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CROP LOSS MODELING AND RESEARCH RESOURCE ALLOCATION

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SUMMARY

1. INTRODUCTION

Any research resource allocation system, regardless of how formal or informal its methodology is, cannot avoid making judgments on two questions (Ruttan, 1982) :
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 society or the receipient of the new knowledge generated ?
Ruttan (1982) in one part of his book on Agricultural Research Policy also implied that the use of systems approaches for research planning had served their usefulness in the 1970's, while in another part, conceded that effective research planning was not feasible unless there was a participatory process involving biological and social scientists.
What I would like to do in this presentation is to illustrate how the systems approach, as we practise it in the 1980's, can provide a mechanism for research planning that is participatory, and provides answers to the two questions above. The resurgence of the systems approach in research resource allocation would not have been possible without advances having been made in some disciplines, notably crop loss assessment, crop/pest surveillance systems and computer-based databases.

2. CASE STUDY : Potato - Pest Management in North Central U.S.A.

The plant protection disciplines of entomology, plant pathology and weed science have traditionally used one tactic (host resistance, chemical, cultural or biological) to control a single pest in cropping systems. The noticeable development of resistance in pest populations to pesticides in the 1960's made scientists in these disciplines very conscious of the complex relationships that existed in agricultural systems, and aware of the need to understand the relationships between host plants, pests, their predators/parasites, the environment, and man. The complexity inherent in man-managed ecosystems, the need to farm for profit and to safeguard the environment and human health through rational pest management, all led to the development of the concept of "integrated pest management" (IPM).

In the North Central region of the USA, potatoes are intensively cropped in four major states - Michigan, Minnesota, North Dakota, Wisconsin - and is relatively the biggest user of pesticides per hectare. A project was initiated in this region in 1983 to conduct an analysis of the biological system and the management system for the potato crop and its associated pests, with the ultimate objective of improving the application of the IPM concept to maintain or increase yield. A potato task force, made up of a project leader, a systems analyst, and one scientist each representing nematology, entomology, weed science and plant pathology, acted as the coordinating force for the entire research planning activity. Initially, cluster analyses using soil variables revealed six major types of potato production areas in the four contiguous states. Each type had sub-areas located in one or more states, e.g. the Red River Valley production area of Minnesota and North Dakota. Within each production area, the decision-making processes of farmers were used to characterize production systems into seed, table-stock and chipping. Further, the decision process in each production system of each production area could be represented as a "decision-tree", from which a potential payoff matrix was designed for estimating benefits associated with any decision.

To reveal knowledge gaps in potato IPM, published literature on each pest was examined to determine usefulness for pest management. A series of matrixes was used to show presence/ absence or amount of research knowledge on pest- pest, pest- crop, pest- environment, pest- pesticide, pesticide- pesticide- pest, etc. interactions. To identify ongoing research sponsored by the USDA, a search was done using the DIALOG information system of all CRIS projects on potato IPM. This revealed areas of research emphases nationwide and within the north central region, with respect to different pests and control tactics. Concurrent with the above activities was a participatory process in which all potato scientists in the four states were asked to identify key pests and major knowledge gaps in their control, and to rank pests/problems needing research. The participatory process ensured that there was general support by the scientists themselves on what the problems were, and what were researchable or likely to result in some payoff in the short term. Further, the process provided an important forum for discussing regional pest problems.

Using a nominal group technique, and analyses of the production area, production system, decision tree, payoff matrix, literature, CRIS projects, and peer scientists rankings, the task force used several iterations to synthesize a list of research needs and priorities for potato IPM in the north central region. Subsequently, the list of research needs was used to solicit grant proposals from all potato scientists in the North Central Region, for funding by the USDA Regional IPM Competitive Grants.

P.Teng : Agricultural Research Policy Seminar April 16 1985

STEPS IN DESIGNING AN INTEGRATED CROP-PEST MANAGEMENT SYSTEM

1. System description

The first step in design is to describe the crop-pest system by detailing its biological system and its management system, using the systems analysis method a la Norton (1982a,b) and Johnson et al. (1985). This phase involves defining the components of the major biological subsystems, e.g. crop subsystem - species, cultivars; pest subsystem - individual pests, parasites and predators. For each subsystem-subsystem combination (e.g. crop 1 - pest 1), a series of analysis matrices is created, to identify the effect of weather, the effect of pesticides, interactions between weather and pesticides, etc. For example, in the weather matrix, the columns would be different weather factors like temperature, relative humidity while the rows would be the life cycle stages of each pest. Each weather factor-life cycle stage "box" would then be filled in with a notation indicating the state of knowledge, vis-a-vis importance for pest management. This kind of analysis also generates questions in the minds of the participating scientists as to how important various aspects of the crop-pest biological system are. The final product is really a conceptual model of the entire crop-pest ecosystem, and can be used for data collection and further research, leading if desired to the development of a detailed system simulation model.

