MANAGEMENT OF THE POTATO TUBER MOTH BY TUNISIAN FARMERS:

A REPORT of ON-FARM MONITORING and a SOCIOECONOMIC SURVEY

INTERNATIONAL POTATO CENTER (CIP)

in collaboration with

Institut National de la Recherche
Agronomique de Tunisie
(INRAT)

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PN-AEC-408

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936-4111.07

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Correct citation:

R. von Arx, P.T. Ewell, J. Goueder, M. Essamet, M. Cheikh, and A. Ben Temine. 1988. *Management of the Potato Tuber Moth by Tunisian Farmers: A Report of On-Farm Monitoring and a Socioeconomic Survey.* Lima, International Potato Center in collaboration with Institut National de la Recherche Agronomique de Tunisie (INRAT). 30 p.

This publication was processed and printed
by the Training and Communications Department,
International Potato Center, Lima, Peru, 1988.

Copies printed: 1 000

XVI–SS–E–16–O–1 000

ISBN–92–9060–122–1

Abstract

The potato tuber moth (Phthorimaea operculella) is the most important potato pest in Tunisia. Populations are low during the cold and rainy winter period, but increase to significant levels during the hot and dry summer months. Tubers are damaged in the field, particularly if the harvest is delayed, and in traditional, rustic stores. Losses to farmers consist of discards, reduced prices for damaged potatoes, increased handling costs, and expenditures on pesticides. Farmers also sustain an opportunity cost when they are forced to sell at low prices to avoid pest damage.

The efficiency of the farmers' control tactics is highly variable --cases of total loss were found. Experienced farmers have developed integrated control strategies which combine cultural practices with the use of insecticides. High hilling, well-timed irrigation, early harvest, rapid handling and storage, and well-designed stores using local materials provide adequate control when combined with a single insecticide treatment as the potatoes are put into storage. They check regularly for increasing pest populations, and sell their produce before damage reaches a level which would affect the price. Less toxic pyrethroids have replaced Parathion as the insecticide most commonly used by farmers. The biological insecticide Bacillus thuringiensis has given good results in experiments.

The development of decision rules, based on entomological research results and the farmers' socioeconomic constraints, can help the extension service to disseminate an improved integrated pest management program. This will require information on the pest, crop and market situation, based on routine observations by entomologists and economists.

Compendio

La polilla (Phthorimaea operculella) es la plaga más importante en Tunisia. Su población es baja durante el invierno frío y lluvioso, pero asciende rápidamente a niveles significativos en los meses calurosos y secos del verano. Sus larvas pueden ocasionar daños a los tubérculos en el campo --especialmente si la cosecha se retrasa-- y causan problemas serios en los almacenes tradicionales rústicos. Los agricultores sufren pérdidas por cuatro razones: papas deshechadas, precios reducidos a causa de daños parciales, costos de manejo elevados, y gastos en pesticidas. También sufren un costo de oportunidad cuando venden su producto a precios bajos para evitar el riesgo de un ataque.

La eficiencia de los medios de control utilizados varía bastante. Algunos agricultores evitan el problema, otros sufren pérdidas totales. Los que tienen experiencia han desarrollado estrategias integradas de control. Combinan varias prácticas culturales --el aporque alto, el riego oportuno, la cosecha en su momento óptimo, el almacenamiento rápido, y un diseño adecuado de almacenes utilizando materiales locales-- con una sola aplicación de insecticida a los tubérculos al momento de almacenarlos. Cada cierto tiempo revisan los almacenes para observar la población de polillas, y venden las papas antes

que la plaga haga daño de modo tal que afecte su precio. Se ha sustituído el parathion, el insecticida más utilizado, por los pirethroides que son menos tóxicos al ser humano. En ensayos experimentales, el insecticida biológico Bacillus thuringiensis ha dado resultados promisorios.

El desarrollo de reglas de acción flexibles, basado tanto en los resultados de la investigación entomológica como en la realidad socioeconómica de los agricultores, podría ayudar al servicio de extensión a promover programas mejorados del control integrado de plagas. Esto requiere información sistemática sobre la plaga, el cultivo, y el mercado, basada en observaciones rutinarias realizadas por entomólogos y socioeconomistas.

Résumé

La teigne (Phthorimaea operculella) constitue le ravageur de la pomme de terre le plus important en Tunisie. Pendant l'hiver, période froide et pluvieuse, les populations de teigne sont peu nombreuses, mais elles croissent et atteignent des niveaux significatifs durant la saison d'eté chaude et sèche. Les tubercules sont atteints dans les champs mêmes, surtout si la récolte se fait de manière tardive, ainsi que dans les magasins traditionnels et rustiques. Les pertes que subissent les paysans se composent des quantités rejetées, des prix réduits à cause de la qualité abîmée des pommes de terre, des frais de maniement plus élevés et des dépenses pour les pesticides. Les fermiers subissent également des coûts d'opportunité lorsqu'ils sont constraints à vendre à des prix réduits pour éviter les dégâts causés par la peste.

L'efficacité des tactiques de surveillance des fermiers varient grandement --on trouve des instances de perte totale. Des fermiers expérimentés ont développé des stratégies intégrées pour maîtriser le ravageur, qui combinent des pratiques de cultures et l'utilisation d'insecticides. Le butage, l'irrigation opportune, des récoltes au bon au bon moment, un maniement et un emmagasinage rapides, et des magasins bien conçus utilisant des matériels locaux, tous ces facteurs permettent un contrôle adéquat lorsque combinés avec un traitement qui consiste en une seule application d'insecticide au moment où les pommes de terre sont emmagasinées. Les fermiers contrôlent les pommes de terre à intervalles réguliers pour détecter les augmentations en nombre des insectes et ils vendent leur produit avant que les dégâtas n'atteignent un niveau susceptible d'influencer le prix de vente. Des pyrethroides moins toxiques ont remplacé le parathion en tant qu'insecticide couramment utilisé par les fermiers. Des expériences menées avec l'insecticide biologique Bacillus thuringiensis ont montré des résultats positifs.

L'élaboration de règles gouvernant la prise de décision, fondées sur des résultats de la recherche entomologique et sur les constraintes socio-économiques des fermiers, peut aider les services de vulgarisation à propager un programme amélioré de traitement intégré de la peste. Ceci nécessitera le rassemblement de renseignements sur la maladie, sur la situation des récoltes et du marché, fondés sur les observations routinières des entomologistes et économistes.

Acknowledgements

The offices of the national extension service (CRDA) in Bizerte and Nabeul supported the on-farm evaluations by providing lists from which the farmers were selected, and other useful information. Data on production costs from the State Farm at Borj El Amri (OMVVM) and market information from the Inter-Agency Vegetable Authority (GIL) are gratefully acknowledged. We would like to thank the staff of the CPRA training center at Saida where an important part of experimental research was conducted, the technical assistants at the Entomology Department at INRAT, and last but not least, the farmers for their cooperation.

I. Introduction

The potato tuber moth (Phthorimaea operculella) is the only economically significant insect pest of potatoes in Tunisia, and throughout North Africa. It attacks both foliage and tubers. Its larvae cause significant damage to both ware and seed potatoes kept in unrefrigerated, rustic stores through the hot summer months. Farmers rely heavily on insecticides. Parathion was commonly dusted onto tubers stored for consumption until 1986, when public health regulations finally mandated its substitution by pyrethroids, chemicals far less toxic to people. According to criteria cited by Mumford and Norton (Mumford and Norton, 1987), local conditions are relatively favorable for the development of a sustainable integrated pest management system which would reduce reliance on pesticides. The spectrum of pests which attack potatoes is narrow, prices for the crop are high, and the tuber moth causes severe and consistent economic losses if it is not controlled.

This report is based on interdisciplinary research carried out jointly by the Entomology Department of the Tunisian National Agricultural Research Institute (INRAT) and the regional office of the International Potato Center (CIP). The two institutions collaborated for several years on studies in the laboratory and under experimental conditions, designed to describe the biology of the pest in the local agro-ecosystems and to test promising component technologies for its control. In 1986, a program of on-farm research was carried out by a team of entomologists and social scientists from both institutions. Observations in farmers' fields and stores and a socioeconomic survey were designed to incorporate data on farmers' knowledge and current practices into the development of a practical IPM program. The results are being used to identify economic and social constraints on the adoption of integrated pest management strategies developed on research stations, and to modify the technology accordingly.

