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A Concept of Pest Risk Analysis

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ABSTRACT

A pest risk analysis curve on a graph is used to present diagramatically 1) the concept of pest risk analysis, and 2) the interaction of biological, economical, social, and political factors with quarantine policies, regulations, or decisions. The culmination of these regulatory activities often leads to a decision about the entry status of a wide spectrum of imported " items ". While the concept pertains to animal as well as plant quarantine matters, this paper concentrates on plant quarantine. Most of the examples presented relate specifically to the pest risk associated with importing plants or plant parts for propagation. Some of the examples presented have wide application in international quarantine circles while others relate only to the United States.

The method of illustrating pest risk analysis as a curve should be useful in effectively communicating quarantine philosophy, principles, policies, and decisions not only to the commercial, lay, and scientific public, but to plant quarantine officers. For within-house quarantine activities, the diagrams may be useful in training, explaining assignments or responsibilities to officers, determining priorities or planning budgets, and as a means for emphasizing the biological aspects of decisions about entry status of imported items.

Introduction

Interwoven into the fabric of international and national plant quarantine decisions, policies and regulations may be the threads of biological, economic, political and social considerations. The strength of this quarantine fabric stems from its high content of biological fibers. Nevertheless, sometimes the product contains a mix of fibers — or is alleged to contain a mix.

In actual practice, on a worldwide scale, occasions arise when a mixture of biological, economic, political and social factors is used in quarantine circles to determine the entry status of imported " items ". It is useful, for the purpose of illustration and understanding, to separate the mixture into its components. When only one of the components, biology, is used to determine entry status, promulgate regulations, or establish policy, such activities are based on pest risk analysis.

Pest risk analysis is a thought process whereby the entry status of plants, plant products, cargo, baggage, mail, common carriers, etc., is based on the calculated risk of inadvertently introducing hazardous pests and pathogens on these items as moved by man.

Objective

The objective of this paper is to present diagrammatically, within the plant quarantine context: 1) a concept of pest risk analysis, and 2) the interaction among biological, political, social, and economic considerations.

Pest Risk Analysis

Scope

A pest risk analysis is necessary in determining the entry status of all " items " moved by man from one geographic region to another. Since the " items " may either harbor hazardous organisms or serve as carriers, estimates must be made of the risk to agriculture or the environment associated with the importation of these " items ".

These " items " or " carriers " range from relatively low risk carriers such as oil tankers to high risk carriers such as living plants. They include, but are not limited to, the following : baggage ; mailed packages ; vehicles passing through border stations ; used farm equipment ; passengers ; agricultural and non-agricultural cargos and their containers, dunage, and packing ; plants including vegetative propagations and seeds ; products manufactured from plant materials ; plant products imported for consumption.

For the purpose of illustrating pest risk analysis, this paper concentrates on the entry status of plant material 1) even though the principles extend to all fields of agricultural regulatory activities including animal quarantine. Some examples presented herein have worldwide application while others relate specifically to the United States.

Pest Risk

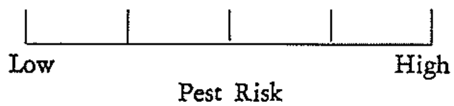
Pest risk is based on an evaluation of its known biological components or variables. These may include, but are not limited to, the following :

1. Effectiveness of inspection methodology in detecting obscure pests in imported plant materials.
2. Availability and effectiveness of treatments should a pest or pathogen be found by inspection.
3. Operation of many independent safeguards.
4. Existence of diseases or disorders in the country of origin for which the causal agent is unknown.
5. Knowledge about the life cycle of organisms of quarantine significance in the country of origin.
6. Availability of technical backstop in the importing country should any hazardous organism be introduced. Technical backstop is a collective term for a cadre of entomologists and plant pathologists, existence of a pest and pathogen survey, a cooperating public, availability of chemicals and application equipment or effectiveness of biological control, etc. Countries lacking an adequate technical baskstop are likely to be conservative in decisions about entry status.
7. The worldwide distribution of organisms of quarantine significance as compiled from a survey of the literature, correspondence and interception records from previous shipments of plant materials.

