# A MANAGEMENT APPROACH TO THE COMPLEXITIES OF THE ROOT-KNOT NEMATODE HAZARD

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A logical and increasingly essential question that a potato grower needs to consider and answer is how to forestall any crop loss due to root-knot nematode tuber damage. The correct route to a solution of this management problem has been the subject of considerable discussion and differences of opinion. One advocated policy is to fumigate nearly every field that is to be planted to potatoes. Such an approach is quite expensive and would mean an extremely large total dollar expenditure for Central Washington production, which should be reduced if at all possible. At the other extreme is the unfortunate practice of ignoring the problem and accepting very unfavorable odds. This latter approach is becoming more and more hazardous because infestations of root-knot nematode (RKN) are becoming more and more wide-spread.

For these reasons, about 5 years ago Washington State University developed a soil detection technique for use in determining whether or not root-knot nematode have infested all, or a portion, of a field scheduled for potato production. The purpose of this paper is to present to the potato grower a suggested management approach to the complexities of the root-knot nematode hazard.

The first step in this management procedure is to ascertain whether <u>any</u> plants that host the root-knot nematode -- weeds as well as crops -- grew to at least near maturity the year prior to the scheduled potato planting. Then, 1 of 2 situations for each field is established:

CASE I -- Host plants (effectively) present

CASE II-- Host plants not (effectively) present

## <u>Host Plants Present</u>

If the previous crop or weed plants are a host to the Northern root-knot nematode, and if either were allowed to reach, or at least approach, maturity so that galls are formed, fumigation is of questionable value for the following year. This is because the nematode in the undecomposed root galls may be protected from the fumigant action.

In this situation, the nematode status of a particular field may be determined in two ways:

1. Observations of the roots of host plants for the presence of root-knot galls. This examination should not be superfluous but should include covering the various portions of the field rather intensively to be certain that infected plants do not exist. The lower-lying areas, particularly, should be checked, as the nematode entering via the water will tend to settle out in low areas. Table I is a list of many common crop and weed host plants.

2. Soil detection. This procedure is explained further at the end of this paper.

TABLE I

INCOMPLETE LIST OF HOST PLANTS -- Northern Root-knot Nematode

| | | |
|---|---|---|
| Alfalfa | Lettuce | Turnip |
| Beans | Onion | Vetch |
| Beet, Table | Garden Pea | Small Bindweed |
| Beet, Sugar | Peppermint | Dandelion |
| Carrot | Potato | Hedgemustard |
| Chard | Radish | Lambsquarter |
| Clover, Alsike | Rutabaga | Mallow |
| Clover, Red | Spearmint, Native | Common Milkweed |
| Clover, Strawberry | Spearmint, Scotch | Russian Knapweed |
| Clover, White | Tomato | Tumbleweed |

If either the investigation of host plant roots or soil detection indicates that nematode are present, growing a non-host crop the following year is suggested. This, of course, also means eliminating any weeds that host this nematode. Then, during the couse of the year, existing galls will decompose and the nematode can then be exposed to the action of a fumigant. It will then be possible to fumigate the field satisfactorily and plant potatoes the following season.

## Host Plants Not Present

In situations where the previous crops and weeds that grew to at least near maturity are not host plants for the Northern root-knot nematode, the question which automatically arises is whether or not fumigation is a necessary investment. This management problem may be approached by evaluating the odds of infestation on a field-by-field basis. To do this, one needs to know and understand the various factors which influence the probability of root-knot nematode presence in a particular field. These factors include:

1. Any history of vegetatively propagated crops;
2. Water source as a potential carrier (well -- project -- reused);
3. Incidence or frequency of host plants in past growing seasons;
4. Past equipment sanitation;
5. Any history in that field or that locale;
6. Whether or not a settling basin is used.

These factors and their evaluation are not developed from research facts. Rather, they are derived from theoretical and practical assumptions and considerations; but they do serve a prupose in providing a basis for an informal judgment. This means, then, that a manager does not have the tools with which to develop the exact odds of root-knot being present in a particular field. However, this is not a critical weakness, because the practical aspects and mathematics of the situation do preclude the need for an accurate estimate of probability.

