CROP LOSS MODELING AND RESEARCH RESOURCE ALLOCATION

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1. INTRODUCTION

The process of allocating resources for research has been approached both formally and informally, with proponents and antagonists of either view. However, what is more at issue is probably not the formality or informality of the approach, but rather whether it realistically reflects research needs. Too often, research resource allocation has not recognized an important component of the process - the researcher - and what he/she is able to contribute to overall policy goals. Similarly, in agriculture, the needs, perceptions and problems of farmers are seldom explicitly built into the planning process. Ruttan (1982) partly addresses the above points when he posed two questions to be addressed by any research resource allocation system:

(i) What are the possibilities of advancing knowledge or technology if resources are allocated to a particular problem area ?, and
(ii) What will be the value to the receipient of the new knowledge generated ?

It is the contention of this paper that the above two questions, and others, may be addressed through the use of a systematic, <u>systems approach</u> to research resource allocation. Although Ruttan (1982) implied that systems approaches had served their usefulness for research planning in the 1970's, I take the counter view, viz. that their potential was not fully utilized because of the formal, methodology quagmire that practitioners of the systems approach fell into in the 1970's. In the 1980's we have become more aware of the interplay between quantitative and qualitative methodology, especially with regards to such a fuzzy system as research planning.

In another part of his book, Ruttan (1982) argued strongly that effective research planning was not feasible unless there was a participatory process involving administrators, social and biological scientists. Yet the participatory process is so much an inherent feature of the systems approach as we know it today !

This presentation will show how a systems approach to research resource allocation, utilizing a strong participatory process, can provide answers to the above two questions posed by Ruttan (1982), as to what knowledge can be advanced and the value of the knowledge. Suffice it to say that together with this reemergence of the systems approach for planning research has been developments in other methodologies that allow a value to be put on knowledge for improving crop production technology. Foremost of these methodologies is <u>crop</u>

loss assessment. The key example used in this presentation will be a potato-pest management system research planning project.

1.1 Basic Concepts

The systems approach represents a holistic view of life, and proposes that a biological system cannot be properly understood or managed by ad hoc knowledge on its components alone. It subscribes to the view that the components of a system interact with each other and are influenced in that interaction by external factors, that a change in one part of the system produces changes in other parts, and that the "whole is more than the sum of its parts". Nearly all biological systems are "open" systems, in the sense that material flows occur into and out of the system; pest management systems have a biological subsystem that is influenced by the external environment. Further, pest (insect, disease, weed) populations exhibit many of the complex, dynamic interactions typical of biological systems and often the only way to adequately understand how these systems function is to build a model (conceptual or mathematical) of the system.

The approach recognizes a hierarchical organization in natural systems. For example, with a disease epidemic, one level of organization is the population, a second lower level has the pathogen and the host as subsystems, while a third lower level has subsystems for pathogen (germination, sporulation, etc.) and host (leaf, stem, etc.), ad infinitum (Teng et al., 1980). When modeling a system, it is necessary at the outset to be clear which levels in the hierarchical organization are being addressed. A conceptual boundary is therefore used to distinguish between the system proper and the system environment. Within the conceptual boundary lies all the state variables that constitute the structure of the system. The system proper may be described and quantified by using state variables, so that at any point in time, the value of a state variable is known (Teng, 1985). External to the boundary lie the driving variables that influence the rate at which the system proper functions. The system environment and the system proper are linked through state and rate equations. A system model may therefore be viewed as a series of equations which collectively describe how the system (and its components) respond to the environment.

A model may be considered any representation of a system in some form other than the original. Thus many types of models exist and it is difficult to have a single system for classifying all models (Teng, 1981). Models represent systems, where a system is a collection of objects united by regular interaction to perform an identifiable function. The world is divided into "systems" and "non-systems".

Although the systems approach, as a problem-solving methodology, often leads to the construction of a model, the model itself is not necessarily the product of practical value in crop or pest management (Ruesink, 1976). Rather, the process of constructing the model, which requires a rigorous examination of the knowledge base on any system, has been shown valuable in generating guidelines for resource allocation. There is therefore a distinction between the systems approach as a philosophy and its use as a methodology (Teng, 1982). Although no consensus exists on terminology, systems research is an encompassing term for activities which have been variously called systems analysis, simulation modeling and system modeling. The systems approach has also been actioned as systems analysis (analysis of system structure and behaviour), system control (manipulation of input), system design (restructuring of existing system or structuring of non-existent system) and system synthesis (major rebuilding of system through modeling).

1.2 Soft versus Hard System Approaches

Two types of systems have been recognized by some workers (Bawden et al., 1984; Checkland, 1981) - 1) those with goals not clearly recognizable and outcomes ambiguous and uncertain, i.e. purposeful or "soft" systems, and 2) those with clear clear goals and/or predictable outcomes, i.e. purposive or "hard" systems. A soft system is exemplified by the activities that collectively represent a pest management decision system while a hard system is exemplified by a pest-host population system. The two types of systems are reflected in the approaches taken to study and manage them, respectively a soft systems approach and a hard systems approach (Bawden et al., 1984). The important difference between the two approaches and systems is that a hard system lends itself to building a quantitative, simulation model while a soft system has more unstructured aspects and may be difficult to model. Soft systems are more typical of the unstructured problems associated with human activities, and are more amenable to the building of "expert systems" than quantitative models. Teng (1985a) has argued that a soft systems approach and its products has more use in the short term for improving crop pest management than a hard approach and models, while Checkland (1981) believes that the hard approach is an extension of the soft.

Both approaches share some common steps and a discussion of these steps will reinforce appreciation of the differences between them. In applying the systems approach, some of the following steps are evident : 1) Specifying and bounding the system in relation to identified problems and objectives, 2) Evaluating the historical and current knowledge about the system, 3) Developing an initial (conceptual) system model, 4) Collecting data and deriving state/rate equations to describe the system, 5) Structuring a detailed system model for computer modeling, 6) Translating the model into a selected language for computer simulation, 7) Sensitivity analyses, verification and validation of model performance, and 8) Model experimentation (Teng, 1985; Teng and Zadoks, 1980). Steps 1-3 are always present in both the soft and hard systems approaches, and have been called systems analysis by Teng (1985). Systems analysis is particularly suited for helping scientists improve their understanding of any system, for showing the relationship between research on different system components, for revealing weaknesses and strengths in current knowledge of the system, for promoting interdisciplinary problem-solving, and for guiding the allocation of scarce resources.

Crop pest management requires a strong interdisciplinary approach to generate and apply pest control knowledge in an integrated fashion. Some of the operational components of a program include pest surveillance, pest forecasting, crop loss assessment and economic injury level identification, all of which share many common techniques with the systems approach. It is therefore not surprising to see many proponents and applications of a systems approach to pest management (Ruesink, 1976; Shoemaker, 1980; Teng, 1982). Many interdisciplinary problem-solving activities embody systems concepts, implicitly or explicitly, and IPC is definitely an interdisciplinary activity.

1.3 The Soft Systems Approach

The soft systems approach has been used to analyse both structured and non-structured systems, even though it is better for non-structured systems with no clearly defined objectives (Checkland, 1981). In the context of plant protection, examples include identifying research needs for potato pest management (Johnson et al., 1985), analysing the status of plant protection knowledge and infrastructures in selected West and Central African countries (Teng, 1985b), and identifying research and extension needs for rice pest management in Malaysia (Norton, 1982) and for millet and cotton in semiarid Africa (FAO,UN, 1984). In using the approach for pest management at the field level, Teng (1985a) adapted the procedures of Norton (1982) and specified distinctive components for applying the approach (Fig. 1). A pest management system may be described by considering a biology / technology subsystem and a management / economics / sociology subsystem (Fig. 1). The first represents the ecosystem and its potential, quantifiable components while the second represents the human activities affecting the ecosystem.

BIOLOGY AND TECHNOLOGY The ecological subsystem may be divided into static and dynamic components for analysis. The static components are those that constitute the structure of the ecosystem, for example the key pests and key crop under consideration. This commonly involves an enumeration of all the pests considered important in the management of the crop, e.g. with the potato cropping system in north central U.S.A., Johnson et al. (1985) identified eight insects and twenty-three diseases as forming the potato system structure. The key entities are other biological organisms, such as predators and parasites, considered important for pest management.

