLICABILITY OF FINDINGS TO OTHER CROPS

In this study, 19 pest management programs located in 8 major cotton-producing states, 3 peanut pest management programs located in the states of Texas and Oklahoma, and the North Carolina tobacco pest management program were described and evaluated in detail. In all evaluations, prime emphasis was placed on the practical, economic effectiveness and feasibility of the programs studied. Most previous reports on pest management programs have dealt primarily with their research and biological (largely entomological) aspects, instead of their economic effectiveness and practicality at the grower level. To the best of our knowledge, comparable, economically oriented, down-to-earth evaluations of pest management programs on other crops do not currently exist.

The present study has shown that there are considerable differences between pest management programs on the same crop in different states, and even within states. For instance, each of the 3 peanut programs evaluated had different objectives, even though all were located in two neighboring states, in the same general area of the U.S. Similar variations in origin, experience to date, and objectives were observed among the cotton programs studied.

Furthermore, it is interesting to note that Oklahoma peanut producers, growing a crop worth $375/acre (1973 U.S. average), were reported willing to pay $8/acre for an integrated pest management/plant health improvement service. California cotton producers, growing a crop worth about $250/acre (1973 California average), pay private consultants $2 to $6/acre for pest management and general production advice, depending on the level of service (Falcon, 1974). On the other hand, North Carolina tobacco producers, growing a crop worth $2,000/acre, have contributed nothing to the cost of their USDA/State-supported insect management program between 1971 and 1973.

Thus, it appears that the biological as well as the economic elements of pest management programs vary greatly between different

crops and geographic areas. This is not surprising in view of the great variations in the farm values of different crops, the importance of insects, diseases, weeds, and other pests in relation to other production problems, the availability of basic prerequisites for successful integrated pest management, and many other pertinent factors. These numerous variables explain why in many ways, each pest management program has at least some unique characteristics, and braod generalizations are of questionable value.

On the other hand, certain observations recurred in most or all of the pest management programs studied in this project and are therefore probably applicable to other crops as well. These include the following.

1. The biological and economic effectiveness of any given program is subject to year-to-year variations due to changes in weather conditions, pest infestation levels, and other seasonal factors. Therefore, evaluation of individual programs over time is likely to be more informative and meaningful than studying different programs or averages for single years in a "time slice" fashion. The latter approach would obscure differences between programs and lead to erroneous conclusions if the year evaluated was unusual, which most years are in one way or another.
2. Most of the cotton, peanut, and tobacco pest management programs evaluated lacked adequate provision for evaluation of their economic and environmental effects in their planning, funding and execution.
3. One of the major constraints on the further expansion of integrated pest management programs appears to be the lack of effective interdisciplinary research, planning, and field implementation of research know-how.

4. There is a shortage of versatile, interdisiplinarily educated and trained crop management scientists, administrators and practitioners.
5. The problem of optimal delivery systems of integrated pest management technologies to growers needs attention. In the majority of the pest management programs studied, the Cooperative Extension Service currently appears to be the primary delivery system. There is a question if in the long run, this role will be compatible with the overall mission of the Extension Service which considers itself primarily an educational agency that should not provide specialized service to individuals. On the other hand, effective pest management delivery and implementation will have to include furnishing specific, individualized advice to growers.
6. As pointed out in greater detail in the section on constraints, integrated pest management at its current state of development shows many of the symptoms of a new commercial product that lacks effective development and marketing management. Several of the programs evaluated appear to be stalled, or headed for trouble at the crucial threshold between research/development and full commercial viability and implementation, without clear plans how and by whom they could or should be lifted across.
7. The foregoing, seemingly critical statements should not take away from the fact that in most of the programs studied in this project, much progress has been made in a relatively short period of time. The USDA/State cooperative program has successfully acted as catalyst; it has mobilized many resources and greatly accelerated the development and expansion of integrated pest

management in the field. The very fact that certain problems of commercial implementation and use of pest management on a large scale at the grower level are now at hand is a result of the success of the program thus far.

COTTON PEST MANAGEMENT PROGRAMS

BACKGROUND

Many studies on the biology, population dynamics and control of cotton insects have been conducted. At the present time, more pest management programs are in operation on cotton than on any other crop in the United States. This is due primarily to two facts, i.e., (1) several of the serious failures of chemical insecticides have involved cotton insects, and (2) almost 50% of the total quantity of insecticides used by farmers in the U.S. in recent years was used on cotton (U.S. Department of Agriculture, 1968b, 1970, 1974b).

Further details on development of pest management programs, especially programs on cotton, have been presented above in the section entitled "Development of Pest Management Programs in the U.S." and are therefore not reiterated here.

A variety of different insect pests occur on cotton in the United States. Their relative economic importance varies in different parts of the country. Cotton pests of the Southern cotton growing areas and their interactions with the cotton plant, with beneficial parasites and predators, and with other elements of the environment are discussed by Parvin (see p. A-2 to A-16). In the Far West, principal pests on cotton include mites, lygus bugs, the cotton bollworm, *Heliothis zea*, the pink bollworm, *Pectinophora gossypiella* (in Southern California and Arizona), and the cotton leaf perferator, *Bucculatrix thurberiella*. These regional differences in the relative abundance and importance of injurious as well as beneficial insects and mites on cotton necessitate different pest management strategies, as discussed in greater detail in Appendices A, B, C, and D.

TRENDS IN COTTON PRODUCTION AND PESTICIDE USE

The U.S. Department of Agriculture has collected data on the quantities of pesticides used by U.S. farmers in 1964, 1966, and 1971. These data are presented in Table 2 , along with the

Table 2: U.S. Cotton Acreage, Insecticide Use on Cotton, and Production of Insecticides, 1964 - 1973

Year	1964	1966	1971	1973
Cotton Acreage (1,000 Acres)	14,836	10,349	12,355	12,501
Insecticide Use on Cotton				
- Total (1,000 lbs. AI)	78,022	65,368	73,357	75,006 1/
- per Acre (lbs. AI)	5.25	6.31	5.93	6.0 1/
Insecticides Produced in U.S. (1,000 lbs. AI)	463,321	561,814	564,818	639,169
Cotton Insecticide Use Relative to U. S. Production	16.8%	11.6%	13.0%	11.7% 1/

Sources: U. S. Dept. of Agriculture (1966, 1968a, 1968b, 1970, 1973c, 1974a, 1974b)

U. S. Tariff Commission (1974)

1/ Estimates

total U.S. cotton acreage, and the total U.S. production of insecticides in the years in question, plus 1973. The U.S. cotton acreage varied from a high of 14.8 million acres in 1964 to a low of 10.3 million acres in 1966; it was close to 12.5 million acres in 1971 and 1973. The USDA insecticide use data indicate that in 1964, an average of 5.25 lbs. of insecticide active ingredients were used on cotton, 6.31 lbs./acre in 1966 and 5.93 lbs./acre in 1971. The quantity of insecticides used on cotton was 16.8% of the total quantity of insecticides produced in the U.S. in 1964, 11.6% in 1966, and 13.0% in 1971.

Assuming that cotton growers used an average of 6.0 lbs. of insecticide active ingredient per acre on cotton in 1973, total insecticide consumption on cotton for that year would have been about 75 million lbs. of active ingredients. This estimate would place the quantity of insecticides used on cotton as percent of the total U.S. production of insecticides at the low end of the scale of the actual experience in 1964, 1966, and 1971 and thus appears plausible.

The data presented in Table 2 do not indicate any trend in the use of insecticides on cotton. All but one of the USDA/State-sponsored cotton pest management programs were initiated only in 1972 and probably did not achieve full effectiveness until 1973 or 1974. It will be interesting to see if these programs will result in a statistically noticeable decrease in the use of insecticides on cotton in the future. The U.S. Department of Agriculture's Economic Research Service is planning a survey of pesticide and fertilizer use practices for crop year 1976. Additional data on pesticide use will be collected as part of the Agency's surveys of costs of production by commodities (Davis, 1974).

USERS, LOCATIONS AND CHARACTERISTICS OF THE PROGRAMS STUDIED

In this project, 19 individual cotton pest management programs were studied. The locations of these programs, superimposed on a dot-map of the U.S. cotton acreage harvested in 1969,

the latest year for which such dot-maps are available, is given in Figure 1 . This map shows that the present study covered most of the major cotton producing areas in the United States.

An overview of the characteristics of the cotton pest management programs evaluated, including their locations, purpose, and starting years are presented in Table 3 . The entries opposite "Ref(erence) Page" refer to the page numbers in the regional reports where these programs are described and assessed in detail. The data in Table 3 pertain to the year 1973, except for a few instances (marked appropriately) where 1973 data were not available. 1973 was chosen as the base year for this overview because it is the most recent year for which data are available at this writing (July - August, 1974). Secondly, many of the USDA/State-supported pest management programs were initiated rather hastily in 1972 and did not have a full year of "normal" operation until 1973.

The cotton pest management programs studied vary considerably in regard to users, purpose, starting year, and acreage covered. The major features of these programs are as follows (programs discussed in approximate decreasing order of acres covered).

Arkansas: The program with the longest history is that in Arkansas, started in 1949 for the purpose of improving cotton insect control in the state. It has been carried out primarily by scouts trained and supervised by the Extension Service. Detailed data on the Arkansas program, by years from its inception to the present, have been collected and evaluated by Carlson and Grube (p. B-8ff). Their report includes number of scouts and scout supervisors; number of counties, cotton acres, cotton fields and farms in the program; scout load characteristics and costs; and grower pest management training activities. In 1973, the Arkansas pest management program was one of the three largest programs studied; it included 204,000 acres on 892 farms in 23 counties and employed 149 scouts. The program operates in practically all cotton-growing counties of Arkansas and covers

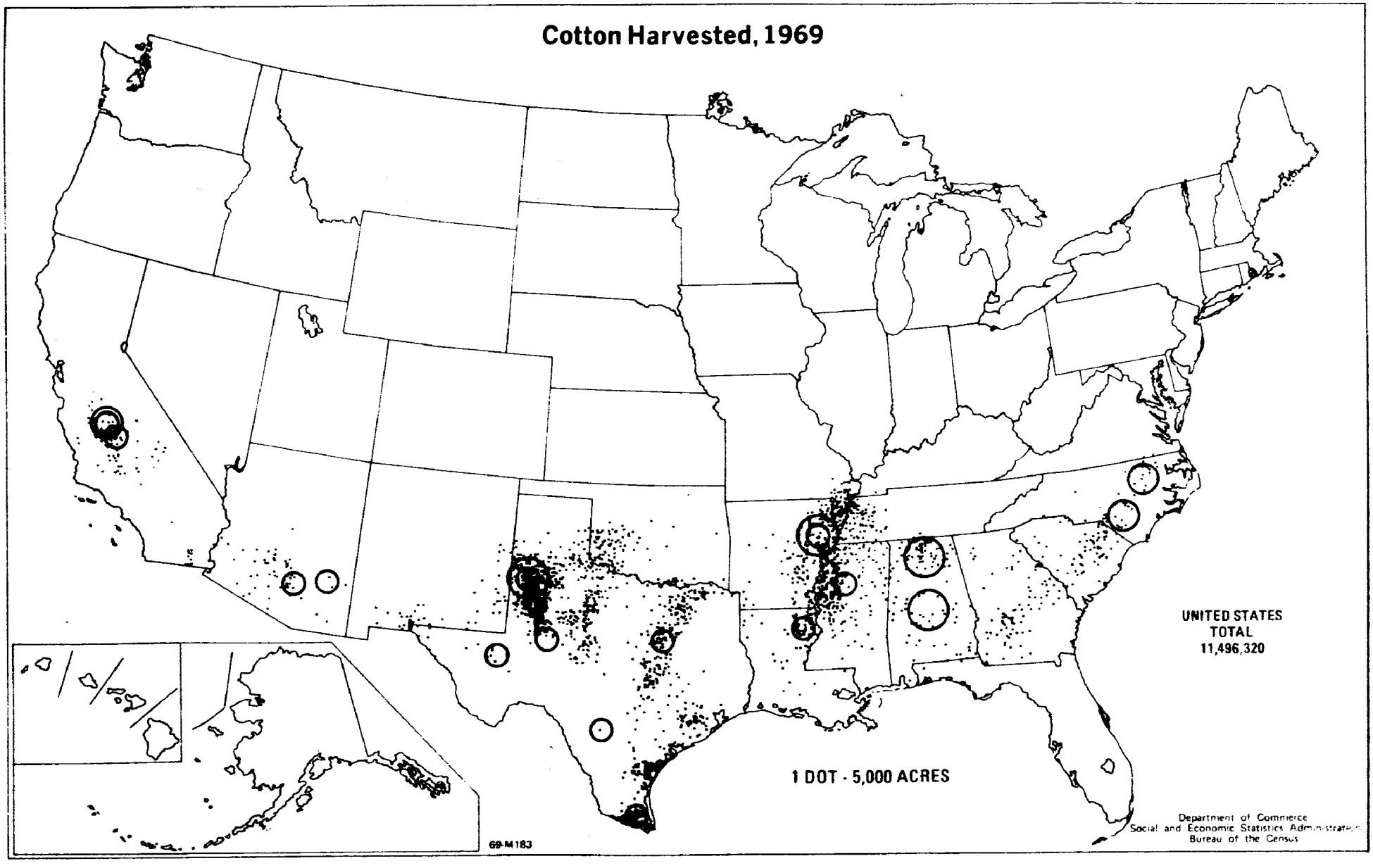

Figure 1: Locations[1/] of the Cotton Pest Management Programs Evaluated in this Report Relative to the Geographic Distribution of Cotton Production in the U.S.