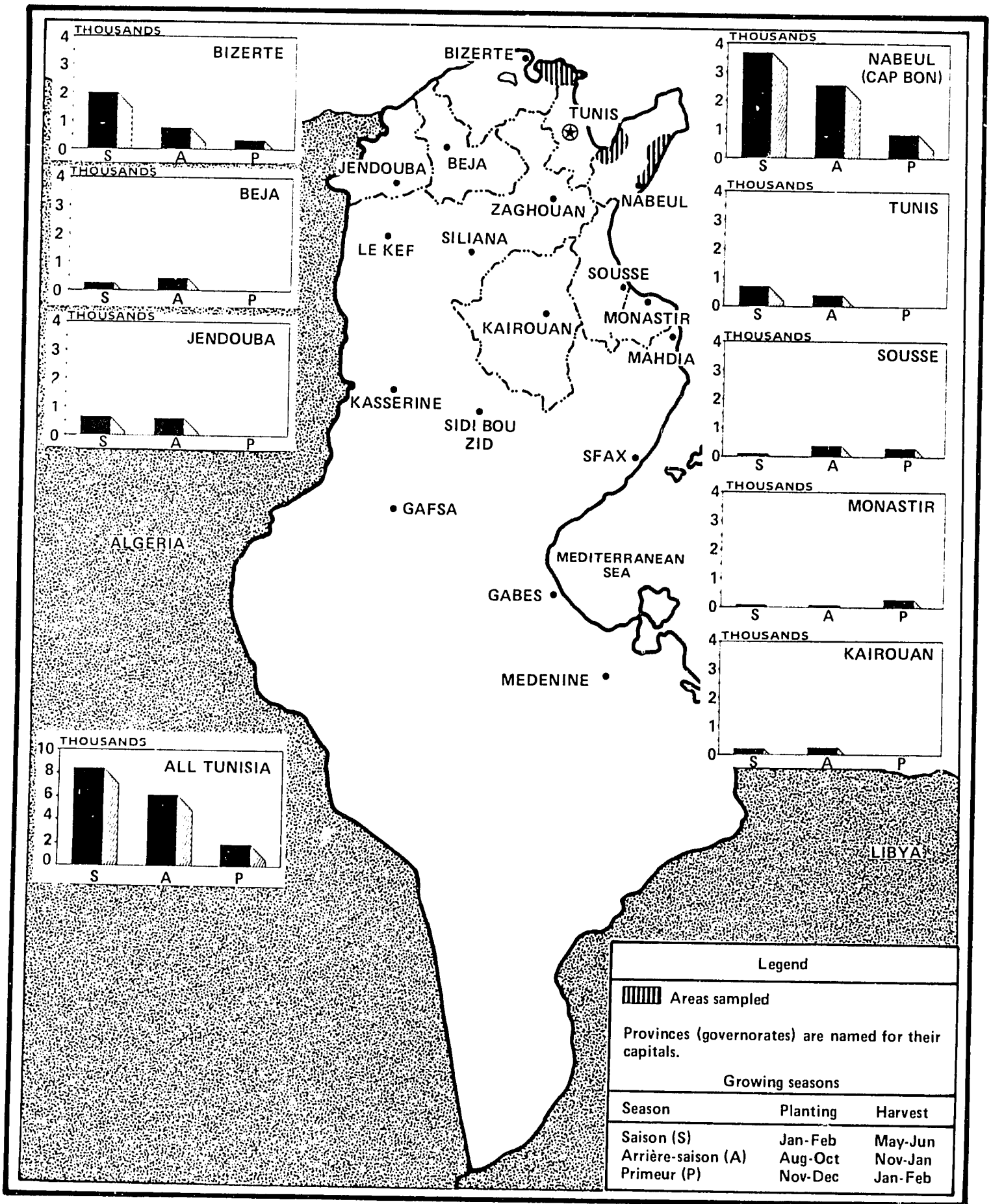
II. Potato Production and Storage in Tunisia

Potatoes have been grown in Tunisia for many years. Production is increasing rapidly --it went from 40,000 tons in 1960 to an estimated 160,000 tons in 1986. Potato production has traditionally been concentrated on small, diversified, irrigated farms in areas of moderate climate along the northeastern coast near the city of Tunis (Figure 1). There are a few large state farms. Government irrigation and credit programs have recently encouraged the expansion of the crop into new areas. The Tunisian climate follows the classic Mediterranean pattern, with the rains concentrated in the cool winter months (Figure 2). Frosts are a hazard from December through February, and the summer is too hot and dry for potato production.

The Annual Production Calendar

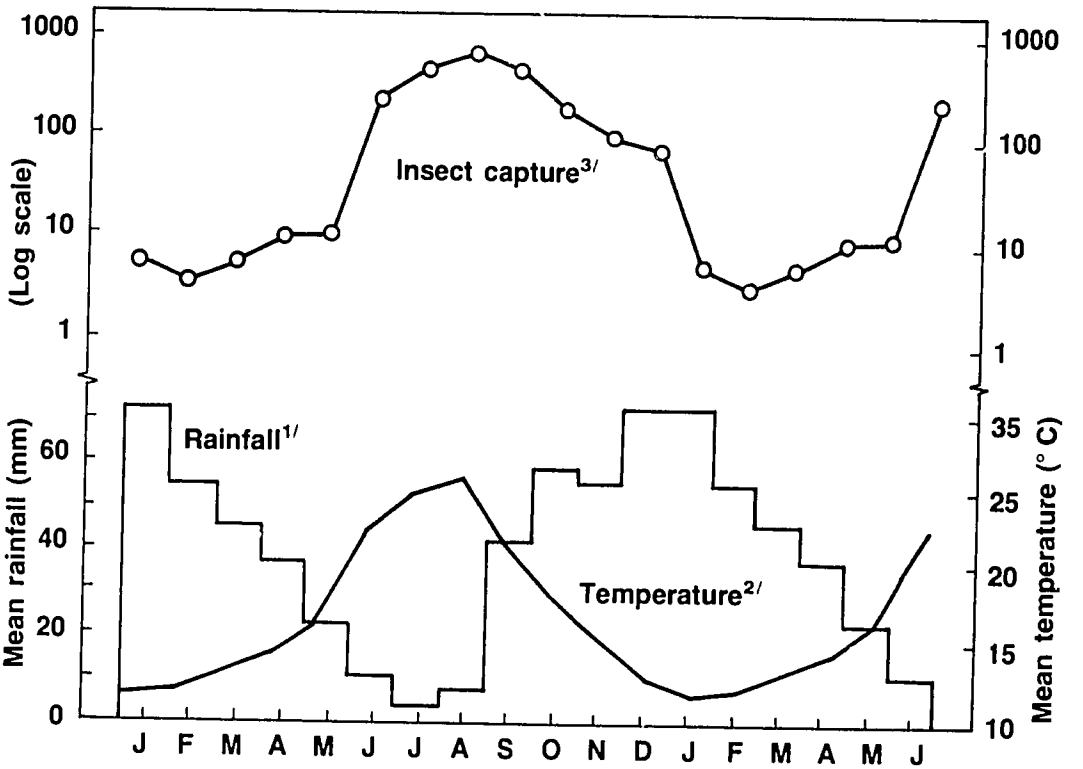
The annual crop cycle begins in January or February, when the main-season (saison) crop is planted with seed tubers imported from Europe. Much of the principal harvest in May and June is put into storage, both to supply the market for the next several months, and as seed for subsequent plantings.

Figure 1. Tunisia: Potato area harvested by province and season, 1984-86, and on-farm research sites, 1986.



Source: Tunisia; Ministry of Agriculture, Department of Vegetable Crops.

Figure 2. Potato production and storage calendar, in relation to patterns of mean monthly rainfall, temperature, and populations of potato tuber moth



Planting (P), harvest (H), and storage (S) dates.

Main season ---P-- --H---- ---P-- --H----
---------S ---
Late season ---P--- ---H----
Early season ---H--- -----P-- ---H----

1/Mean rainfall for month, 1900-1950. 2/Mean temperature for month, 1900-1950. 3/Average weekly capture of adult male tuber moths from 4 traps in month, 1985.

Sources: Climatic data for Grombalia, Cap Bon; Section de Bioclimatologie, INRAT; tuber moth populations for Korba, Cap Bon; Laboratoire d'Entomologie, INRAT.

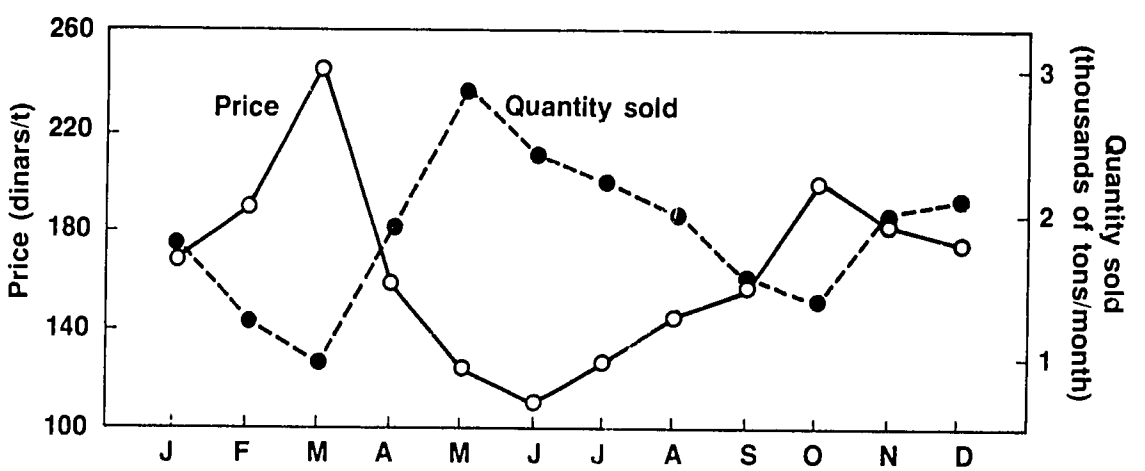
Late-season (arrière-saison) plantings start in August, and supply the market from mid-October through the end of the year. A very much smaller early-season (primeur) crop is planted in frost-free areas in November and December. Part of this harvest is exported to Europe. A program for the production and storage of improved seed to help expand these later plantings has been set up by the Inter-agency Vegetable Authority (GIL) with technical assistance from CIP (Horton and Monares, 1984; Horton et al., 1986).