The dynamic components analysis produces information that is represented as two-dimension rectangular matrices (Fig. 2). Some matrices commonly used are those dealing with pest-time profile, crop loss, pest - weather, pesticide, predators/parasites, pest-pest interactions and pest-crop growth stage profile. An example using the pest - weather effects matrix (Fig. 2) illustrates the potential of this form of analysis. For each pest identified in the static system structure, life processes important for understanding the populations dynamics of the pest or for forecasting is arranged as horizontal rows in the matrix. The vertical columns are weather variables considered necessary for pest growth, development and survival. The "box" of intersection between a weather variable (e.g. temperature) and a life process of the pest (e.g. sporulation) may be used to denote a) what the effect of the weather variable is, b) how complete the knowledge is / whether a quantitative relationship exists or c) what the source of the information is. In Fig. 2, the boxes are filled in with either a +, -, 0, or ?, respectively denoting that a weather variable has a positive, negative, null or unknown effect on the pest life process. The kind of analysis performed using this matrix presents a summary of what is known or not known of the effect of weather on different pests. It is also capable of revealing where areas of past research emphasis have been, and from this point to areas which may be critical for pest forecasting but have not been researched. The matrix is therefore a descriptive framework of our current knowledge of different aspects of the pest ecosystem. How many "boxes" are filled in further gives an indication of how much data is available for developing a system model for computer simulation.

A series of matrices to analyze all the important dynamic components of the pest ecosystem (Fig. 1) will lead to an improved undertanding of the knowledge base available for improving crop-pest management. Although these analyses appear subjective, they are a simple way of summarizing even quantitative information into a common format. Results from the analyses may form the basis for designing management procedures, for example, a matrix with different tillage practices as columns and different pests as rows will show clearly which tillage practices affect several pests and which pests are not suited for cultural control (Norton, 1982). The full use of this matrix analysis technique will be discussed in Section 2 with the case study.

MANAGEMENT, ECONOMICS AND SOCIOLOGY The static components used for analysis are enterprise budgets and payoff matrices and the dynamic components are studies on farmers' perceptions of pests and their control, decision trees and decison models. Enterprise budgets categorize the direct and indirect costs of crop production in general and pest control specifically. These provide a basis for determining the short term economic value of improving pest management, as well as for analysis of longer term benefits to be expected from research on pest management (Johnson et al., 1985).

Pest management programs designed by scientists are likely to fail unless they recognize the needs of farmers and the ability and receptivity of farmers to new technology (Teng, 1985a). Data provided through intensive surveys are good measures of the farmers' needs

(Mumford, 1981). Farmers' decision processes further need to be analyzed and considered in the design of any pest management program. Norton (1976) has developed a decision-tree procedure based on operations research, which traces the many decisions involved in producing a crop, from before planting up till harvest.

The soft systems approach enables a systematic definition of the knowledge base for improving pest management. However, there are other factors to be considered in the design and implementation of pest management programs. The infrastructure for information generation, information synthesis, information adaptation, information dissemination and information reception and evaluation, also needs to be analyzed. Often, the lack of improvement in pest management practices is not due to a lack of knowledge or avialable technology, but to the dissemination or adaptation processes (Teng, 1985a).

2. CASE STUDY : POTATO PEST MANAGEMENT

2.1 The Rationale

Potatoes are intensively cropped in four major areas of the North-Central Region - North Dakota, Minnesota, Wisconsin and Michigan - and of the vegetable crops is the biggest user of pesticides per unit area. Many pests (insects, diseases, weeds) are known to affect potatoes in this region and pest control practices are an essential component of potato production. It is also known that much research effort has been invested and is being invested in potato pest control, yet there continues to be questions on how much of this research has been translated into practical information that can be integrated into grower knowhow.

The Integrated Pest Management (IPM) concept, first proposed in the 1960's in response to insecticide failures, subsequently developed into a convenient and useful framework for addressing the issue of integrating pest control knowledge. Traditionally, the plant protection disciplines of entomology, plant pathology and weed science have concentrated on single pest, single tactic (host resistance, chemical, biological, cultural) approaches to pest control. At best, multiple pests have been controlled using the same tactic, or multiple tactics have been used for the same pest. True integration of pest control as suggested by the IPM concept, in which the interactions between pests, their environment and control tactics are explicitly recognized, has been limited by the difficulties involved in generating (research) and disseminating (extension) integrative knowledge.

In view of the resources already expended in the North-Central Region on potato IPM research, and the potential for new resources through the National IPM effort, a unique opportunity was recognized to use a systems approach for identifying the knowledge gaps in potato IPM in the region, and to involve scientists in a participatory manner to arrive at recearch needs and priorities. It was postulated at the outset that this would lead to improved resource allocation and greater accountability of new knowledge to improve IPM via the program.

A potato task force was formed to conduct the research planning process, with representatives from North Dakota (D. Nelson, Weed Scientist), Minnesota (P. Teng, Phytopathologist /Systems), Wisconsin (D.Rouse, Phytopathologist) and Michigan (G.Bird, Nematologist). The potato task force leader was P. Teng and subsequently the working group was expanded to include S. Johnson (MN, Systems analyst), S. Adams (WI, Plant Physiologist/ Modeller) and E. Grafius (MI, Entomologist). The task force met five times over one and a half years, and in the following activities involved every potato scientist in the North-Central Region.

2.2 Potato Systems Analysis and Description

The specific objectives of the project were defined by the task force to be :

a. Identify and characterize the major potato production areas and systems in the North Central states of MI, MN, ND and WI.
b. Conduct a descriptive analysis of the identifited potato production systems through ecosystem and management system analysis.
c. Identify information gaps in the potato pest ecosystem/management system described, with respect to information generation, synthesis, dissemination and reception, using subjectve and objective approaches.
d. Identify information needs in potato IPM.
e. Identify research needs and priorities for potato IPM.

This analysis was conducted on (1) the biological subsystem , consisting of descriptions of static and system structures and system dynamics, and (2) the management sybsystem, consisting of production systems, decision-trees and enterprise budgets. With the biological subsystem, both micro (single field) and macro (regional) aspects were examined.

CONCEPTUAL MODEL OF POTATO PEST MANAGEMENT SYSTEM The potato pest system was characterized into a system proper consisting of the state variables of crop, pests, predators/parasites, production practices, farmer and control measures. System environment included the exogenous variables of weather and "immigrant" pests. The key components of the pest subsystem were defined as:
-insects (green peach aphid, potato aphid, potato leafhopper, aster leafhopper, potato flea beetle, Colorado potato beetle, wireworm and seed corn maggot),
-diseases (late blight, early blight, leak, white mold, Rhizoctonia canker, silver scurf,Fusarium rot, Verticillium rot, blackleg, ringrot, common scab,wart, lesion nematode, root knot nematode, stubby

root nematode, potato leafroll virus, potato virus x and y, tobacco rattle, potato yellow dwarf, alfalfa mosaic, aucuba and rugose), -weeds (red root pigweed, canadian thistle, russian thistle, yellow foxtail, green foxtail, lambs quarters, kochia, wild mustard, wild oats, crabgrass, ragweed, smartweed, yellow nutsedge, purslane, bindweed and black nightshade).

The dynamics of the system proper and the interactions between system components were described by a series of "matrices" - weather/pest, weather/pest life stages, pest occurrence/time, pest/pest interactions, pest/cultural control methods, pest/pesticide, etc. These matrices were a simple way to identify where the knowledge gaps were and where the commonalities between pests were.

CLUSTER ANALYSIS OF PRODUCTION AREAS   Potato production in the MI, MN, ND and ND were separated into six distinct production areas based on soil characteristics by means of a clustering of means procedure.

The soil attributes used to statistically define production areas were soil pH, soil permeability and available water holding capacity. Average county values were estimated using detailed soil survey data in consultation with soil scientists. The clustering procedure minimized the Euclidean/geometric mean distance between the cases and the center of clusters. Cluster 1 included 11 counties from MI,MN and WI; Cluster 2 included 15 counties from all four states; Cluster 3 included 12 counties from MI, MN and WI; Cluster 4 included 11 counties from MI, WI and MN; Cluster 5 included 16 counties from MI, WI and MN; Cluster 6 included 10 counties from MI, Mn and ND. The clusters represent the lowest common number of attributes across the region.

POTATO PRODUCTION DECISION TREES   A decision tree characterizes all the decisions a farmer has to make to produce a potato crop. A generic decision tree was developed which consisted of 5 trees, each representing different times of the production process : Year(s) before planting, Fall before present potato crop, Spring of present potato crop through planting, After planting through approaching harvest, and Potato harvest. The main decision nodes (many subnodes of each not detailed here) were, for
Years before planting - rotation (length, crop type),
Fall before present crop - tillage (type, reduced/non reduced), soil tests, fertilization, fumigation,
Spring through planting - tillage, seed, pack soil, planting, soil at planting, water,
After planting - tillage, weed control, irrigation, disease control, nematode control, insect control, inspections, tags, rouging,
Harvest - sprout inhibitor, vine killer, digger, storage.
The trees were developed from interviews with researchers, extension workers and farmers.

PAYOFF MATRIX ANALYSIS Each decision tree was converted into a payoff matrix, in which each decision node was assigned a cpst-benefit ratio or actual $ value. A top-down analysis was done, with three pest scenarios for each decision node (low, medium, high pest intensity) and with the outcome of each decision subtracting from a specified yield goal (3 levels, representing risk neutral, risk adverse, risk seeking farmer). This analysis helped improve the task force's understanding of the dynamics of decision making.

