**Developing Matrices for the Selection of Recovery Plans in the National Plant Disease Recovery System**

**(or)**

**Are Generic Plans Feasible and Appropriate?**

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## Prioritizing Plant Diseases

- 1st NPDRS Workshop – April 2006 (Memphis, TN)
- 2nd NPDRS Workshop – April 2007 (St. Louis, MO)
- 3rd NPDRS Workshop – October 2008 (San Antonio, TX)
- 4th NPDRS Workshop – March 2011 (Dallas, TX)




## Generic Plans

- General consensus on the concept of generic plans, although there was some discussion if generic plans were appropriate at all, given the diversity of pathogens, hosts, environments, etc.
- However, there was no consensus on exactly what a generic plan would look like and which pathogens and diseases might serve as models.



## Generic Plans

- Plant diseases that might serve as models for many others might be those that –
  - are caused by similar types of pathogens
  - occur on similar hosts
  - are disseminated in similar ways
  - survive in similar ways
  - are managed in similar ways

## Plant Disease Recovery Plans

**Completed**

- Citrus variegated chlorosis
- Citrus greening
- Downy mildews of corn
- Late wilt of corn
- Red leaf blotch of soybean
- Laurel wilt of redbay
- Plum pox
- Potato wart
- Ralstonia bacterial wilt
- Rathyibacter poisoning
- Scots pine blister rust
- Stem rust of wheat (Ug99)
- *P. kernoviae* tree / shrub diseases

**In development**

- Citrus leprosis
- Cyst nematode
- Laurel wilt of avocado
- *Phytophthora* spp. of trees / shrubs
- Walnut thousand cankers
- Wheat blast



## Criteria for prioritization

- USDA Select Agent and Toxins List



## USDA Select Agent and Toxins List (2008)

- *Peronosclerospora philippinensis* (Philippine downy mildew of corn)
- *Phoma glycinicola* (Red leaf blotch of soybean)
- *Ralstonia solanacearum* race 3 biovar 2 (Bacterial wilt of solanaceous crops)
- *Rathayibacter toxicus* (Slime disease / Rathyibacter poisoning)
- *Sclerophthora rayssiae var. zeae* (Brown stripe downy mildew of corn)
- *Synchytrium endobioticum* (Potato wart)
- *Xanthomonas oryzae – all pathovars* (Bacterial leaf blight of rice)
- *Xylella fastidiosa CVC strain* (Citrus variegated chlorosis)



## USDA Select Agent and Toxins List (2008)

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## Criteria for prioritization

- USDA Select Agent and Toxins list
- Economic value of host crop



## Criterion A. Economic value of host

**(USDA Agricultural Statistics 2008)**

- Corn - $52.1 billion (92.6 million acres)
- Soybeans - $26.7 billion (62.8 million acres)
- Wheat - $13.7 billion (51 million acres)
- Cotton - $6.2 billion (10.5 million acres)
- Forest lumber - $5.2 billion
- Potatoes – $3.9 billion (1.1 million acres)
- Rice - $3.4 billion (2.9 million acres)
- Citrus - $2.9 billion (876,000 acres)
- Apples - $2.4 billion (615,000 acres)
- Cucurbits - $1.6 billion (503,000 acres)



## Criterion: Economic value of host

**(USDA Agricultural Statistics 2008)**

- Corn - $52.1 billion (92.6 million acres)
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- Cucurbits - $1.6 billion (503,000 acres)



## Criterion A. Economic value of host

**(USDA Agricultural Statistics 2008)**

- Mushrooms - $9.5 million (NA)
- Cherries - $6.5 million (118,000 acres)
- Pistachios – $5.5 million (114,000 acres)
- ……
- ……
- ……
- ……
- ……

## Economic value of host

- The reality is that any plant disease worthy of having a recovery plan prepared would be on a high value crop!



## Criteria for prioritization

- USDA Select Agent and Toxins list
- Economic value of host crop
- Type of host (crop)



## Type of Host

- Field crops (soybean, cotton, maize, etc.)
  Soybean rust, PDM, late wilt, brown stripe mildew, red leaf blotch
- Small grains (wheat, rice, barley, etc.)
  Stem rust Ug99, wheat blast (in develop.)
- Forage crops
  Rathyibacter poisoning
- Vegetables (tomatoes, potatoes, beans, etc.)
  R.s.r3b2, potato wart, (potato cyst and root-knot; in develop.)
- Ornamentals (cut flowers, potted plants, landscape, etc.
  R.s.r3b2, Ramorum blight (SOD)



## Type of Host

- Fruit and nut trees (citrus, stone & pome fruits, nuts)
  CVC, HLB, citrus canker, plum pox, (laurel wilt avocado, walnut canker, in develop.)
- Landscape, plantation and forest trees
  *P. ramorum, P. kernoviae*, Scots pine blister rust, *Phytophthora* spp.
- Annuals
  Potato wart, R.s.r3b2, stem rust, wheat blast (in develop.), DM corn, late wilt, soybean rust, red leaf blotch, potato cyst nematodes (in develop.)
- Perennials
  CVC, HLB, canker, laurel wilt avocado, plum pox, laurel wilt redbay, Scots pine rust, *P. kernoviae, P. ramorum* et al., walnut canker & citrus leprosis (in develop.)