1/ Program locations identified by circles.

Table 3 : Characteristics, Costs and Benefits of 19 Cotton Pest Management Programs, 1973[1/]

Program	Arkansas PM Program	North Carolina Cooperatives	North Carolina Commercial Operations	Mississippi PM Program	Alabama PM Program
Location	Eastern half of State	Several Counties		Grenada-Yalobusha co.'s	North, West & Central Ala.
Purpose	Insect pest suppression	Group purch. of insect control	Insect pest suppression	Insect pest (boll weevil) suppression	Insect pest suppression
Ref. Page	B-8, B-35 ff	B-13 ff., B-42 ff.		A-31 ff.	A-41 ff.
Year Started	1949	1967	1968	1972	1972
Area	23 Counties	Several Counties		2 Counties	17 Counties
Acres) in PM	204,000	33,516	11,700	13,827	115,000
Farms) in PM	892	401	58	97	599
Fields) in PM	5,726				3,280
# Scouts	149	37	10	13	73
# Scout Supv.	6				9
Acres/Scout	1,417	1,027	1,625	1,063	1,575
Pest Mgmt. Acreage Ratio	18% of State cotton acr.	18.4% of State cotton acreage	6.4%	73% of cotton acr. in area	40% of cotton acr. in area
Insect Management Costs, $	per Acre	per Acre		per Acre	per Acre
Scouts	1.04	1.18		1.25	1.25
Scout Travel	0.01				
Scout Supv.	0.08*	1.80			
Co. Agents	0.28*				
Prof. Support	0.09*	1.61*			
Other	0.07*				
Subtotal	1.57	4.59			
Insecticides	5.40	15.50		13.34	18.79
Application	3.60	11.74		8.30	
Total	10.57	31.82		21.64	
Growers' Funds	10.05	30.22		1.25	1.25
Public Funds*	.52*	1.61*			
Benefits:					
Cotton Yield	+ 8%	+ 230 lb[8/]		No data	Above state avg.
Insectic. Use	- 20%	+ 24%		- 2.3 appl.'s	- 2 to 4 appl.'s
Product. Cost	- 1%[7/]	+ $10		- $5.20[9/]	- $6.78
Profit	+ 9%	+ $84		Increased	Increased

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Table 3 : Characteristics, Costs and Benefits of 19 Cotton Pest Management Programs, 1973[1/]

Program	Louisiana	California		Arizona	
	1972	Pest Mgmt.			
Location	Catahoula, Grant & Tensas Par.	Consultants San Joaquin Valley	Scout Program San Joaquin Valley	Graham Co. Safford Valley	Pinal Co.
Purpose	Insect pest suppression	Suppr. Lygus & bollworms	Improve cotton prod.	Pink boll-worm control	Insect pest suppression
Ref. Page	A-46 ff.	C-6 ff.	C-21 ff.	C-42 ff.	C-43 ff.
Year Started	1972	1950	1972	1968	1971
Area	3 Parishes	6 counties	3 counties	1 county	1 county
Acres)	5,600	200,000	19,000	4,492	31,508
Farms) in	70		101	35	85
Fields) PM	230				
# Scouts	6		13[5/]		46
# Scout Supv.			7[5/]		12
Acres/Scout	933				
Pest Mgmt. Acreage Ratio	10% of Cotton Acreage in area	22% in San Joaquin V.	3% in 3 counties	About 25% of the county	
Insect Management Costs, $	per Acre (1972)	per Acre (1971)	per Acre	per Acre (1971)	per Acre (1972)
Scouts	2.45*	2.33	1.30	1.65	1.00
Scout Travel			-17.00		
Scout Supv.					
Co. Agents					
Prof. Support					
Other					
Subtotal					
Insecticides	17.24	4.20		13.50	26.35
Application	10.90				
Total	30.59	6.53		15.15	27.35
Growers' Funds	28.14	6.53	2.00-2.50[5/]	15.15	27.35
Public Funds*	2.45	--	2.00-3.00* 3/5/		
Benefits:					
Cotton Yield	No data[10/]	+.16 to .43 bale	Insufficient data	Insufficient data	Insufficient data
Insectic. Use	No data[10/]	- $3 to 11	- $5 to 10	Decreased	- $11 to 14
Product. Cost	No data[10/]	- $1 to 9	- $3 to 8	Insuff. data	- $10 to 13
Profit	No data[10/]	+ $16 to 65	+ $3 to 8 ± chg. in yield	Insuff. data	+ $10 to 13 ± chg. in yield

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Table 3 : Characteristics, Costs and Benefits of 19 Cotton Pest Management Programs, 1973[1/]

Program	Texas				
Location	High Plains	Glasscock County	South TX Rio Grande Valley	Pecos Research Station	East Texas, TX Dept. of Corrections
Purpose	Diapause boll weevil suppression		Avoid *Heliothis* damage	Insect pest suppression (demonstration)	
Ref. Page	D-6 ff.	D-23 ff.	D-34 ff.	D-45 ff.	D-56 ff.
Year Started	1964	1968	1973	1968	1970
Area	Several co.'s	1 county	3 counties	2 counties	Several co.'s
Acres) in PM	186,000 (1972)	16,200	23,000		5,757 (1972)
Farms) in PM					
Fields) in PM					
# Scouts					
# Scout Supv.					
Acres/Scout					
Pest Mgmt. Acreage Ratio		100% in proj. area	10-15% in proj. area		
Insect Management Costs, $	Entire Program	per Acre	per Acre	per Acre	per Acre
Scouts			5.00	5.00	5.00
Scout Travel					
Scout Supv.	172,180				
Co. Agents					
Prof. Support					
Other	85,313*				
	68,142				
Subtotal	325,635				
Insecticides	449,738				
Application	136,195		18.77	0.00	3.78
Total	911,568	1.51			
Growers' Funds	413,127	0.76	23.77		
Public Funds*	498,441*	0.75*			
Benefits:					
Cotton Yield	+ 4.0%	No change	No change	+ 28.3%	+ 19.1%
Insectic. Use	- 82%	- 83%	- 33.7%	- 86.0%	- 50.2%
Product. Cost	- 8.2%	- 3.7%	- 6.8%	- 13.0%	- 0.5%
Profit	+ 8%	+12.0%	+57.3%	+100.0%	+143.1%

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Table 3 : Characteristics, Costs and Benefits of 19 Cotton Pest Management Programs, 1973[1/]

Program	Texas			
Location	Rio Grande Valley	Blacklands Hill and Ellis co.'s	Trans-Pecos Reeves and Pecos co.'s	Frio Co. & neighboring counties
Purpose	Insect pest suppression; cotton production improvement			
Ref. Page	D-76, 88 ff.	D-99, 108 ff.	D-120, 130 ff.	D-141, 151 ff.
Year Started	1972	1972	1972	1971
Area	3 counties	2 counties	2 counties	1 county
Acres) in IPM	15,632	10,266	8,600	1,422
Farms) in IPM	77	59	28	20
Fields) in IPM		208	134	28
# Scouts	12	7	9	-
# Scout Supv.				
Acres/Scout	1,303	1,467		
Pest Mgmt. Acreage Ratio	5% in project area	Near 100% in project area	25% in project area	100% in the county
Insect Management Costs, $	Entire Program	Entire Program	Entire Program	Entire Program
Scouts	18,771	9,317	9,558	--
Scout Travel	4,552	1,405	2,078	--
Scout Supv.				
Co. Agents[2/]	21,817	16,659	28,588*	18,879*
Prof. Support				
Other	3,010	2,625	4,606*	1,424*
Subtotal	48,150	30,006	44,830	20,303*
Insecticides Application				
Total				
Growers' Funds	3,933	5,865	13,555	--
Public Funds*	36,792*[3/] 7,425*[4/]	20,941*[3/] 3,200*[4/]	21,275*[3/] 10,000*[4/]	15,053*[3/] 5,250*[4/]
Benefits:				
Cotton Yield	+ 25.1%	+ 11.5%	+ 6.1%	+ 0.9%
Insectic. Use	+ 11.4%	- 30.0%	+ 2.0%	-25.4%
Product. Cost	+ 5.0%	- 2.8%	- 3.0%	+ 2.9%
Profit	+112.5%	+ 23.9%	+36.5%	- 6.0%

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Footnotes pertaining to Table 3:

* Public funds

1/ Unless another year specified

2/ Incl. travel costs

3/ Federal (USDA) funds

4/ State funds

5/ Data from USDA Summary for 1973

6/ Decrease only in 1973, 6-year average shows no decrease

7/ Increase due to scouting costs less reduced costs of insecticides

8/ Midpoint of range of yield increases, 96 to 363 lb/acre

9/ Approximate savings relative to other producers in the area for the same year, based on average cost per insecticide application of $2.26/acre

10/ Only 30% of producers in program followed scouting recommendations

an estimated 18% of the state's total cotton acreage.

Initially, the Arkansas program was a "prescription insecticide program" (refer to the discussion of different types of cotton insect control programs per Newsom, as relayed by Parvin, p. A-19 ff.). Beginning in 1968, cotton growth monitoring was added, and field-checking and monitoring of traps and sugar lines for additional insects have recently been added. In addition, Arkansas has for many years provided grower pest management training by scouting schools, radio and TV programs, county insect letters, and county pest management demonstrations. It is estimated that today, 40-50% of all Arkansas cotton growers (and/or their families) scout their own fields, that 80% of all Arkansas cotton acres are scouted, and that practically all cotton growers in the state apply at least some pest management principles. Thus, there are practically no "controls" or "non-pest management" cotton areas in the state.

As described in greater detail by Carlson and Grube (p. B-2ff.), the infusion of USDA funds into the Arkansas cotton pest management program came at a very opportune time. These funds were used primarily to imporve scout supervision and thus the quality of the scouting program. This has re-invigorated growers' confidence in the program and was instrumental in bringing additional acreage under pest management.

California: The "pest management consultants" program in California has almost as long a history as the Arkansas pest management program. It started in about 1950, based on research by, and guided by University of California entomologists. In 1973, private pest management consultants serviced an estimated 200,000 acres of cotton in California's San Joaquin Valley, that is about 22% of the total acreage in the Valley. (For further details, see Norgaard, p. C-6 ff. of this report). Initially, California's "supervised insect control" revolved around the management of the key pest insects on California cotton, the lygus bug, *Lygus hesperus*, and the

bollworm, Heliothis zea. Today, some private consultants' services are still limited to counting insects and making treatment recommendations to the growers, while others have adopted a more comprehensive crop management (as opposed to insect management) approach. This development received considerable added impetus with California's participation in the USDA/State-supported cotton pest management program in 1972. Systematic monitoring of cotton development, and development of dynamic economic thresholds for lygus were included in the California "scout program" beginning in 1972 (Norgaard, p. C-21 ff.; Falcon, 1972; Smith and Falcon, 1973).