The system description of the management system includes analyzing the decision process of the farmer by using a decision-tree to structure all the decisions he/she encounters before, during and after each "season" (Norton and Mumford, 1983a). Each decision can then be evaluated relative to potential value for crop or pest management. A monetary value may also be assigned to each decision point and an enterprise budget created for estimating the cost-benefit of any management decision, its associated risk, etc. (Johnson et al., 1985b). A payoff matrix is also created from this analysis of farmer decisions, to help in estimating potential benefit from conducting research on any decision point.

Apart from describing the crop-pest system, it is also necessary that the system for conducting research, for extension, for local training of trainers, etc. be described and analyzed for potential improvement.

2. Defining problems to be resolved

The system description step results in a determination of the major components of the system, their linkages and their role in the decision process of the farmer. It also defines how much is currently known on all aspects of the crop-pest system, and what the knowledge gaps are. Following the system description, it is necessary to determine how much of the current research, extension and teaching effort is addressing the knowledge gaps involved in the biology/management of the system. At the same time, an effort has to be made to involve the scientists in a common institution (e.g.

within a province country), in a participatory process of defining the constraints on system improvement and which of these constraints deserve priority for action. The final product of this step is to secure an agreement, through participation of all scientists, of what the major crop-pest biologic or management problems are, how they should be addressed, and what the action timetable is. All these should be done with the framework created in the system description step. Here too, information on the occurrence of crop management problems, the magnitude and recurrence of pest problems, data on production constraints obtained through on-farm surveys or experiments, would all serve to help problem definition. A listing of priorities for research, extension, teaching, (and training in the case of developing countries) should then be evident.

3. Setting objectives and timetables for implementing system improvement via research, extension and teaching.

In applying the systems approach to integrated crop-pest management, it is important that the objectives for distinct activities be clearly defined, for known time periods. A periodic review is needed of these objectives, the success or otherwise in meeting them and their relationship to the overall goal of improving the crop-pest management system. Within the context of the preceeding steps, a framework can be created for linking traditional, basic and applied research approaches to the systems research process (Dent and Blackie, 1979).

This step generates much of the information for system improvement. Implicit in this is the generation of information through research, the synthesis of the information, its dissemination and an evaluation of the acceptibility of the "new" knowledge by farmers. A continuing process of data gathering to provide feedback on system status or improvement would be very useful, using concepts and techniques that have been successfully tested (James and Teng, 1979; Heong, 1983; Teng, 1984).

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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

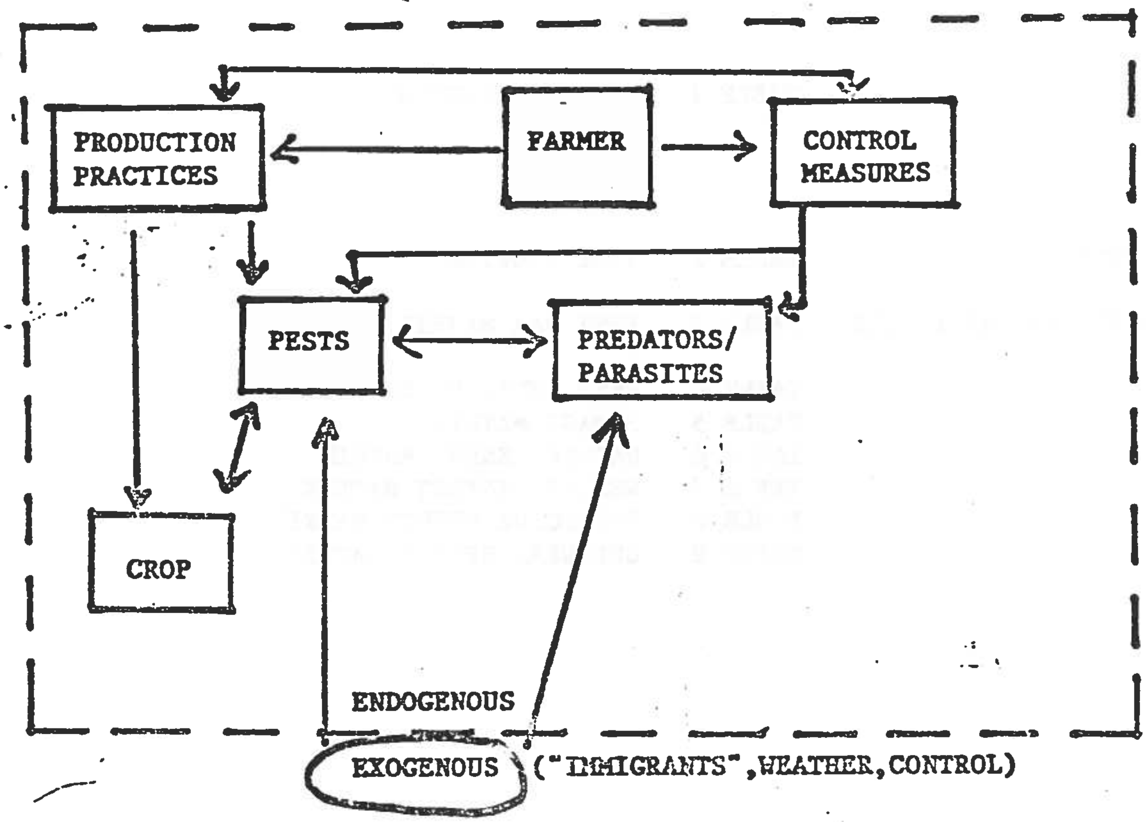
3. Potato IPM Research Plan for North Central Region