1) Since US regulations and policies are subject to change, this paper is not intended as a reference for determining the entry status of any specific plant material. Persons interested in ascertaining the entry status of plant material should write the Permit Unit, Plant Protection and Quarantine Programs, APHIS, USDA, Federal Building, Hyattsville, MD 20782, USA.

8. Information on the probability of introduction and establishment of organisms, such as the ecological range of hazardous organisms as compared with the ecological range of their hosts in the importing country, hitchhiking ability of organisms, ease of colonizations, etc.

Pest risk may be shown on the abscissa or X axis of a graph as follows:



The relationship of pest risk to any one of the above components that relate to foreign organisms may be diagrammed as a line on a graph with various levels of pest risk on the X-axis and of its component on the Y-axis. For example, the relationship of pest risk to the hitchhiking and colonization ability of the pest is illustrated in figure 1A. The relationship of pest risk to those of its components that relate to activities at plant inspection stations or ports of entry may also be diagrammed. These activities include the effectiveness of eradicant chemical treatments, relative volume of plant material in a consignment, the relative number of inspectors or inspection stations (fig. 1B), etc. When an increase of the level of one of these activities, such as the

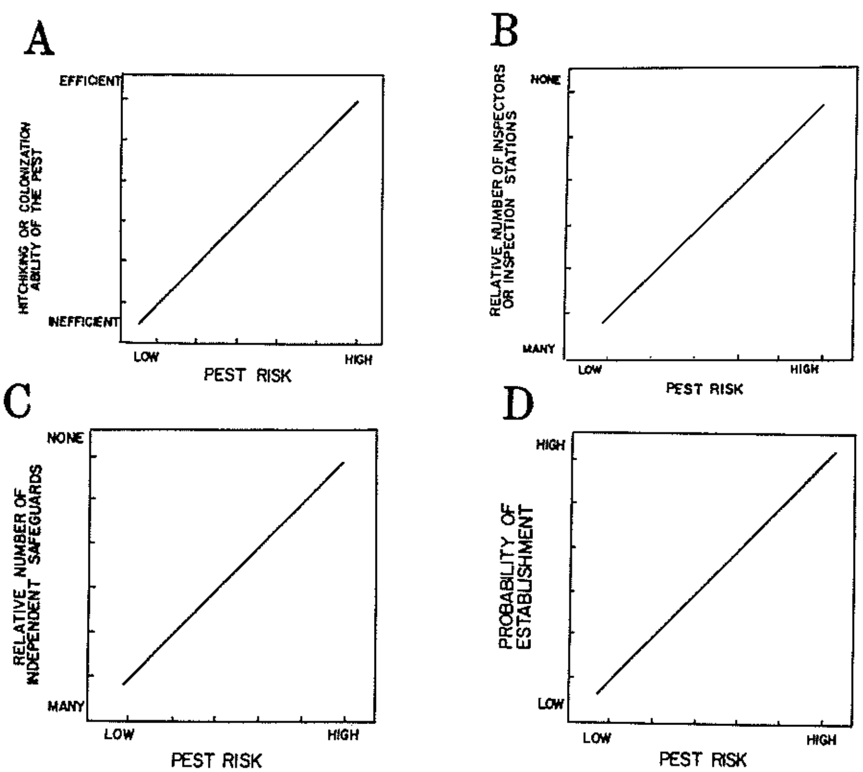


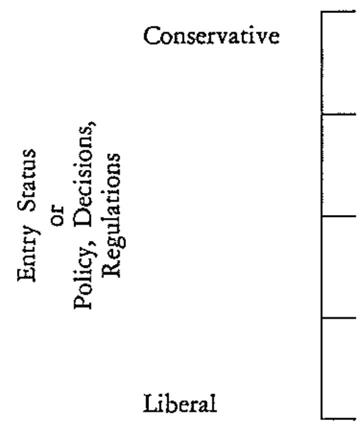
Fig. 1
The relationship of pest risk to four of its components: A: hitchhiking or colonization ability of the agent; B: relative number of inspectors or inspection stations; C: relative number of independent safeguards; and D: probability of establishment.