ENTERPRISE BUDGETS Ten enterprise budgets were developed to represent the different production systems (seed, table, chipping potatoes) in the six production areas characterized in the cluster analysis. Each enterprise budget is an itemized list of the costs of potato production, including costs of pest control measures. The budgets were developed from interviews with Farm Management specialists in the four states, farmers and marketing board personnel. High cost items throughout the region were machinery, seed and fertilizer. Crop protection costs were relatively low, less than 10-15% of total costs in most production systems. However, when considered in conjunction with the payoff matrices, pest control assumed importance as protecting the overall investment instead of just reducing crop losses.

2.3 Identification of Research Needs

THE KNOWLEDGE BASE FOR POTATO PEST MANAGEMENT The national AGRICOLA database was searched for published literature on the potato pests identified in Paragraph 9 (above), for 1970-1984, and the information was evaluated by the task force, with assistance from other potato scientists in the four states. There were 19 citations for nematodes, 835 for diseases, 285 for insects and 490 for weeds. Many citations not located by the computer search were made available by potato scientists in the region. Each citation was rated on a scale of 0-3 (0=not applicable, 1-poor, 2=good, 3=excellent) for applicability to potato IPM. Citations were classified according to pest and any of the following 6 categories - chemical control, non chemical control, life cycle of pest, plant part affected, pest progress/dynamics, two-way pest interactions, three-way pest interactions. For all pests, most of the published literature concerned chemical control (79% of nematode citations, 64% of insect citations, 42% of weed citations, 27% of disease citations). For all pests, there was very little published literature on interactions between and within pest types (insect, weed, disease).

ONGOING RESEARCH The USDA CRIS Dialog Information system was accessed to obtain a list of all potato projects for all states in the U.S.A. Potato projects at each of the 12 state agricultural experiment stations, funded by non-Federal sources, were obtained with assistance from NC-166 state representatives. All projects were categorized by state and any of the following - IPM, breeding, chemical control, non chemical control, survey, other. There was a total of 140 CRIS potato projects, located in 32 states. The north central region had 8% of its projects on IPM, compared with the national average of 24%. In the north central region, 2 CRIS projects were designated IPM, 3 breeding, 4 chemical control, 3 non chemical control, 2 survey and 4 other (marketing, utilization).

SURVEY OF POTATO SCIENTISTS All potato workers in the four state area were surveyed and asked to rank each potato pest (Paragraph 9, above) in each production area cluster (Paragraph 10,11 above) for importance for research. Across all clusters, the importance rankings for the top 15 pests, in order of decreasing rank were : lesion nematode, red root pigweed, Colorado Potato beetle, ringrot, potato leafhopper, Verticillium wilt, lambs quarters, early blight, aster leafhopper, blackleg, yellow foxtail, green peach aphid, Rhizoctonia, late blight, potato flea beetle.

2.4 The Product : Research Guidelines

The process summarized above

(i) identified the knowledge base for potato pest management,
(ii) identified the extent of ongoing research in the north central region, and
(iii) identified the importance of different pests and topic areas for research using objective and subjective means.

The task force met twice to synthesize all the above information into research topics that could improve potato IPM in the north central region. These topics were subsequently incorporated into the FY 1985 guidelines for competitive funding of IPM research in the north central region.

The research topics are :

a. Epidemiology of diseases and Ecology of insects and weeds, with emphasis on
- Quantitative environment-pest population dynamic interactions and models (for all pests except late blight).
- Predictive systems or models.
- Pest dispersal (primarily Colorado potato beetle, Columbia root-knot nematode, potato cyst nematode).
- Pest survival (primarily ring-rot, Colorado potato beetle, root-lesion nematode and northern root-knot nematode).

b. Pest-crop interactions, with emphasis on
- Interactions related to plant growth and yield, and yield/crop loss assessment (especially "early dying" syndrome).
- Development of management thresholds
- Pest-crop model development and validaton.

c. Development and validation of biological monitoring for IPM, with emphasis on
- Pest assessment methods (especially weeds).
- Pest sampling procedures.
- Regional distribution of key pests.

d. Development of innovative control tactics (especially for Colorado potato beetle, weeds, soil-borne pests - Verticillium spp., and root lesion nematode, northern root knot nematode, potato root nematode).

e. Pest management science, with emphasis on
- Pesticide resistance management, in particular the determination of strategies leading to prolonged life of a chemical in the field (especially against late blight, green peach aphid, Colorado potato beetle).
- Integration of two or more management tactics for single or multiple pests.
- Pest-crop ecosystem design.
- Socio-economics of IPM implementation.
- Macro-level (regional) IPM strategies.
- Reduction of environmental and human risks.

The priority pests for research, unless otherwise stated above, are as follows
a. Insects : Colorado Potato Betle, green peach aphid, potato leafhopper, potato flea beetle.
b. Nematodes : Root lesion and northern root.
c. Weeds : Red root pigweed, green and yellow foxtail, other broad leaf weeds, perennial weeds and wild oats.
d. Diseases/pathogens :
Priority Group 1 - Early blight, Verticillium wilt, blackleg, Ringrot, softrot.
Priority Group 2 - Late blight, Fusarium dry rot, rhizoctonia, scab, potato leafroll virus.
Priority Group 3 - Potato virus X, PVY, spindle tuber viroid, purple top (aster yellows) mycoplasma - organism.

IPM research is a product-oriented research, with a continuing need to demonstrate improvements in the system. The research planning process on potato IPM described in this document needs to be supported by a research evaluation and information synthesis process, to ensure that information generated through competitive grants has relevance for the science and can be applied in an integrated manner to improve potato IPM in the north central region.

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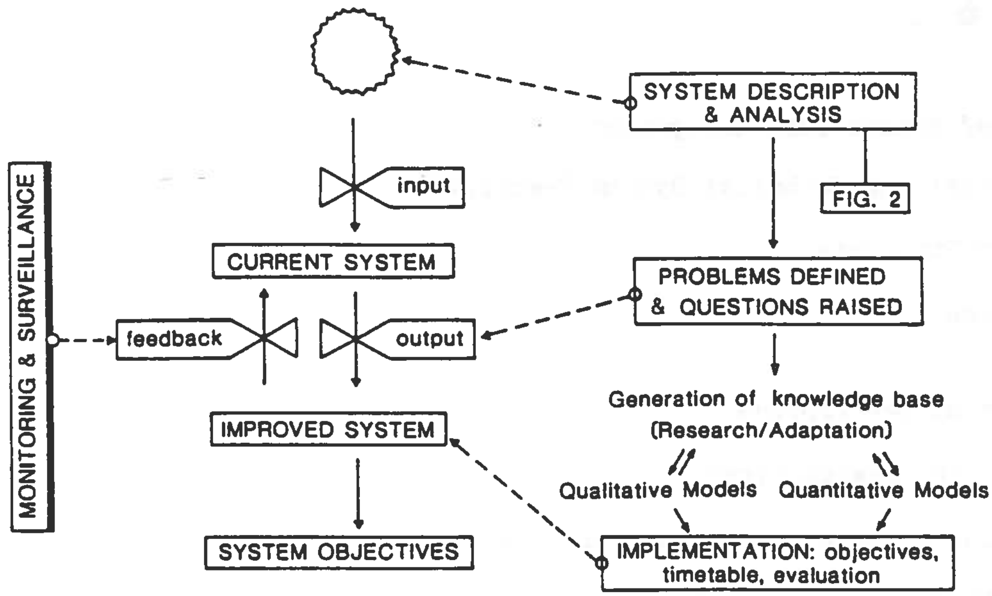


Figure 1. Steps in the design of an Integrated Program for Crop-Pest Management using the Systems Approach.