In this program, the Cooperative Extension Service in California engaged the services of private pest management consultants. In this manner, the total cotton acreage under pest management was extended more rapidly than would have been the case otherwise, while at the same time, private-enterprise pest management consulting received a substantial boost, instead of possible competition from a publicly financed pest management program.

Texas High Plains: This program, comprising 186,000 acres in 1973, is aimed at boll weevil suppression, as reported in detail by Lacewell and Casey (p. D-6 ff.). This program was initiated in 1964 with the objective of preventing further spread of the boll weevil. The program was instigated by a cotton grower organization, Plains Cotton Growers, Inc., and was implemented jointly by this organization and Texas A & M University, Texas Tech University, and the U.S. Department of Agriculture. The program essentially accomplished its initial purpose of suppressing boll weevil populations in the High and Rolling Plains of Texas. In 1970, about 360,000 acres of cotton received a total of 1,170,000 acre-treatment with insecticides for diapause boll weevil control. In 1972, the "base acreage" in the program declined to 186,000 acres.

A second, much smaller diapause boll weevil control program in Texas is in Glasscock County. It covered about 16,200 acres

in 1973. For further details, see Lacewell and Casey, p. D-23 ff.

Alabama: The Alabama pest management program is the fourth largest in acreage among those studied in this project. In 1973, it covered 115,000 acres on 599 farms in 17 counties; employing 73 scouts. This represents a rapid expansion from about 39,000 acres under the same program in 1972. In Alabama, as in other cotton states in the Midsouth, the key pest of cotton is the boll weevil. A characterization of key pests, occasional pests, and secondary pests of cotton in the Midsouth, and of the relationships between these insect pests and the development of the cotton crop has been provided by Parvin (p. A-2ff.). Details of the Alabama pest management programs (1972 and 1973) have been documented and analyzed by Parvin (p. A-36 to A-45).

Mississippi: The Missippi pest management program is very similar to that in Alabama. It also started in 1972 and covered 13,827 acres in 1973, its second year of operation. Details on both program years for Mississippi are provided by Parvin, p. A-25 to A-35.

North Carolina: Organized cotton pest management activities started in about 1967 in North Carolina. In 1974, 11 farmer-directed pest control cooperatives and 3 commercial firms were actively involved in cotton pest management in the state. The acreage under these programs grew from a few thousand in 1967 to about 50,000 acres in 1973, and to 76,000 acres in 1974. In 1973, 459 farms were involved, and 47 scouts were employed (for further details, see Carlson and Grube, p. B-3 ff., B-13 ff., B-42 ff.).

The cooperatives, also known as "spray groups", serve several insect control functions. They provide scouting, aerial applicator services, insecticide purchase in bulk, bookkeeping insect trap monitoring, and insecticide use decisions. The latter are made either by individual managers (farmers and/or persons trained in entomology), or by some or all members of the board of directors. Cooperative members transfer rights and responsibility for insect control to the cooperative. Most of these groups operate on an area-wide basis. As described in

greater detail by Carlson and Grube (p. B-13 to B-21), the cooperatives vary considerably in number of years of experience, acreage covered, number of members, number of scouts employed, and operating and decision-making procedures.

The USDA-supported North Carolina cotton pest management pilot project worked with 6 of these cooperatives in 1973, covering about 24,000 acres of cotton. Federal project funds were used to furnish each group a scout supervisor, personnel to collect background data, forms to record scouting results, clerks to transcribe data, computer programming, and data processing. Varying degrees of guidance on the operation of scouting programs and the use of insecticides were provided by project personnel. In this manner, federal funds in North Carolina (as in California) were used to upgrade and expand existing private-enterprise cotton pest management activities.

In addition to these cooperatives, three commercial cotton pest management organizations operated in North Carolina in 1973. At least two of them have been in business for a number of years. For further details, see Carlson and Grube, p. B-21.

Texas: Among all states studied in this project, Texas appears to have the largest number and variety of cotton pest management programs. The program characteristics, users and locations, all operating details, and effectiveness, costs and returns have been documented and evaluated in great detail by Lacewell and Casey (Appendix D of this report). Their evaluation covers 9 individual cotton pest management programs; 4 of these are part of the USDA-supported "Texas scout" or Texas cotton insect management program.

The diapause boll weevil suppression programs in the Texas High Plains and in Glasscock County have already been mentioned. In 1973, the remaining 7 Texas pest management programs combined covered about 65,000 acres on more than 200 farms in 16 counties, employing 28 scouts. Program users include the Pecos Research Station, the Texas Department of Corrections, and several groups of individual growers in areas ranging in size from 1 to 3

counties. Purposes of these programs include demonstration of the feasibility of pest management (in contrast to unilateral reliance on chemical insecticides); avoidance of damage by cotton bollworms (especially Heliothis virescens) through the use of short-season, early maturing, determinate cotton cultivars which permit cotton harvest before these insects become economically damaging; general cotton insect pest suppression; and cotton production improvement.

Lacewell and Casey (p. D-4 to D-5) point out that beyond the publicly supported pest management programs in Texas, there is considerable activity in pest management consulting in the private sector. Approximately 30 entomologists who are members of the Texas Association of Consulting Entomologists provide cotton growers with pest management advice. In addition, there are 15 to 20 insect scouts who, while not members of the Association, work as private consultants to producers relative to cotton insect population control. It is estimated that about 300,000 to 400,000 acres of crops are scouted annually in Texas by private consultants.

Louisiana: This program was initiated in 1972, and the only information available on the program is for the 1972 crop season. This program, one of those in the USDA/State Cooperative Program, was conducted in portions of Catahoula, Grant and Tensas parishes; these parishes are representative of major cotton farming areas in Louisiana. In 1972, 70 producers and 5,600 acres participated in the program, and 6 scouts were employed.

PROGRAM COSTS

The quality and quantity of data available on the types and amounts of costs associated with the establishment and operation of pest management programs vary widely for the different programs evaluated in this study. Carlson and Grube (Appendix B) accumulated and analyzed a great volume of cost data from the Arkansas pest management program (dating back as far as 1960), and for some of the North Carolina pest management cooperatives.

However, in both the Arkansas and North Carolina programs reviewed, there is no delineation between establishment or start-up costs and ongoing operating costs. In both instances, the programs started small, essentially by "self-ignition", and developed to their present dimensions gradually, over about 25 years in the case of Arkansas, and over several years in the case of the North Carolina programs.

Operating cost data for 1973 for these Arkansas and North Carolina programs are included in Table 3 . Many further details, including information for prior years, are reported in Carlson and Grube's complete account in Appendix B.

Very good, detailed operating cost data are available for most of the Texas programs for 1972 and 1973 (Lacewell and Casey, Appendix D). Again, only data for 1973 have been included in Table 3 , and the reader is referred to Lacewell and Casey's report for further details, and for data for 1972 and earlier years.

The Texas report is the only one that provides program cost details broken down by implementation costs, annual overhead, annual operating costs, and state-level implementation, coordination and operating costs. For each year of the program, Lacewell and Casey provide the following details:

Implementation costs broken down by items, including mapping, grower contact, recruitment, and scout training; and by source of funds, separated by federal and state funds.

Operating (program) costs broken down by items, including salaries for county extension personnel, scouts, and clerical help; travel expenses for county extension personnel and scouts; and supplies, miscellaneous, and incidentals. Source of funds by items is broken down by 3 categories, i.e., federal funds (USDA grant), state funds (Texas Agricultural Extension Service), and producer contributions.

State implementation, coordination and operating costs broken down by items and source of funds.

Estimated implementation and operating costs for 7 regional pest management programs in Texas are summarized in Table 4

Much less detail on program costs is available from the Mississippi, Alabama, Louisiana, California, and Arizona programs.

As the data summarized in Table 3 for 1973 indicate, the costs of the different programs varied considerably. Scouting costs (including scout salaries and travel expenses) ranged from $1.05 per acre in Arkansas to $5.00/acre in several Texas programs, and up to more than $10/acre in the California scout program (which includes plant growth measurements, in addition to insect counts). A tabular comparison of costs for scouting only follows:

Arkansas	$1.05/acre
North Carolina	1.18/acre
Mississippi	1.25/acre
Alabama	1.25/acre
Arizona	1.00-1.65/acre
Louisiana	2.45/acre
Texas	5.00/acre

Costs of scout supervision, county agents or extension entomologists contributing to programs, professional support, and other items (clerical and computer time, supplies, etc.), are given only in a few instances, some per acre, some for entire programs.

From the data summarized in Table 3 , ratios of overhead costs (including scout supervision; county agents/extension entomologists; professional support; and "other") to scouting costs (scout salaries and travel) have been computed for those programs for which adequate data are available (Table 5). Arkansas had by far the lowest supervision and overhead costs (1 : 0.5), followed by Texas' Rio Grande (1 : 1.1) and Blacklands (1 : 1.8) programs. In North Carolina and in Texas' Trans-Pecos programs, cost of supervision and overhead were almost 3 times as high as the scouting costs.

Table 4: Estimated Implementation and Operating Costs for Regional Pest Management Programs on Cotton in Texas

Program	Implementation Costs[1/]	Operating Costs/Year
High Plains	$70,000 - 100,000	$600,000 - 1,350,000
Glasscock Co.	18,000	11,000 - 100,000
East Texas	Nil	2,000
Rio Grande Valley	13,000 - 48,386	48,150
Blacklands	9,500 - 27,555	30,006
Trans Pecos	1,800 - 17,479	44,830
Frio County	1,100 - 13,397	20,303

1/ The ranges given include estimated implementation costs in the low value, and implementation plus first year operating costs in the high value since so much of the first year's efforts were directed to program organization and development.

Source: Lacewell, R. D. (1975)

Table 5: Comparison of Scouting Costs vs. Costs of Supervision and Overhead for Selected Cotton Pest Management Programs, 1973

Program	Unit	Scouting[1/]	Supv. & Overhead[2/]	Scouting Costs: Supv. & Overhead
Arkansas[3/]	per Acre	$ 1.05	$ 0.52	1 : 0.5
N. Carolina[4/]	per Acre	1.18	3.41	1 : 2.9
Texas				
- Rio Grande[5/]	Program	$23,323	$24,827	1 : 1.1
- Blacklands[6/]	Program	10,722	19,284	1 : 1.8
- Trans-Pecos[7/]	Program	11,636	33,194	1 : 2.9

1/ Incl. scout salaries and travel

2/ Incl. scout supervisors; county agents/extension personnel (salaries and travel); professional support; clerical and computer time

Sources:

3/ Carlson and Grube, p. B-41

4/ Carlson and Grube, p. B-45

5/ Lacewell and Casey, p. D-91

6/ Lacewell and Casey, p. D-106

7/ Lacewell and Casey, p. D-127

The detailed reports on these programs indicate that in the Arkansas program, scout supervision may be suboptimal. The North Carolina costs of supervision and overhead are so high because the USDA grant funds were used to beef up already existing supervision, and to provide data collection and processing for previously established programs. The supervision and overhead costs in the Texas Trans-Pecos program are relatively high because the county extension entomologist carries out most of the field scouting responsibilities.

In summary, this report provides detailed implementation cost data for 6 of the 9 regional cotton pest management programs in Texas, and operating cost data for all programs evaluated. The majority of the operating cost data are detailed and broken down by items such as salaries, supervision, materials and supplies, etc., and also by source of funds (Federal, State, grower contributions, etc.). The operating cost data provided go back to 1960 for the Arkansas program, to 1964 for the Texas High Plains program, and to 1968 for the Glasscock County, Texas program. For most other programs, operating cost experiences are reported for 1972 and 1973. Table 3 includes 1973 operating cost data by items and by source of funds for all cotton pest management programs studied to the extent that the authors of the 4 regional reports (Appendix A - D) were able to obtain this information. Table 4 (p. 64) summarizes estimated implementation and annual operating costs for 7 Texas programs, and Table 5 (p. 65) compares scouting costs with cost of supervision and overhead for 5 of the programs studied.

PROGRAM EFFECTIVENESS

The effectiveness of cotton pest management programs was measured by several different criteria, including:

- -- Cotton yields,
- -- Pesticide use,
- -- Production costs,
- -- Profit to growers.