relative number of inspectors or other independent safeguards (fig. 1C), is associated with a decrease in pest risk, the characteristic curves shown in figure 1A, B, and C may be drawn. In turn, as the pest risk increases, the relative probability of establishment is enhanced (fig. 1D).

Entry Status

"Entry status" is a term used herein to cover the entire range of decisions or policies that serve as guidelines for rules and regulations that govern whether or not a potential carrier is enterable, and if enterable, under what safeguards. Attitudes toward entry status may range from "conservative" to "liberal"; but "liberal", in this context, does not imply "lax". The most liberal attitude is that plant material may enter freely without agricultural regulatory restrictions. The most conservative attitude is that the plant material is excluded without any exceptions.

Those decisions, policies, rules, and regulations that relate to entry status may be shown on the ordinate (Y axis) of a graph as follows:



Throughout the remainder of this paper, the Y axis will refer to the entry status of plant materials as determined by decisions, policies, or regulations.

Biological Components

A good pest risk analysis is the matching of the attitude about entry status with estimated pest risk. In figure 2A, point A represents a situation in which the pest risk is low and, therefore, the entry status is liberal. Point B represents a situation in which pest risk is known to be high and the entry status is conservative. Point C represents a case where the pest risk lies midway between low and high and the entry status midway between liberal and conservative. In actual practice, this midway position might entail entry under permit or some other appropriate safeguards or specified restrictions.

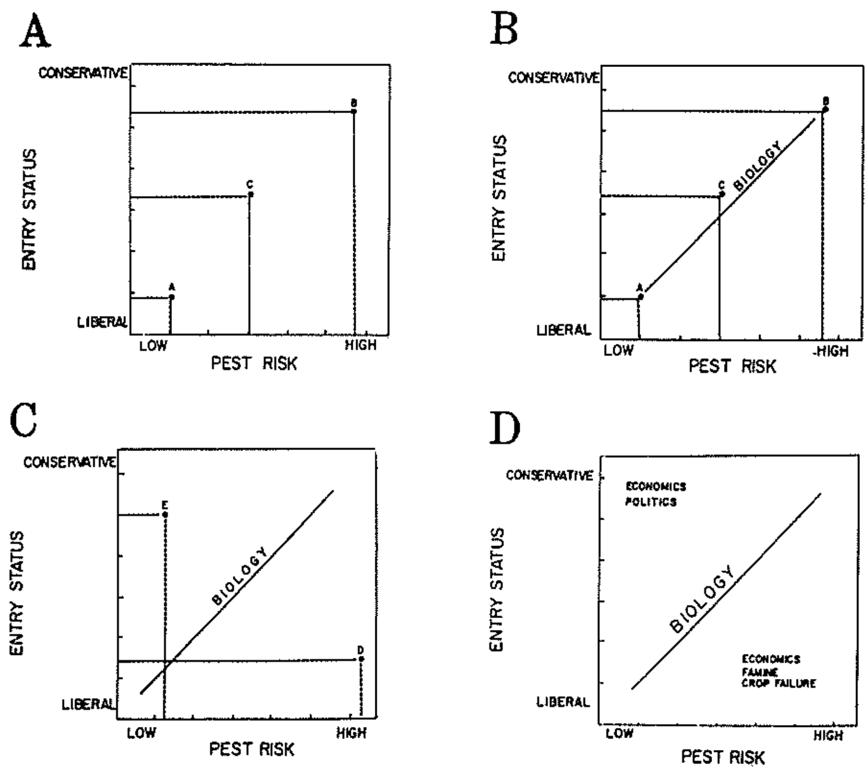


Fig. 2
The biological or pest risk anlysis curves. A and B show points A, B, and C, where pest risk is matched with entry status. C shows points D and E where pest risk is not matched with entry status. D shows the relationship between biological, economic, political, and social factors and the pest risk analysis curve.

