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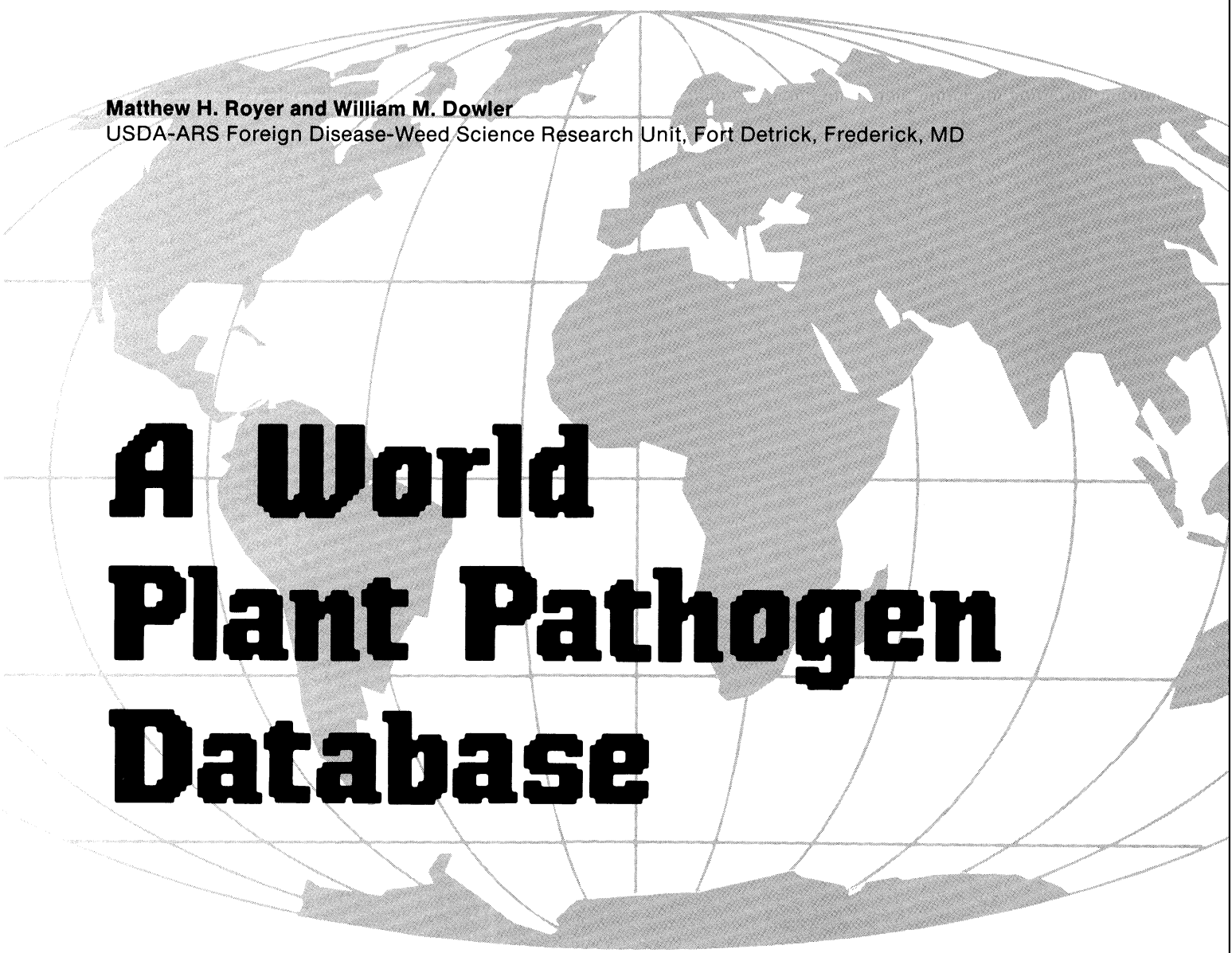