An effort to evaluate the 1972 USDA/State-sponsored cotton pest management programs has been undertaken by Womach (1974). Cotton project questionnaires for evaluation of the 1972 program were sent to project leaders in the latter part of 1973. Question forms were returned and tabulated in the spring and summer of 1974. Womach's report includes data, all for 1972 by states, on the following items:

Cotton acres planted,
Program participation,
Scouting activities (numbers of scouts, acreage scouted, fields scouted, acres per scout, fields per scout),
Numbers of scout supervisors,
Time lapse between scouting and recommendations to producers,
Degree of producers' compliance with program pest control recommendations,
Contributions from private consultants, industry representatives, and regulatory agencies in the pest management programs,
Cost items (professional support, scout supervisors, scouts, clerical, computer, supplies, totals),
Sources of funds (USDA, state, grower, totals),
Producer contributions per acre and as a percent of scouting costs,
Program costs per acre scouted,
Percent of 1972 producers who agreed to participate in 1973,

Number of pest management organizations in the pest management project areas,

Cotton yields for participating and non-participating growers (only 11 of 14 states provided yield data for program participants, and only 4 of the 14 states provided yield estimates for non-participants),

Pesticide application rates and costs for program participants,

Target pests,

Number of economic threshold infestations and number of pesticide applications,

Insecticides used most frequently,

Effects of diapause boll weevil control on pesticide use,

Measures of scout safety.

Womach concluded in part as follows:

"From the first year's data, it is not possible to draw any firm conclusions about the cotton pest management program's effects upon economic efficiency or environmental quality. The limited information available indicates that in some states positive benefits did result. Several factors contributed to the lack of evidence in 1972 on the benefits of the program. First of all, and most important, the designers and leaders of the program did not or could not build in a control sample to serve as a comparison group with the cooperating producers. It is recognized that adequate control samples are difficult to obtain because of the large acreage involved and the diversity of pest and cultural conditions. Secondly, prior to initiation of the program little information was available to document and assess the size and severity of environmental and economic problems related to pest control and pesticide use. Finally, as the initial year of a three-year program, 1972 does not serve as an entirely valid indicator for the success of the program".

Analysis of all 19 pest management programs evaluated in this study indicates that most of them suffer, although in varying degrees, from the same deficiency, i.e., lack of planning and provision for meaningful measurements of program effectiveness and comparisons between program participants and non-participants. By far the most useful data in this regard come from the Texas programs as documented by Lacewell and Casey in Appendix D. They report, for each year of most Texas programs, cotton yields (lint, seed, and totals), insecticide inputs, production costs (variable pre-harvest and harvest costs, fixed costs, and totals), and net returns. These data are given for participating growers and for carefully selected, reasonably comparable non-participating growers.

Carlson and Grube (Appendix B) were able to supply some actual yield comparisons between pest management cooperative members and non-members in North Carolina. As already mentioned above, comparing Arkansas farmers who use pest management to those who do not is impractical because essentially all Arkansas cotton growers apply at least some pest management principles. In the absence of possibilitties for direct comparisons, Carlson and Grube evaluated the effect of scouting on early season insecticide treatments, and the effect of infestation records on marginal productivities of insecticides (p. B-22 ff.).

In the report on Mississippi, Alabama and Louisiana, Parvin (Appendix A) compared the quantities and costs of insecticides actually used in 1972 and 1973 by pest management program participants to a "norm", derived from the approximate costs of producing cotton in the Midsouth for producers using a calendar or "womb to tomb"-insecticide program (for further details, see p. A-51 ff.).

Criteria employed by Norgaard for measuring the effectiveness of the cotton pest management programs in California and Arizona include cotton yields by quantity and by value, and total pest management costs including pesticides, application and consulting fees. These data are compared for pest manage-

ment program participants and non-participants, or for averages for the program compared to appropriate county averages.

Data on pest management benefits for all programs evaluated, including effects on cotton yield, insecticide use, production costs and growers' profits for 1973 are summarized in the lower part of Table 3 , p. 52-55.

The differences in the quantity and quality of the available data on program benefits made quantification of these benefits a very difficult task. It was not possible to present all benefit data in terms of one common denominator; instead, some are given in terms of percent, some in terms of dollar values.

Effects on yield

Cotton yield increases in 1973 were reported in 11 of 13 programs for which yield data are available, i.e., Arkansas, North Carolina, Alabama, California (private consultants), and in 7 programs in Texas.

In 2 programs, i.e., Glasscock County, Texas, and South Texas, there were no changes in yield. In both of these programs, the program objective was to prevent yield decreases from infestations of the bollweevil (Glasscock County) or from bollworms (South Texas program). Therefore, "no decrease", or "no change" (in yield) in these cases means that the program was successful.

No information on yield effects was available from the remaining 5 programs, i.e., Mississippi, Louisiana, the California "scout program", and both Arizona programs.

Quantifiable yield increases ranged from + 0.9 to + 28.3%, and from about 80 to 230 lbs. of cotton per acre. (For further details, refer to Table 3 , p. 52-55.

Effects on insecticide use

Fourteen of the 17 pest management programs for which insecticide use data are available reported decreases in the quantities of insecticides used on cotton under pest management, i.e., Arkansas, Mississippi, Alabama, both California and both Arizona programs, and 7 Texas programs. Two Texas programs (Rio Grande

Valley and Trans Pecos) reported increased use of insecticide per acre, but insecticide use per pound of cotton produced declined. Increased insecticide use was also experienced in the North Carolina programs, suggesting that insecticide use may have been suboptimal in areas not under pest management.

In the 14 programs where the use of insecticides decreased, reductions were within the following ranges: 20 to 86%, $3 to 14/acre, or 2 to 4 insecticide applications/year. Insecticide use increases ranged from 2 to 24%.

Effects on production costs

Production cost changes can be caused in several different ways by pest management programs. Production costs may increase by the cost of the pest management program, decrease by savings in pesticide inputs, or move in either direction by combinations of these factors.

Among the pest management programs evaluated, 7 of 9 Texas programs and 6 others experienced net decreases in production costs; the latter included Arkansas, Mississippi, Alabama, both California programs, and Pinal County, Arizona. Production cost decreases from adoption of pest management practices ranged from 1 to 13%, or form $1 to 13/acre.

There was an increase in production costs in 3 programs, i.e., North Carolina (+ $10/acre), Rio Grande Valley Texas (+5.0%), and Frio County, Texas (+ 2.9%).

No adequate data on production costs were available for the remaining 2 programs, i.e., Louisiana, and Graham County, Arizona.

Effects on growers' profits

From the cotton producers' standpoint, this is undoubtedly the most important indicator of the degree of success of cotton pest management programs. It is therefore significant that the effectiveness of the cotton pest management programs evaluated was most clearly demonstrated by this criterion.

Fifteen of the 16 programs for which adequate data are available resulted in increased profits to growers, i.e., all programs

except Frio County, Texas, which experienced a decrease in growers' profits of 6% in 1973, and the Louisiana and Graham County, Arizona programs for which available data are insufficient. Quantifiable profit increases ranged from 9 to 112.5%, or from $3 to 84/acre. (For further details, refer to Table 3, p. 52-56.)

In summary, the effects of the pest management programs evaluated on cotton yields, insecticide use, production costs and growers' profits were as follows, expressed in numbers of programs in each category:

Effect	*Yield*	*Insecticide Use*	*Production costs*	*Growers' profit*
Increase	11	3	3	15
Decrease	-	14	13	1
No change	2	-	-	-
No data	5	1	2	2
Totals	18	18	18	18

These program effects are summarized in the preceding section on program effectiveness, and tabulated in quantified form (to the extent available) in Table 3 , p. 52 ff. Detailed discussions of these pest management program benefits for 1973, the base year for Table 3 (except as indicated), and for additional program years are presented in the regional studies, Appendices A through D. For easy access to these detailed data in the appendices, Table 3 includes references to the Appendix page numbers for each of the programs evaluated.

These findings concerning the effectiveness of cotton pest management programs are very significant and encouraging. It is somewhat surprising that these practical effectiveness indicators have not been more thoroughly studied, and that they have not been widely utilized and publicized. Data such as those summarized in this section, especially

data on increased profits, will "sell" pest management to farmers far more effectively than other measures.

CONSTRAINTS ON EXPANSION OF COTTON PEST MANAGEMENT PROGRAMS

In accordance with the objectives of this study as set forth above (p. 2-3), all of the authors of the regional reports addressed the question of constraints on the expansion of the cotton pest management programs which they studied. Some of these have already been covered in whole or in part in the general discussion on this topic above (p. 32-42) but each regional investigator's comments are summarized below in order to provide a complete, coherent account of their views.

Parvin (p. A-29) mentions the following "potential roadblocks" to the successful further development of the pest management concept:

-- lack of sufficient numbers of trained personnel;
-- current attitudes of the insecticide industry, commercial applicators and growers;
-- cooperation between members of all disciplines involved in crop production;
-- difficulties in developing and registering for use insecticides that are especially needed in pest management;
-- convincing producers to accept the economic threshold concept, obtaining information on their insecticide applications, and satisfying their request for more personal attention by project staff;
-- early termination of the scouting program as a result of early fall school starts.

Carlson and Grube (p. B-54 ff.) point out that in Arkansas, ineffective scout recommendations were threatening to restrict further expansion of the cotton pest management program. However, this has been at least partially corrected in the past few years with the increase of scout supervision made possible through the USDA funds. In addition, they mention the following problems:

Arkansas:

-- inadequate support of the pest management program, especially scout training, on the part of county agents in many cotton counties;
-- inadequate understanding of the program by many growers, aerial applicators and insecticide sales firms;
-- inadequate use of the extensive information collected by scouts and compiled in computers;

North Carolina:

-- shortage of trained and experienced pest management leaders in the cooperatives;
-- lack of adequate scout supervision when cooperatives become too large;
-- inadequate cotton insect warning systems (insufficient use of light traps, sugar lines, radio announcements, and other warnings, especially in regard to bollworms;
-- combination of pest management with chemical and application services which may result in higher insecticide use than necessary.

Norgaard (p. C-49 ff.), based on his evaluation of the California and Arizona cotton programs, mentions the following constraints:

-- inadequate demonstration and advertising of the economic advantages of pest management by government agencies in California, despite ample justification in terms of health, safety, and environmental quality;
-- inadequate exploitation and implementation of available economic data;
-- high cost per acre of delivering pest management to small fields.

Lacewell and Casey's comprehensive report does not include an item on "constraints"; instead, they approach the problem from the positive side and entitle the section in question "components of a successful program" (p. D-190 ff). The following items are included in this category:

-- program support by a strong producer organization;
-- strong individual producer support of the program, coordinated through the producer group or association;
-- County extension entomologists possessing above-average competence, initiative, enthusiasm and ability;
-- a strong research component developing optimum pest management strategies and new and innovative approaches in all phases of cotton production, oriented toward local or regional climatic and other requirements, and effective flow of information between research and implementation;
-- continued governmental support, justified by documentation of actual and potential benefits to producers as well as to society.

PEANUT PEST MANAGEMENT PROGRAMS

BACKGROUND

Peanuts are beset with a variety of pest problems. Insect pests of peanuts include the lesser cornstalk borer (*Elasmopalpus lignosellus*), the red-neck peanut worm (*Stegasta bosquella*), the burrowing bug (*Pangaeus bilineatus*), and several foliage-feeding insects. Economically important fungus diseases of peanuts include Cercospora leaf spots (*Cercospora arachidicola* and *C. personata*), Southern blight (*Sclerotium rolfsii*), and several soil-borne pathogens including *Pythium*, *Rhizoctonia*, and *Fusarium* species. In addition, peanuts are attacked by several species of nematodes including the root-knot nematode (*Meloidogyne* sp.) and the root lesion nematode (*Pratylenchus brachyurus*). A variety of weeds can also be a problem, especially in irrigated peanuts. The occurrence and severity of these pests vary considerably between different peanut growing areas.

To a greater or lesser degree, commercial peanut growers in the U.S., especially in Virginia and Georgia, have practiced pest management out of practical necessity for many years before the term became widely known and used. Organized pest management programs on peanuts were initiated under the auspices of the USDA/State cooperative pest management program in Comanche County, Texas and in 3 counties in Oklahoma in 1973. Lacewell and Casey (Appendix E of this report) evaluated one additional peanut pest management program in Texas, i.e., one started by private initiative in Frio County in 1971.