A curve based on biological considerations results when points A, B, and C are connected such as shown in figure 2B. Whenever pest risk is plotted against entry status and the point falls on or near the curve, a good pest risk analysis is made. One may, therefore, assume that the quarantine decision was strictly biological in nature. When points fall away from this curve, the decision must be based on non-biological considerations. Point D in figure 2C depicts such a case in which the pest risk was high but the entry status was liberal. Similarly, point E shows a situation where the pest risk was considered as low and the entry status, nevertheless, was conservative.

Non-biological Components

As pointed out previously, when pest risk is plotted against entry status and the points fall off the biological curve, it becomes apparent that a non-biological factor is operative. When it is possible to differentiate non-biological factors, they usually are classified broadly as economic, social or political (fig. 2D).

An example of a social factor is a food shortage or famine. Some countries, to avert famine, may import high risk plant materials that in other times they might either prohibit or import with restrictions or safeguards. In times of single crop failures, countries may temporarily become more liberal about the entry status of this crop than when the local production was high. For example, in 1976 when there was a shortage of potatoes in Europe, some European countries imported potatoes from areas where bacterial ringrot (incited by *Corynebacterium sepedonicum* [Spiek. & Kotth.]) Skapt. & Burkh.) occurs. In previous years when there were no shortages, potatoes were prohibited from these same areas.

Economic factors may influence quarantine decisions when a government, on behalf of a pressure group, imports or excludes plants or plant parts on the basis of economic rather than biological reasons. When this situations is plotted, the point appears as low pest risk *vs* conservative entry status as shown in figure 2D. It is beyond the scope of this paper to become more specific on this point. However, among plant quarantine officials, there is general agreement on the theory that countries who wish to impose economic barriers should resort to tariffs rather than promulgating phytosanitary regulations that are not biologically sound.

Political factors may override biological factors if decisions are used as an instrument of a country's foreign policy. One may infer, but not prove, that political or economic factors may dominate if the entry status of low risk material is conservative, or, conversely, if the entry status of high risk material is liberal.

Communicating the Concept of Pest Risk Analysis by the Use of the Biological Curve

By illustrating pest risk analysis diagrammatically as a curve on a graph, one can effectively communicate quarantine philosophy, principles, policy and decisions not only to quarantine officiers but to the scientific, commercial or lay public.

The curve might be particularly useful should it be necessary to explain a quarantine decision or activity that is against the interest of the importer. For example, a quarantine officer might use the curve when an importer questions the need for denying entry, applying mandatory treatments, or delaying consignments for the purpose of inspection.

The pest risk analysis curve is even more useful in in-house quarantine matters. In training activities, the curve aids the trainee to understand the interaction of biological, economic and political factors. The curve may be useful to a supervisor in explaining the reason behind a work assignment given to an employee or why certain quarantine programs are necessary. The curve may even be useful to quarantine officers in diagramming priorities or discussing budgetary matters.

A quarantine officer may explain US quarantine regulations by using the pest risk analysis curve in the following manner.

Entry Status in the United States of Plants and Seeds

The entry status of plants and seeds to be imported into the United States can be shown on a single biological curve. For example, figure A3 shows the principal categories of plants whose entry is regulated under Quarantine 37 (Code of Federal Regulations, Title 7, Chapter III, Part 319, Foreign Quarantine Notices, Subpart 37, Nursery Stock, Plants and Seeds). These categories are ranked in table 1 together with a citation to US regulations and a description of the category.

TABLE 1 Categories of plants and plant parts imported into the United States for plant propagation under the provisions of CFR 319.37 1) and relative pest risk of these categories.