The Storage Season

The annual cycle of the price of potatoes in the Tunis wholesale market reflects the seasonal pattern of production and supply (Figure 3). Short-term fluctuations are dampened by government regulations. Prices are lowest in June, at the height of the main harvest. There are two peaks; one in October, just before the late season crop (arrière-saison) comes on the market, and the other in March, before the first new potatoes of the main crop appear.

It is too hot to produce potatoes between July and October, so farmers store a portion of their main-season harvest in expectation that the cost and probable losses due to tuber moth damage, shrinkage, and other causes will be compensated by an increase in the price. This is a risky decision, as neither the level of pest damage nor the market price can be known in advance. As it does not rain in this period, permanent storage buildings are not necessary. The traditional storage system is to heap the tubers in a shaded place --a shallow trench under a tree or a rough shelter of boughs. The heap is covered with a protective barrier of paper or jute, and then piled over with a thick layer of straw, potato haulms, or other handy material. Refrigerated stores are used only for seed over extended periods.

Figure 3. Seasonal patterns of average monthly price and quantity of potatoes sold in wholesale market in Tunis, 1980-1985[1/].



[1/] During this period, the average value of 1 Tunisian Dinar was US$1.50.
Source: Tunisie, Groupement Interprofessionel des Légumes (GIL).

III. The Potato Tuber Moth

Annual Population Cycle

The seasonal trends of potato tuber moth populations are strongly influenced by the climatic conditions. Moth densities are very high during the hot summer months and drop in the cold and rainy winter season to levels which vary depending on the severity of the cold spells and the amount of rainfall (von Arx et al., 1987). However, all developmental stages are found throughout the year and no diapause has been recorded for this insect. Populations are high between March and October, so late harvests of the main-season crop, potatoes in stores for seed or consumption, and early plantings of the late season crop, are subject to attack.

Economic Damage to Stored Potatoes

Tuber moth larvae feed on the leaves and stems of the crop in the field, but our research has shown that they rarely do enough damage under Tunisian conditions to affect yields. Near the end of the crop cycle, the larvae find their way down through cracks in the soil. They burrow into the tubers, creating galleries, and deposit excrement at the outlets. They are moved into the stores with the harvested crop, where they spread rapidly within the heap. Wounds produced by the insect provide entry to fungus and bacterial diseases.

Although almost all farmers dust with insecticides, between 10 and 50 or 60 percent of the tubers in a storage heap are routinely attacked by tuber moth larvae. Seriously damaged tubers are discarded --a complete loss-- or are fed to livestock. The price penalty for intermediate degrees of damage is variable, and a significant share of the burden of the loss is shifted from farmers to consumers. Particularly at the end of the storage season in September and October, and in years when supply is short, consumers have no alternative but to buy potatoes with significant damage. Tubers perforated with worm holes and dusted with insecticides --until 1986, with garishly purple Parathion-- are commonly seen in retail markets.

Experimental Research to Identify Promising Control Components

Before 1986, the cooperative research program of INRAT and CIP was carried out on experiment stations and state farms (Table 1). Starting in 1978, adult populations of the tuber moth were monitored using pheromone-baited water traps, to study seasonal patterns and regional variations of pest densities. Damage by larvae in experimental fields and stores was studied in relation to the stages of crop development and different control methods. The relative susceptibility of commonly grown varieties was compared.

Table 1. Summary of Research Program on the Potato Tuber Moth of the National Program (INRAT) and the International Potato Center (CIP), 1979-1986.

Research Topic	Methodology	Where Done	No. of years	No. of sites
Seasonal population patterns	Monitoring of adults with pheromone traps	Experiment Station	8	1
	Counts of larvae in fields and stores	State farm	2	2
		Farmers' fields	1	8
Pest damage	Assessment of pest damage in field and in stores	Experiment station	3	1
		State farm	3	2
		Farmers' fields	1	45
Host resistance	Comparison of commercial varieties	Laboratory	1	1
Control methods	Evaluation of cultural practices, chemical & biological insecticides, and pheromones	Experiment station	6	1
		State farm	4	1
		Farmers' fields	1	44
	Analysis of socio-economic factors behind farmers' practices	Farmer survey	1	44
Market factors	Monitoring of seasonal patters of price and quality	Wholesale	4	1
		Retail	1	2

The results demonstrated that the use of insecticides in the field is not an effective way to prevent infestation in stores. Enough insects can survive and propagate in the heap to cause economic damage. Direct control in stores is usually necessary. Trials of the biological insecticide *Bacillus thuringiensis*, which is not at all toxic to people, are very promising (von Arx, et al., 1987). Nevertheless, no insecticide provides more than partial control, so cultural practices which reduce infestation are critical components of any integrated pest management program. The following practices have been shown effective under experimental conditions, both in Tunisia and in other parts of the world (Foot, 1975; Shaheen, 1979; Shelton and Wyman, 1979):

Frequent irrigation right up to the harvest prevents the soil from cracking, which makes it difficult for tuber moth larvae to move from the soil surface down to the tubers.

Deep planting and high hilling have the same effect.

Timely harvest, before the pest population builds up to critical levels, reduces initial infestation in the storage heap. The results of experiments indicate that yields do not increase after the foliage begins to mature and turn yellow, but that the percent of damaged tubers goes up dramatically the longer the harvest is delayed.

Rapid handling and careful selection after harvest reduce the exposure of the potatoes to possible infestation before they are put into storage.

Good design and construction of traditional stores with a thick layer of straw or other clean material over the heap provides effective, low cost protection against re-infestation. Infested materials, such as dried potato haulms, should be avoided.

IV. On-farm Research Methods

Once the principal control components had been tested under experimental conditions, on-farm research was instituted to document levels of pest damage and current control practices in farmers' fields and stores. On-farm trials are usually designed to test the effect of new or improved production components on yields and net returns in comparison with the farmers' current practices. This method is appropriate when a new component such as variety, fertilizer, insecticide or storage technique can be compared with a fixed current practice. In IPM programs, however, a number of control components, which by themselves depend on variable factors, must be adapted to the specific conditions on the farm. For example, the choice of "the right" date for the harvest or for the application of an insecticide depends on the temperature, the physiological age of the crop, the pest density, the expected price of the product, the farmer's need for cash, and other factors. The level of pest attack and the combination of control tactics varies significantly from farmer to farmer and from one year to another. One cannot simply choose a "typical farmer's practice" against which to compare proposed improvements one at a time. This means that it is very important to look systematically at a range of farmers' pest problems and practices, to see how an IPM program can be flexibly adapted to variable conditions. The analysis of proposed alternatives must include key socioeconomic aspects of the problem.

The regions of Bizerte and the Cap Bon were selected for continuous monitoring and a survey. These are the oldest and most important potato two growing areas in the country. Farmers with long experience with the potato tuber moth problem were expected to have developed a variety of control methods. The on-farm research was conducted by a team of two entomologists, two economists, and three technical assistants from INRAT and CIP.

Continuous monitoring of six case study farmers

In cooperation with the extension service, six farmers (three in each region) were selected for intensive case studies. They were visited at weekly intervals through the 1986 growing and storage season. The populations of adult tuber moths were monitored using 4-pheromone baited water traps. To monitor damage, weekly samples of 30 plants were taken as the plants matured during the two to three weeks before the farmers harvested. The weight of tubers and the percentage of tubers damaged by the tuber moth were observed. At the same time, the area of soil covered by the potato plants' foliage was measured using a grid 30 x 70 centimeters subdivided in 30 quadrants (CIP, 1986) and the plants' maturity was estimated according to the scale developed by Regel and Sands (1983) (Table 2). During the storage season, the traditional stores were opened up and sampled once every month to estimate the percentage of damaged and rotten tubers. Each farmer was interviewed one or more times, and information about irrigation, pest management, and other practices in field and storage were recorded on standardized forms.