## Cost of Insurance

The above statement can perhaps be better understood in the context of the fundamental insurance decision equation. This concept compares the cost of a critical event if it should occur (crop loss) times the probability that that event will occur, with the cost of insuring against the loss (fumigation). Mathematically, the question is: whether the probability of the loss ($P_L$), times the cost should the loss occur ($C_L$), is greater than the cost of the insurance ($C_{INS}$). If so, then insure:

$$\text{If } P_L \times C_L > C_{INS}, \text{ Then Insure}$$

$$\text{Or, If } P_L > \frac{C_{INS}}{C_L}, \text{ Then Insure}$$

To illustrate, consider the decision that must be made as to whether or not to fumigate a potato field as insurance against root-knot nematode. The following assumptions are made for our use:

A. Cost of fumigation = \$45.00 per acre.

B. Cost of serious infestation = \$600.00 per acre.

C. No soil detection service is available.

D. The decision-maker is capable of assessing the approximate probability of root-knot nematode infestation.

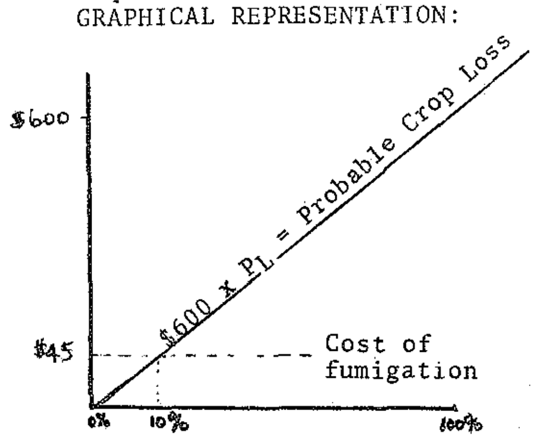
By substituting these values in the equation derived above:

$$\frac{C_{INS}}{C_{LOSS}} = \frac{\$45.00}{\$600.00} = 0.075 = 7.5\%$$

Since the \$600.00/A. loss assumed will seldom, if ever, occur over an entire field, we can logically operate on the premise that if the probability of root-knot nematode (RKN) is greater than about 1 in 10 (10%), the prudent decision is to fumigate rather than to take the chance of crop loss. This is indicated in Graph I, which depicts the relative costs of the two alternatives for each probability level.

GRAPH I

GRAPHICAL REPRESENTATION:




IF the probability of RKN is greater than about one in ten (.10), then the prudent decision is to fumigate.

New Variable -- Soil Detection

With the capability of reliably detecting root-knot nematode in the soil, the insurance conception can similarly be applied to preventing possible waste from unnecessary fumigation. Just as in Graph I, the probable crop loss from failing to fumigate ($C_L$ X $P_{RKN}$) is directly related to the probability that there IS an RKN infestation, so in Graph II the probable waste from unnecessary fumigation is directly related to the probability that there IS NOT an RKN infestation ($C_L$ X $[1-P_{RKN}]$). For our purposes, we will conservatively assume the cost of RKN detection to be no greater than $4.00/A. The cost of fumigation is, again estimated at $45.00/A.

$$P_L = (1-P_{RKN})$$

$$C_L = \$45.00 \text{ for Fumigation}$$

$$C_{INS} = \$4.00 \text{ for Soil Detection}$$

The question posed is: at what probability of RKN should a potato grower insure against loss from unnecessary fumigation?

Insurance Equation: If $P_L > \frac{C_{INS}}{C_{LOSS}}$ Then Insure

Restated: $(1-P_{RKN}) > \frac{4}{45}$

$$1 - \frac{4}{45} > P_{RKN}$$

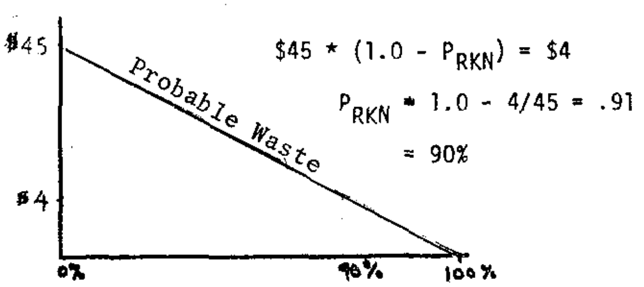
Insure if $P_{RKN} < 0.91$

This is demonstrated graphically in Graph II: one should insure against loss from unnecessary fumigation by using soil detection, if the $P_{RKN}$ is less than 90%.