A workshop on peanut and tobacco pest management, sponsored jointly by the Cooperative Extension Service and Oklahoma State University, was held at Oklahoma City, Oklahoma in February of 1974. At this meeting, peanut and tobacco pest management strategies and tactics were discussed, including the progress in specific projects, use of remote sensing techniques, data collection and handling procedures, grower support, economic thresholds for insects, nematodes, and diseases of peanuts, and monitoring

for pesticides. The workshop proceedings include a brief progress report on the pest management project in Comanche County, Texas, for 1973 by Hines and Hoelscher (1974), and a very comprehensive, detailed report on Oklahoma's 1973 peanut pest management activities by Sturgeon et al. (1974).

TRENDS IN PEANUT PRODUCTION AND PESTICIDE USE

In the United States, peanuts were harvested for nuts on about 1.5 million acres in 1973. The geographic distribution of this peanut acreage was as follows: 269,000 acres in the Virginia-North Carolina area; 792,000 acres in the Southeast (including South Carolina, Georgia, Florida, Alabama, and Mississippi), and 435,000 acres in Oklahoma, Texas, and New Mexico. For the entire U.S., the average yield per acre of peanuts harvested in 1973 was 2,323 lbs. Farmers received an average price of $0.162/lb. Total U.S. peanut production in 1973 was about 3.5 billion lbs., worth about $560 million at the farm level, or about $375/acre (U.S. Department of Agriculture, 1974d).

The use of fungicides, insecticides and herbicides on peanuts in 1966 and 1971, and the U.S. peanut acreage in 1964, 1966 and 1971 are summarized in Table 6. Pesticide use data are available only for the years 1966 and 1971, from surveys of the quantities of pesticides used by farmers conducted by the U.S. Department of Agriculture for these years. In a similar USDA survey covering 1964, peanuts were not disaggregated, and farm pesticide uses have not been surveyed since 1971. No data on the quantities of nematicides used on peanuts are available for any of the years covered by the USDA farm pesticide use surveys.

The total U.S. peanut acreage increased slightly from 1964 to 1971, from about 1.4 million acres in 1964 to 1.46 million acres in 1971. In 1973, 1,496 million acres of peanuts were grown, an increase of about 7% over 1964 (USDA, 1974d).

The use of insecticides on peanuts increased slightly from 1966 to 1971, i.e., from 5.5 million lbs. of active ingredients (AI) in 1966 (3.9 lbs. AI/acre) to almost 6 million lbs. (4.1 lbs. AI/acre) in 1971.

Table 6 : U. S. Peanut Acreage and Use of Insecticides, Fungicides and Herbicides on Peanuts, 1964 - 1973

Year	1964	1966	1971
Peanut Acreage[1/] (1,000 Acres)	1,397	1,418	1,455
Pesticide Use on Peanuts			
Insecticides			
- Total (1,000 lbs. AI)	N.a.	5,529	5,993
- per Acre (lbs. AI)	N.a.	3.9	4.1
Fungicides[1/]			
- Total (1,000 lbs. AI)	N.a.	1,108	4,431
- per Acre (lbs. AI)	N.a.	0.8	3.1
Herbicides			
- Total (1,000 lbs. AI)	N.a.	2,899	4,374
- per Acre (lbs. AI)	N.a.	2.0	3.0
Nematicides	N.a.	N.a.	N.a.
Fungicides, Insecticides and Herbicides 1/			
- Total	N.a.	9,536	14,798
- per Acre	N.a.	6.7	10.2

1/ Acreage harvested for nuts

2/ Excl. sulfur

Sources: U. S. Department of Agriculture (1968b, 1968c, 1970, 1973a, 1974a)

The use of fungicides almost quadrupled from 1966 to 1971, i.e., from 1.1 million lbs. of active ingredients (0.8 lb. AI per acre) in 1966 to 4.4 million lbs. (3.1 lbs. AI/acre) in 1971.

The use of herbicides on peanuts increased by about 50% from 1966 to 1971, i.e., from 2.9 million lbs. of active ingredients (2.0 lbs. AI/acre) in 1966 to 4.4 million lbs. (3.0 lbs. AI/acre) in 1971.

The combined volume of fungicides, insecticides and herbicides used on peanuts amounted to 9.5 million lbs. of active ingredients (6.7 lbs. AI/acre) in 1966, increasing to 14.8 million lbs. (10.2 lbs. AI/acre) in 1971. These data indicate that the production of peanuts in the United States involves rather heavy annual inputs of chemical pesticides.

USERS, LOCATIONS, AND CHARACTERISTICS OF THE PROGRAMS STUDIED

In this project, 3 peanut pest management programs were studied. The location of these programs, superimposed on a dot-map of the U.S. peanut acreage harvested for nuts in 1969 (the latest year for which such dot-maps are available), are given in Figure 2.

Table 7 provides an overview of the characteristics, costs and benefits of the 3 peanut pest management programs evaluated in detail by Lacewell and Casey (Appendix E), including program location; objectives; starting year; area; acres, farms and fields in the program; number of scouts and scout loads; program costs; source of funds; and benefits obtained. The entries opposite "Ref(erence) Page" refer to the page numbers in Appendix E where these programs are described and analyzed in detail. The data in Table 7 pertain to the year 1973. For 2 of the 3 programs, this was the starting year. Important features of the 3 programs are as follows.

Frio County, Texas Program: This program was initiated in 1971 under the direction of the Frio County Peanut Improvement Association, with assistance from the Texas Agricultural Experiment Station and Extension Service. This program is focused on

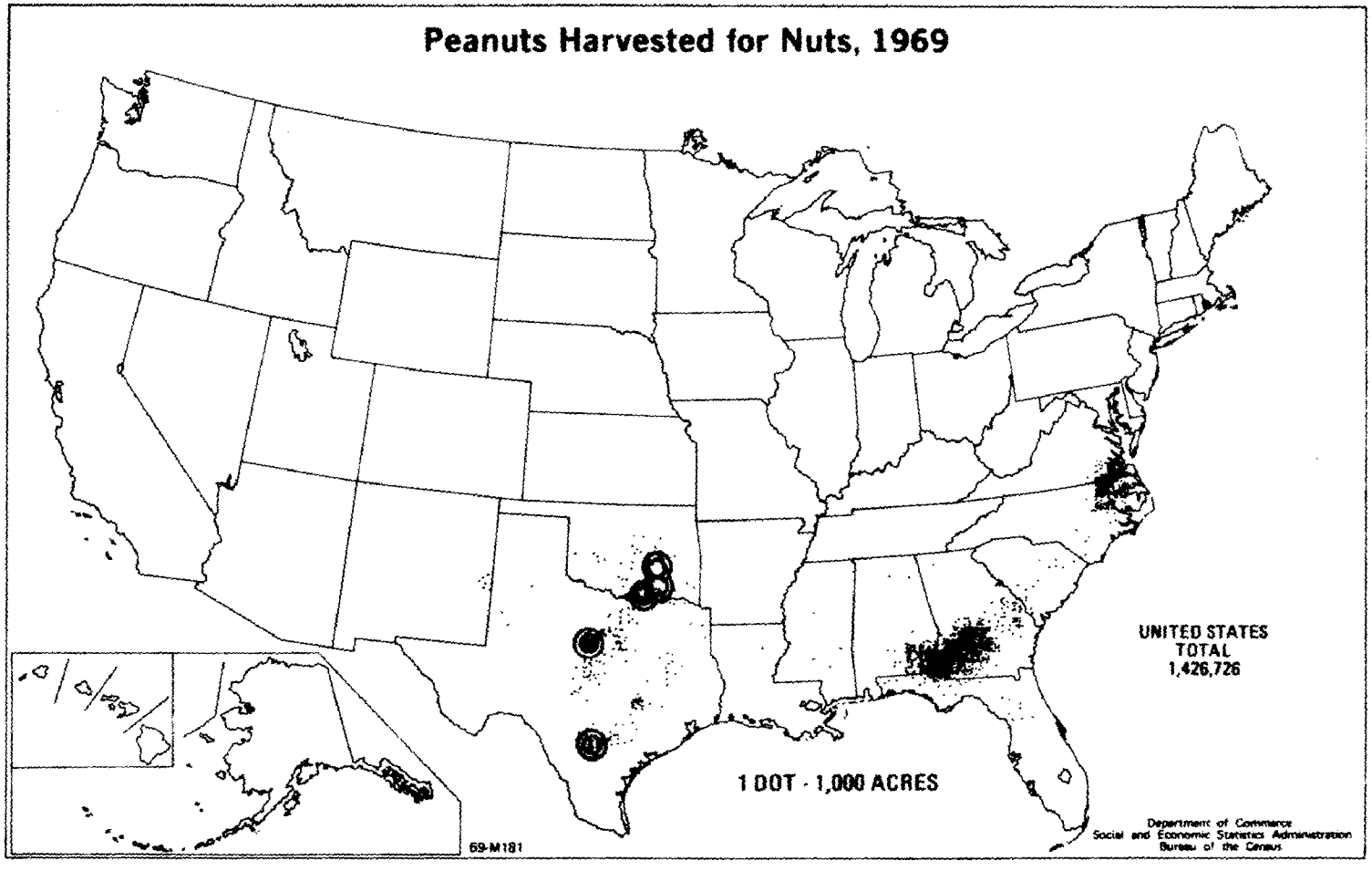

Figure 2: Locations of the Peanut Pest Management Programs Evaluated in this Report Relative to the Geographic Distribution of Peanut Acreage in the U.S.
(Program locations indicated by circles)

Table 7 : Characteristics, Costs and Benefits of 3 Peanut Pest Management Programs, 1973

Program Location	Frio County, Texas	Comanche County, Texas	Atoka, Hughes & Marshall Co., Okla.
Objective	Insect pest suppression	Insect pest suppression 3/	Plant health improvement
Ref. Page	E-3 to 18	E-19 to 38	E-39 to 56
Year started	1971	1973	1973
Area	1 County	1 County	3 Counties
Acres) in IPM	6,558	1,315	394
Farms) in IPM	23	33	8
Fields) in IPM		42	
# Scouts	4	3	1 team
Acres/Scout	1,640	435	
IPM Acreage Ratio	Abt. 30% of peanut acres in the county	Abt. 2% of peanut acres in the County	40% of peanut acreage of particip'g farms
Pest Management Costs, $	Entire program 2/	Entire program	Entire program
Scouts	6,558	2,686	1,500
Scout Travel		879	
Extension Service	765	20,187	5,600
Professional Support	459	13,000	8,100
Other 1/	100	3,381	5,800
Total	7,882 (1.20/acre)	40,133 (28.77/acre 4/)	21,000 (53.16/acre)
Source of Funds, $			
Grower Funds	6,558 (1.00/acre)	300 (0.25/acre)	-
State Funds	1,324 (0.20/acre)	26,850	8,600
Federal Funds	-	10,683	12,400
		2,300 5/	
Benefits:			
Yield Quantity	No change	+ 9.0 to 29.0%	- 25.3 to + 92.2%
Yield Quality	+ 19.0%	No data	No data
Pesticide Use	- 50.0%	No data	- 80.6 to + 177.8%
Production Cost	- 1.5%	No data	- 43.5 to + 47.8%
Profit	+ 3.0 to 15.0%	+ 3.0 to 133.0%	- 18.0 to + 144.0%

1/ Incl. clerical, supplies, equipment, adm. overhead, etc.
2/ Insect pests only
3/ Program objectives included monitoring plant diseases, nematodes, weeds, and soil fertility
4/ Based on total of $40,133 less $2,300 implementation funds = $37,833 : 1,315 acres
5/ Implementation funds

control of the burrowing bug, Pangaeus bilineatus, an insect that first became economically important in this part of Texas in about 1968. Burrowing bugs pierce the peanut hull and feed on kernels, causing yellow to dark spots on the kernel that are termed "pitting" by peanut graders. This damage reduces peanut quality, and penalties are assessed to producers by peanut buyers, based on the percent of kernels damaged. Such penalties for pitted peanuts can range from $3.40 per ton for 2% damaged kernels to $100 per ton for 10% damaged kernels. In 1970, Frio County peanut producers' collective revenue losses due to burrowing bug damage was about $122,000. These losses occurred almost entirely from peanut quality reduction as the burrowing bug does not significantly affect peanut yields.