A World Plant Pathogen Database

Plant diseases pose international threats to agriculture because of the increased travel, trade, and movement of people and materials throughout the world. Therefore, the likelihood of transporting unwanted plant pathogens into areas in which they have not been established is increasing. For example, the Animal and Plant Health Inspection Service (APHIS) of the U.S. Department of Agriculture reported 46,058 separate quarantinable interceptions of pests (plant pathogens, insects, mites, mollusks) at ports of entry in 1986 (1). APHIS generally assumes that at least 600 occasions of foreign pest entry occur yearly in the United States from natural or other means (T. Wallenmaier, APHIS, *personal communication*).

An international warning system is needed to alert us of these potential disease threats and to provide a mechanism for making the benefits of research and hands-on experience available internationally. Expert opinion and data pertaining to the potential for pathogen spread, injury to crops, and control of pests should be provided as part of the system to determine whether nonestablished (foreign) plant pathogens have the potential to damage our agricultural economy through yield losses, embargoes, or alterations in trade patterns. Pest risk assessment (PRA) is one means of evaluating this pest information.

PRA was defined by an ad hoc committee of the North American Plant Protection Organization in 1984 as: "The process of systematic evaluation through which a judgement is achieved regarding the potential danger (threat) posed to agricultural, forestry and horticultural crops by destructive organisms if they are introduced into an environment where they do not yet occur, or if they are allowed to spread within an environment into which they have recently been introduced." An example of PRA in action is the decision to eradicate citrus canker outbreaks in Florida (5).

PRAs are generally established on a crop-by-crop or commodity-by-commodity basis according to political boundaries (country, state, etc.). This is because actions are based on the interest and ability of a political division to legally intercept, identify, and decide whether the risks of pest importation with that commodity are real. Some information

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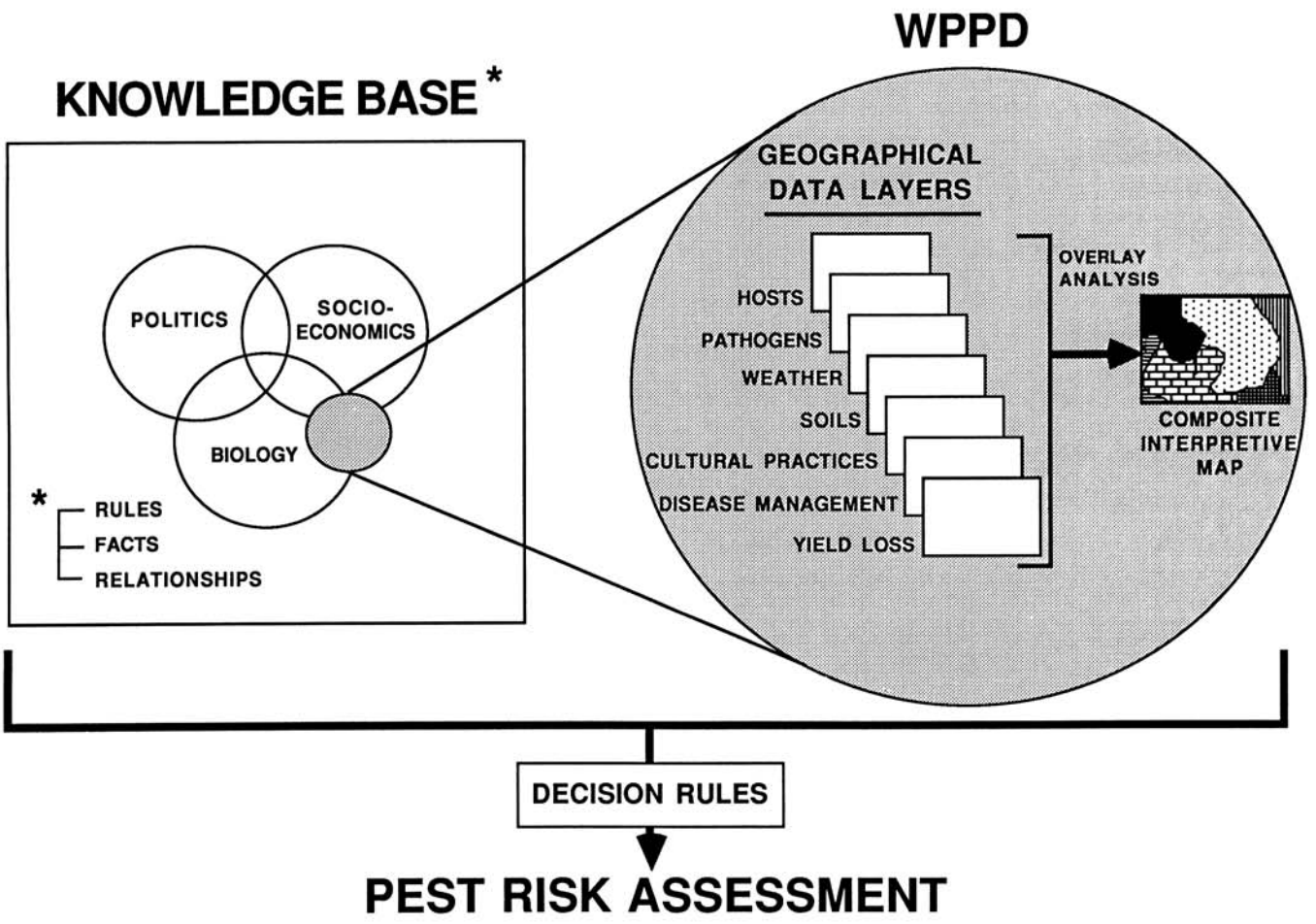