Category	Regulations 1)	Description	Pest risk ranking 2)
Prohibited (plants & seeds)	319.37(b)	Plants and certain seeds prohibited except under Departmental Permit for scientific purpose under designated safeguards such as passage through a quarantine station.	1
Postentry quarantine plants	319.37-19	Plants maintained under quarantine on the property of the importer.	2
Regulation 6 plants	319.37-6	Permit required, inspection upon entry and treatment if necessary.	3
4b seeds	319.37-4(b)	Permit required, inspection upon entry and treatment if necessary.	4
4a seeds	319.37-4(a)	Permit not required, subject to inspection upon entry, and treatment if necessary.	5
Preclearance, bulbs	319.37-3	Permit not required, inspection at origin rather than upon entry ; for bulbs grown, stored, packed & inspected according to USDA preclearance standards.	6

1) CFR 319. 37=Code of Federal Regulations, Title 7, Chapter 319 Part 319 Foreign Quarantine Notices, Subpart 319.37 Nursery Stock, Plants, and Seeds.
2) Arranged in order of highest pest risk first.

Entry Status of all Seeds Under US Quarantines

The entry status of imported seeds as regulated by various quarantines may also be shown on a pest risk analysis curve (fig. 3B). In this figure, the Y axis shows prohibition or entry under various safeguards.

Berberis, cotton, and bamboo are prohibited from all countries ; consequently, they are shown as a point on the biological curve showing the highest pest risk. Rice is prohibited from all countries except Mexico ; consequently, it is shown by a point on the curve just below *Berberis*, cotton, and bamboo. Citrus seed may enter from all countries but is subject to a mandatory treatment against the bacterial incitant of citrus canker ; consequently, the point showing pest risk falls midway between low and high. Most vegetable seeds are admitted without permit but are subject to inspection. This liberal entry status is related to the low pest risk currently assigned to most vegetable seeds.

Relationship Between Safeguards, Pest Risk, and Entry Status

The interaction of pest risk and entry status with safeguards may be shown diagrammatically (fig. 3C). The Y axis shows a range of entry status actions that a country may prescribe extending from prohibited without exception to freely enterable. The diagram illustrates that safeguards are necessary for all entry status actions except the two extremes. Safeguards include permits, phytosanitary certificates with or without added declarations, inspection, treatment, quarantine, etc.

In the United States, no genera or species of plants are prohibited without exception and none are freely enterable. However, in some countries, plants may be prohibited without exception even to government services. An example is the prohibition of coconut from countries where diseases of unknown etiology occur.