## Criteria for prioritization

- USDA Select Agent and Toxins list
- Economic value of host crop
- Type of host (crop)
- Type of pathogen



## Type of pathogen

- Fungi (chytrids, ascos, basidos)
- Stramenopiles (downy mildews, *Phytophthora* spp)
- Bacteria (Eubacteria, XLB, PLB)
- Viruses
- Nematodes

Which taxa and how many of each?



## Type of pathogen

- Fungi (chytrids, ascos, basidos)

  Stem rust of wheat, soybean rust, Scots pine rust, late wilt of corn, laurel wilt redbay, laurel wilt avocado, potato wart, wheat blast, walnut canker

- Stramenopiles (Oomycota)

  *Philippine DM corn, brown stripe mildew corn, P. kernoviae, P. ramorum, Phytophthora spp.*

- Bacteria

  *R. solanacearum* r3b2, Rathayibacter poisoning, citrus greening (HLB), citrus variegated chlorosis

- Viruses

  Plum pox, citrus leprosis (in develop.)

- Nematodes

  Cyst and root-knot nematodes (in develop.)



## Criteria for prioritization

- USDA Select agent and toxins list
- Economic value of host crop
- Type of host (crop)
- Type of pathogen
- Type of host x type of pathogen matrix

## Host x Pathogen Taxa

Host

| Pathogen Taxa | Forage | Small grains | Field crops | Fruits & Nuts | Forest & Land-scape | Veggies | Orna-mentals |
|---|---|---|---|---|---|---|---|
| Viruses | | | | | | | |
| Bacteria | | | | | | | |
| Fungi (Rusts) | | | | | | | |
| Fungi (Other) | | | | | | | |
| Downy mild. (Oomycota) | | | | | | | |
| Phytophthora (Oomycota) | | | | | | | |
| Nematodes | | | | | | | |



## Host x Pathogen Taxa

Host

| Pathogen Taxa | Forage | Small grains | Field crops | Fruits & Nuts | Forest & Land-scape | Veggies | Orna-mentals |
|---|---|---|---|---|---|---|---|
| Viruses | | | | CLV, PPV | | | |
| Bacteria | Rb tox. | | | CVC, HLB | | Rsr3b2 | Rsr3b2 |
| Fungi (Rusts) | | SRW | ASR | | SPBR | | |
| Fungi (Other) | | WB | LWC, RLBS | LWA | WC, LWR | PW | |
| Downy mild. (Oomycota) | | | PDM, BSDM | | | | |
| Phytophthora (Oomycota) | | | | | Pk, Pr, P. spp. | | |
| Nematodes | | | | | | PGCN | |

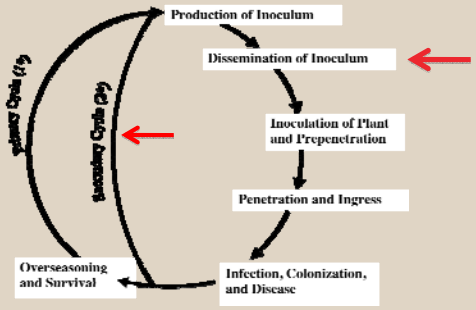


## Criteria for prioritization

- USDA Select agent and toxins list
- Economic value of host crop
- Type of pathogen
- Type of host (crop)
- Type of host x type of pathogen matrix
- Pathogen epidemiology / dissemination



## Generic plant disease cycle



## Pathogen Dissemination

- Wind or wind-blown rain
- Water-borne
- Soil-borne
- Seed / plant-borne
- Vector-borne
- Mechanical (equipment, etc.)
- Others



## Host x Pathogen Dissemination

Host

| Dissemination | Forage crops | Small grains | Field crops | Fruits & Nuts | Forest & Landscape | Veggies | Orna-mentals |
|---|---|---|---|---|---|---|---|
| Wind dispersed | | | | | | | |
| Wind / rain dispersed | | | | | | | |
| Seed-borne | | | | | | | |
| Vector-borne | | | | | | | |
| Soilborne | | | | | | | |
| Over-season. | | | | | | | |
| | | | | | | | |



## Host x Pathogen Dissemination

Host

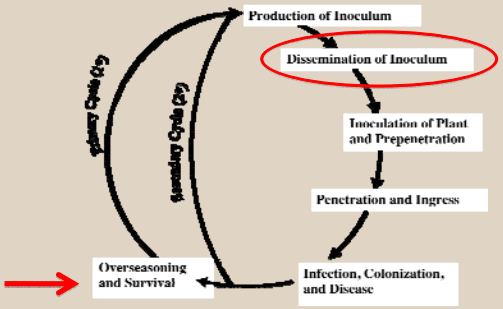
| Dissemination | Forage crops | Small grains | Field crops | Fruits & Nuts | Forest & Landscape | Veggies | Orna-mentals |
|---|---|---|---|---|---|---|---|
| Wind dispersed | | WSR, KB, WB | ASR RLB PDM | | SPBR, Pk, Pr | | |
| Wind / rain dispersed | | | | CC | Phytoph. spp | Rsr3b2 | Rsr3b2 |
| Seed-borne | | KB | LWC | | | Rsr3b2 | Rsr3b2 |
| Vector-borne | Rb tox | | | CLV, PP HLB | LWRb | | |
| Soilborne | Rb tox | | LWC RLB | | | PW, PCN Rsr3b2 | Rsr3b2 |
| Over-season. | | KB, WB, WSR | RLB PDM | | Phytoph. spp | PW, PCN | |
| | | | | | | | |