When the burrowing bug first became a problem, peanut producers in Frio County reacted by heavy insecticide use. Results were unsatisfactory, and problems from secondary pests began to appear. This prompted the Frio County Peanut Improvement Association to seek help from the Texas Agricultural Experiment Station after the 1970 growing season. The pest management program evaluated by Lacewell and Casey was initiated jointly by the peanut growers and the Texas Agricultural Experiment Station and the Texas Agricultural Extension Service in 1971. In 1973, the program covered 6,558 acres on 23 farms and employed 4 scouts. The average workload was 1,640 acres per scout.

Comanche County, Texas Program: This program was initiated in 1973. Its prime objective is control of the lesser cornstalk borer (Elasmopalpus lignosellus), an insect that can reduce peanut yields by 50% or more. Peanut producers' efforts to control this insect in the late 1960's and early 1970's were reaching the point of routine insecticide applications at regular intervals, primarily by aircraft. Intervals between applications were being reduced and quantities of insecticides applied increased, but insect control remained unsatisfactory. The Texas Agricultural Experiment Station and Agricultural Extension Service began working with producers in this area by providing more specific

recommendations on appropriate insecticides, application methods, and timing of applications. In 1973, a pilot peanut pest management project was initiated in Comanche County under the auspices of the USDA/State cooperative program. In addition to providing regular insect surveys, program objectives include monitoring plant diseases, nematodes, weeds, and soil fertility.

In 1973, its start-up year, this program included 1,315 acres (about 2% of the total peanut acreage in the county), divided into 42 fields on 33 farms. Three scouts were employed. The average scouting workload was 435 acres per scout.

Oklahoma Program: In Oklahoma, peanuts are an important crop in many counties. Oklahoma peanut producers have experienced a variety of pest problems over the years, including most of the peanut insects, diseases, nematodes and weeds mentioned above (p. 76). An organized pest management program on peanuts was conducted in Oklahoma for the first time in 1973, supported in part by USDA funds. Due to late approval of the State plans, the program had a late and hasty start. It was largely a demonstration porgram, with opportunity to gain experience in operational problems such as obtaining grower support, scout workloads, integration of disciplinary inputs, etc. In 1973, 394 acres on 8 farms, located in 3 different counties, were in the program. One scout team conducted all field survey work.

PROGRAM COSTS

Some cost data are available for each of the 3 peanut pest management programs evaluated in this study. However, since 2 of the 3 programs (Comanche County, Texas, and the Oklahoma program) were initiated only in 1973, the first-year operating costs of these programs probably included substantial non-recurring start-up expenses.

Frio County, Texas: Implementation costs of this program are estimated by Lacewell and Casey at $2,109, (p. E 8-9), consisting of $1,497 for salary and travel expenses of an entomologist surveying the problem, and $612 for scout training. These funds were provided by the Texas Agricultural Extension Service

($1,344) and the Texas Agricultural Experiment Station ($765).

The operating costs of the Frio County program by years, cost elements and source of funds are detailed by Lacewell and Casey (p. E-11, Table E-4). In 1973 (Table 7 , p. 81), these costs totaled $7,882, equivalent to $1.20/acre. Growers contributed $6,558 ($1.00/acre) while the balance, $1,324 was contributed by the Texas Agricultural Extension Service ($865) and the Texas Agricultural Experiment Station ($459).

Comanche County, Texas: In this program, implementation cost elements include mapping, grower contacts, recruiting, scout training, data handling and processing, area delineation, and procedure development. The Texas Agricultural Extension Service contributed $9,950; the Texas Agricultural Experiment Station $5,000, the balance of $2,300 came from USDA cooperative funds.

Total operating costs of this program in 1973 were $40,133, equivalent to $28.77/acre for the 1,315 acres in the program (not including in the total costs $2,300 federal implementation funds). This cost is obviously excessively high on a per-acre basis, even considering the fact that the program was not limited to insect management, but included in its objectives monitoring of plant diseases, nematodes, weeds, and soil fertility. Additional years' experience will be required to determine if program costs can be brought into an economically attractive relationship to program benefits. The program was increased from 1,315 acres in 1973 to 2,800 acres in 1974, with a goal of 7,000 acres for 1975. Participating growers' contributions were increased from $0.25 per acre in 1973 to $1.00/acre in 1974. These are encouraging signs. Participating growers have indicated that in the future, they would be willing to pay all scouting costs up to $3.50 per acre.

Oklahoma: For the Oklahoma program, specific implementation costs are not available. Lacewell and Casey (p. E-48) suggest that implementation costs experienced in Comanche County, Texas ($17,250) may be relevant to the Oklahoma program.

Operating costs for the Oklahoma program by expense items and by sources of funds are detailed by Lacewell and Casey

(p. E-49, Table E-17) and summarized in Table 7 (p. 81). The total operation costs of $41,000 include $20,000 for "field support". This amount was provided by the Hughes County Peanut Growers, for support of the Hughes County demonstration farm. This sum is not included in Table 7 . Assuming that $21,000 were spent to operate the scouting activities of the Oklahoma program, the resulting cost for the 395 acres in the program amounts to $53.16/acre. These costs are, obviously, completely beyond the realm of economic feasibility. It must be remembered that for this program also, 1973 was the start-up year. Program principals in Oklahoma are aware of several opportunities for greater efficiency and economy of the program which will be implemented in subsequent years.

In summary, this report provides implementation cost data for 2 peanut pest management programs (Frio County, Texas, p. E-10) and Comanche County, Texas (p. E-29); 4-year operating cost data for 1 program (Frio County, p. E-11); and first-year operating costs for the remaining 2 programs, i.e., Comanche County (p. E-31) and the Oklahoma program (p. E-49).

Implementation costs were estimated at $2,109 for the Frio County, and at $17,250 for the Comanche County programs.

The operating costs in Frio County (providing insect management only) average about $1.20/acre. First-year costs in the Comanche County program were $28.77/acre, in the Oklahoma program, $53.16/acre. It is emphasized that both of the latter programs were initiated in 1973, the only complete year for which operating cost data are currently available. In addition, both of these programs include not only insect problems, but cover plant diseases, nematodes, weeds, soil fertility, and general plant health problems.

PROGRAM EFFECTIVENESS

The effectiveness of the peanut pest management programs studied was measured by the following criteria:

-- Yield quantity,
-- Yield quality,
-- Pesticide use,
-- Production costs,
-- Profit to growers.

Quantification of these parameters for the programs evaluated is difficult because none of the programs provided in their design for adequate, let alone rigorous economic evaluation.

Effects on yield

Frio County, Texas: As outlined above, this program was initiated by producers for the purpose of obtaining relief from the burrowing bug, an insect that had developed into a key problem, causing substantial peanut quality reductions. In the absence of other pertinent data, Lacewell and Casey (p. E-14) compared the quantities of peanuts damaged by the burrowing bug and the resulting losses in producer revenues for Frio County for 1970, the last year prior to initiation of the pest management program, to the years 1971, 1972, 1973 and 1974 in which the program was in operation. This type of comparison, as the authors point out, does not take into account variations in burrowing bug populations from year to year, nor losses due to other factors such as water shortage, weeds, fertilization, etc., and tends to exaggerate program benefits in light infestation years. In 1970, there were 9,020,000 lbs. of peanuts damaged, costing producers $121,700 in lost revenues. In 1971, these losses were reduced by about 90%. There were only minimal peanut quality losses in 1972, and none in 1973 or 1974.

Lacewell and Casey concluded that in 1973, the program resulted in a 19% increase in peanut quality. There were no effects on the quantities of peanuts harvested as compared to non-participants.

Comanche County, Texas: In this program, there were likewise no "control groups" available for measuring the effectiveness of

the pest management program for participating growers. Lacewell and Casey compared the peanut yields of participating producers in 1973 to their own 1971-1972 average yields, and to the County average for 1973. On this basis, the average yield for participating producers, on irrigated as well as on nonirrigated fields, exceeded both their own yields for 1971-1972, and the County average yields for 1973 (p. E-27, Table E-9). Participating growers' yield increases ranged from 9 - 29% (Table 7 , p. 81). Peanut quality was not at issue in the Comanche County program because the key insect in this area, the lesser cornstalk borer, affects yield quantity, but not quality.

Oklahoma program: In this program, yield quantity and quality were recorded for growers participating in the program, separated by irrigated and nonirrigated fields. However, there are no comparable data for non-participating growers. Thus, an assessment of the effects of the program on peanut yields (quantity or quality) of participating growers is not possible.

The 1973 Oklhaoma program also included a field demonstration test in Hughes County, established to evaluate and compare various chemical and cultural practices. Four different management strategies designated as A, B, C, and D were compared. Management level A applied chemical pesticides recommended for the area regardless of need. Management level B-plots received pesticide treatments only when control was needed as indicated by periodic field surveys, with emphasis on minimal pesticide use. Management level C was designed to represent practices considered typical for area peanut producers. Management level D received little or no pesticide applications. Yields and returns per acre from these different management strategies were as follows (from Sturgeon et al., 1974, as discussed by Lacewell and Casey, p. E-47, Table E-16, of this report):

Management strategy	Yield, lbs.per acre	Grade, %	Gross returns, $/A	Total cost, $/A	Net returns $/A
A	4,370	67	684	275	410
B	2,746	68	432	187	245
C	2,274	66	354	186	168
D	1,697	59	243	105	138

Management strategy A incurred the highest production costs, but was clearly superior to the other 3 strategies in regard to yield, and gross and net returns. These results are difficult to interpret because this strategy involved not only higher inputs of chemical pesticides, especially for insect and nematode control, but also use of one additional fertilizer application, and of a growth regulator. The additional fertilizer application as well as the growth regulator application were omitted in plots B, C. and D.

The program benefit data for the Oklahoma program provided by Lacewell and Casey and included in Table 7 are based on comparing the effects of management levels A, B and D to level C.

In summary, the data presented in greater detail by Lacewell and Casey in Appendix E of this report indicate that one of the three peanut pest management programs evaluated (Frio County, Texas) did not change peanut yield quantity, but increased quality by 19% by reducing insect damage. The Comanche County, Texas program increased peanut yield quantity by 9-29%, but did not affect quality. Data available on the Oklahoma program on 8 farms are not adequate for evaluation of program effects on peanut yield quantity or quality. In a demonstration plot, different pest management and cultural strategies affected peanut yield changes from - 25.3 to + 92.2%.

Effects on pesticide use

Pesticide use data available for the 3 peanut pest management programs evaluated are incomplete, but some program effects are evident.

Frio County, Texas: In this program the quantities of pre-emergence and postemergence insecticides used by participating peanut producers declined from 3.12 lbs. AI/acre in 1971, the first year of the program, to 2.44 lbs. AI/acre in 1972, and to 0.97 lbs. AI/acre in 1973, then re-increased slightly to 1.37 lbs. AI/acre in 1974. There are no comparable data on participating producers' insecticide use practices prior to 1971, nor on the quantities of insecticides used by non-participating producers during the period 1971-1974. Lacewell and Casey point out that burrowing bug infestations in Frio County were heavy in 1971 and 1972, while 1973 and 1974 were light infestation years. Therefore, the marked reduction in the use of insecticides in 1973 and 1974 cannot be entirely attributed to the effects of the pest management program. Nevertheless, Lacewell and Casey believe that the program contributed to reduced (- 50%) and more efficient use of insecticides (p. E-16).

There are no data on the kinds and amounts of pesticides other than insecticides used in Frio County by participating or non-participating peanut producers.

Comanche County, Texas: In this program, quantities of insecticides, herbicides, nematicides, and fungicides used by participating growers were recorded. However, there are no comparable data for non-participating producers. Based on pesticide use patterns in previous seasons, Lacewell and Casey perceive "some indication (that) producers are more effectively using pesticides", but a more definite statement regarding the effects of this program on pesticide use cannot be made (p. E-34).

Oklahoma: In this program, pesticide uses were recorded for the 8 participating growers, but again, no comparable data for non-participating producers are available. In the Hughes County demonstration plots, pesticide inputs varied from -80.6 to

+177.8% of typical local practice. Results indicate that increased pesticide inputs could substantially increase peanut yields. However, as pointed out above, the increased yields and returns in the high pesticide-use plots may have been due, at least in part, to the application of a growth regulator and/or an increased fertilizer rate.