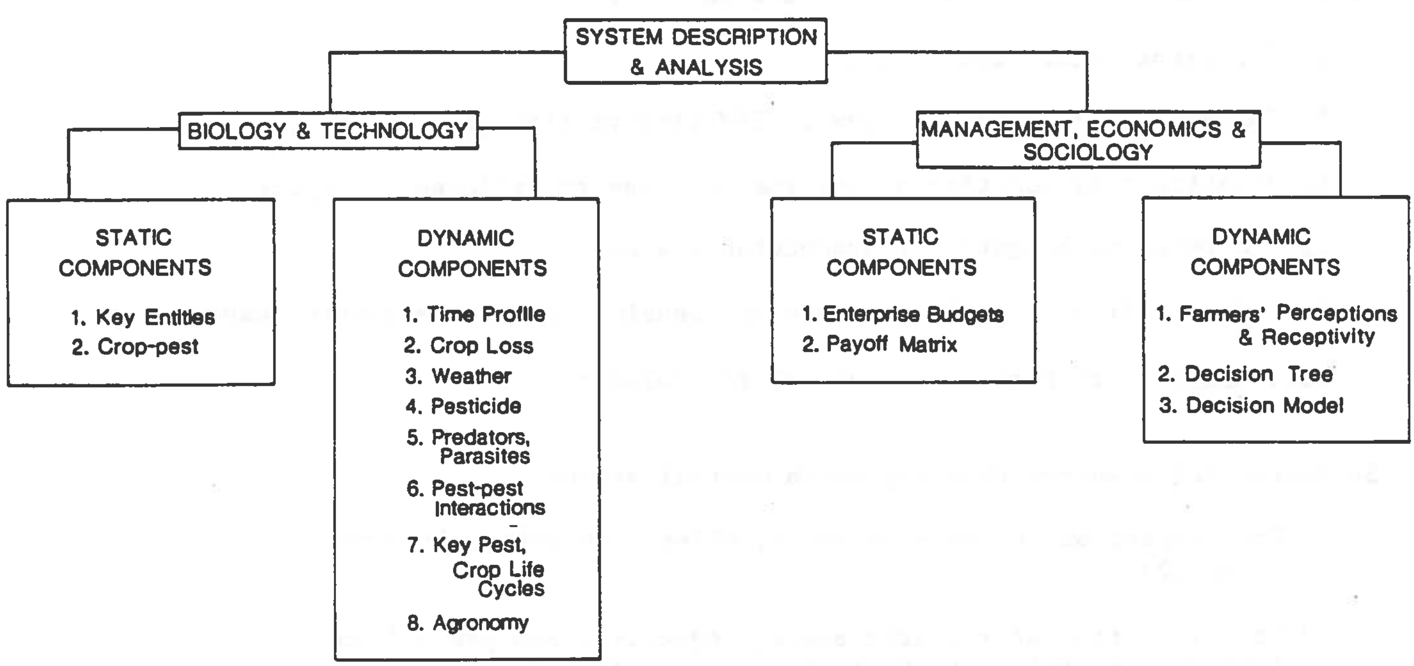


FIGURE 2. Components of a soft systems approach for crop-pest management system analysis. (After Norton, 1982a)

NC-166.

1. Analysis of Potato Pest Management

1.1 Ecological and Technical System Description

A. System Structure

B. Dynamics

1.2 Management Description

A. Production System Types

B. Decision-trees of management options

C. Quantifying the value of management options (Enterprise Budgets)

2. Analysis of IPM Research Needs

2.1 Past and Current Research on Potato Pests

A. AGRICOLA database searches.

B. USDA CRIS search, national and NC region

2.2 Information needs, gaps and solutions in IPM

A. RET needs identified in (1).

B. Channels of information flow in IPM :information gaps.

C. Benefits from solution of information gaps to different clientiele.

i) Enterprise budgets for production systems

ii) Feasibility of yield increase by reducing research/extension gap

iii) Analysis of risk and potential for solution

3. Potato IPM Research Plan for North Central Region

3.1 Prioritization of research needs, objectives and goals from (1) and (2).

3.2 Prioritization of research needs, objectives and goals from Delphi Process aplied in NC region and nationally.

3.3 Final research prioritization plan by Potato Task Force and NC-166 Technical Committee.

1.1 ECOLOGICAL AND TECHNICAL SYSTEM DESCRIPTION

A. STRUCTURE

COMPONENTS	TABLE 1	PEST COMPONENTS

B. DYNAMICS

CHANGES OVER TIME	TABLE 2	TIME PROFILE
PEST REQUIREMENTS AND ABILITIES	TABLE 3	PEST R&A MATRIX
INTERACTIONS	TABLE 4	PEST INTERACTION MATRIX
	TABLE 5	DAMAGE MATRIX
	TABLE 6	NATURAL ENEMY MATRIX
	TABLE 7	WEATHER EFFECT MATRIX
	TABLE 8	PESTICIDE EFFECT MATRIX
	TABLE 9	CULTURAL EFFECT MATRIX

TABLE 1 KEY COMPONENTS OF POTATO PEST SYSTEM

PEST GROUP	COMMON NAME	GENUS SPECIES
INSECTS	Green peach aphid	Mysus persicae
	Potato aphid	Macrosiphum euphorbiae
	Potato leafhopper	Empoasca fabae
	Aster leafhopper	Macrosteles fascifrons
	Potato flea beetle	Epitrix cucumeris
	Colorado potato beetle	Leptinotarsa decemlineata
	Wireworm	Ctenicera
	Seed corn maggot	Hylemya platura
DISEASES	Late blight	Phytophthora infestans
	Early blight	Alternaria solani
	Leak	Pythium spp.
	White mold	Sclerotinia sclerotiorum
	Rhizoctonia canker	Rhizoctonia solani
	Silver scurf	Helminthosporium solani
	Fusarium rot	Fusarium solani,F.roseum
	Verticillium wilt	V. alboatrum,V.dahliae,etc.
	Armillaria dry rot	A.mellea
	Blackleg	Erwinia carotovora
	Ring rot	Corynebacterium sepdonicum
	Common scab	Streptomyces scabies
	Wart	Synchytrium endobioticum
	Lesion nematode	Pratylenchus penetrans
	Root knot nematode	Meloidogyne hapla
	Stubby root nematode	Paratrichodorus
	Potato leafroll	
	Potato Virus X,Y	
	Tobacco rattle	
	Potato Yellow dwarf	
	Alfalfa mosaic	
	Aucuba	
	Rugose	
PREDATORS		
PARASITES		
VERTEBRATE PESTS		
WEEDS		

POTATO PEST SYSTEM

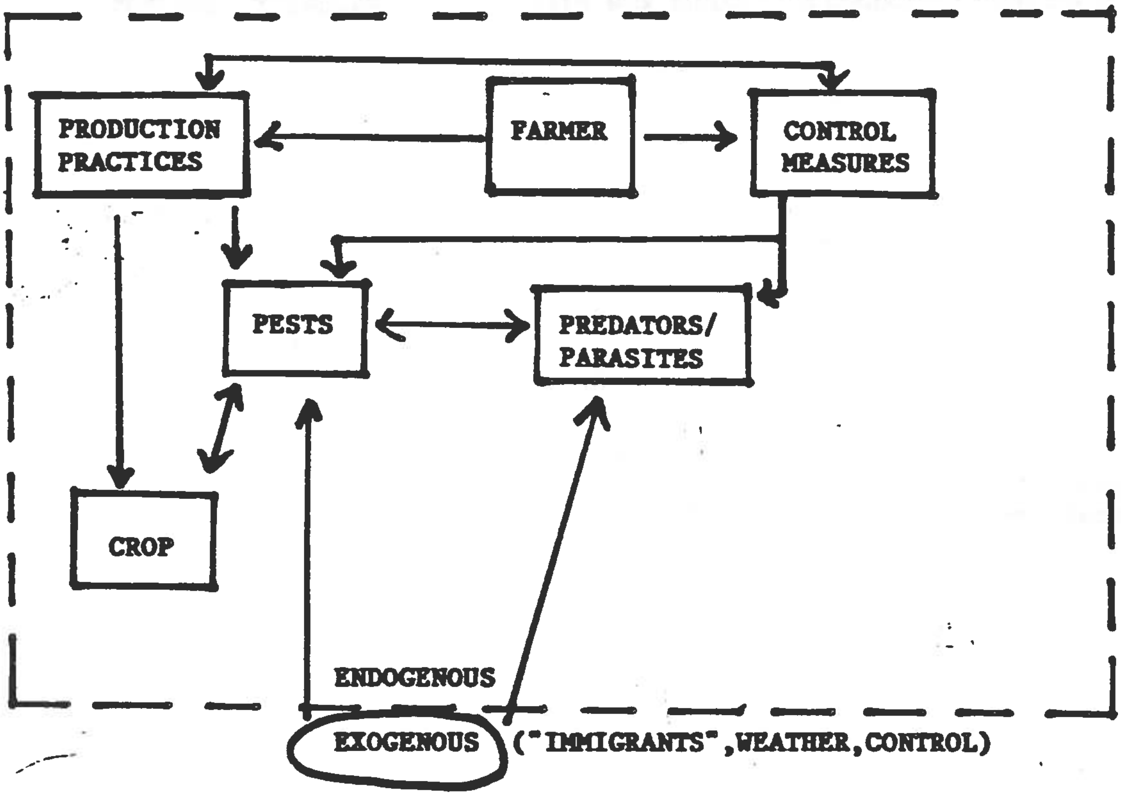


TABLE 2 TIME PROFILE FOR POTATO PEST SYSTEM

ACTIVITY	PLANTING	EMERGENCE	GREEN ROW FILL	MATURITY	HARVEST
Yield formation					
NPK demand					
insects					
predators					
parasites					
diseases					
[redacted]					
nematodes					
vertebrates					
weeds					

TABLE 3 PEST REQUIREMENT AND ABILITY MATRIX

PEST	KEY REQ.'S	GENERATION TIME	ALTERNATIVE HOSTS	SOURCE	DISPERSAL
insects					
diseases					
e.g. Early blight		2-5 days	tomato	tubers debris	passive(air) m

TABLE 4 PEST INTERACTION MATRIX

	1 P.infestans	2 A.solani	3 S.scerotiorum	N
A.P.infestans				
B.A.solani				
C.S.sclerotiorum				

TABLE 5 DAMAGE MATRIX

INJURY CAUSED TO PLANT PART

PEST	Seed piece	Young shoot	Leaf area	stems	tuber
P.infestans					
A.solani					
etc.					
POSTULATED/ KNOWN EFFECTS					
tuber number					
tuber weight					
tuber quality					

TABLE 6 NATURAL ENEMY MATRIX

	PARASITES				PREDATORS				DISEASES	
	EGG	NYMPH	LARVA	PUPA	EGG	NYMPH	LARVA	ADULT	VIRAL	ETC.
	Myr.	Tr. etc.						spider		
P.leafhopper										
CPB										
ETC.										