Table 2. Plant maturity rating as determined by leaf and stalk condition according to Regel and Sands (1983)

Rating	Name and code	Leaf and stalk condition
0	Tops dead, TD	Plant tops are dead, stalks are dry
1		Stalks are slightly sappy
2		Sappy stalks, with a few yellow leaves
3	Golden leaf, GL	Leaves are a golden yellow
4		Plants are yellow with a tinge of green
5		Plants are yellow with obvious green visible
6		Plants are 50% green and yellow
7	Yellow-green, YG	Plants are green with obvious yellow visible
8		Plants are green with a tinge of yellow
9	Dark green leaf, DG	Plants are green with the first evidence of yellow appearing
10		Absolutely no evidence of yellowing, leaves are green, growth is lush

Survey of 38 farmers

A single-visit survey was carried out in late September 1986, near the end of the storage season, to discover the frequency of key pest management practices in a representative sample of farmers. This moment was chosen as a time when farmers could sum up the experience of the season, and when some potatoes would still be found in storage heaps. The extension service (CRDA) in the province of Bizerte provided a list of all the potato farmers, with an estimate of the area they had planted to potatoes and other crops. This was used as a sampling frame, so that the size distribution of the farms in the

sample would approximate that in the region as a whole. The same basic guide was used in the Cap Bon region, where no complete list was available. Local extension agents helped to identify the farmers for the case studies and the interviews, and accompanied the team on many of the days in the field. This was a good opportunity to establish and strengthen contacts between researchers and extensionists, important for the application of the research results in practice.

Thirty eight farmers with a total of about 50 hectares of main-season potatoes were interviewed. This is a small sample of the nearly 6000 hectares in potato production in the two regions, but it was not designed as the basis for broad inferences about the population of farmers as a whole. That would have required a lengthy and expensive research project with specially trained enumerators, data processors, etc. Instead, the goal was to get an interdisciplinary team of biological and social scientists out in the field to gather as much information as possible related to tuber moth management from a representative cross-section of farmers.

Spot survey of retail markets

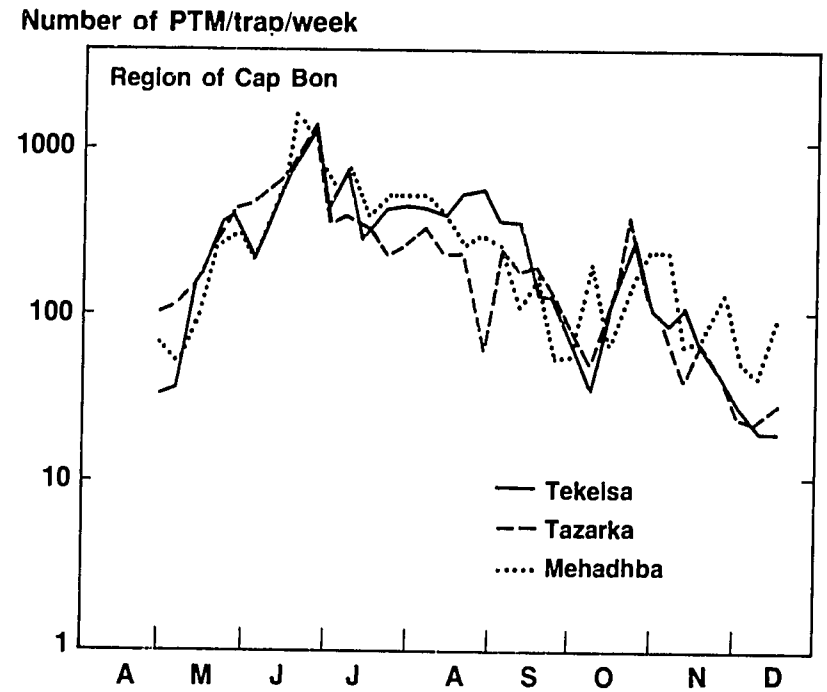
As much of the economic loss to tuber moth is due to reduced prices for damaged potatoes, information was needed from markets. Average prices in the principal wholesale market in Tunis were made available by the Inter-agency Vegetable Commission (GIL). They did not, however, have information about the enalties on reduced quality, a complex empirical problem as there are not standard grades in Tunisia. As a first approximation of the relationship between quality and price in retail markets, researchers from INRAT went out and purchased samples in two markets every two weeks during the storage season. The potatoes were evaluated for price, fresh weight, damage, and consumable weight after peeling and removing damaged flesh.

V. Results

Pest Population Patterns

The population trends observed by pheromone trapping of adult moths in the potato plots of the six case-study farmers are illustrated in Figure 4. The population densities follow the same patterns within each region, but differences between the regions were observed. In Cap Bon, populations built up faster to higher levels in the period before the harvest. During the last week of June over 1,000 moths per trap were counted. During the following storage period (August-September) populations declined to the same level as those in Bizerte, and fluctuated between 100 and 500 moths per trap per week. At the beginning of October catches were significantly reduced in Cap Bon due to high rainfall (in some places over 200 millimeters in one day). Population densities were less affected by rains in Bizerte, and remained high. During November and December a steady decline of the populations was observed in both regions.

Figure 4. Potato tuber moth (PTM) captures in pheromone baited water traps in three farmers' fields in Cap Bon and Bizerte during the cropping and storage season of 1986.



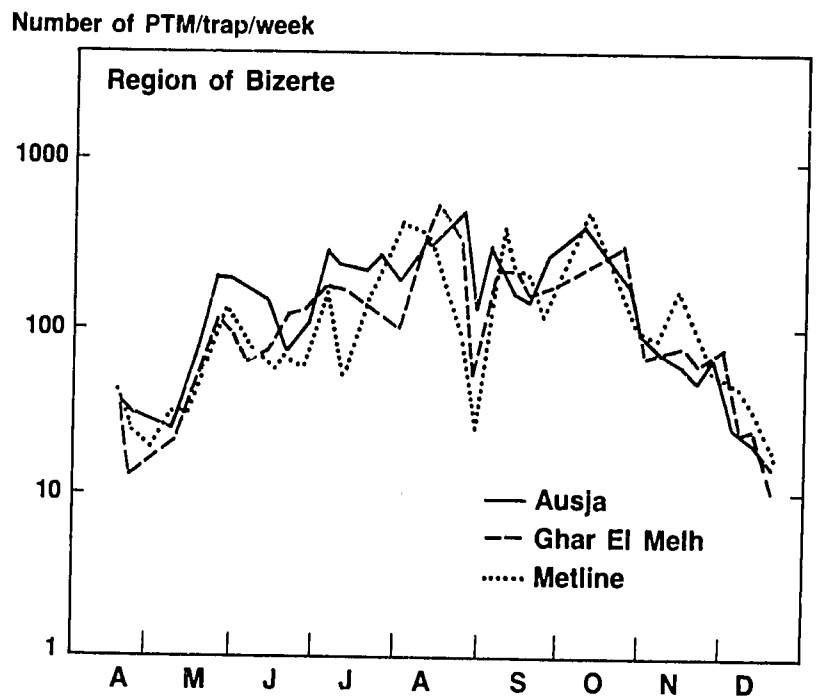
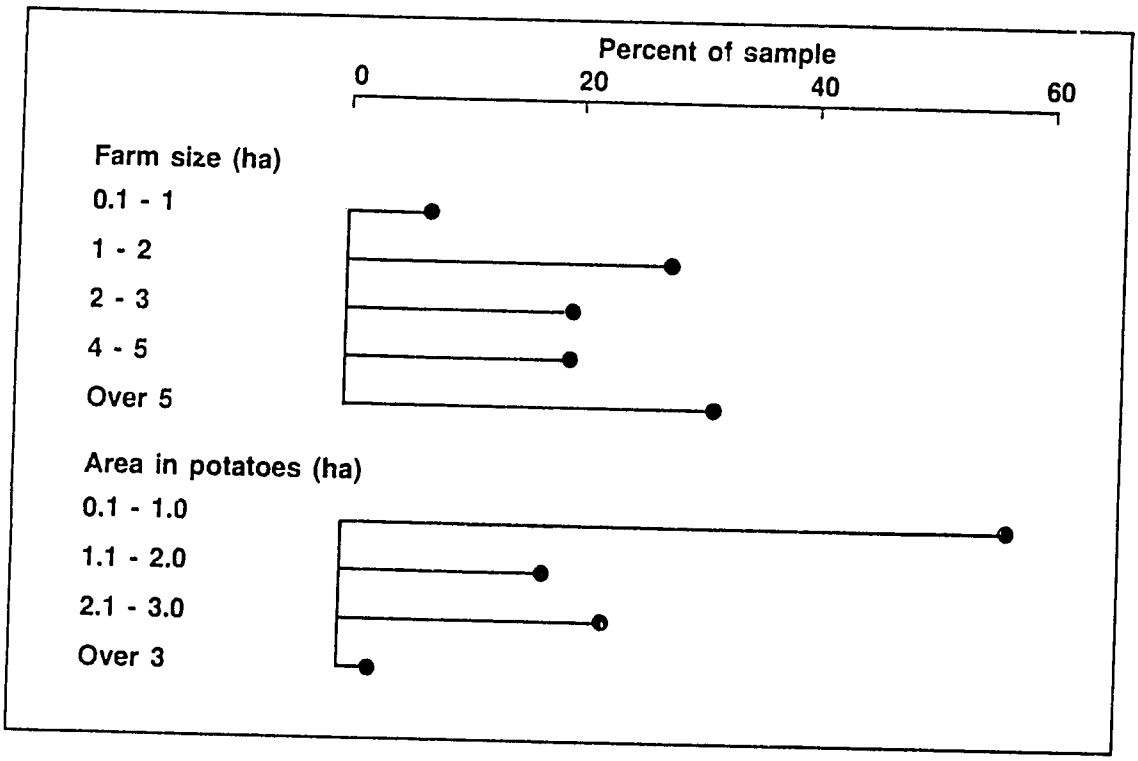


Figure 5. Farm size and area in potatoes (n = 38).