In summary, one of the three peanut pest management programs reviewed resulted in decreased pesticide use. There are no adequate data for a meaningful evaluation for the other two programs studied. Field test plot results indicate that in one area in Oklahoma, current pesticide use levels may be suboptimal, and that increased pesticide use would increase peanut yields.

Effects on production costs

Production costs can be affected in several ways by pest management programs. They could be increased by the cost of the program, decreased by savings in pesticide inputs, or affected in either direction by combinations of these factors.

Complete, detailed production cost records are not available for any of the peanut pest management programs studied, with exception of the demonstration plots in Hughes County, Oklahoma, in 1973 (see p. A-21). In comparison to local conventional practice ("Management Strategy C"), different other management strategies caused changes in total production costs ranging from - 43.5 to +47.8%.

In the Frio County, Texas program, participating producers' production costs decreased slightly (-1.5%) due to decreased insecticide inputs.

No adequate production cost data are available for the Comanche County, Texas program.

Effects on growers' profits

From the peanut producers' standpoint, profit is undoubtedly the most important indicator of the degree of success of pest management programs.

Frio County, Texas: The pest management program resulted in improved peanut quality, decreased use of insecticides, decreased production costs, and a net increase in growers' collective profits estimated by Lacewell and Casey at over $60,000 per year on the average. In years of high burrowing bug infestations, benefits of the program are estimated at $120,000 or more.

Comanche County, Texas: Average peanut yields for a sample of participating growers were compared to a comparable sample of non-participating growers. There were 5 growers using irrigation, and 5 growers not using irrigation in each sample. The average yield per acre for participating producers was 1,917 lbs., worth $268.38. Non-participating growers' yield average was 1,835 lbs. per acre, worth $256.90. Thus, participating producers had an average yield increase of 82 lbs. of peanuts per acre, worth $11.48. Program participants contributed only $0.25/acre toward the cost of this program.

Oklahoma: Data available are not adequate for estimating the effects of the program on the net returns of the 8 growers participating in the team monitoring program. Observations from the demonstration plots in Hughes County indicate highest net returns ($410/acre, see p. E-47) from the highest level of pesticide use. The application of pesticides as needed, based on pest infestation monitoring, produced a net return of only $245/acre. However, as pointed out above, measures other than pesticide inputs may be responsible in whole or in part for the high return experienced at the highest level of pesticide use in this instance.

In summary, net profits of peanut growers participating in pest management programs increased in the two programs for which some data are available for evaluation. In one of these programs (Frio County, Texas), growers' increased profits, based on 4-year averages, ranged from 3 to 15% and exceeded the full costs of the pest management program several times. In the other two programs (Comanche County, Texas, and Oklahoma), program costs in 1973, the first year of operation of both programs, were excessively high

($28.77 and $53.16/acre, respectively, see Table 7), but were largely or entirely paid for from public funds. Net profit changes ranged from + 3 to +133% in the Comanche County, Texas program, and from - 18.0 to + 144% in the Oklahoma demonstration program.

TOBACCO PEST MANAGEMENT PROGRAMS

BACKGROUND

Tobacco is attacked by a number of different pests. Important insect pests of tobacco in the U.S. include the tobacco budworm, *Heliothis virescens*, and the tobacco hornworm, *Manduca sexta*. Tobacco budworms inflict damage on tobacco primarily by larval feeding in the terminal vegetative parts of tobacco early in the growing season. Tobacco hornworms, especially the last of the five larval stages of this insect, feed on tobacco leaves; they are capable of completely defoliating tobacco plants.

Plant diseases affecting tobacco include brown spot, *Alternaria longipes*; black shank, *Phytophthora parasitica* var. *nicotianae*; and mosaic, a virus disease. Several species of nematodes and weeds may interfere with production. In addition, chemical plant growth regulators are used extensively on tobacco for "sucker control". Suckers are shoots developing from adventitious buds in leaf axils which, if allowed to grow, would produce foliage and flowers of no commercial value and would thus prevent maximum production of marketable tobacco leaves. Chemical plant growth regulators have been developed to control sucker growth.

An excellent discussion of tobacco pests, of their interactions with plant growth regulators and other production factors, and of scientific approaches to their management has recently been presented by Rabb et al. (1974).

As in the case of peanuts, commercial tobacco growers in the U.S. have practiced pest management to a greater or lesser degree for many years, without specific scientific guidance and before the term as such became known.

TRENDS IN TOBACCO PRODUCTION AND PESTICIDE USE

In 1973, about 890,000 acres of tobacco were grown in the U.S. Average yield per acre was 2,011 lbs. Growers received an average price of $0.897/lb. The total U.S. tobacco production in 1973 was about 1.8 billion lbs., worth about $1.6 billion at the

farm level, or about $1,800/acre (U.S. Department of Agriculture 1973b).

The quantities of pesticides (insecticides, fumigants, fungicides, growth regulators) used on tobacco in 1964, 1966 and 1971, according to the USDA surveys for these years, and the U.S. tobacco acreage for the same years are summarized in Table 8. Pesticide use data are available for 1964, 1966, and 1971 for insecticides, fumigants, and growth regulators, and for fungicides only for 1964. No disaggregate data on the use of herbicides on tobacco are included in any of the USDA surveys of the quantities of pesticides used by U.S. farmers.

The total U.S. tobacco acreage ranged from 1,078,000 acres in 1964 to 838,000 acres in 1971. It comprised 892,000 acres in 1973 (U.S. Department of Agriculture, 1974c).

The total quantity of insecticides used on tobacco was about 5 million lbs. of active ingredients (AI) in 1964, and about 4 million lbs. in 1971. On a per-acre basis, use of insecticides on tobacco ranged from a low of 3.9 lbs. in 1966 to 4.8 lbs. in 1971.

The data on the use of fumigants on tobacco included in Table 8 may be misleading because between 1964 and 1971, the USDA changed its procedures. In the earlier years, space and soil fumigants were not separated. In recent years, there has been a trend to greater use of broadcast soil fumigants on tobacco which is not reflected in the USDA data reported in Table 8, probably due to the fact that space fumigants were included in the earlier figures but not in those for 1971 (Good, 1974a).

Because of these problems, fumigants and fungicides have not been included in the totals and averages at the bottom of Table 8, and the data on the use of fumigants on tobacco appear to be of limited usefulness and should not be over-interpreted.

The use of growth regulators on tobacco increased greatly from 1964 to 1971. The total quantity of growth regulators applied to tobacco doubled during this period, from 2.5 million lbs. AI in 1964 to almost 5 million lbs. in 1971. On an area basis, plant

Table 8: U.S. Tobacco Acreage and Use of Pesticides on Tobacco, 1964 - 1971

Year	1964	1966	1971
Tobacco Acreage[1/] (1,000 Acres)	1,078	972	838
Pesticide Use on Tobacco:			
Insecticides[2/]			
- Total (1,000 lbs. AI)	4,997	3,791	3,999
- per Acre (lbs. AI)	4.6	3.9	4.8
Fumigants			
- Total (1,000 lbs. AI)	15,066	10,334	4,429
- per Acre (lbs. AI)	14.0	10.6	5.3
Growth Regulators			
- Total (1,000 lbs. AI)	2,484	3,058	4,978
- per Acre (lbs. AI)	2.3	3.2	5.9
Fungicides			
- Total (1,000 lbs. AI)	2,359	N.a.	N.a.
- per Acre (lbs. AI)	2.2	N.a.	N.a.
Herbicides	N.a.	N.a.	N.a.
Total, Insecticides and Growth Reg.'s			
- Total (1,000 lbs. AI)	7,481	6,849	8,977
- per Acre (lbs. AI)	6.9	7.0	10.7

1/ All types of tobacco

2/ Excl. petroleum

Source: U.S. Department of Agriculture (1968c, 1968b, 1970, 1973a, 1973b, 1974a)

growth regulator use increased by more than 150%, from 2.3 lbs. AI/acre in 1964 to 5.9 lbs./acre in 1971.

The combined volume of tobacco insecticides and growth regulators increased from about 7.5 million lbs. AI in 1964 to 9.0 million lbs. in 1971. This increase is due primarily to the increased use of growth regulators. On an area basis, the use of insecticides and growth regulators combined amounted to 6.9, 7.0 and 10.7 lbs. AI/acre in 1964, 1966 and 1971, respectively.

USERS, LOCATIONS AND CHARACTERISTICS OF THE PROGRAMS STUDIED

Figure 3 presents an overview of the geographical distribution of the U.S. tobacco acreage in 1969 by way of a dot-map (1969 is the latest year for which such dot-maps are available). The total U.S. tobacco acreage in 1969 was 877,000 acres, relatively close to the 892,000 acres grown in 1973. Tobacco production statistics indicate that the geographical distribution of tobacco in the U.S. per Figure 3 is still representative for 1973.

North Carolina is the leading tobacco-producing state in the U.S. with about 375,000 acres, that is more than 40% of the U.S. total.

North Carolina appears to be the only state in which an organized tobacco pest management program meeting the criteria set forth in the introduction to this report is currently in operation. The locations of North Carolina's 3 major tobacco pest management programs are indicated by circles in Figure 3 .

North Carolina's tobacco pest management program was one of the two "pilot pest management projects" initiated in 1971 with support from the USDA/State cooperative program.

Table 9 summarizes the characteristics, costs and benefits of the North Carolina tobacco pest management program for the three years for which data are available, 1971-1973, based on Carlson and Cooper's more detailed description and analysis in Appendix F of this report.

In 1971 and 1972, the program was operated in 5 counties, expanding to 10 counties in 1973. It included:

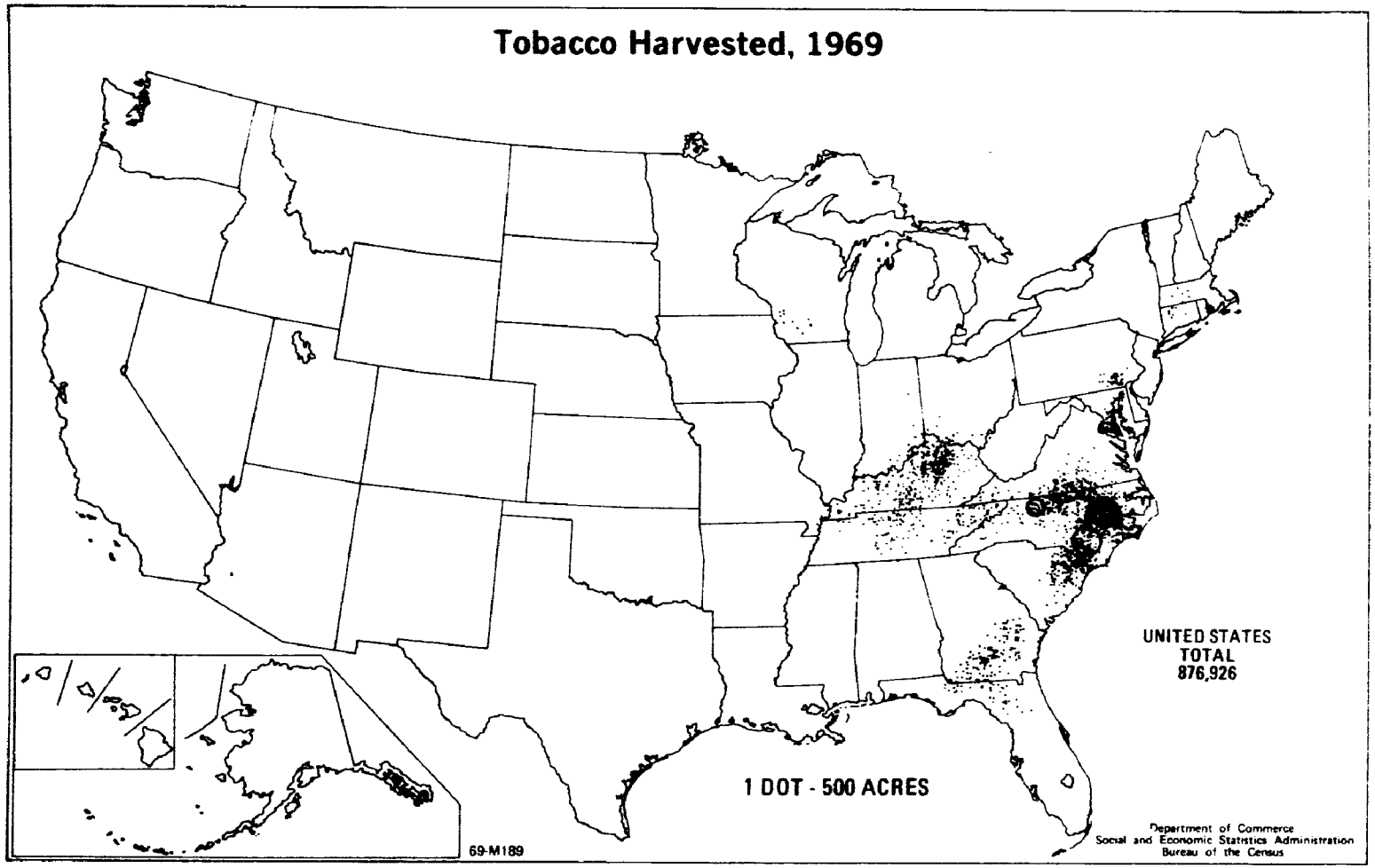

Figure 3 : Locations of the Tobacco Pest Management Programs Evaluated in this Report Relative to the Geographic Distribution of Tobacco Acreage in the U.S. (Program locations indicated by circles).