Fig. 1. The World Plant Pathogen Database (WPPD) provides a core of biological data as well as geographically oriented biological data for interpretation in pest risk assessment.

that is crucial to PRA may not be available, however. Plant protection experts usually know the important disease problems in their own country well, but because of limited library facilities, language barriers, and little contact with scientists outside their country, they may not be aware of foreign plant disease problems. For example, on-line bibliographic databases (computerized information systems accessible through a telephone) are currently available and affordable to developed countries but not to many developing countries. Johnston (2) points out that even the existing computerized bibliographic databases ". . . are of a general nature, designed to serve a wide range of users, and are therefore to some extent deficient for plant quarantine [PRA] purposes."

A country with access to information about the threat of foreign plant diseases could prepare for a new disease and minimize its effect on crop production. Unfortunately, there is no information system that can be directly used to assess the threat that foreign plant pathogens or pathogens of "quarantine significance" pose to agriculture.

The exchange of germ plasm, of information pertaining to disease resistance, and of personnel among cooperating countries greatly enhances the identification of threatening plant diseases. Quarantines that attempt to stop the inadvertent introduction of plant pests on germ plasm obviously can hinder this exchange. To be most effective, therefore, quarantines need to be based on information according to biogeographical rather than political boundaries. A global pest information system is vital if regulated movement of plant materials is to continue and plant quarantines are to be minimized.

The USDA-ARS Foreign Disease-Weed Science Research Unit (FDWSRU), formerly the Plant Disease Research Laboratory, held a workshop on exotic diseases in May 1984 to assess some of the problems of obtaining foreign plant disease information. The purpose of the meeting was to identify those foreign diseases or research approaches that should be investigated by ARS. Several attendees suggested that information exchange pertinent to PRA internationally needed considerable improvement. For example, they suggested tapping international professional societies, national research centers, regional plant protection organizations, agricultural universities, and cooperative international programs fostering agricultural research as sources of plant disease information not accessible in journals. Experts at the workshop recommended, among other things, that an international database be constructed to gather information on pathogens, diseases, and addresses of workers knowledgeable about exotic diseases. We address this recommendation herein and describe progress toward a World Plant Pathogen Database (WPPD).