Myr.=Myramidae Tr.=Trichogrammatidae

TABLE 7 WEATHER EFFECT MATRIX

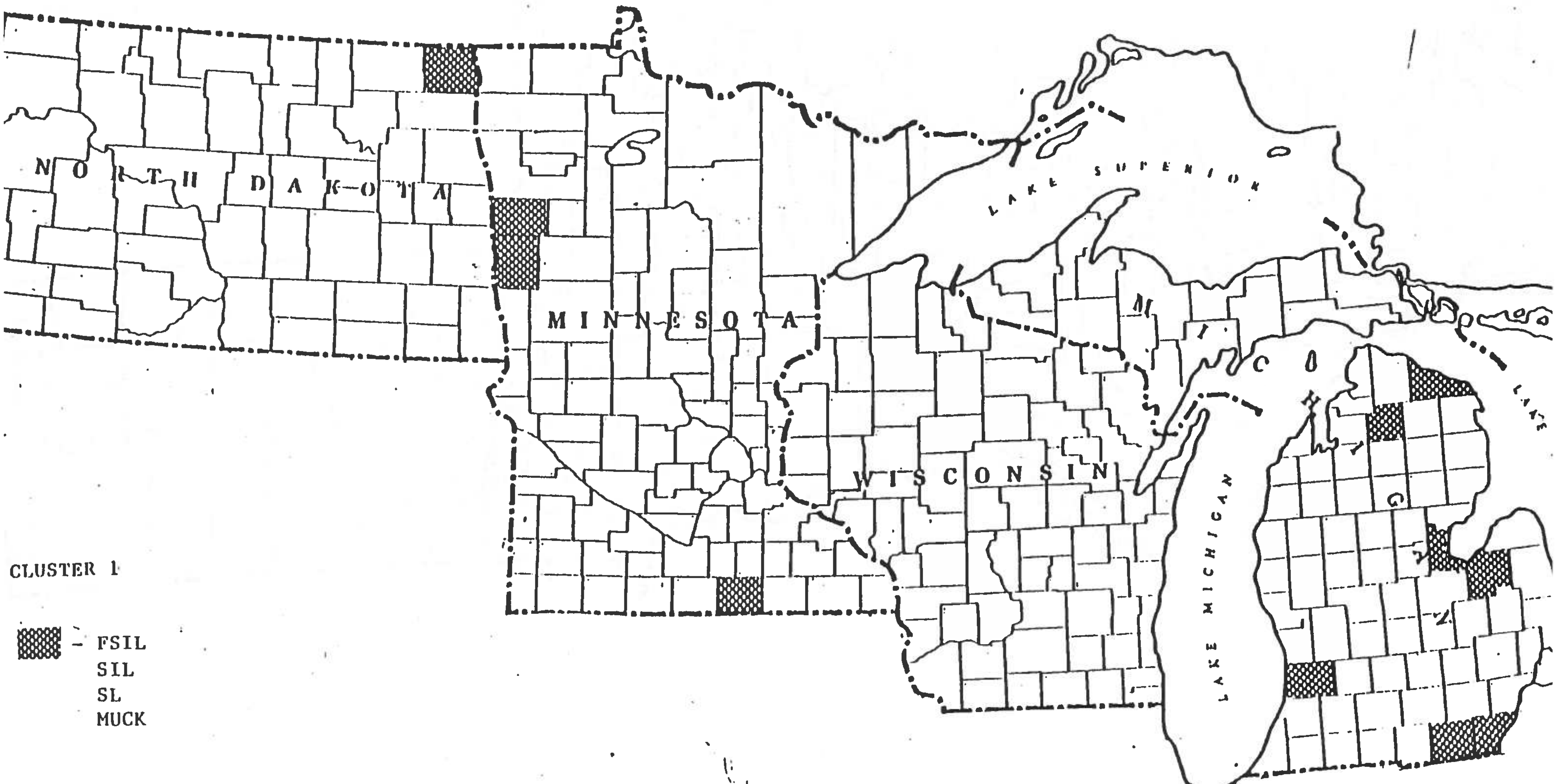
	STAGE OF CROP			
	VEGETATIVE		REPRODUCTIVE	
	(HOT/DRY)	(COOL/WET)	(HOT/DRY)	(COOL/WET)
PESTS				
P.infestans				
P.leafhopper				
ETC.				

TABLE 8 PESTICIDE EFFECT MATRIX

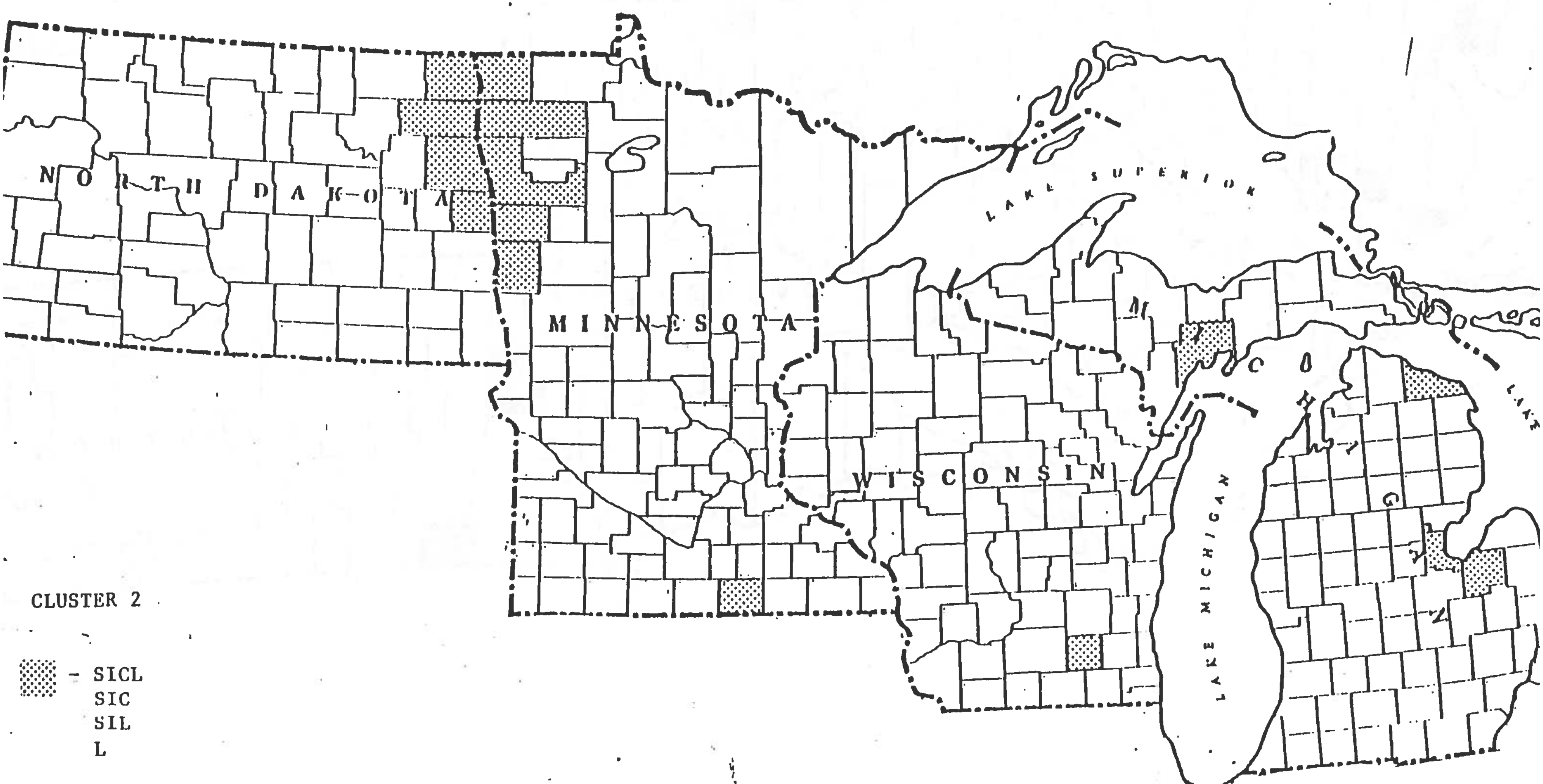
	INSECTICIDE	FUNGICIDE	HERBICIDE	OTHERS
	(names..)			
PESTS				
P.infestans				
P.leafhopper				
ETC.				