Characteristics of the Sample Farmers

With the exception of one large cooperative enterprise, the sample farms were small, with an average of about five hectares in production (Figure 5). The average area planted with main-season potatoes was between one and two hectares. Most operations were diversified fruit and vegetable farms: 47 percent of the farmers also grew fruit trees, 26 percent other vegetables and 32 percent other crops, mainly grains, forrages and grapes. Only 13 percent were cultivating potatoes exclusively. Potatoes are often grown between the rows of young trees in orchards, and in other complex arrangements. Animal production is an important part of the local farming systems. Twenty nine outof 38 farmers (76%) raised cattle; sheep and horses were also common. Well over half (63%) of the operations were large enough to provide full-time employment to the farmer and his family. Among those who depended on supplemental off-farm work, agricultural labor was the most important activity cited (20%), followed by white collar jobs (10%), and commerce (3%).

The farmers had many years of experience. Seventy five percent had grown potatoes for more than ten years. The potato tuber moth problem seemed to have been increasing in the course of their experience. Only 37% said that they had faced this pest for more than ten years. When asked about the highest and lowest yields they had obtained recently, farmers gave responses which ranged from total losses to over 40 tons per hectare, with means for maximum yield of 27.1 tons per hectare and for minimum yield of 9.5 tons per hectare.

Two thirds of the farmers estimated yields between 11 and 15 tons per hectare in 1986, which was considered a disappointing season by 82 percent of them. In spite of the fact that most of the crop land received at least supplemental irrigation, low rainfall was the most commonly cited reason for low yields (45%), followed by poor seed quality and inappropriate varieties (12 and 9 percent, respectively).

The basic technology of production was quite homogeneous. Most farmers (63%) hired in a tractor for land preparation and then performed the rest of the field operations with animals and hand labor. In only 21% of the cases was animal traction used for soil preparation. Only 8 farmers (21%) worked with credit.

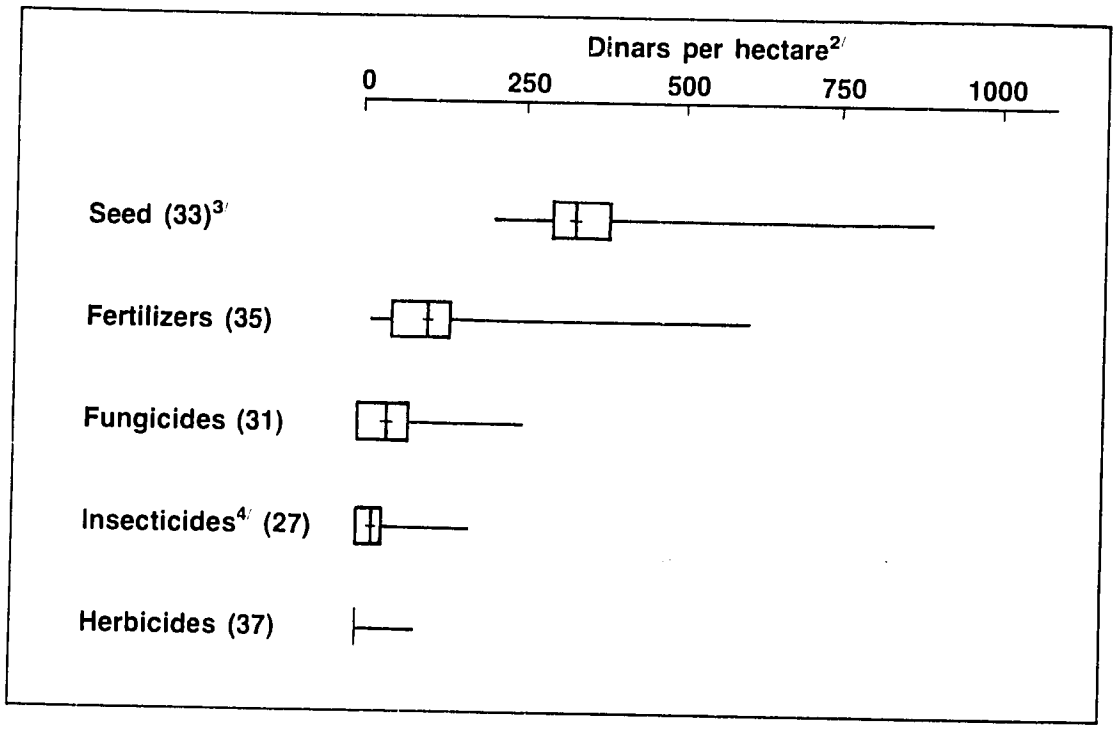
The questionnaire detailed the cost of purchased inputs but not labor, even though this is one of the highest costs of potato production. We could not expect farmers to recall all investments of both family and hired labor in a single interview at the end of the season. We did not feel that detailed data on labor use would add enough to our understanding of pest management practices to justify the cost of collecting them.

The most expensive purchased input was seed, which is imported from Europe for the main-season planting. It cost between 340 and 370 dollars per ton. The median expenditure was 260 dollars per hectare; extremes ranged from $250 to over $1,000 (Figure 5). The Tunisian market has a strong preference for the Dutch variety Spunta, which was planted by 92 percent of the farmers. Seed is imported and distributed through government agency, who insist that farmers maintain some diversity and buy more than one variety. Among those the most important were Cristal (cultivated by 42% of the farmers), Diamant (21%), Claustar (16%), and Atica (11%). All but two of the farmers used chemical fertilizers. Median expenditure was about 100 dollars per hectare; the extremes ranged from zero to over $500.

Farmers' Pest Control Practices

Farmers use variable combinations of chemical and cultural methods to control the tuber moth. Through experience and through contact with an extension service with wide coverage, at least some of the farmers were using all of the cultural practices which the INRAT/CIP project has shown to be effective under experimental conditions (Table 3). Nevertheless, no one of them was cited by even 40% of the farmers--poor practices persist and there is much room for improvement.

Figure 6. Expenditures on inputs in main season by sample potato farmers[1].



[1] These "box-and-whisker" graphs are constructed as follows: the vertical line in the middle of each box marks the median observation. Each box goes from the lower to the upper quartile, and the horizontal "whiskers" extend out to the extreme observations, marking the range. [2] At the time of the survey, 1 Tunisian dinar = US$1.23. [3] The number of farmers who provided enough information about the input to calculate the cost per hectare. [4] Applied both in the field and in storage.

Table 3. Management Practices Cited by Farmers as Helpful to Reduce Infestation by Potato Tuber Moth
(n=36)

Practice	No. of farmers	%
Timely harvest*	14	39
Good cover over stored potatoes*	13	36
Rapid handling between harvest and storage*	12	33
Apply insecticide in storage*	11	31
Harvest in damp soil	8	22
Irrigate right up to harvest*	4	11
Apply insecticides in field	4	11
Frequent irrigation*	2	6
Harvest only in cool weather	2	6
Harvest only when plants are completely mature	2	6
Careful selection before moving tubers into storage*	2	6
Apply insecticides during harvest	2	6
Harvest while the tops are still green	1	3
Fumigate soil before planting	1	3
No practice necessary or effective	4	11