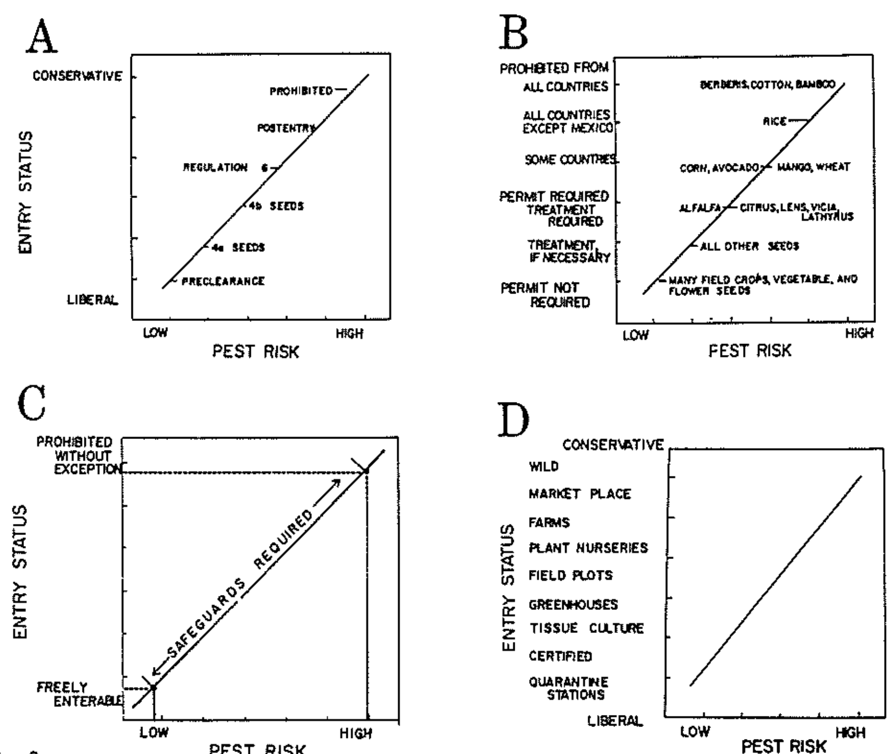


Fig. 3
The use of the pest risk analysis curve to illustrate US quarantine regulations for plants. A: entry status of plants or seeds under Code of Federal Regulations, Title 7, Chapter III, Part 319, Foreign Quarantines, Subpart: Nursery stock, plants and seeds. B: entry status of seeds under all US foreign regulations. C-D: the use of pest risk analysis curves to illustrate principles or problems in plant quarantine. C: the relationship of safeguards to entry status and pest risk. D: the relationship between entry status and the sources of imported germplasm.

Application of Pest Risk Analysis Diagrams to Specific Problems in Plant Quarantine

The pest risk analysis diagram has been applied to illustrate specific problems in plant quarantine in the United States. Examples follow for: A) Citrus canker incited by the bacterium *Xanthomonas citri* (C. Hasse) Dowson, B) risks associated with importing germplasm, C) risks associated with differences in growing sites of imported commercial plants, D) quarantine actions at Inspection Stations for foliage plants with foliar pathogens, and E) little cherry disease incited by the little cherry agent.

Citrus Canker

Citrus plants or plant parts imported into the United States are regulated under the Code of Federal Regulations (CFR) as follows: Under CFR 319.19, plants or vegetative propagations are prohibited from all countries; under CFR 319.28, fruits are prohibited from countries where *X. citri* and other pests are known to occur; under CFR 319.56, fruits are admissible from stated countries; and under CFR 319.37 —4(b), seeds are admissible subject to permit, inspection, and mandatory chemical treatment.

An exception is made in CFR 319.28 in that fruits of *Citrus reticulata* Blanco var. Unshu from Japan (a country where *X. citri* is known to occur) are admissible into Hawaii and through North Pacific ports intc Alaska, Idaho, Montana, Oregon, and Washington. The basis of this exception is the interaction of a number of independent safeguards and pest risks. If one increases the number of safeguards which operate independently, and as a result pest risk is lowered, then one can assume a more liberal position about entry status as shown diagramatically in figures 1C and 3C. Eleven safeguards have been instituted for the entry of Unshu fruit for consumption from Japan, as follows:

1. The citrus fruits are grown and packed in isolated citrus canker-free areas established by the Japanese Ministry of Agriculture and Forestry (MAF).
2. The only citrus that can be grown in these approved areas is the Unshu orange. All other citrus is eradicated.
3. Unshu oranges are highly resistant to citrus canker, caused by *X. citri.*
4. Each approved area is bounded by a buffer zone which is free from species of *Citrus* and *Poncirus.*
5. These areas are inspected by MAF and US Department of Agriculture (USDA) inspectors during the course of the growing season.
6. Fruits from the approved areas are subject to a preharvest bacteriophage test to determine the presence of bacteria.
7. Samples of fruits are inspected after harvest by MAF and USDA inspectors in both the collection sheds and packing areas.
8. Fruit then receives a bactericidal treatment.
9. Fruit is subjected to a second bacteriophage test prior to export.
10. Upon discharge at a US port, the fruit is subjected to an examination by USDA before it is released.
11. Fruits are released only to approved non citrus-growing States in the Pacific Northwest.