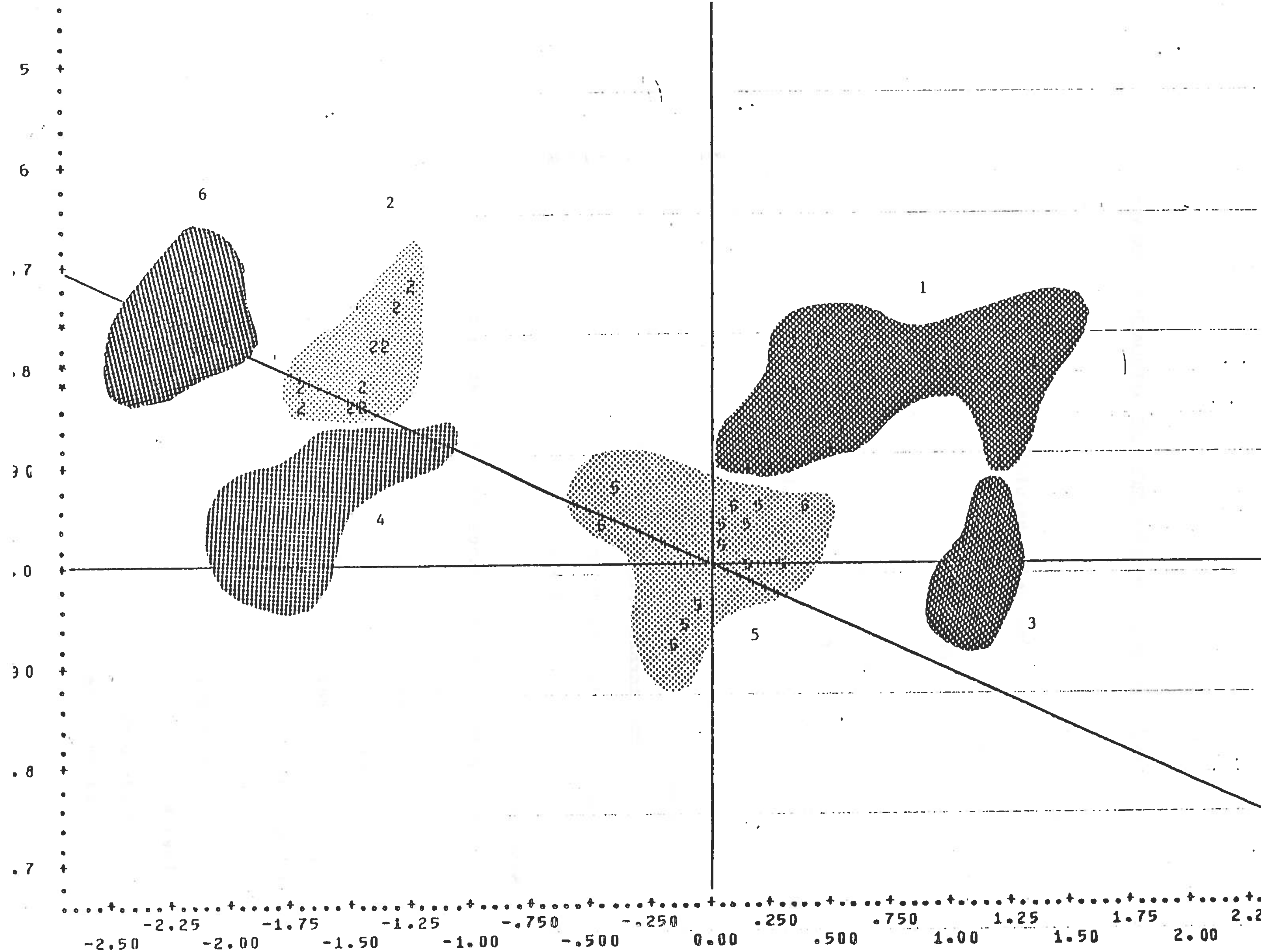
TABLE 9 CULTURAL EFFECTS MATRIX

	ROTATION	TILLAGE	FERTILIZATION	ETC.
PESTS				
P.infestans				
A.solani				
P.leafhopper				
Verticillium				
Predators				
Parasites				
ETC.				



NORTH DAKOTA
MINNESOTA
WISCONSIN
MICHIGAN
LAKE SUPERIOR
LAKE MICHIGAN
LAKE
CLUSTER 1
- FSIL
SIL
SL
MUCK


NORTH DAKOTA
MINNESOTA
WISCONSIN
MICHIGAN
LAKE SUPERIOR
LAKE MICHIGAN
LAKE
CLUSTER 2
- SICL
SIC
SIL
L



5
6
.7
.8
.0
.8
.7
1
2
3
4
5
6
-2.50
-2.25
-2.00
-1.75
-1.50
-1.25
-1.00
-.750
-.500
-.250
0.00
.250
.500
.750
1.00
1.25
1.50
1.75
2.00

AFTER PLANTING POTATO CROP AND APPROACHING HARVEST

- tillage
    - post-plant,pre-emergence herbicide application
        - type
            - broadcast
                - rate
            - band
                - rate
                    - incorporated
                    - nonincorporated
    - harrow (blind cultivation)
    - shovels
        - times through field
    - sweep/rolling cultivator
        - times through field
- weed control
    - post-plant, post-emergence herbicide application
        - broadcast
            - rate
        - band
            - rate
- irrigation
    - type
        - strategy
- diseases
    - seed-borne
    - nonseed-borne

incidence

intensity

prevalence

- crop destination
  - fresh market
  - processor
  - seed
    - certified
    - foundation
    - carryover

which one

- bacterial
  - black leg (Erwinia carotovora)
  - soft rot (Erwinia carotovora)
  - ring rot (Corynebacterium sepedonicum)
  - pink eye (Pseudomonas fluorescens)
  - scab (Streptomyces scabies)
    - common
    - acid-tolerant
- fungal
  - powdery scab (Spongospora subterranea)
  - leak (Pythium spp.)
  - early blight (Alternaria solani)
  - late blight (Phytophthora infestans)
  - grey mold (Botrytis cinerea)
  - white mold (Sclerotinia sclerotiorum)
  - rhizopus soft rot (Rhizopus spp.)
  - silver scurf (Helminthosporium solani)

        - black spot (Colletotrichum atramentarium)
        - Fusarium rot or wilt (Fusarium spp.)
        - Verticillium wilt (Verticillium spp.)
        - Rhizoctonia diseases (Rhizoctonia solani)
    - insect toxins
        - hopper burn
        - psyllid yellows
    - viral (including viroids and mycoplasmas)
        - PLRV (potato leaf roll virus)
        - PVA (potato virus A)
        - PVX (potato virus X)
        - PVS (potato viruus S)
        - CMV (cucumber mosaic virus)
        - TMV (tobacco mosaic virus)
        - TRV (tobacco rattle virus)
        - PYDV (potato yellow dwarf virus)
        - PSTV (potato spindle tuber viroid -- VIROID)
        - BCTV (sugar beet curly top viroid -- VIROID)
        - PVY (potato virus Y)
        - calico virus
        - rugose (PVY + PVX)
        - aster yellows (purple top) (MYCOPLASMA-LIKE)
- control
    - chemical
        - type
            - rate
        - application method
            - ground

            - air
        - water volume used with chemical
        - sprayer pressure
        - enhancers used (sticker-spreaders)
        - accuracy of delivery
        - boom size
    - nonchemical
        - method

- nematodes
    - abundance (incidence/severity)
    - prevalence
        - crop destination
            - fresh market
            - processer
            - seed
                - certified
                - foundation
                - carryover
        - which one
            - lesion (Pratylenchus spp.)
            - root-knot (Meloidogyne spp.)
            - stubby-root (Paratrichodorus spp.)
    - control
        - chemical
            - type
                - rate
            - application method
                - ground

- applicator size
- nonchemical
  - method
- insects
  - what generation
  - which stage (instar)
  - prevalence
  - defoliation level
  - abundance
    - crop destination
      - fresh market
      - processer
      - seed
        - certified
        - foundation
        - carryover
    - aphid
      - green peach (Myzus persicae)
      - potato (Macrosiphum euphorbiae)
    - Colorado potato beetle (Leptinotarsa decemlineata)
    - cutworm (misc. spp.)
    - European corn borer (Ostrinia nubilalis)
    - potato flea beetle (Epitrix cucumeris)
    - potato leafhopper (Empoasca fabae)
    - aster leafhopper (Macrosteles fascifrons)
    - grasshoppers (misc. spp.)
    - cabbage looper (Trichoplusia no)
    - tarnished plant bug (Lygus lineolaris)

- potato psyllid (Paratroiza cockerelli)
- potato tuberworm (Phthorimaea operculella)
- wireworm (Limonius spp.)