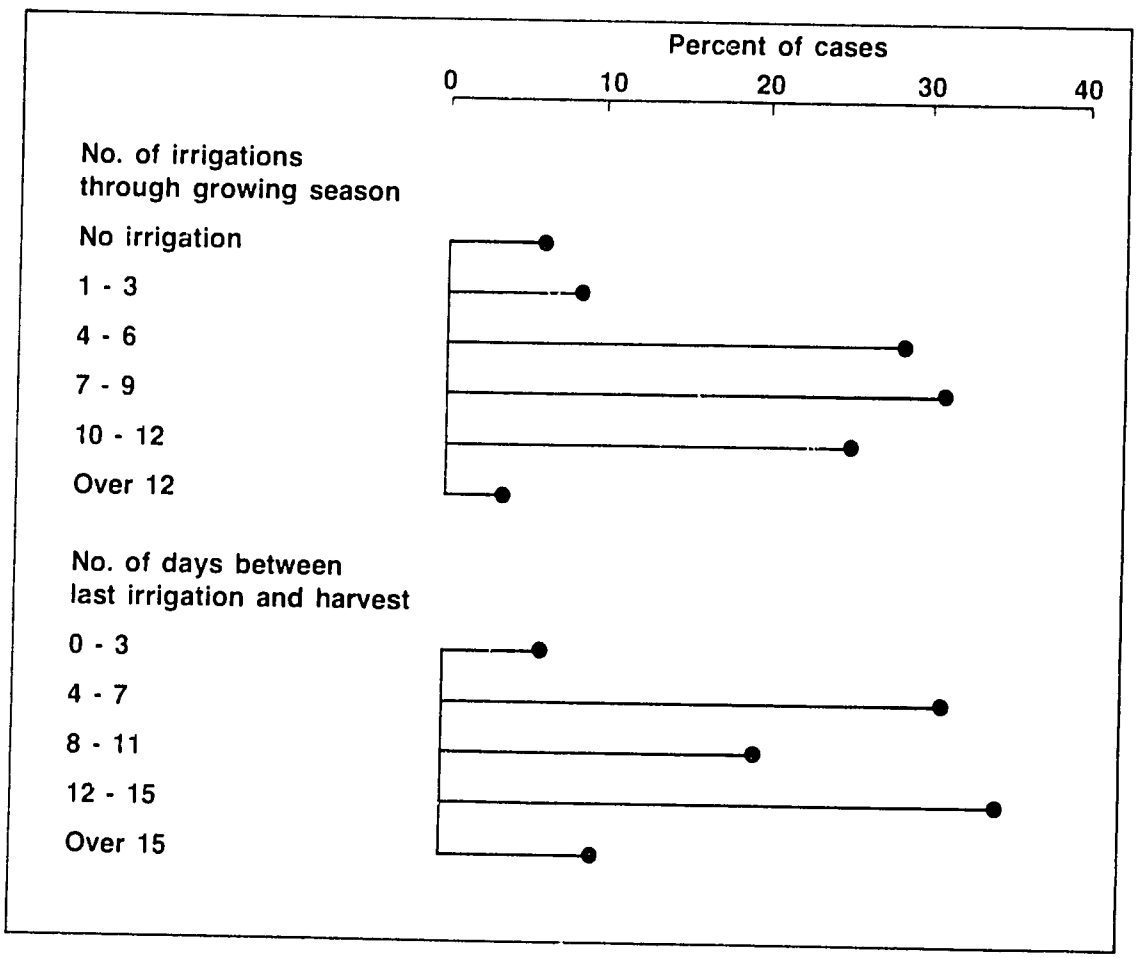
* Practice proven to have effect in experiments carried out by INRAT/CIP project.

Source: Farmer interviews.

Application of Pesticides in the Field. Pesticides are a relatively minor cost of production. Although late blight (*Phytophthora infestans*) and other fungus diseases are not a problem every year, the only way to control them is to apply chemicals in advance, as a preventive measure. Eighty five percent of the farmers in the sample sprayed fungicides at least once, nearly half of the them more than three times. Potato tuber moth was the only economically significant insect pest, although cut worms and a few others are seen occasionally. Insecticide applications would only be justified in intreme cases, but 46 percent of the farmers did spray in the field. Weed control on these small, intensive operations is most always by hand. Only 16 percent of the farmers applied a herbicide once, mainly *Sencor* (Metribuzin), to save labor.

Irrigation. Keeping the soil moist not only increases yields, but is also an important practice to prevent the formation of cracks through which tuber moth larvae can move down to the tubers. Ninety percent of the farmers in the sample had their own wells and pumps, which gave them flexible control over their irrigation schedule. Only 16% reported significant problems of water shortage. Nevertheless, irrigation frequency varies considerably. Many farmers start irrigating rather late in the season (April) to economize on water (Figure 7). Tubers are particularly vulnerable to tuber

Figure 7. Irrigation practices of sample farmers in main season, in Bizerte and Cap Bon districts, 1986 (n = 31).



moth if the soil is allowed to dry and crack just before the harvest. In 62% of the cases, the harvest was delayed more than one week after the last irrigation. Ten percent of the farmers waited more than two weeks, which probably increased the risk of tuber damage considerably. One of the case study farmers used sprinkler irrigation, which is known to reduce tuber moth damage (Shelton and Wyman, 1979). The lowest pest attack at harvest was observed in his field.

Timely Harvest. Timely harvest, to get the tubers out of the ground and away from sources of infestation, is probably the most important cultural practice for the control of the potato tuber moth. Two thirds (68%) of the interviewed farmers reported losses at the time of harvest. In 22% of the cases, losses were more than 10% of the total yields. The harvest is a complex operation at a busy time of the year which requires hiring workers, arranging transport, etc. Twenty four respondents (63%) reported no problems which delayed harvest, but this should be checked with further field work in May and June. Shortage of labor was cited as the reason for delayed harvest in 26% of the cases, conflicts of other crop harvests in 11%, and 17% of the farmers mentioned other reasons. Table 4 outlines the factors which determine the harvest date.

Table 4. Tunisia: Factors Cited by Farmers to Determine Best Time for Harvest

(n = 38)

	Number	Percent[1]
When skins become firm	28	74
When plants and stems die back	22	58
When leaves turn yellow	20	53
When normal period after planting is completed	4	11
When soil is dry	1	3
No response	5	13

1 Percentages sum to over 100% because some farmers gave more than one response.

Source: Farmers interviews

Figure 8. Tuber yield in relation to the time period (days) before farmers' harvest.

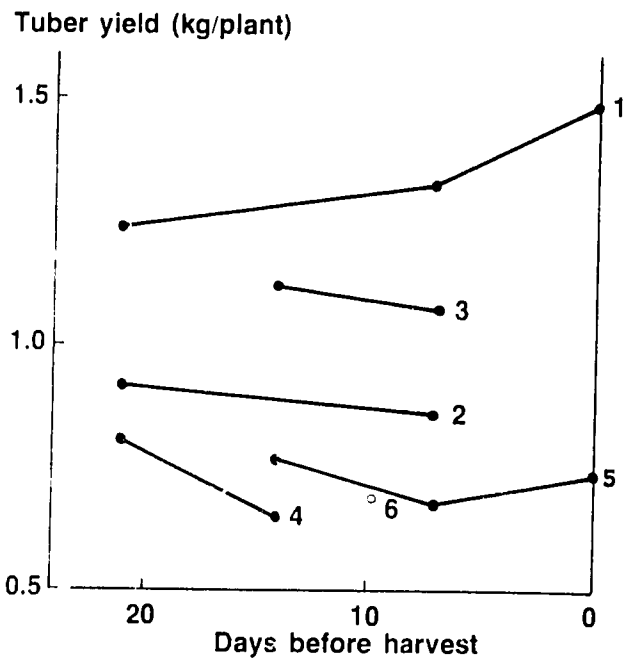
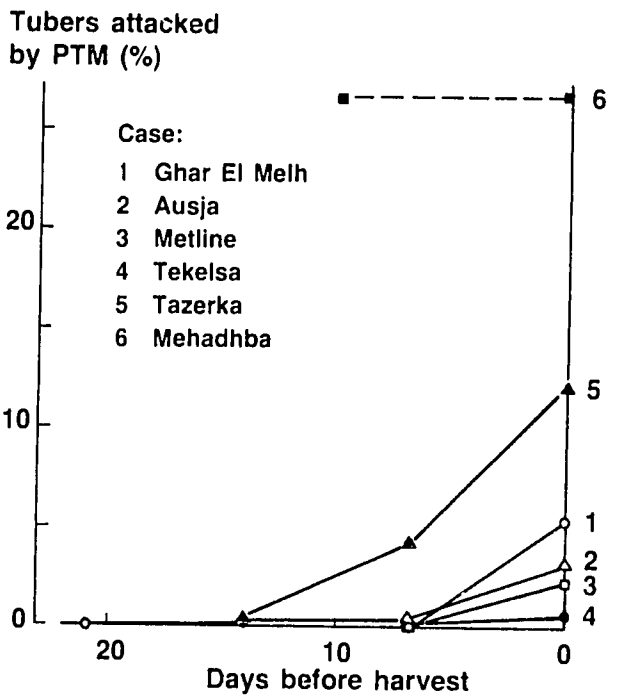


Figure 9. Tubers attacked by potato tuber moth (PTM) in relation to the time period (days) before farmers' harvest.



Damage on tubers is closely related to plant maturity and increases rapidly after the soil cover drops below 50% and the rating for leaf senescence declines below 6 (plants 50% green and yellow, Figures 10 and 11). We found wide variability in the rate of damage increase among the six farmers, presumably due to other cultural practices. To avoid serious pest damage, farmers should be advised to harvest just after the leaves show obvious symptoms of yellowing (maturity level 7), but at the latest before the golden-yellow stage (maturity level 3), particularly if tuber moth population densities are high. The application of the systemic insecticide Dyfonate (Fonofos) to the soil at germination by the farmer of Ausja to control cut worms, did not reduce the buildup of the tuber moth population and subsequent damage at harvest.