For discussion purposes, it is interesting to speculate about the chances of a citrus canker lesion showing up in the admissible States. Two assumptions may be made: 1) at least 8 of the above 11 safeguards operate independently in a statistical sense, and 2) there is only one chance in 10 (a very conservative estimate which would vary with the safeguard) that a fruit with a citrus canker lesion will show up in the States as a result of a failure of the safeguard. Under these assumptions, one could speculate that the odds are $1x10^8$ or 1:100,000,000 that fruit with a citrus canker lesion will enter the United States. Furthermore, the risk of the pathogen circumventing the final safeguard is low enough to defy calculations; namely — what are the chances that the "estimated" one infected-fruit-per-100,000,000-fruits that might enter the Pacific Northwest would end up near a citrus plant growing in the south and successfully serve as an inoculum source to infect a living citrus plant? This exercise illustrates the concept that many independently operating safeguards justify a liberal entry status.

Risks Associated With Importing Germplasm from Various Sources

The pest risk analysis diagram may also be used to illustrate the interaction between pest risk (X axis) and the entry status of imported plant germplasm obtained from different sources (Y axis) (fig. 3D). Wild or "collected" germplasm such as seeds, cuttings, tubers, or plants obtained from remote areas are shown on the biological curve as a point representing conservative entry status and higher pest risk. Wild or collected germplasm is often obtained from countries or areas not studied by plant pathologists or entomologists. Consequently, there are often no reports in the scientific literature about pests from those regions. More significantly, the importations are wild species of crop genera for which there are also often no reports.

Germplasm collected in the markets, such as tubers or seeds, is considered also as high-risk because the collector does not see the mother plants. Viruses, bacteria, and internally borne fungi would escape detection.

On the other hand, germplasm which is passing through a quarantine station shows on the biological curve as a point representing low pest risk and liberal entry status. This interaction presupposes that the germplasm has been grown in quarantine and tested for obscure pests such as indexing for viruses.

Risks Associated with Foreign Growing Sites of Imported Plants

The pest risk analysis diagram may be used to show the interaction between pest risk and the entry status of foreign plants or vegetative propagations produced commercially at various types of growing sites (fig. 4A).

As with germplasm collected as wild plants (fig. 3D), commercial plants collected in the wild present a greater risk than those produced in the greenhouse. Whether produced in the field or greenhouse, those grown on raised benches are less of a risk than their counterparts grown on ground or floor benches. The interaction of these sites and pest risk are shown in figure 4A.