Solution

The time is right for a computerized information network to help us define the risks and to "give alert" to these threats. A computerized system would permit the processing of large volumes of data and would be of interest to those involved with the international movement of germ plasm, plants, and plant products and those concerned with plant quarantines. WPPD was conceived to fill some of the information requirements for PRA, while recognizing that not all of the requirements for PRA could be fulfilled by WPPD alone. WPPD provides a *core* of biological data as well as *geographically oriented* biological data for interpretation in PRA (Fig. 1). We propose to initiate

standardized regionalized versions of WPPD that can be made available to foreign cooperators on personal computers to enhance everyone's ability to recognize disease threats.

Information Systems

Information needed for PRA may appear in professional journals and texts or may remain as largely internal publications. Databases may help store and retrieve some of this information, and we note that the USDA's *Agricultural Databases Directory* (6) lists 428 separate databases generated from 272 database producers. Many of these databases are deficient for PRA, however. Exceptions are WPPD and the pest survey and reporting systems operating at local, state, and national levels. In the United States, Plant Protection and Quarantine of USDA-APHIS initiated the Cooperative National Plant Pest Survey and Detection Program, which supports the computerized National Agricultural Pest Information System (NAPIS) that provides, among other data, information on the occurrence of nonestablished or foreign pests within each state. These pest survey databases are potential resources to develop and test models for predicting the geographical distribution of pests.

Rationale

Researchers around the world have biological information that is useful to minimize quarantines. However, no "database standards" beyond keywords in bibliographic databases have been established to assist in this information transfer. A computerized information system would: 1) help to standardize some of this information, 2) make the information more readily available, and 3) provide data in a form appropriate for PRA. The database should provide data to determine which foreign plant pathogens have the ability to spread rapidly, cause significant losses, and are difficult to control.

We conduct research in our laboratory to determine the relative threat that foreign pathogens or pathogens of quarantine significance pose to U.S. agriculture (3). Because of the nature of these "threat determinations," FDWSRU communicates with APHIS both to identify these threats and to decide on what research is required to provide certain information for PRA. The central role of FDWSRU in the USDA's line of research to recognize and miminize foreign disease threats makes it an ideal location for developing a WPPD.

Development of a WPPD

Database content. Many variables affect plant diseases, and we acknowledge that we could not possibly synthesize or catalog all information with equal precision. Plant disease literature pertains to many aspects of a pathogen's biology that are independent of the interaction with the host, as well as data concerning the host. Some of these data are directly applicable to disease management. For example, we may know that a given fungal pathogen's mycelial growth is optimal during 10 hours of relative humidity >95% at 12–15 C. Field observations may indicate that disease development is favored by 2 days of relative humidity >90% at a mean temperature of 10–15 C under cloudy conditions. We would tend to input the latter data because disease development under natural conditions reflects the integration of many factors, only some of which may be reported in the literature.

WPPD is a synthesis of observations pertaining to weather conditions that are marginally and optimally conducive to disease development, disease management methods, yield loss variability, host phenology with respect to disease development, mechanisms of pathogen dispersal and survival, and geographical occurrence of pathogens. The geographical data in WPPD are appropriate for spatial overlays and interpretation of data relationships (Fig. 1).

Two primary sources of data are used for input into WPPD: 1) documented or collated data and 2) data contributed by cooperators in the form of questionnaires. Data obtained from incoming questionnaires and published in journals are added daily. The source of all information in the database is referenced in the database, and literature and questionnaire data can be merged in a report.