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.

POTATO PEST SYSTEM



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		

TABLE 2 TIME PROFILE FOR POTATO PEST SYSTEM

ACTIVITY	PLANTING	EMERGENCE	GREEN ROW FILL	MATURITY	HARVEST
Yield formation					
NPK demand					
insects					
predators					
parasites					
diseases					
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.				

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

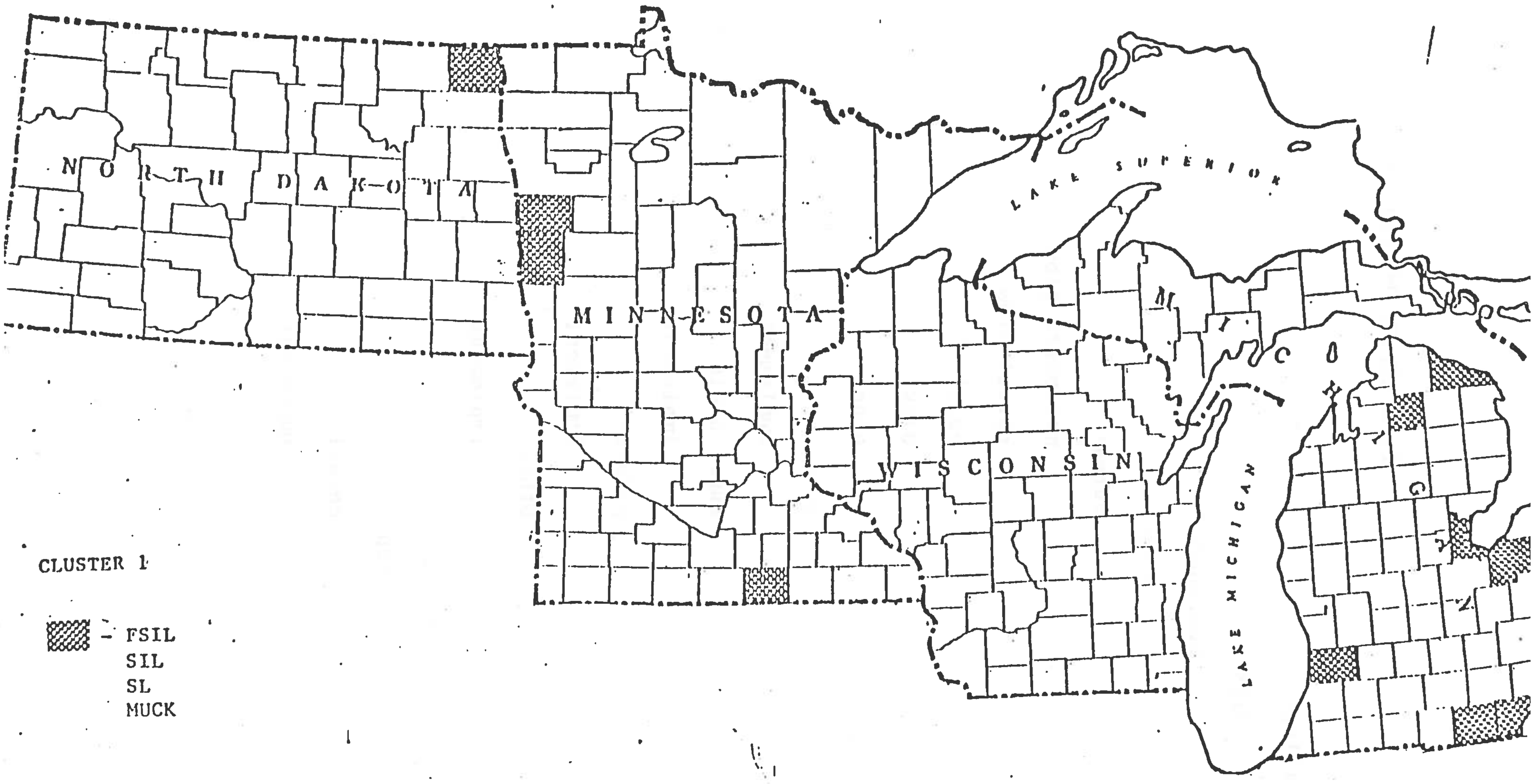
	IPM	BREEDING	CHEMICAL CONTROL	NON-CHEMICAL CONTROL	SURVEY	OTHER
Michigan	3	1	4	2	0	2
Minnesota	0	5	4	0	1	2
North Dakota	0	2	1	2	0	1
Wisconsin	4	1	4	3	1	3