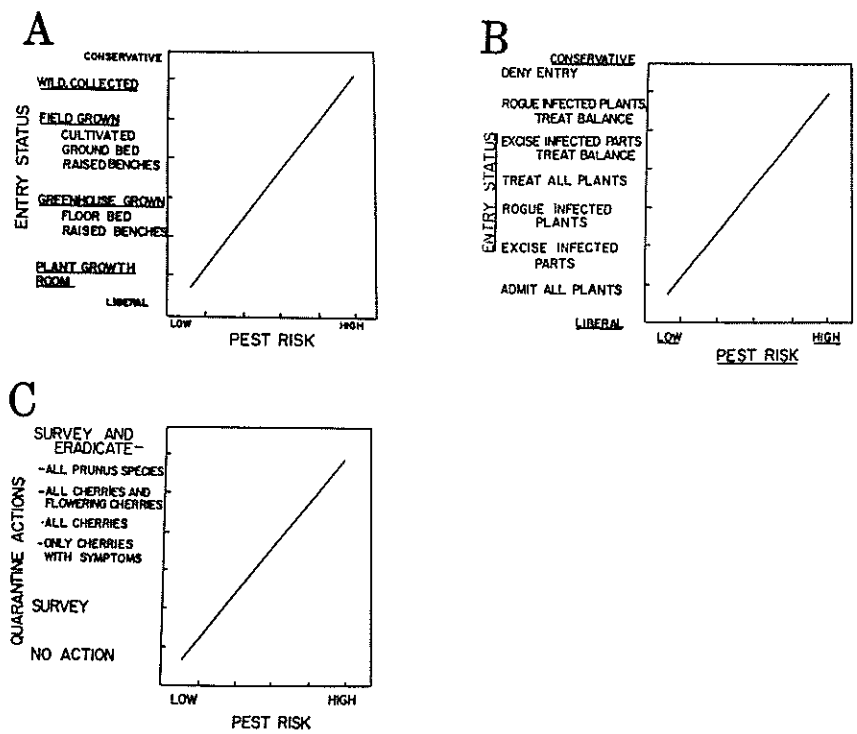


Fig. 4
The use of the pest risk analysis curve to illustrate specific problems in plant quarantine. A: the relationship of pest risk to the entry status of commercially grown plants harvested from various types of growing sites. B: entry status of plants with foliar pathogens as influenced by quarantine actions taken at inspection stations. C: quarantine action that could be taken against the little cherry agent detected in a small area of the State of Washington.

Quarantine Actions at Inspection Stations Against Foliar Pathogens

The interaction of pest risk and the entry status of plants with foliar pathogens is depicted in figure 4B. Various quarantine actions that might be taken by an inspector finding foliar pathogens are listed on the Y axis. These actions range from denying entry (highest pest risk) to admitting the entire consignment without treatments.

Little Cherry Disease Incited by the Little Cherry Agent

The little cherry disease, as found in dooryard cherries in a 40-square-mile area in the State of Washington, presents an interesting plant quarantine problem that may be illustrated by the pest risk analysis curve. The problem is that there are many quarantine actions that could be taken against the pathogen but, in the author's judgment, not enough information is known about the pathogen or its spread to determine the pest risk. In essence, if one could determine what risk to US agriculture in general or the

US cherry crop in particular was associated with this outbreak, one might be in a better position to decide which one of several quarantine actions, if any, should be instituted as a regulatory control.

In figure 4C, the pest risk to US agriculture is shown on the X axis ranging from low to high. However, instead of showing entry status on the Y axis, as with figures 2 and 3, the Y axis shows various quarantine actions. The actions include the following : 1) destruction of all species of *Prunus* in a given geographic area ; 2) destruction of *P. avium, P. cerasus*, and all flowering cherry species in a given geographic area ; 3) destruction of all sweet and sour cherries in the area ; 4) destruction of only sweet and sour cherries showing diagnostic symptoms (either with or without confirmatory laboratory staining results) ; 5) survey for symptoms to determine the distribution of the agent in *P. avium* and *P. cerasus* in the western States or the entire United States ; and 6) no regulatory action.

The little cherry disease is incited by a graft-transmitted agent assumed to be virus-like but not yet proven as such. The agent appears to spread in commercial orchards by an aerial vector (or vectors) as yet unidentified. The agent is transmitted in nursery operations when nurserymen propagate from infected sources.

Hosts include sweet cherry (*P. avium*), sour cherry (*P. cerasus*), Duke cherry (*P. avium* x *P. cerasus*), and flowering cherries (including *P. serrulata, P. subhirtella, P. yedoensis*), bitter cherry (*P. emarginata*), and rootstocks such as mahaleb (*P. mahaleb*) and mazzard (*P. avium*).

In some varieties of sweet and sour cherry, diagnostic symptoms are produced, whereas infected flowering cherries are usually symptomless.

The little cherry agent has been transmitted by budding or grafting to diagnostic indicator plants from flowering cherries in Great Britain, Japan, and from several States in the United States. The role of flowering cherries in the natural spread of the agent to commercial cherries is unknown. However, field observations suggest that the pathogen spreads more efficiently from fruiting cherries to fruiting cherries than from flowering cherry to fruiting cherry.

In the author's judgment, the problem presented by the little cherry agent in dooryard cherry in Washington is to determine which one or more of the quarantine actions shown on the Y axis should be implemented so that the quarantine action and pest risk interact somewhere on the pest risk analysis curve.