Handling and Storage. Twenty one percent of the farmers in the sample did not move the tubers directly into the final storage facility after harvest. Reasons included the lack of labor and the need to consolidate tubers from several fields into a single storage heap. This made it necessary to set up provisional systems of "pre-storage" to shade the potatoes against the sun. This is a dangerous period for infestation because tuber moth larvae are often plentiful in the disturbed soil of the field where tubers are heaped up, and in the dried potato haulms which are the handiest material to use as cover.

In most cases, the final storage heaps were located under trees right along the edge of the harvested field (47%) or less than 500 meters away (37%). The tubers were heaped up and protected from light, high temperatures, and tuber moth attack by using different covering material as mechanical barriers.

Insecticide Use in Stores. Two thirds of the sample sprayed or dusted the heaps with insecticides. Four (11%) applied again and one a third time. Twelve farmers (32%) did not use insecticides in storage. Since Parathion had been banned the previous year by the Tunisian Government, the pyrethroid Deltamethrine (Decis and K'otrine) was the most commonly used product both in storage and in the field. It is also widely used for other fruits and vegetables on the same farms, a situation which may lead to the development of resistence.

The six case-study farmers illustrate the variable efficiency of tuber moth control during storage (Table 5). Two farmers achieved adequate control of both initial damage and population build-up during storage (Ghar El Melh and Ausja), two avoided initial damage by harvesting early but did not treat properly in storage (Metline and Takelsa) whereas the two others (Mehadhba and Tazerka) had problems before harvest, but were able to bring relatively high initial infestations under control during storage, but culling out damaged tubers and using insecticides efficiently.

Periodic Inspection of Heaps. Most farmers (88%) checked their heaps several times during the storage period, some (32%) as often as once a week. They smelled for a sign of rot, checked for the presence of adult tuber moths,

Figure 10. Tuber attack by the potato tuber moth (PTM) in relation to the soil cover.

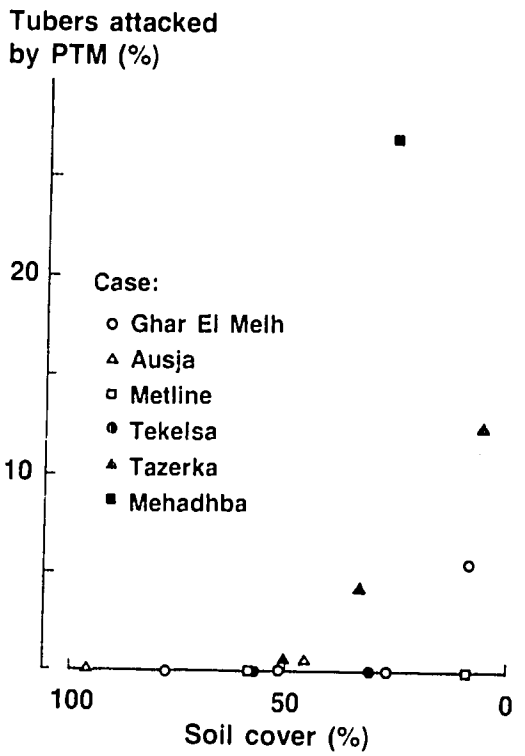


Figure 11. Tuber attack by the potato tuber moth (PTM) in relation to the maturity index of the plant foliage.

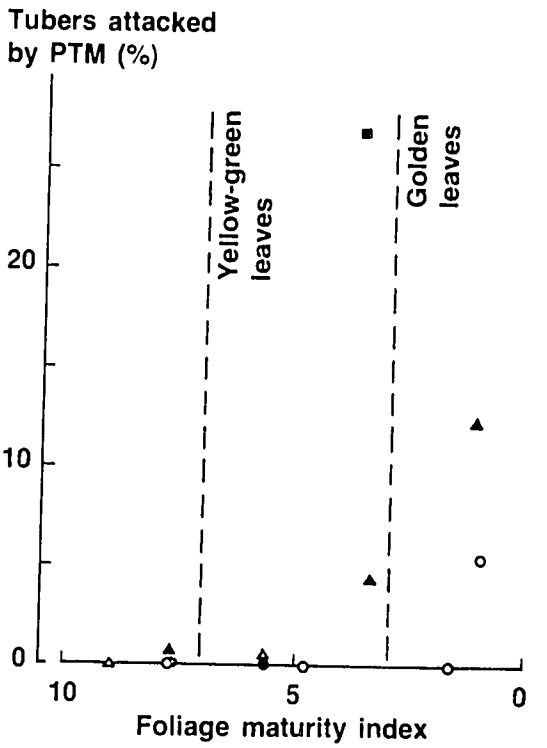


Table 5. Potato tuber moth (PTM) damage in traditional stores of the six farmers of Bizerte and Cap Bon (Tunisia, 1986)

Farmer	Observation	Days after harvest	PTM damage (%)	Tubers rotten (%)	Insecticide treatments and storage methods[1]
BIZERTE					
Ghar El Melh	May 29	0	5.4[2]	0.0	Application of Decis and Parathion for prestorage. 2nd application of Decis and sprout inhibitors for final storage. Cover with paper bags and 30-40 cm potato haulms and weeds.
	June 19	21	4.7	0.0	
	July 3	35	9.0	1.0	
Ausja	June 5	0	3.3	0.0	June 5 application of Decis (15ml/t) for prestorage. July 3 application of K-Othrine (1kg/t) and sprout inhibitors (1kg/t) for final storage. Cover with paper bags and 40 cm potato haulms treated with Decis.
	July 3	28	4.7	0.3	
Metline	June 19	0	2.3	0.0	Decis application and cover with paper bags for prestorage. Cover with 30-40 cm potato haulms and 10 cm reeds for final storage.
	July 3	14	9.3	0.3	
	August 7	49	25.0	1.0	
CAP BON					
Mehadhba	June 13	0	26.7	2.3	Decis (70 ml/t) and K-Othrine (2.5 kg/t). Cover with jute sacks and 20-30 cm haulms.
	July 8	25	28.7	0.3	
	August 21	69	20.0	0.7	
Tazarka	June 3	0	12.3[2]	0.0	Decis (60 ml/t) and Kafil (60 ml/t). Cover with paper bags and layer of Tamarix.
	June 17	14	4.7	0.0	
	July 8	35	14.7	0.0	
	August 21	79	-	-	
Takelsa	June 3	0	0.7	0.0	Decis Cover with 20-30 cm straw.
	July 8	35	16.0	0.0	
	August 21	79	13.7	0.0	

1 Decis = Deltamethrine (25% a.i.) liquid, K-Othrine (0.05% a.i.) powder, Kafil = Permethrine (10% a.i.) liquid, sprout inhibitor = CIPC (2% a.i.) powder, Tamarix = Branches of a local shrub (Tamariscus).

2 Observations on 10 times 3 consecutive plants harvested from the potato plots, otherwise on 3 times 100 tubers taken at random from the stored potatoes.

checked that the protective cover remained intact, and sampled tubers for damage. If necessary, they applied more insecticide, sorted out damaged tubers, or decided to sell their stocks immediately.

Although prices rose steadily over the storage season, the farmers tended to sell their potatoes in several lots. Tuber moth damage and fear of further infestation were cited by nearly 30% of the farmers as the major reasons for early sales (Table 6). Short-term cash flow problems and uncertainty about future prices, however, were more important factors influencing the decision about when to sell.

Table 6. Farmers' Reasons for Selling Potatoes at a Particular Time

	First sale (n = 31)		Last sale (n = 25)	
	No.	%	No.	%
Need for cash	18	58	13	52
Tuber moth attack	9	22	7	28
Price slump	5	16	6	24
Weight loss	3	10	1	16
Attractive offer	3	10	1	4

Source: Farmer interviews

A High Damage Threshold

As virtually all potatoes in retail markets between July and October come out of these rustic, unrefrigerated stores, consumers have come to accept quite high levels of damage. This fact is illustrated in Figure 12. The data points are derived from a series of experiments. They show the percentage of potatoes with one or more tuber moth entry holes, graphed against the average degree of damage, expressed as the average number of holes per tuber. The price penalties, shown as shaded areas on the graph, are derived from interviews with the farmers.

In the survey, we carried around samples of potatoes with different degrees of damage, and asked the farmers what price they would receive for each. Almost all of them said that towards the end of the storage season in September and October, buyers would accept tubers with one entry hole at the same price as unblemished potatoes. Tubers with two or three holes were penalized with a mark-down which averaged 50% of full value, distributed as shown in Table 7. Without exception, the farmers said that tubers with three or more holes were rejected by buyers. Putting the two together, we can see that farmers are not really penalized until at least 40 percent of the tubers in a heap are attacked.