Table 9: Characteristics, Costs and Benefits of the North Carolina Tobacco Pest Management Programs, 1971 - 1973

Program Location	3 areas in North Carolina		
Objective	Insect pest suppression		
Year started	1971		
Year	1971	1972	1973
Area	5 Counties	5 Counties	10 Counties
Acres) in IPM	8,032	8,498	11,350
Farms) in IPM	1,531	1,680	813
Fields) in IPM	3,076	3,339	3,448
# Scouts	37	39	33
Farms/Scout	41.2	43.1	24.6
Fields/Scout	83.1	85.6	104.5
Acres/Scout	217.1	217.9	343.9
Sites/Field	5	5	4
Insect Management Costs, $	per Acre	per Acre	per Acre
Scouts	5.49	5.33	3.94
Scout Travel	1.03	0.81	0.76
Scout Supv.	N.a.	1.47	1.38
Co. Agents	N.a.	1.32	1.32
Prof. Support	N.a.	3.75	3.44
Other 1/	N.a.	5.12	6.29
Subtotal	14.91	17.80	17.13
Insecticides	3.25	2.12	2.18
Application	5.52	3.61	4.37
Total	23.68	23.53	23.68
Source of Funds:			
Scouting Program	Public funds	Public funds	Public funds
Insecticides & Appl.	Grower funds	Grower funds	Grower funds
Benefits:			
Yield	No change	No change	No change
Insecticide Use	- 22.5%	- 43.5%	- 29.0%
Production Costs	- $2.51/acre 2/	- $5.55/acre 2/	- $4.73/acre 2/
Profit	+ $2.51/acre 2/	+ $5.55/acre 2/	+ $4.73/acre 2/

1/ Incl. clerical, data processing, env. monitoring, ongoing research, regulatory personnel, supplies, insect identification, and Exp. Sta. & Extension administration.

2/ Due to reduced use of insecticides, disregarding scouting costs.
Program participants did not contribute to the scouting costs which, if they had to be borne by growers entirely, would more than offset the savings in costs of insecticides and their application.

8,032	acres	in	3,076	fields	and	1,531	farms	in 1971
8,498	acres	in	3,339	fields	and	1,680	farms	in 1972
11,350	acres	in	3,448	fields	and	813	farms	in 1973

Thirty-seven scouts were employed in 1971, 39 in 1972, and 33 in 1973.

When the program was expanded to 5 additional counties and to a total of 11,350 acres in 1973, the number of fields increased only slightly to 3,448, and the number of participating farms decreased by about 50%. Thus, there were considerably more acres per field and per farm in the program in 1973 as compared to the first two years. At the same time, the number of sites sampled per field was reduced from 5 in 1971 and 1972 to 4 in 1973. These changes resulted in considerable improvements in scouting efficiency in 1973. Only 33 scouts were employed in 1973.

PROGRAM COSTS

Public and farm costs of the North Carolina tobacco pest management program were analyzed in detail by Carlson and Cooper (p. F-22 to F-39). These costs are summarized on a per-acre basis in Table 9 . No breakdown of implementation vs. ongoing operating costs is available for this program.

Scouting costs per acre (including scout salaries and travel) decreased from $6.52 in 1971 to $6.14 in 1972, and to $4.70 in 1973, even though scout wage rates rose from $2.48/hour in 1971 to $2.76 per hour in 1973. Changes in the work accomplished per hour were thought to have caused this reduction in scouting costs. A detailed mathematical analysis of all scouting cost elements by Carlson and Cooper indicates that the size of program farm is related to travel expenses; on large farms, scouts have to drive greater distances to cover all fields. It is further believed that significant decreases in total scouting costs were obtained by paying scouts by a "piece rate" incentive scheme, instead of by the hour. Additional program cost savings in 1973 as compared to the preceding years were realized by reducing the number of sites per field from 5 to 4, and by counting pests only when the crop was at the most susceptible stage of growth. These program changes all

contributed to reducing the time spent per field.

While the per-acre cost for scouting decreased substantially from 1972 to 1973 (Table 9 , p. 98 ; Table 3.5 p. F-28), program costs for clerical and data processing services, and for ongoing research, regulatory personnel, supplies, insect collection and identification, and experiment station and extension administration increased from 1972 to 1973, offsetting most of the savings in the scouting costs. Thus, total program costs decreased by only $0.67 per acre from 1972 to 1973. If participating growers' costs for insecticides and application are added to the program costs, total insect management costs for program participants varied very little between the 3 program years.

For each of the 3 program years, scouting costs alone were higher than the savings in costs of insecticides and application realized by program participants, as discussed in greater detail below, p. 102-103.

PROGRAM EFFECTIVENESS

From 1971 - 1973, the North Carolina tobacco pest management program focused primarily on the 2 major foliar insect pests of tobacco, the tobacco hornworm and the tobacco budworm. In fact, it called itself an insect pest management program (Ellis, 1974). Program objectives included maximum natural suppression of budworms and hornworms by beneficial species; application of selective insecticides only as needed, as determined by weekly scouting; effective sucker control as an aid to suppressing the hornworm; and early stalk destruction to suppress overwintering pests and diseases. These objectives were designed primarily to reduce unnecessary insecticide use and, thereby, save growers production costs and increase their profits without loss in tobacco yield or quality (Carlson and Cooper, p. F-2).

The effectiveness of the North Carolina tobacco pest management program was measured by several criteria, including yield quantity and quality, pesticide use, production costs, and profit to growers. In addition to these parameters, Carlson and Cooper provide data on the abundance of pest and beneficial insects by

years and pest management program areas (p. F-9, Table 2.3), and on timeliness of stalk destruction (p. F-19, 20). These authors rejected the degree of pest management acceptance as measured by percent of acreage scouted in a county as a useful benefit indicator, pointing out that acceptance due to program benefits is difficult to distinguish from acceptance due to project "salesmanship".

As with most other pest management programs studied, the design of the North Carolina tobacco program did not include provision for measuring program effects in comparison to suitable non-program "control groups".

Effects on yield

The program did not include yield quantity or quality improvement among its objectives. Carlson and Cooper made a comprehensive study, involving 4 counties in the program, in an attempt to isolate possible program-related effects on tobacco yields (p. F-14 ff.). Random samples of 50 farms in the program and 50 farms not in the program were taken from County Agricultural Stabilization and Conservation Service (ASCS) records in Wilson, Columbus, Bladen, and Cumberland Counties for the years 1969 through 1973. Four types of yield differences were tested for each county, i.e., (1) years before the program for non-program farms compared to program farms; (2) years during the program for non-program farms compared to program farms; (3) non-program farms, years before the program compared to years during the program; and (4) program farms, years before the program compared to years during the program.

In a further effort to identify any program effects on tobacco yields, another set of tests was made involving Wilson, Bladen and Columbus Counties. For each county, yields for the years before the program were compared to yields for each year during the program for program and non-program farms.

The results of the two tests were in good agreement with one another, indicating that the North Carolina tobacco pest management program had no significant positive (or negative) effects on tobacco yields.

Effects on pesticide use

Carlson and Cooper (p. F-31 ff., Table 3.8) report the number of insecticide applications, and pounds of insecticides applied per acre per year for participating farms by counties for 1971, 1972, and 1973. In each of the 3 years, the program means were substantially below the USDA estimates for all North Carolina tobacco farms in 1971. For instance, unpublished 1971 USDA survey data indicate that the average use of insecticides in Surry County was 2.03 lbs. per acre, that is 4.6 times the quantity used in the same county in 1971 by program participants. As summarized in Table 9 , Carlson and Cooper concluded that the program reduced insecticide inputs by 22.5% in 1971, 43.5% in 1972, and 29.0% in 1973 (3 year average = - 31.7%).

Quantities of other pesticides (fumigants, fungicides, herbicides, growth regulators) used on tobacco were apparently not studied or recorded in the North Carolina tobacco pest management program and consequently, no information is available on the effects (if any) of the program on inputs of pesticides other than insecticides.

In summary, the program resulted in a decrease in the use of insecticides in each of the 3 program years for which data are available at this time. Reductions in insecticide inputs ranged from 22.5 to43.5%; the 3-year average reduction was 31.7%.

Effects on production costs

Detailed production cost records are not available for the North Carolina tobacco pest management program. According to Carlson and Cooper (p. F-27 ff., Table 3.6), the estimated cost of insecticides plus application for all tobacco farms in North Carolina was $11.28/acre in 1971. The same cost for pest management program farms in 1971 was estimated at $8.77/acre, indicating a cost saving of $2.51/acre for program farms. If the insect control costs for non-program growers were the same in 1972 and 1973 as in 1971, cost savings for program participants would have been $5.55/acre in 1972 and $4.73 per acre in 1973. However, partici-

pating growers did not contribute any funds to the cost of the pest management program.

In each of the 3 program years, the cost of scouting (scout salaries and travel expenses) alone exceeded the monetary value of the insecticide and application costs saved, even though significant increases in scouting efficiency and decreases in scouting costs were achieved in 1973, as outlined above (p. 99 and Table 9 , p. 98), and in greater detail by Carlson and Cooper (p. F-22 ff., Tables F-3.4, 3.5). If growers had had to bear the entire cost of the pest management program, their production costs would have increased substantially in comparison to non-program growers.

Effects on growers' profits

Tobacco growers participating in the North Carolina pest management program experienced, on the average, a small profit increase due to savings in insecticides and application, ranging from $2.51 to $5.55/acre (3-year average = $4.26/acre). However, as pointed out above, they did not contribute to the scouting costs. Scouting costs alone, disregarding other program cost elements, more than offset the savings in costs of insecticides and application.

Thus, one has to conclude that it probably would be difficult to promote this program on a voluntary basis. To save about $4 - 5/acre, partially or totally offset by program costs, would not be attractive for tobacco growers. In addition, county agents would be reluctant to spend time on a program that has no yield or quality improvement objectives.

Effects on tobacco sucker control and stalk destruction

Promotion of effective sucker control through properly timed application of chemical growth regulators was included among the prime objectives of North Carolina tobacco pest management program. Program effects on stalk destruction are discussed by Carlson and Cooper (p. F-19, 20). Early stalk destruction

reduces overwintering populations of tobacco hornworms and budworms by eliminating the food sources for these insect pests when they are entering diapause. The degree of properly timed stalk destruction during 1971-1973 left much to be desired, but the program appears to have contributed significant improvements. For instance, in Wayne and Wilson Counties, approximately 98% of harvested tobacco fields contained undestroyed stalks by the end of August in 1971. In 1972, only about 35% of the fields contained undestroyed stalks at the same time, but in 1973, the percentage of fields with undestroyed stalks went back up to 55%. In Columbus and Bladen Counties, there was significant improvement in stalk reduction between 1971 and 1972, but no further improvement from 1972 to 1973.

The requirements for the timing of stalk removal vary, depending upon the pest or disease that is to be suppressed. However, quantitative data on the effects of stalk destruction, and thus evidence with which to convince growers, appears to be lacking (p. F-20).

In summary, the program appears to have resulted in some improvements in stalk destruction timing.

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