Table 7.5.1. 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	PEST PROG	2-WAY INTER	3-WAY INTER
DISEASES	835	228	133	192	227	90	98	31
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	68	5	12	29	19	2	5	2
Ring rot	14	2	2	10	3	0	1	0
Scab	25	8	10	6	3	0	0	0
Late blight	359	114	75	58	97	49	12	4
VIRUSES								
PVA	5	0	1	1	3	0	1	0
PVX	74	3	9	21	36	8	9	3
PVS	17	1	2	7	5	2	5	2
CMV	4	1	0	1	0	1	2	1
TMV	6	0	1	3	1	1	1	1

Table 8.5.1. Results of survey of potato workers in Michigan, Minneosta, North Dakota, and Wisconsin, by soil clusters (appendix 2.7.1) 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



CLUSTER 1

- FSIL
SIL
SL
MUCK

FALL BEFORE POTATO CROP

- tillage
  - type
    - nonreduced
      - crop
        - cereal
          - moldboard plow
          - chisel plow
          - cultivate
          - disk
          - other
        - corn
          - implement
        - sugar beets
          - implement
        - potatoes
          - implement
        - other
          - implement
    - reduced
      - crop
        - cereal
          - implement
        - corn
          - implement
        - other
          - implement

soil test

fertilization

anhydrous

rate

other

rate

fumigation

type

rate

RETURNS			
round white potatoes	165cwt	3.50	577.50
TOTAL RETURNS			577.50
PLANTING COSTS			
field cultivator - 28 ft	.074h/A	53.28	3.94
springtooth drag - 48 ft	.033h/A	44.99	1.48
round white certified seed	15cwt	6.00	90.00
seed treatment	15cwt	.45	6.75
seed cutting	15cwt	.60	9.00
row marker - 6 row	.134h/A	84.83	11.37
truck filler	.174A/h	32.21	5.60
planter - 6 row (picker type)	.174h/A	118.73	20.66
heavy truck (3 required)	.174h/A	49.28	25.72
labor	1.11h/A	6.25	6.94
FERTILIZER			
anhydrous ammonia	75lb	.13	9.75
anhydrous applicator	.079h/A	84.98	6.71
nitrogen	25lbs	.22	5.50
phosphorus	50lbs	.22	11.00
potassium	60lbs	.10	6.00
lime	0lbs	.0075	.00
labor	.079h/A	6.25	.49
SPRAYING COSTS			
aerial application	4	3.50/A	14.00
ground spray rig - 50 ft	.042h/A	33.56	1.41
herbicide	1	5.00	5.00
insecticide			
planting	1	21.00	21.00
foliar	1	8.75	8.75
fungicide	4	3.70	14.80
sprout nip	1	12.00	12.00
vine killer	0	12.00	.00
labor	.042h/A	6.25	.26
CULTIVATION			
cultivator - 6 row (4 times)	.109h/A	28.61	12.47
labor	.436h/A	6.25	2.73
HARVEST COSTS			
potato harvester - 2 row	.402h/A	103.73	41.70
heavy truck (3 required)	.402h/A	49.28	59.43
disk - 21 ft	.098h/A	54.97	5.39
field cultivator - 28 ft	.074h/A	53.28	3.94
labor	3.39h/A	6.25	21.19
OTHER COSTS			
fuel	20gal/A	1.12	22.40
land charge	1667.00/A	.039	65.01
land tax	1667.00/A	.006	10.00
light truck	1.25h/A	20.18	25.23
promotion tax	165cwt	.03	4.95
crop insurance	577.50	.025	14.44
interest on cash costs	335.11	.065	21.78
TOTAL COSTS			608.79