## Criteria for prioritization

- USDA Select agent and toxins list
- Economic value of host crop
- Type of pathogen
- Type of host (crop)
- Type of host x type of pathogen matrix
- Pathogen epidemiology / dissemination
- Pathogen epidemiology / survival and establishment

## Generic plant disease cycle






## Pathogen survival and establishment

- Obligate vs. non-obligate parasite
- Alternant or alternative hosts
- Survival structures
- Vector survival
- Survival in association with host (seed, bud wood, cuttings, etc.)
- Continual reintroduction of inoculum
- Climatic constraints (Environmental Risk Zones)
- Other



## Host x Survival Mechanism

Host

| Survival mechanism | Forage crops | Small grains | Field crops | Fruits & Nuts | Forest & Landscape | Veggies | Orna-mentals |
|---|---|---|---|---|---|---|---|
| Obligate parasite | | | | | | | |
| Non-obligate | | | | | | | |
| Survival structures | | | | | | | |
| Vector | | | | | | | |
| Seed or plant part | | | | | | | |
| Reintro-duction | | | | | | | |
| Environ. Risk Zones | | | | | | | |



## Host x Survival Mechanism

Host

| Survival mechanism | Forage crops | Small grains | Field crops | Fruits & Nuts | Forest & Landscape | Veggies | Orna-mentals |
|---|---|---|---|---|---|---|---|
| Obligate parasite | | WST | PDMC BSDM | CLV,CVC HLB, PPV | SPBR | PGCN | |
| Non-obligate | Rb tox | WB, | LWC, | LWA | Pk, Pr. P. spp. | Rsr3b2 PW | Rsr3b2 |
| Survival structures | | WST, WB | LWC,PDM RLBS | LWA | Pk, Pr. P. spp. | PGCN PW | |
| Vector | Rb tox | | | HLB, CLV PPV | LWRb | | |
| Seed or plant part | Rb tox | | LWC | HLB, PPV, CVC | | PW | |
| Reintro-duction | | WST, WB | | | SPBR, LWRb | Rsr3b2 | Rsr3b2 |
| Environ. Risk Zones | | | PDMC LWC | | P. spp. | | |

| | Forage | Small grains | Field crops | Fruits & Nuts | Forest & Land-scape | Veggies | Orna-mentals |
|---|---|---|---|---|---|---|---|

| Viruses | | Forage crops | Small grains | Field crops | Fruits & Nuts | Forest & Landscape | Veggies | Orna-mentals |
|---|---|---|---|---|---|---|---|---|
| Bacteria | | | | | | | | |
| Fungi (Rusts) | Foliar | | Forage crops | Small grains | Field crops | Fruits & Nuts | Forest & Landscape | Veggies | Orna-mentals |
| Fungi (Other) | Root rots | Wind dispersed | | Forage crops | Small grains | Field crops | Fruits & Nuts | Forest & Landscape | Veggies | Orna-mentals |
| Downy mild (Oomycota) | Vascular wilts | Wind / rain dispersed | Obligate parasite | | | | | | | |
| Phytophthora (Oomycota) | Seed rots | Seed-borne | Non-obligate | | | | | | | |
| Nematodes | Fruit rots | Vector-borne | Survival structures | | | | | | | |
| | Rusts | Soilborne | Vector | | | | | | | |
| | Mildews | Over-seasoning | Seed or plant part | | | | | | | |
| | | | Reintro-duction | | | | | | | |



## Criteria for prioritization

- USDA Select agent and toxins list
- Economic value of host crop
- Type of pathogen
- Type of host (crop)
- Type of host x type of pathogen matrix
- Pathogen epidemiology / dissemination
- Pathogen epidemiology / survival and establishment
- Risk or threat factor



**The risk (R) of a given pathogen can be defined as:**

$$R = A \times E \times S \times H \times (1 - C)$$

**R** = Risk

**A** = Probability of introduction

**E** = Probability of pathogen establishment

**S** = Probability of spread from initial point

**H** = Probability of major damage (hazard)

**C** = Probability of control or containment

L.V. Madden & M. Wheelis 2003. Ann. Rev. Phytopathol. 41:155-176

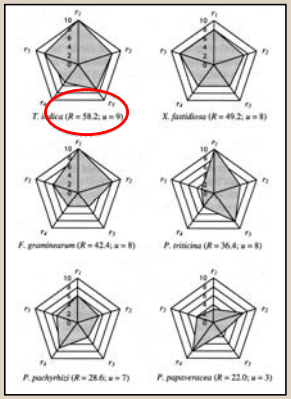


## Risk Evaluation Scheme (RES)

**Fig. 1** Risk profile, completed by risk aggregated score and degree of uncertainty, as the result of the risk evaluation scheme (*RES*) for the nine selected plant pathogens. The five sections (scored on the [0–10] integer scale) of the RES are: importance of the target crop ($r_1$), ease of use of the pathogen ($r_2$), epidemic potential of the pathogen ($r_3$), obstacles to swift and effective response ($r_4$), potential global or regional consequences ($r_5$). The risk aggregated score $R$ is given by the equation

$$R = \frac{1}{n}\left(\left(\sum_{i=1}^{n-1} r_i \times r_{i+1}\right) + r_n \times r_1\right)$$

with $n=5$. The degree of uncertainty $u$ (scored on the [0–10] integer scale) is an empirical assessment of the quality and quantity of scientific information available for completing the RES