- control
  - chemical
    - type
      - rate
    - application method
      - ground
      - air
      - boom size
  - nonchemical
    - method

- misc. chemicals (i.e. 2-4-D for red skin color, fertigation)
  - type
    - rate
  - application method
    - ground
    - air
    - boom size
    - irrigation
- inspections
  - field
  - Florida Test
- tags
  - certified
  - foundation
- rouge plants

COST FACTORS FOR DECISIONS IN THE PAYOFF MATRICES

	Non-seed producer low	Non-seed producer med	Non-seed producer high	Non-seed producer cost	Seed producer low	Seed producer med	Seed producer high	Seed producer cost
Years in rotation								
0	0.80	0.70	0.65	$ 0.00	0.80	0.70	0.65	$ 0.00
1	.90	.80	.70	15.00	.90	.80	.70	15.00
2	1.00	.95	.90	30.00	1.00	.95	.90	30.00
3+	1.00	1.00	.95	45.00+	1.00	1.00	.95	45.00+
Fumigation								
yes	1.00	1.00	1.00	200.00	1.00	1.00	1.00	200.00
no	1.00	1.00	.95	0.00	1.00	1.00	.95	0.00
Fertilization								
low				10.20				10.20
medium				22.50				22.50
high				54.00				54.00
Crop desination								
processing								
fertilization								
low	.65	.60	.55					
medium	.80	.75	.70					
high	1.00	.95	.80					
fresh market								
fertilization								
low	.65	.60	.55					
medium	.80	.75	.70					
high	1.00	.95	.80					
seed								
certified								
fertilization								
low					1.00	.98	.95	
medium					1.00	1.00	.98	
high					1.00	1.00	1.00	
foundation								
fertilization								
low					1.00	.95	.90	
medium					1.00	1.00	.95	
high					1.00	1.00	1.00	
carryover								
fertilization								
low					1.00	.95	.90	
medium					1.00	1.00	.95	
high					1.00	1.00	1.00	
Planting stock								
foundation	1.00	1.00	1.00	150.00	1.00	1.00	1.00	150.00
certified	1.00	.95	.90	90.00	1.00	.95	.90	90.00
carryover	.95	.80	.70	60.00	.95	.80	.70	60.00

Wound healing								
yes	1.00	1.00	1.00	0.00	1.00	1.00	1.00	0.00
no	1.00	.95	.90	0.00	1.00	.95	.90	0.00

	Non-seed producer				Seed producer			
	low	med	high	cost	low	med	high	cost
Seed-treat with insecticide								
yes	1.00	1.00	1.00	6.00	1.00	1.00	1.00	6.00
no	1.00	1.00	.95	0.00	1.00	1.00	.95	0.00
Seed-treat with fungicide								
yes	1.00	1.00	1.00	3.00	1.00	1.00	1.00	3.00
no	1.00	1.00	.95	0.00	1.00	1.00	.95	0.00
Seed-treat with nematicide								
yes	1.00	1.00	1.00	20.00	1.00	1.00	1.00	20.00
no	1.00	1.00	1.00	0.00	1.00	1.00	1.00	0.00
Warm seed								
yes	1.00	1.00	1.00	0.00	1.00	1.00	1.00	0.00
no	.98	.98	.98	0.00	.98	.98	.98	0.00
Soil conditons at planting								
good	1.00	1.00	1.00	0.00	1.00	1.00	1.00	0.00
fair	.95	.95	.95	0.00	.95	.95	.95	0.00
poor	.90	.90	.90	0.00	.90	.90	.90	0.00
Pre-plant herbicide								
yes	1.00	1.00	1.00	8.00	1.00	1.00	1.00	8.00
no	1.00	.98	.95	0.00	1.00	.98	.95	0.00
Post-plant herbicide								
yes	1.00	1.00	1.00	8.00	1.00	1.00	1.00	8.00
no	1.00	.98	.95	0.00	1.00	.98	.95	0.00
Ring rot severity	1.00	.98	.95	0.00	.99	.95	0.00	0.00
Other seed-borne bacteria	1.00	.98	.95	0.00	1.00	.98	.95	0.00
Control seed-borne fungi								
yes	1.00	1.00	1.00	10.00	1.00	1.00	1.00	10.00
no	1.00	.98	.95	0.00	1.00	.98	.90	0.00
Control foliar blights								
yes	1.00	1.00	1.00	28.80	1.00	1.00	1.00	28.80
no	1.00	.90	.80	0.00	.95	.80	.70	0.00
Control nematodes								
yes	1.00	1.00	1.00	200.00	1.00	1.00	1.00	200.00
no	1.00	1.00	.95	0.00	1.00	1.00	.95	0.00
Control foliar-feeding insects								
yes	1.00	1.00	1.00	33.25	1.00	1.00	1.00	33.25
no	1.00	.95	.90	0.00	1.00	.95	.90	0.00
Control plant								

juice suckers								
yes	1.00	1.00	1.00	12.25	1.00	1.00	1.00	36.75
no	.98	.90	.80	0.00	.90	.80	0.00	0.00

	Non-seed producer low	med	high	cost	Seed producer low	med	high	cost
Control tuber-feeding insects								
yes	1.00	1.00	1.00	21.00	1.00	1.00	1.00	21.00
no	1.00	1.00	.95	0.00	1.00	1.00	.95	0.00
Fixed costs				453.51				601.37
foundation seed producer								607.62
Returns per cwt								
processing				3.50				
fresh market				5.50				
foundation								10.00
certified								6.00
carryover								4.00

BUDGET #1

ETURNS			
ound white potatoes	165cwt	3.50	577.50
OTAL RETURNS			577.50
LANTING COSTS			
ield cultivator - 28 ft	.074h/A	53.28	3.94
pringtooth drag - 48 ft	.033h/A	44.99	1.48
ound white certified seed	15cwt	6.00	90.00
eed treatment	15cwt	.45	6.75
eed cutting	15cwt	.60	9.00
ow marker - 6 row	.134h/A	84.83	11.37
ruck filler	.174A/h	32.21	5.60
lanter - 6 row (picker type)	.174h/A	118.73	20.66
eavy truck (3 required)	.174h/A	49.28	25.72
abor	1.11h/A	6.25	6.94
ERTILIZER			
nhydrous ammonia	75lb	.13	9.75
nhydrous applicator	.079h/A	84.98	6.71
itrogen	25lbs	.22	5.50
hosphorus	50lbs	.22	11.00
otassium	60lbs	.10	6.00
ime	0lbs	.0075	.00
abor	.079h/A	6.25	.49
PRAYING COSTS			
erial application	4	3.50/A	14.00
round spray rig - 50 ft	.042h/A	33.56	1.41
erbicide	1	5.00	5.00
nsecticide			
planting	1	21.00	21.00
foliar	1	8.75	8.75
ungicide	4	3.70	14.80
prout nip	1	12.00	12.00
ine killer	0	12.00	.00
abor	.042h/A	6.25	.26
ULTIVATION			
ultivator - 6 row (4 times)	.109h/A	28.61	12.47
abor	.436h/A	6.25	2.73
ARVEST COSTS			
otato harvester - 2 row	.402h/A	103.73	41.70
eavy truck (3 required)	.402h/A	49.28	59.43
isk - 21 ft	.098h/A	54.97	5.39
ield cultivator - 28 ft	.074h/A	53.28	3.94
abor	3.39h/A	6.25	21.19
THER COSTS			
uel	20gal/A	1.12	22.40
and charge	1667.00/A	.039	65.01
and tax	1667.00/A	.006	10.00
ight truck	1.25h/A	20.18	25.23
romotion tax	165cwt	.03	4.95
rop insurance	577.50	.025	14.44
nterest on cash costs	335.11	.065	21.78
OTAL COSTS			608.79

Tab 6
6.7.1

Table 1. CRIS projects on potatoes for the United States.