GRAPH II

New Variable

R.K.N. Soil Detection



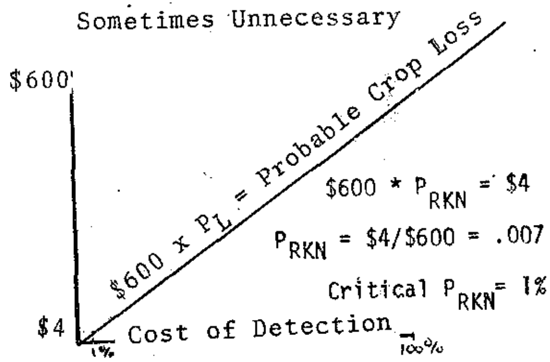

Insure against Loss from unnecessary fumigation by using soil detection service, IF the probability of RKN is less than 90%.

Probability of such waste is: $1.0 - P_{RKN}$

GRAPH III

Detection Expense is

Sometimes Unnecessary




Cost of detection is so low that it is cheaper than the risk, even if the probability of RKN is as low as 1%.

Graph III compares the cost of soil detection with the cost of serious crop loss. (This is directly analagous to GRAPH I.) The insurance equation is:

$$P_{RKN} = \frac{C_{INS}}{C_L} = \frac{4}{.600} = 0.007 = 1\%$$

While the cost of a soil detection would be wasted where there is very little chance of RKN infestation, GRAPH III indicates that the cost of detection is so low relative to the cost of a serious loss that detection is cheaper than the risk, even if the $P_{RKN}$ is as low as 1%.

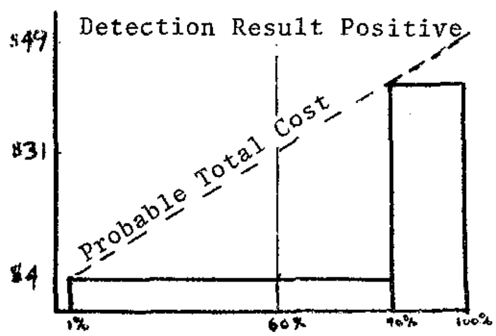
Long Run Averages

The concept of probability is valid only in terms of a large number of fields. Consider 100 fields of equal size, each with an estimated $P_{RKN}$ of 60%. Soil detection would determine which 60 fields were infested. Hence, as demonstrated graphically in GRAPH IV, $4.00/A. would be spent for detection, plus $45.00/A. on 60% of the acreage. This represents an average per acre cost of $4.00 for detection, plus $27.00 (.6 x 45) for fumigation.

GRAPH IV builds upon the three previous graphs, showing that the $4.00 detection cost will NOT be incurred where the probability of RKN is either very low or very high; otherwise, the $4.00 is spent for detection, and an additional $45.00 is spent for fumigation of infested acreage.

GRAPH IV

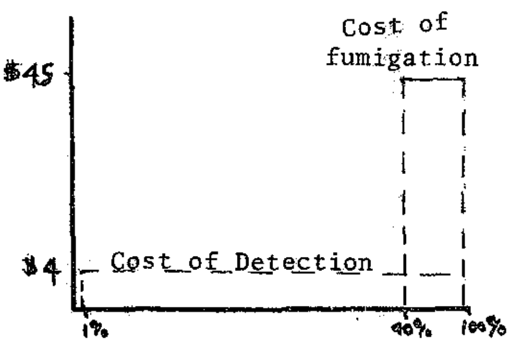
Long Run Averages--




Where the probability of RKN = 60%, the prudent farm manager will spend $4 for soil detection plus $45 for fumigation if needed. There is a 60% chance that he will need to fumigate -- a probable cost of ($45 * .60 =) $27.

GRAPH V

FARM MANAGER'S ANALYSIS:




The farm manager needs to determine only whether the probability of RKN is less than 1%, or greater than 90%. If neither, then he should have a soil detection test.

Farm Manager's Analysis

The analysis which a potato grower would accordingly make is summarized in GRAPH V, which is derived directly from GRAPH IV. The grower need only determine whether the $P_{RKN}$ is less that 1%, or greater than 90%. If between 1% and 90%, he should order a soil detection test. This can be done for each field by expressing the probability of root-knot nematode in one of three categories, as follows:

Category 1 -- Probability of RKN less than 1%:

In this situation, no soil detection appears necessary. However, we should recognize that if any of the previously listed factors that influence the probability of root-knot nematode suggest its presence, one should automatically place the probability of root-knot nematode at greater than 1%. That is, if alfalfa or beets or a similar host crop have been grown in the field, or if reused water is used for irrigation, the probability should automatically be greater than 1%. Similarly, if vegetatively propagated crops such as potatoes or mint have been grown on that field, the probability of infestation is greater than 1%.

Two examples wherein the probability might be less than 1% are virgin land, or land which has been farmed only a very few years and irrigated from wells or other nematode-free water.