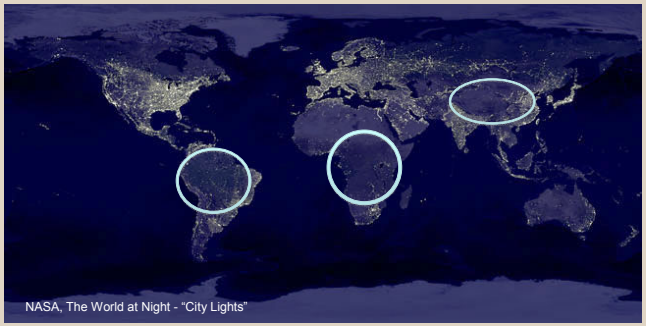


Suffert, et al. 2009. Food Sec. 1:221-232

R = (r1 x r2 + r2 x r3 + r3 x r4 + r4 x r5 + r5 x r1) / 5

$\mu$ = degree of uncertainty of information

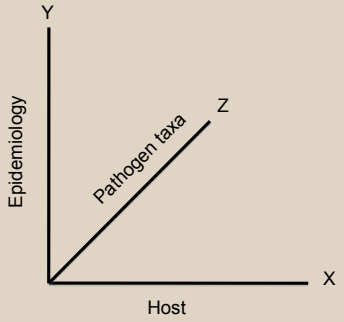
Most diseases of concern are exotic!




Bad guesses = bad decisions!

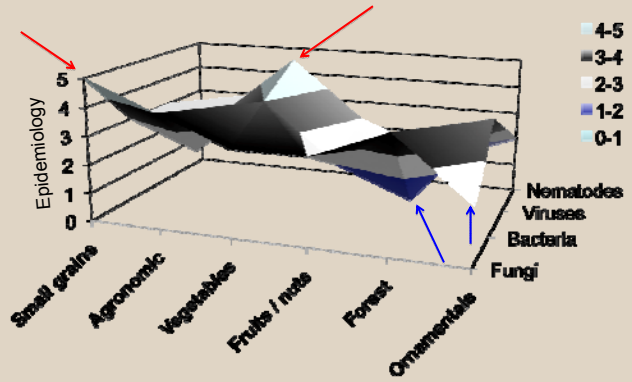


**3-Dimensional Matrix (Pathogen x Host x Epidemiology)**




Martyn, 2011. 4th NPDRS workshop






Martyn, 2011. 4th NPDRS workshop



## Criteria for prioritization

- USDA Select agent and toxins list
- Economic value of host crop
- Type of pathogen
- Type of host (crop)
- Type of host x type of pathogen matrix
- Pathogen epidemiology / dissemination
- Pathogen survival and establishment
- Risk or threat factor
- Response and management strategy

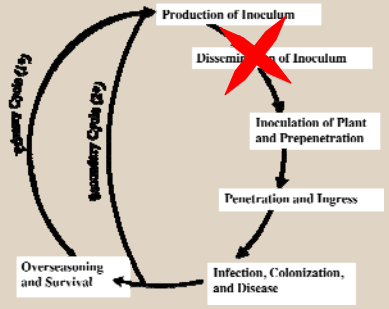
## Principles of Plant Disease Management[1]

1. Exclusion
2. Eradication
3. Protection
4. Resistance
5. Therapy
6. Avoidance

[1]National Academy of Sciences. 1968. Principles of Plant and Animal Pest Control. Vol 1. Plant Disease Development and Control. NAS Publ. #1596. Washington, D.C. 205 pp.

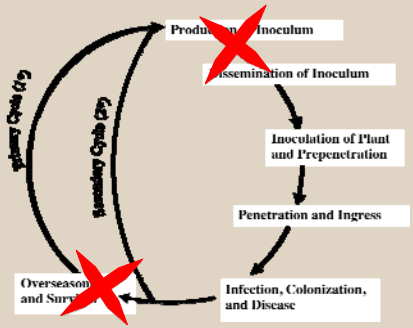


- Exclusion (Dissemination of pathogen)
  - Quarantines, inspections, certification programs, sanitation of equipment, etc., vector management, surveillance and monitoring programs, …..



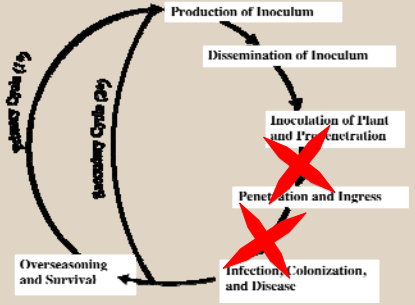



- Eradication (Overseasoning & Survival and production of inoculum)
  - Host destruction, sanitation, seed or plant treatment, fumigation, alternate host destruction, certification programs, vector management, crop rotation / fallow, residue management, ….