State/# of CRIS Projects ...				State /# of CRIS Projects
1. ND-4	11. AZ-0	21. CT-2	31. NC-0	41. ID-7
2. MI-13	12. MO-2	22. MA-1	32. MS-0	42. NY-18
3. WI-13	13. LA-2	23. UT-0	33. AK-1	43. NM-0
4. MN-12	14. OK-0	24. NJ-3	34. KY-0	44. HI-0
5. NE-4	15. TX-0	25. CA-7	35. SC-0	45. MT-0
6. KS-5	16. NV-1	26. RJ-1	36. ME-5	46. WY-0
7. OH-4	17. WA-12	27. GA-0	37. TN-0	47. AR-0
8. IA-0	18. CO-4	28. DE-1	38. WV-2	48. NH-0
9. IL-0	19. FL-1	29. PA-1	39. AL-1	49. VT-1
10. IN-2	20. OR-5	30. VA-2	40. MD-2	50. SD-2
				51. DC-1

ALL 50 STATES

	IPM	BREEDING	CHEMICAL CONTROL	NON-CHEMICAL CONTROL	SURVEY	OTHER
PROJECTS	39	29	34	27	13	18
STATES	20	13	20	12	10	10

32 states with potato projects (plus Washington, D.C.)
140 Total potato projects.

MI, MN, ND, WI

	IPM	BREEDING	CHEMICAL CONTROL	NON-CHEMICAL CONTROL	SURVEY	OTHER
PROJECTS	4	5	11	5	4	23
STATES	2	3	4	3	2	4

Table 2. Non-CRIS projects on potatoes in Michigan, Minnesota, North Dakota, and Wisconsin.

	IPM	BREEDING	CHEMICAL CONTROL	NON-CHEMICAL CONTROL	SURVEY	OTHER
Michigan	xx	xx	xx	xx	xx	xx
Minnesota	--	5	4	--	1	2
North Dakota	--	2	1	2	--	1
Wisconsin	4	1	4	3	1	3

Table 3. Breakdown of published work as retrieved from the AGRICOLA information retrieval sevrice, 1970 to present.

PEST	LIT CIT	CHEM CTRL	NON-CHEM CTRL	LIFE CYCLE	PLANT PART	DISEASE PROG	2-WAY INTER	3-WAY INTER
DISEASES	126	77	10	4	23	15	49	7
Silver scurf	5	3	1	1	1	2	1	0
Rhizoctonia	32	14	3	0	6	3	3	0
Leak	1	1	0	0	0	0	1	0
White mold	2	2	0	0	0	0	0	0
Early blight	38	32	3	1	5	0	18	0
Fusarium	5	3	1	0	1	0	4	1
Verticillium	43	22	2	2	10	10	22	6
Blackleg	xx	xx	xx	xx	xx	xx	xx	xx
Ring rot	xx	xx	xx	xx	xx	xx	xx	xx
Scab	xx	xx	xx	xx	xx	xx	xx	xx
Late blight	xx	xx	xx	xx	xx	xx	xx	xx
Wart	xx	xx	xx	xx	xx	xx	xx	xx
VIRUSES								
PVA	xx	xx	xx	xx	xx	xx	xx	xx
PVX	xx	xx	xx	xx	xx	xx	xx	xx
PVS	xx	xx	xx	xx	xx	xx	xx	xx
CMV	xx	xx	xx	xx	xx	xx	xx	xx
TMV	xx	xx	xx	xx	xx	xx	xx	xx

Table 3. continued.

PEST	LIT CIT	CHEM CTRL	NON-CHEM CTRL	LIFE CYCLE	PLANT PART	DISEASE PROG	2-WAY INTER	3-WAY INTER
TRV	xx	xx	xx	xx	xx	xx	xx	xx
PYDV	xx	xx	xx	xx	xx	xx	xx	xx
PSTV	xx	xx	xx	xx	xx	xx	xx	xx
BCTV	xx	xx	xx	xx	xx	xx	xx	xx
PVY	xx	xx	xx	xx	xx	xx	xx	xx
Calico	xx	xx	xx	xx	xx	xx	xx	xx
Aster yellows (purple-top)	xx	xx	xx	xx	xx	xx	xx	xx
Rugose (PVX+PVY)	xx	xx	xx	xx	xx	xx	xx	xx
NEMATODES								
Lesion	xx	xx	xx	xx	xx	xx	xx	xx
Root knot	xx	xx	xx	xx	xx	xx	xx	xx
Stubby root	xx	xx	xx	xx	xx	xx	xx	xx
WEEDS	490	204	57	96	98	66	23	1

Table 3. concluded.

	LIT CIT	CHEM CTRL	NON-CHEM CTRL	LIFE CYCLE	PLANT PART	DISEASE PROG	2-WAY INTER	3-WAY INTER
INSECTS	285	181	80	16	10	34	7	0
Green peach aphid and Potato aphid	86	42	6	4	1	20	0	0
Potato leafhopper	6	2	2	1	2	0	0	0
Potato flea beetle	4	0	1	2	0	0	0	0
Colorado potato beetle	169	120	71	7	7	11	6	0
Wireworm	19	16	0	2	0	3	0	0
Seed corn maggot	1	1	0	0	0	0	1	0

Table 4. Results of survey of potato workers in the Michigan, Minneosta, North Dakota, and Wisconsin, by soil clusters (appendix A). Numbers are percentage of total rankings for pest type. The numbers are valid only within a pest type (*i.e.* not between diseases and insects).

	SOIL CLUSTER 1	2	3	4	5	6
DISEASES						
Early blight	47.0	47.9	xx.x	xx.x	xx.x	50.9
Verticillium	50.8	51.8	xx.x	xx.x	xx.x	58.8
Viruses	14.7	15.0	xx.x	xx.x	xx.x	19.5
Ring rot	55.9	57.0	xx.x	xx.x	xx.x	64.1
Black leg	46.6	47.5	xx.x	xx.x	xx.x	52.7
Rhizoctonia	28.4	29.0	xx.x	xx.x	xx.x	25.8
Scab	24.9	23.4	xx.x	xx.x	xx.x	20.2
Fusarium	21.3	21.7	xx.x	xx.x	xx.x	24.0
Silver scurf	10.3	10.5	xx.x	xx.x	xx.x	6.8
Late Blight	28.4	27.6	xx.x	xx.x	xx.x	32.1
Leak	6.4	6.5	xx.x	xx.x	xx.x	7.5
Pink eye	1.3	1.3	xx.x	xx.x	xx.x	1.5
White mold	1.9	1.3	xx.x	xx.x	xx.x	2.3
Botrytis	2.6	2.6	xx.x	xx.x	xx.x	xx.x
INSECTS						
Aster leafhopper	40.7	41.8	xx.x	xx.x	xx.x	31.7
Potato leafhopper	53.8	55.2	xx.x	xx.x	xx.x	44.3
Green Peach Aphid	31.1	31.9	xx.x	xx.x	xx.x	33.2

Table 4. continued.

	SOIL CLUSTER					
	1	2	3	4	5	6
Potato aphid	20.6	21.1	xx.x	xx.x	xx.x	6.7
Colorado Potato Beetle	59.9	58.9	xx.x	xx.x	xx.x	74.6
Potato Flea beetle	26.0	26.7	xx.x	xx.x	xx.x	30.5
Wireworm	9.1	8.7	xx.x	xx.x	xx.x	13.3
Seed corn maggot	5.6	5.1	xx.x	xx.x	xx.x	8.7
NEMATODES						
Lesion	72.7	72.7	xx.x	xx.x	xx.x	81.8
Root knot	9.1	0.0	xx.x	xx.x	xx.x	0.0
Golden	18.2	18.2	xx.x	xx.x	xx.x	18.2
WEEDS						
Red root pigweed	69.7	69.7	xx.x	xx.x	xx.x	71.0
Canadian thistle	15.3	15.3	xx.x	xx.x	xx.x	15.8
Russian thistle	2.6	2.6	xx.x	xx.x	xx.x	3.2
Yellow foxtail	36.1	36.1	xx.x	xx.x	xx.x	38.4
Green foxtail	16.3	16.3	xx.x	xx.x	xx.x	14.2
Lambs quarters	42.6	42.6	xx.x	xx.x	xx.x	37.4
Kochia	17.6	17.6	xx.x	xx.x	xx.x	21.6
Wild mustard	12.4	12.4	xx.x	xx.x	xx.x	15.2
Wild oats	7.4	7.4	xx.x	xx.x	xx.x	9.0
Crabgrass	7.9	7.9	xx.x	xx.x	xx.x	9.7
Ragweed	5.3	5.3	xx.x	xx.x	xx.x	6.5

Table 4. concluded.

	SOIL CLUSTER					
	1	2	3	4	5	6
Smartweed	22.1	22.1	xx.x	xx.x	xx.x	3.2
Yellow nutsedge	0.0	0.0	xx.x	xx.x	xx.x	6.5
Purslane	2.6	2.6	xx.x	xx.x	xx.x	3.2
Bindweed	2.6	2.6	xx.x	xx.x	xx.x	2.6
Black nightshade	0.0	0.0	xx.x	xx.x	xx.x	3.2