Literature. Journals, texts, internal reports, International Research Center reports, Food and Agriculture Organization of the United Nations regional plant protection bulletins, disease compendia, Commonwealth Mycological Institute publications, U.S. Agency for International Development publications, and

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William M. Dowler

Dr. Dowler is the research leader of the USDA-ARS Foreign Disease-Weed Science Research Unit, Fort Detrick, Frederick, Maryland. He received his B.S. and M.S. degrees from the University of Missouri, Columbia, and his Ph.D. degree (1961) from the University of Illinois. He conducted a research program on stone fruit diseases at Clemson, South Carolina, as an ARS research plant pathologist until 1975, when he joined the USDA-ARS National Program staff at Beltsville. He became research leader at Fort Detrick in 1981. His research interests include the physiology of fungal spore germination and the interaction of plant growth regulators and beneficial fungi for biological control of weeds.

many other sources are reviewed for pertinent data. These sources provide *core* data applicable to most areas where a given disease is established and *specific* data concerning a given geographical region.

Questionnaires. Some data are not readily available from the literature and must be obtained by personal contact with experts in foreign countries or individuals in the United States who are knowledgeable about foreign plant diseases. Therefore, a questionnaire was developed to standardize the information obtained from experts (Fig. 2). A questionnaire is completed for each disease and each ecological/geographical region or specific site. We encourage individuals to respond to the questionnaire, to notify us of directories of plant pathologists in foreign countries, and to suggest improvements in the questionnaire and methods for obtaining and disseminating the information.

We recognize that some information is subjective, but such information provides insight (and an international directory of experts) for investigating the relationships among the data. Subjective data may reflect the *perceived* importance of a particular pathogen in a geographical region and may provide a unique view of events that are often difficult to quantify for disciplines working largely independently. For example, Norton and Mumford (4) purport that the ". . . complexities and dynamics of pest control decision problems are determined as much by social, economic, technological, and political developments as by biological and ecological processes."

Development tools. We have been developing the requirements for a computerized WPPD through a personal-computer database language, dBASEIII Plus (Ashton-Tate, CA). This software, initially used to design file structures and prototypes for database maintenance, was chosen for ease of use and allowed us to change our data structures as necessary without the intervention of a database administrator. We are now using relational database software, FOCUS (Information Builders, Inc., NY), that operates on a mainframe as well as on a personal computer. FOCUS software supports complex relationships among data across files and allows us to maintain the "master files" on a mainframe, distribute subsets for use on personal computers to interested parties, and run updates generated on the personal computers against the master files on the mainframe, thereby maintaining file integrity.

Data standards. The only data standards in force for WPPD are the codes used to refer to the basic components of the database: the pathogen, the host(s), and the geographical division. These codes are necessary to link unique identifiers to

WORLD PLANT PATHOGEN DATABASE

A Name and address of contributor:

B Geographical area(s) to which this questionnaire applies:
Country _____ State(s) _____
Ecological region(s)/site(s) within above state(s)
_____
Elevation ___ to ___ meters. No. of hectares represented ___

C Crop (Genus species...) _____
Pathogen (Genus species...) _____
Common disease name _____

D 3 Pathogens simultaneously causing yield loss (Genus species)
1. _____
2. _____
3. _____

E

Commercial yield loss	With respect to geographical area in B			Nationally
	%loss	Yield (Kg/ha)	% of area with this loss	%loss
Least loss				
Average loss				
Most loss				

F Loss assessment (√ appropriate boxes) Subjective ☐ &/or by experimentation/survey/sampling ☐. Seasonal quantity ☐ &/or quality ☐ loss. Assessed before ☐ or after ☐ harvest. Yield loss observed ☐ years with respect to ☐ number of cultivars. Loss by future weakening of perennial crop ☐ or contamination of planting area ☐. Postharvest loss ☐.

G Crop growth stages when: Crop is 1st infected _____
Symptoms 1st appear _____ Disease is most prevalent _____

H Crop growth stages and environmental contitions frequently associated with the disease cycle for the geographical area specified in B.

Stage in disease cycle	Temperature C			Relative humidity %		Cloudy or shady + or -	Rain or snow + or -	Soil + or -			Environment * duration (hours or days)		Growth stages	
	opt.	min.	max.	low	high			satur-ated	moist	dry	min.	max.	begin	end
Epidemic duration														
Latent period														
Infectious period														
Survival or over-wintering														
Example for Epidemic duration	25	15	40	80	100	?	?	?	+	-	7 days	30+ days	tiller-ing	head-ing

* Duration of the environmental condition that is frequently associated with a particular stage in the disease cycle.