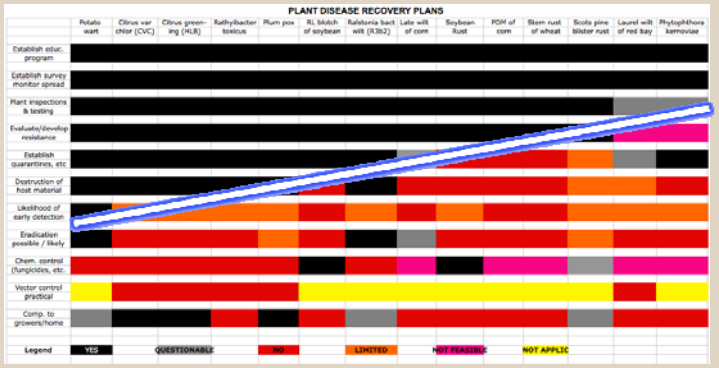

- Protection, Therapy and Host Resistance (Penetration, Infection, Ingress and Colonization)
  - Fungicides (protective & systemic), insecticides, germplasm screening and cultivar development, …



## Recovery plan matrix by response and mitigation strategy

| | Dis 1 | Dis 2 | Dis 3 | Dis 4 | Dis 5 | Dis 6 | Dis 7 | Dis 8 | Dis 9 | Dis 10 | Dis 11 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Educ. program | | | | | | | | | | | |
| Survey & monitor | | | | | | | | | | | |
| Plant test. & inspec. | | | | | | | | | | | |
| Eval / devel resistance | | | | | | | | | | | |
| Establish quarantine | | | | | | | | | | | |
| Destruction host mat. | | | | | | | | | | | |
| Likelihood early detec. | | | | | | | | | | | |
| Eradication poss. / prob | | | | | | | | | | | |
| Chem. ctrl. practical | | | | | | | | | | | |
| Vector ctrl. practical | | | | | | | | | | | |
| Comp. to growers / homeowner | | | | | | | | | | | |








## Potential diseases for new recovery plans

- Bacterial leaf blight & streak of rice ✔
- Grapevine black foot
- Fusarium wilt of date palm
- Potato yellowing virus
- Citrus black spot
- Sweet orange scab
- European Larch canker
- Chrysanthemum white rust
- Gladiolus rust
- Japanese oak wilt



## Grapevine Black Foot Disease

- *Vitis vinifera*, *Vitis* spp.
- Complex (?) of *Cylindrocarpon spp.*
- First reported in France (1961); from Italy (1984), Portugal (2000), Argentina (2001), Germany (2003), Brazil, New Zealand & South Africa (2004), California (2005), Spain & Chile (2007), Uruguay (2010)
- Root lesions and necrosis (black foot), reduced root biomass, reduced vine vigor, scorched foliage, reduced yield and death.
- Most serious on grapevine nurseries and young vineyards

## How does grapevine black foot disease fit in the recovery plan matrices?

- Important host (grape)
- Fungal pathogen
- Soilborne (long-lived survival structures)
- Control strategy
  - Exclusion (disease-free rootstock certifications)
  - Eradication (fumigation, host destruction, replant)
  - Host resistance (rootstock)
  - Therapy (systemic fungicides)



## Fusarium Wilt of Date Palm

- *Fusarium oxysporum* f. sp. *canariensis*; f. sp. *palmarum*
- Limited distribution in US (CA, FL, NV; SC, TX - 2011)
- Primarily an ornamental landscape palm in U.S. (25° N - 35° N)
- Approx. 5,300 acres of commercial date production in California



## How does Fusarium wilt of date palm fit in the recovery plan matrices

- Important hosts (*Phoenix canariensis, P. dactylifera, other palm species)*
- Soilborne pathogen
- Long-lived survival structures (chlamydospores)
- No significant aerial inoculum
- Control strategy
  - Exclusion (seedling certification, nursery inspections)
  - Eradication (host destruction, replant)
  - Therapy (systemic fungicides - ?)



## Potato Yellowing Virus (PYV)

- Bromoviridae: *Ilarvirus*
- *Myzus persicae (aphid)*
- First reported from Peru & Chile (1992)
- March 2011 reported from Ecuador
- EPPO Quarantine Pest
- Hosts – cultivated and wild potatoes, tomatoes, peppers
- Symptoms – yellowing, stunting, reduced yield

## How does potato yellowing virus fit into the recovery plan matrices?

- Important hosts (Solanaceous crops)
- Aphid-transmitted (*Myzus persicae*)
- Seed-transmitted in potato and pepper
- Control strategy
  - Exclusion (quarantine, seed certification)
  - Eradication (host destruction - tillage)
  - Genetic resistance (selection and breeding)
  - Vector control not practical or of limited effectiveness



## Citrus black spot

- *Guignardia citricarpa (Phyllostica citricarpa)*
- *Citrus spp.* (oranges, lemons, grapefruit, limes, etc.)
- Occurs throughout world (Asia, Africa, So. Am., Australia)
- Confirmed in US in two FL counties - Apr 7, 2010
- Primary inoculum is ascospores from lesions on fallen leaves
- Long latency period for fruit symptoms