Figure 12. Relationship between percent of tubers in storage heap attacked by potato tuber moth, average severity of damage, and price penalty at farm gate

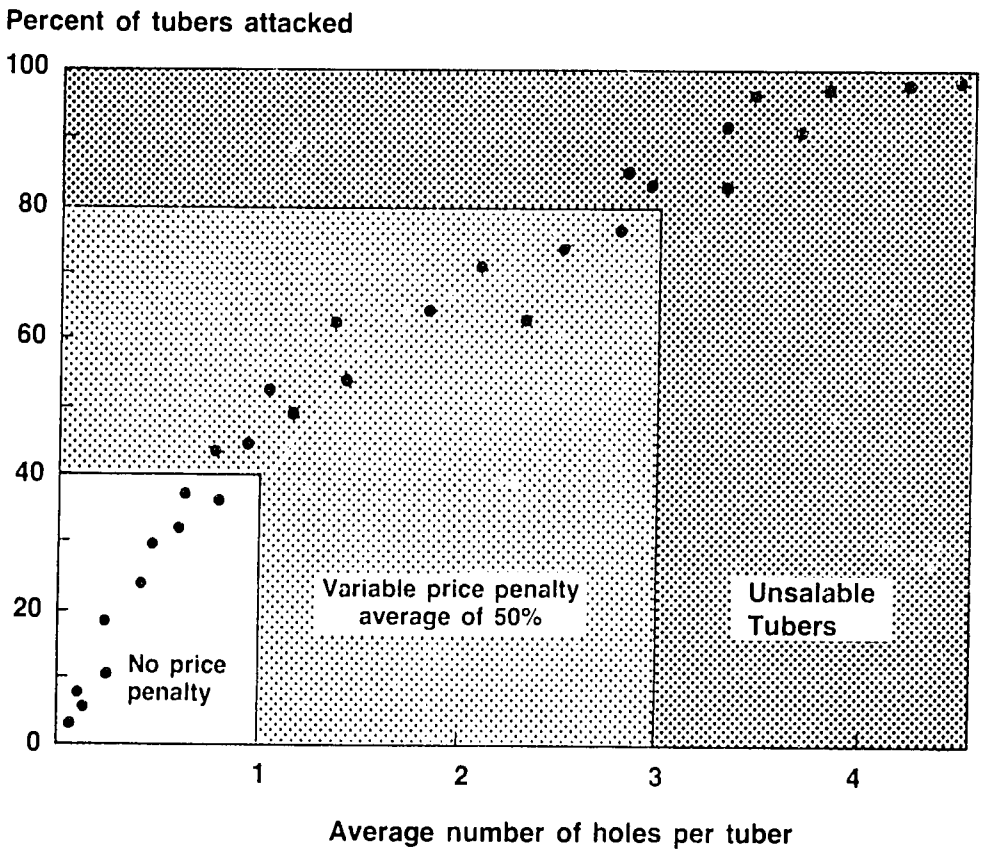


Table 7. Farmers' Assessment of the Expected Price of Tubers with Two or Three Tuber Moth Entry Holes, as Percent of Price for Undamaged Tubers

(n = 35)

Percent Price Penalty	No. of Cases	%
No penalty (same price)	1	3
1 - 25	6	17
26 - 50	17	49
51 - 75	6	17
76 - 99	0	0
100 (tubers unsalable)	5	14

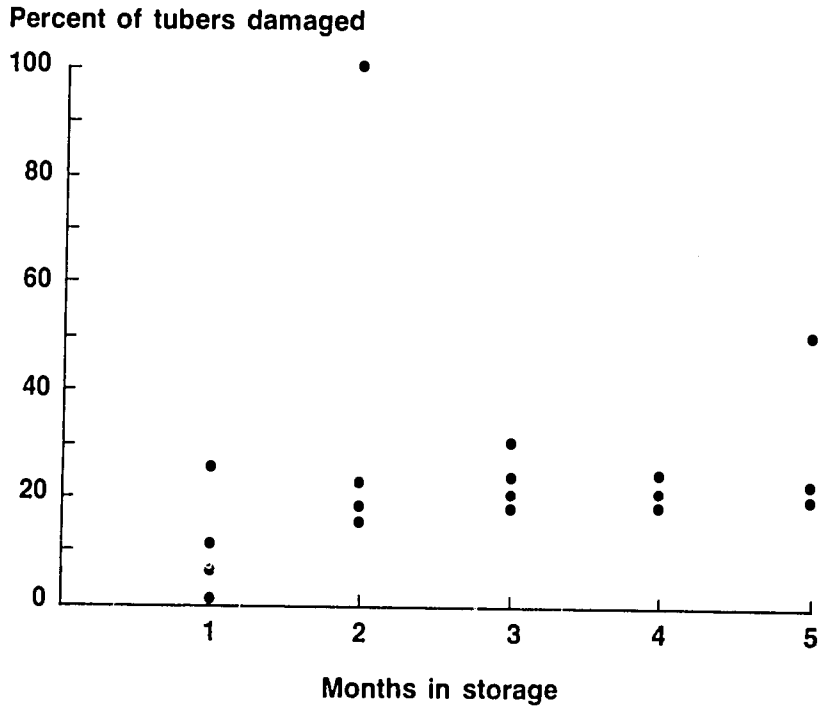
Source: Farmer interviews

The approximate magnitude of this threshold is also indicated by the data in Figure 13, which shows the damage in farmers' stores which were sampled periodically. Repeated experimental results have shown that even in heaps which have been treated with insecticides, the damage curve tends to slope steeply upward over time. Farmers inspect their heaps, and cull damaged potatoes out before catastrophic loss occurs. With two exceptions, those in the sample were able to keep damage below forty percent infestation throughout the storage season. As we have seen, this corresponds to the average damage of one hole per tuber for which the price would not be penalized. Nevertheless, farmers do suffer economic loss if they are forced to sell early in a market where prices tend to rise.

This high damage threshold means that consumers absorb considerable losses due to pest damage. Preliminary data from the small sample taken in retail markets show that between 30 and 40 percent of the weight of tubers purchased between late August and early October must be discarded in the kitchen before cooking. This burden is carried disproportionately by the poorer strata of the population, who cannot pay premium prices for selected, top-grade potatoes. They also tend to buy smaller tubers, which suffer more than proportionate damage due to the higher surface/volume ratio.

This high damage threshold is not likely to last forever. Production outside of the main season is bringing better quality fresh potatoes into the market over a wider and wider season. This competition will inevitably raise the acceptable damage threshold for tubers coming out of storage. This will force farmers to increase the application of pesticides, or to otherwise improve the effectiveness of control. Farmers in newly opened production zones face warmer conditions, favorable for the pest, and are less experienced with cultural control methods. They too are likely to depend more heavily on insecticides. These trends might lead Tunisian potato producers onto a pesticide treadmill.

Figure 13. Tuber moth damage observed in farmers' stores, 1986



Discussion and Conclusions

The potato tuber moth damages tubers both at harvest and in storage, thereby reducing the quality of the tubers and the prices farmers receive. It is a chronic rather than an acute problem, increasing costs for handling and insecticide applications, and affecting the quality of produce available in the market. Experienced farmers in the regions where potato production is concentrated have empirically developed integrated pest management strategies, combining cultural and chemical methods, which provide adequate control under most conditions. Government regulations have banned the toxic chemical Parathion, and farmers seem to have adjusted to the use of alternative products.

Regular monitoring of the potato heaps for pest development is an important component in their pest management strategy. Relatively superficial checks seem to be sufficient to avoid significant losses in most cases, given the high threshold level. There are, however, extreme differences between the farmers, ranging from excellent pest control using only cultural practices to total losses in spite of insecticide application.

This short-term study of a small sample is only a first step. It should be complemented with data taken under farmers' conditions at other important moments in the crop cycle. The next priority should be during the harvest and storage operations, from mid-May through early July, when the critical decisions about harvest timing, postharvest handling and storage methods are made. Other production areas in Tunisia and other countries with tuber moth problems--where climatic conditions, irrigation systems, farmers' experience, and market tolerance may be less favorable--deserve further study. Pest damage and the market situation should be monitored over the period of years. Routine channels of information should be developed between INRAT's Entomology and Economics departments, GIL, and the extension services.

The intensive case study of six farmers provided very useful information on the timing of tuber moth control methods and the decision-making process during the season. Compared with the results of experiments carried out on research stations, these data were influenced by more uncontrolled factors which increase their variability. Missing data were more frequent, because communications sometimes broke down, and the farmers harvested or sold before the team could take samples

Nevertheless, on-farm research includes socio-economic components which are crucial in pest management programs. Problems peculiar to research stations, such as small plot size and interference with other trials, are avoided. Intensive observations at regular intervals are time consuming, so only a limited number of farmers can be included. A more representative, bigger sample was interviewed in a single-visit survey to gather some information on the variability of the control practices and farmers' constraints. Nevertheless, the results most accurately reflect conditions at the moment in the year when the interviews were done. Another survey at harvest time would highlight different aspects of the problems that farmers face.

Poor management is the most important reason for low yields and high losses due to tuber moth. Getting researchers out to the field to study farmers' problems directly is the basis for finding better solutions. Training and extension can increase the proportion of farmers who are using the improve crop protection methods. The development of IPM programs based on decision rules for different ecological and economic situations will require the development of techniques for the continuous and standardized monitoring of the pest situation, the assessment of climatic data, and market surveys.

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