I Inoculum sources, methods of survival, and dispersal _____

J Host range (Genus species...) Natural _____
Experimental _____

K Practiced control measures _____

L Literature citations _____

Fig. 2. Questionnaire for obtaining standardized information for World Plant Pathogen Database.

scientific names, common names, and synonyms for pathogens; scientific names, common names, and synonyms for hosts; and country, state, province, or any other geographical division name to unique geographical codes. These codes facilitate the updating of the master files from "update files" and minimize ambiguity and errors when entering and retrieving pathogen, host, and geographical data. The content is therefore "standardized" in that these data are manipulated across files through the use of these codes.

Compatibility with other databases. WPPD is compatible with the Environmental Protection Agency (EPA) pest databases, such as the National Pesticide Information Retrieval System, and with NAPIS through the EPA pest and plant codes. Thus, data pertaining to threatening plant diseases may be used by EPA and APHIS through common codes to avoid ambiguity. Where political boundaries are used, the U.S. Department of State listing of division names is consulted. The U.S. Bureau of Standards supplies the codes that refer to political divisions and provide a basis for conversion to codes used by other databases internationally.

Availability. Specialized printed reports for cooperators are limited. We are working toward distributing the database on diskettes, removable hard disks, or optical diskettes for use on personal computers. The cooperator could then search for, add, or change information, generate reports, and periodically send the update files to us so we could run an "update program." We could then send new master files to the cooperator so that the cooperator would receive current information from all cooperators who are exchanging data on the same level. This would permit regionalized subsets of the larger information system to serve the needs of specific geographical locations while providing an opportunity for experts in particular regions to contribute and in turn receive data from other cooperators. Updates and modifications to the overall database could therefore be performed regionally with local expertise. Data format would always conform to that specified in the overall information system.

There are no plans to make the data available through an on-line network. Rather, WPPD is proposed to operate as a *functional* network of expertise and data exchange. The distributed database would require an MS-DOS/PC-DOS personal computer equipped with a hard disk with a minimum of 20 megabytes of storage.

Recommendations, Observations

The development of a WPPD is a first step in an inexpensive (compared with on-line services) and timely exchange of computerized pest information for pest risk analysis internationally.

It is likely that specialized databases will continue to be developed in plant protection. The number of users gaining access to computerized services internationally is increasing, and data-collecting activities probably will be shared and the cost of complete centralization dispersed. If these specialized databases are to share information as a network, all should have common data elements, e.g., pest codes. Therefore, we make several recommendations and observations:

1. An international cooperative effort is needed to establish *standard guidelines for PRA* with respect to the risks associated with germ plasm exchange.

2. A working group should be organized to identify *criteria and database search strategies* for pest risk analysis and to guide the development of standards.

3. WPPD will provide *current knowledge* of the status of plant diseases in various parts of the world and will greatly enhance our ability to decide if an nonestablished (foreign) disease is in urgent need of investigation so we may prepare for the pathogen should it be imported.

4. WPPD will provide *biological guidance for developing countries* to follow quarantines.

5. WPPD will allow us to *identify areas* where environments are favorable or unfavorable for plant pathogens to prosper and will allow us to utilize quarantines more effectively.

6. WPPD will enhance *freer movement of germ plasm* as a result of the synthesis and dissemination of biological data and will permit movement of germ plasm according to ecological rather than political boundaries.

7. WPPD will encourage *uniformity of quarantine measures* (since pests do not respect political boundaries) and permit quarantines based on ecological data.

8. WPPD will, for the first time, provide a *single source of biological information pertinent to PRA*, database content standards, and uniform international application of data to provide a foundation for allowing free international movement of plants and plant products.

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