## How does citrus black spot fit into the recovery plan matrix?

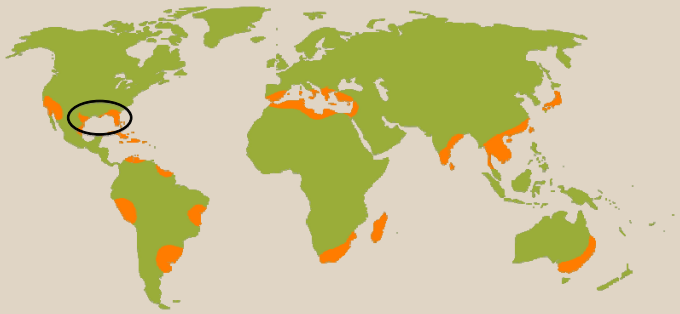
- Important host - Citrus
- Fungal pathogen
- Survival in leaf and fruit debris
- Spread by wind and rain, fruit movement and nursery stock
- Control strategy
  - Exclusion (quarantines)
  - Protection (fungicides)
  - Eradication (sanitation, destruction of infected fruit and nursery stock)



## Sweet orange scab


- *Elsinoë australis*
- Sweet orange in addition to tangerines & grapefruit
- Primarily a fresh market concern. Prevalent in South America (ARG, BOL, BRA, ECU, PAR, URG)
- First detected in U.S. (TX, LA, MS - Jul 2010) and then in Fl (Dec 2010) and AZ (Jan 2011)
- Control would be same as for citrus scab (*E. fawcetti*)
  - Quarantines, fungicides, inspections, surveys, sanitation, fruit destruction
- Requires significant moisture, Florida and Texas would be impacted most. Establishment unlikely in CA & AZ (Thayer, et al. 2003. Pest assessment: Sweet orange scab. USDA,APHIS,PPQ

## World Citrus Production
### US Environmental Risk Zone for Sweet Orange Scab



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## Japanese Oak Wilt (JOW)

- *Raffaelea quercivora* – symbiotic ascomycete
- Ambrosia beetle - *Platypus quercivorus*
- Presently only in Japan, but spreading rapidly
- Mgt. same as *Ceratocystis fagacearum* oak wilt
  - Individual high value trees
  - -Trunk injections
  - -Root trenching
  - -Destruction of infected trees
  - Limited control options in forests and natural landscapes


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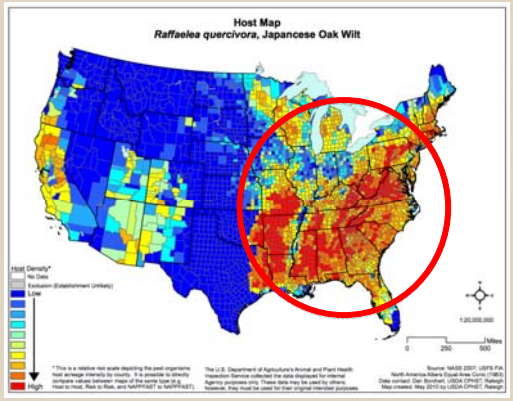
## Risk map for JOW

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## European Larch Canker (ELC) – *Larix* spp.

- *Lachnellula willkommii* (Ascomycete)
- Serious in Europe, currently restricted to Maine in US, NE Canada)
- Quarantine pest (USDA-APHIS PPQ regulation 7 CFR 301.91)
- Limited control options in forests and natural landscapes – risk zone


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## Chrysanthemum white rust

- *Puccinia horiana*
- Established in Europe, Asia, Africa, CA, SA, Australia
- Has occurred in U.S. (CT, MI 2008) but eradicated
- Primarily affects florist mums. Many other varieties are resistant
- Economic impact of $4 – $20 million (1997 dollars)
- Control strategy
  - Exclusion (quarantines, surveillance and monitoring)
  - Eradication (plant destruction)
  - Protection (fungicides)



## Gladiolus rust


- *Uromyces transversalis*
- Established throughout Africa, limited distribution in southern Europe (France, Italy, Portugal, Malta, Spain)
- Localized in South America (Brazil, Argentina), Caribbean, Mexico, Australia and New Zealand.
- Detected in U.S. (FI, CA, MN) in Apr 2006.
- Eradicated from FL & MN. Still reported in one CA county (http://pest.ceris.purdue.edu/searchmap.php?selectName=FJAAUBU)
- Control strategy
  - Eradication (plant destruction), quarantines, surveys, fungicides



## Host x Pathogen Taxa

Host

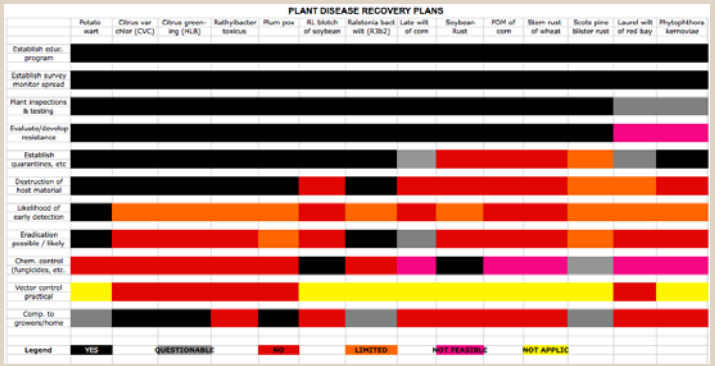
| Pathogen Taxa | Forage | Small grains | Field crops | Fruits & Nuts | Forest & Land-scape | Veggies | Orna-mentals |
|---|---|---|---|---|---|---|---|
| Viruses | | | | CLV, PPV | | | |
| Bacteria | Rb tox. | | | CVC, HLB | | Rsr3b2 | Rsr3b2 |
| Fungi (Rusts) | | SRW | ASR | | SPBR | | |
| Fungi (Other) | | WB | LWC, RLBS | LWA | WC, LWR | PW | |
| Downy mild. (Oomycota) | | | PDM, BSDM | | | | |
| Phytophthora (Oomycota) | | | | | Pk, Pr, P. spp. | | |
| Nematodes | | | | | | PGCN | |