Category 2 -- The probability of RKN is greater than 1% and less than 90%:

In this situation, and considering either 100 or 1000 fields, the manager will, in the long run, save money by ordering a soil detection test first and fumigating only those fields where the test for root-knot nematode is positive.

Category 3 -- The probability of RKN is greater than 90%:

When root-knot galls have been observed on host plants in a particular field in the past, or there have been some infected potato tubers in previous years, or if for some other reason the manager is at least 90% certain nematode are present, the mathematics favor going ahead and fumigating without spending money for soil detection.

There is, however, a possible role for soil detection in this situation. That is, where a partial infestation only of a large field may exist, the segmentation technique of sampling may indicate areas of the field that are not infested, and accordingly do not need fumigation. In this event, money would be saved by avoiding fumigation of the entire field.

Public Concern

The management considerations and procedures outlined above for the potato grower to use in evaluating a method of handling the root-knot nematode hazard have been limited to operating procedures and economic considerations. That is, the cost of detection has been compared to the cost of fumigating, which in turn has been compared to the possible crop loss if root-knot nematode affect the salability of the potato crop. The entire public, knowingly or unknowingly, is concerned with these decisions that influence the overall cost of food production and the corresponding economic well-being of the farmer. Similarly, the entire public is concerned about environmental pollution. Therefore, the potato grower and other necessary elements of the food production chain, such as the chemical industry and the food processor, need to consider the effects of (in this case) fumigation with respect to environmental quality.

Our commonly used soil fumigants must vaporize to the gaseous state in the soil in order to function. During the course of the period following fumigation, and prior to or during planting and other tillage operations, a significant portion of the fumigant is lost from the soil into the atmosphere. These vapors, of course, normally evolve slowly, and are rapidly diluted so as to be non-toxic. Consequently, this can be described as incremental pollution, wherein small quantities over a period of time have no measurable effect on air quality. However, as is true with many other types of incremental pollution, we need to begin minimizing the total pollutant that enters the environment in order to have an impact on the total amount of pollution. This, then, raises the question if any polluting chemical should be distributed into the environment if not needed. The converse question is: should we attempt to grow the food and fiber that we now need without the use of chemicals? Obviously the answer requires common sense, rather than complete promiscuity in the use of chemicals or the adoption of blanket controls forbidding the use of many of our chemicals. In this case, the economic aspects (i.e., the cost of detection vs. the cost of fumigation) are identical with environmental considerations. This is a fortuitous situation that will tend to lower the cost of food production rather than raise it; in contrast, with many types of pollution problems, the necessary disposal procedures tend to raise the cost of the commodity produced.

## Reliability of Soil Detection

Two laboratory methods of detection are available and have been used. These are the bio-assay technique and the microscopic technique. The bio-assay is without doubt the more accurate and reliable method. Comments made in this paper are designed to apply only to the use of the bio-assay laboratory technique and the intensive sampling procedure outlined 5 years ago by WSU.

The obvious crucial question about the bio-assay detection method is its reliability. After having been developed by WSU, this technique has been employed during the past 4 years in Central Washington. There have been no known cases of crop loss when this bio-assay test was negative. On this basis, it would appear that the odds against significant crop loss when the bio-assay detection is negative are very favorable. We do need to recognize, however that these are biological measurements, based on field soil samplings. Therefore the detection technique cannot be represented as being 100% certain. However, in view of the economic and environmental considerations discussed above, and especially in view of the successful use of this technique during the past 4 years, it would appear that the risk of crop loss when the test is negative is very acceptable.

In connection with the reliability of the bio-assay soil detection procedures, it is necessary to recognize the following key points with respect to this technique:

1. The field must be segmented into 2 to 3 acre units and each unit sampled carefully and separately. This intensive sampling is the real key to the successful use of soil detection. If not practiced, most of the management approaches outlined in this paper become invalid.

2. The sampling should be biased to micro-basins (when discernible) within each segment in order to sample areas which are most likely to have nematode.

3. Fall sampling is ordinarily necessary, and complete mixing of the sample is critical.

4. The bio-assay laboratory determination requires about 90 days for completion. Involved are transplanting an indicator host (tomato) in the greenhouse, allowing time for complete root permeation of the soil in the pot, allowing time for the gall to develop after the nematode infects the root. For best results, the plants are grown under lights as well as favorable moisture and heat condtions. After about 90 days, the roots of the tomato plants are carefully washed and examined for a gall or series of galls. If even one gall is observed, that segment is considered to be infested with root-knot nematode.