## Host x Pathogen Taxa

Host

| Pathogen Taxa | Forage | Small grains | Field crops | Fruits & Nuts | Forest & Land-scape | Veggies | Orna-mental |
|---|---|---|---|---|---|---|---|
| Viruses | | | | CLV, PPV | | PYV | |
| Bacteria | Rb tox. | BLBR | | CVC, HLB | | Rsr3b2 | Rsr3b2 |
| Fungi (Rusts) | | SRW | ASR ORS | | SPBR | | CWR, GR |
| Fungi (Other) | | WB | LWC, RLBS | LWA,GB F CBS, SOS | WC, LWR FWDP ELC, JOW | PW | |
| Downy mild. (Oomycota) | | | PDM, BSD | | | | |
| Phytophthora (Oomycota) | | | | | Pk, Pr, P. spp. | | |
| Nematodes | | | | | | PGCN | |


PLANT DISEASE RECOVERY PLANS
Potato wart
Citrus var chlor (CVC)
Citrus green-ing (HLB)
Rathyibacter toxicus
Plum pox
RL blotch of soybean
Rahlstonia bact wilt (R3b2)
Late wilt of corn
Soybean Rust
POM of corn
Stem rust of wheat
Scots pine blister rust
Laurel wilt of red bay
Phytophthora kernoviae
Establish educ. program
Establish survey monitor spread
Plant inspections & testing
Evaluate/develop resistance
Establish quarantines, etc
Destruction of host material
Likelihood of early detection
Eradication possible / likely
Chem. control (fungicides, etc.
Vector control practical
Comp. to growers/home
Legend
YES
QUESTIONABLE
NO
LIMITED
NOT FEASIBLE
NOT APPLIC




Grapevine black foot
Potato yellow-ing virus
FW date palm
Establish educ. program
Establish survey monitor spread
Plant inspections & testing
Evaluate/develop resistance
Establish quarantines, etc
Destruction of host material
Likelihood of early detection
Eradication possible / likely
Chem. control (fungicides, etc.
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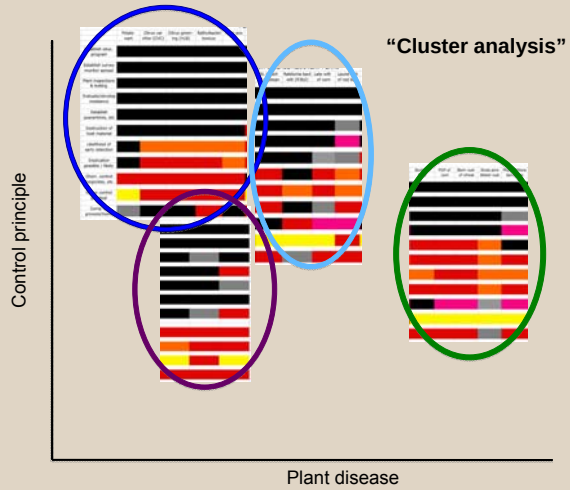
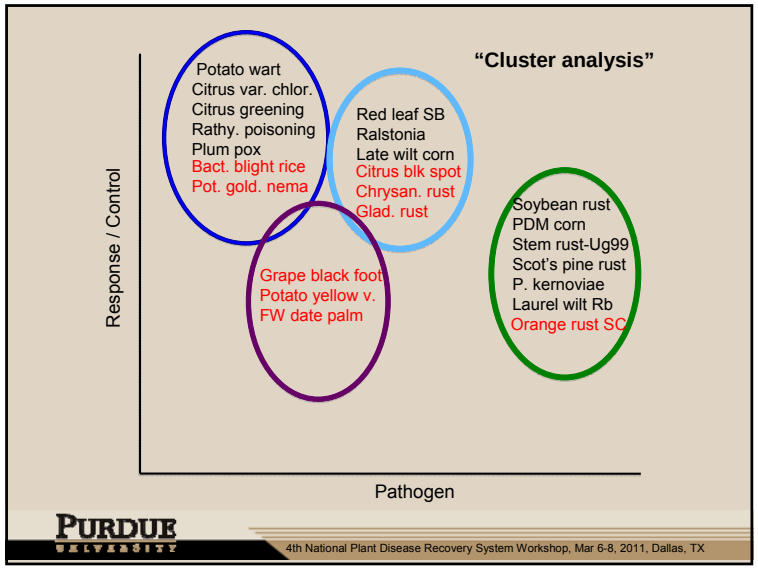
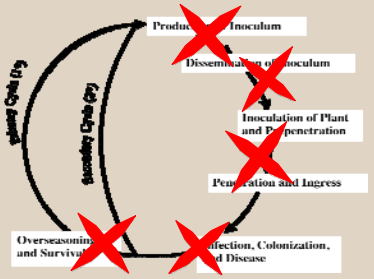

"Cluster analysis"
Control principle
Plant disease






## Control Strategy

- Exclusion
- Eradication
- Protection
- Therapy
- Resistance






What is generic about generic plans?



## Recovery Plan Components

- Introduction
- Symptoms
- Spread
- Monitoring, Detection and Identification
- Response
- USDA Permits
- Economic Impact
- Mitigation & Disease Mgt
- Infrastructure & Experts
- Research, Extension & Education Priorities

## Recovery Plan Components

- Introduction - Specific
- Symptoms - Specific
- Spread - Generic
- Monitoring, Detection and Identification – Specific
- Response - Generic
- USDA Permits - Specific
- Economic Impact - Specific
- Mitigation & Disease Mgt - Generic
- Infrastructure & Experts - Specific
- Research, Extension & Education Priorities - Specific



## Generic Plans: Are They Feasible?

- 2-D matrix design based on various combinations of type of host, type of pathogen, type of disease, etc.
  - Advantage: Straight-forward, simply fill in the boxes
  - Disadvantage: Too many boxes, where to stop?
- Risk / Threat Analysis
  - Advantage: Quantifies diseases on likely introduction and establishment scenarios
  - Disadvantage: Often lacks critical data for assigning values – "bad guesses = bad decisions"



## Generic Plans: Are They Feasible?

- 3-D matrix based on type of host, type of pathogen and basic epidemiology (spread, survival, disease cycle)
  - Advantage: Quantifies diseases
  - Disadvantage: Difficult to assigned values; unknowns
- Cluster analysis based on basic response and control strategy.
  - Advantage: Groups similar diseases by response
  - Disadvantage: Grey areas - "Lumpers and splitters"; defining criteria



## Summary

- Which of the prioritization methods is the most appropriate?
- Are any of the methods appropriate or feasible?
- Can recovery plans be "genericized"?
- If not, why not?
- We are at the point to either -




## Economic value of host

- The economic value of a particular plant is more than just the cash value. It also encompasses the regional or global impact.
  - For example, small specialty crops, like mint. Approximately 25,000 acres in U.S
  - Northern Indiana, Pacific northwest
  - Ranked 4th (peppermint) and 5th (spearmint) globally; 1st in oil quality and U.S. has 60% of world market
  - Approximately 30% of US mint oil is exported
- The reality is that any plant disease worthy of having a recovery plan prepared would be on a high value crop!



## Exclusion and Eradication

- Often the first strategies attempted for exotic pathogens
- Quarantines, certification and inspection, surveillance and monitoring, removal of symptomatic and asymptomatic hosts
- Expensive & controversial
- Not always appropriate – disease and situation specific
  - ✔ Citrus canker and plum pox
  - ✗ Asian soybean rust and wheat stem rust

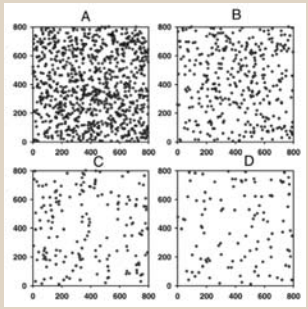


## Can eradication be optimized and 'generized'?

- 1900 ft rule for citrus canker (groves), 125 ft (door-yard) and 1640 ft rule for plum pox.
- Optimal eradication distance is dependent on the density and spatial pattern (aggregation) of the host in the landscape (trees, plantation, fields).
- Optimal eradication radius minimizes the total # of hosts removed and still effective at eradicating the disease.
- Optimal eradication radius increases with both the aggregation and density of the host

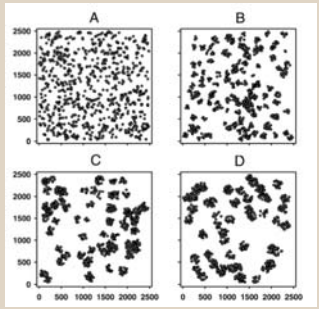
S. Parnell, T.R. Gottwald, C.A. Gilligan, N.J. Cunniffe and F. van den Bosch. 2010. The effect of landscape pattern on the optimal eradication zone of an invading epidemic. Phytopathology 100:638-644.

## Density




1,000 hosts per A) 0.7 km$^2$, B) 1.9 km$^2$, C) 4 km$^2$, D) 5.8 km$^2$

## Clustering



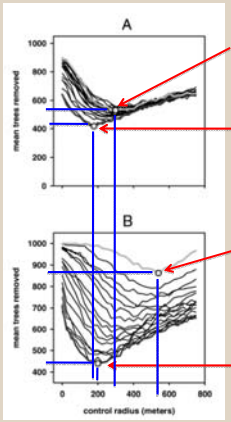

1,000 hosts per A) 1,000 clusters, B) 143 clusters, C) 71 clusters, D) 50 clusters

Parnell, et al. 2010. Phytopathology 100:638-644



A. Clustering

B. Density




Optimum @ highest

Optimum @ lowest

Optimum @ highest

Optimum @ lowest

Fig. 3. The mean number of hosts removed during eradication for different lengths of control radius. A) The effect of varying the level of clustering of hosts. B) The effect of varying the density of hosts. (Parnell. et al. 2010)