Ecology of Disease

Theme: AGRICULTURE

GRAINS



Prof Peter O'Donoghue

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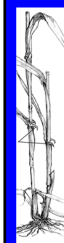
Australian Grain Industry



- Annual production ~ 40 million tonnes
- Worth an estimated $8 billion
- Four distinct product groups:
  - Wheat - includes bread wheats, and durum wheat used in pasta products
  - Coarse grains - includes barley, sorghum, oats, triticale and maize (used for stock feeding and malting purposes)
  - Oilseeds - includes canola, cottonseed, sunflower seeds and soybeans (vegetable oils)
  - Pulses - includes lupins and field peas
    - important in crop rotation for soil nitrogen enhancement and breaking disease cycles
    - consumed in dairy, pig, poultry, beef feedlots

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Wheat

- most important crop worldwide, in terms of acreage and human food
- Australian industry
  - wheat is largest grain crop in Australia
  - average of 16 million tonnes produced each year
  - third largest wheat exporter in the world

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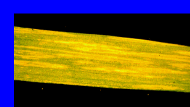
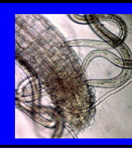
Diseases of Wheat

- Bacterial (7)
  - bacterial stripe
- Fungal (48)
  - stem rust
- Viral (36)
  - wheat spindle streak mosaic
- Nematodes (12)
  - lesion nematode

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Barley

- one of first cultivated crops (used as food and medication since Biblical times)
- 4th most widely-grown cereal in world
- tolerant of drought, heat, and salinity
- native to Near East, close relative of wheat
- Australian industry
  - second largest cereal crop grown
  - 2.5–3.5 million hectares
  - malting barley and malt exports worth ~$300 million annually (30% of worlds trade)

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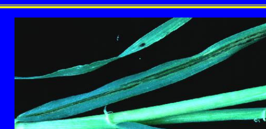
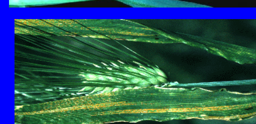
Diseases of Barley

- Bacterial (5)
  - bacterial blight
- Fungal (39)
  - barley stripe
- Viral (25)
  - barley yellow dwarf
- Nematodes (5)
  - root lesion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Diseases of cereal crops

Huge potential for disaster
- crop density/continuous distribution
- synchronized growth/development
- seasonal environmental conditions
- ease of spread/transmission
- pathogen biodiversity
  - multiple hosts
    - obligative/facultative
    - paratenic/reservoir hosts
    - insect vectors
  - aerobiology
    - dissemination/dispersal
    - infectivity

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Exemplars – cereal crop diseases

Wheat stem rust
- fungal disease
- discoloration
- production limiting
- heteroecious (2-host)
- aerobiology

Barley yellow dwarf disease
- viral disease
- discoloration
- stunting
- heteroxenous (2-host)
- vector-borne (aphids)

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Wheat Stem Rust

- aka black rust
  - caused by fungus *Puccinia graminis* f. sp. *tritici*
    - *forma specialis* - host-specific subspecies
    - heteroecious (requires two unrelated host plants (wheat and barberry) to complete life cycle
  - Rust fungi are obligate parasites
    - require living host tissue for growth and reproduction
    - cannot exist as saprophytes
    - in absence of living host tissue, they survive as spores

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Wheat Stem Rust

- Causes cereal yield losses in several ways
  - fungus absorbs nutrients from plant tissues
  - pustules damage epidermal tissue:
    - interferes with transpiration
    - increased desiccation
    - secondary infection by other fungi and bacteria
  - Interference with vascularity results in:
    - reduced grain yield
    - shrivelled grains
  - Stem rust also weakens stems
    - plants fall over, in heavy winds and rain (crops cannot be mechanically harvested)

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Wheat Stem Rust

- Complex life-cycle
  - Heteroecious (requires two hosts, wheat and barberry)
  - Five spore stages
    - Stage 0: Spermogonia (sing.=spermogonium) (receptive hyphae + spermatia [sing.=spermatium])
    - Stage I: Aeciospores in aecia (sing.=aecium)
    - Stage II: Urediniospores in uredia (sing.=uredium)
    - Stage III: Teliospores in telia (sing.=telium)
    - Stage IV: Basidiospores on basidia (sing.=basidium)
  - 0 and I (spermogonium, aeciospores) on barberry
  - II and III (urediospores, teliospores) on wheat
  - IV (basidiospores) on neither (transitional stage that initially infects barberry)

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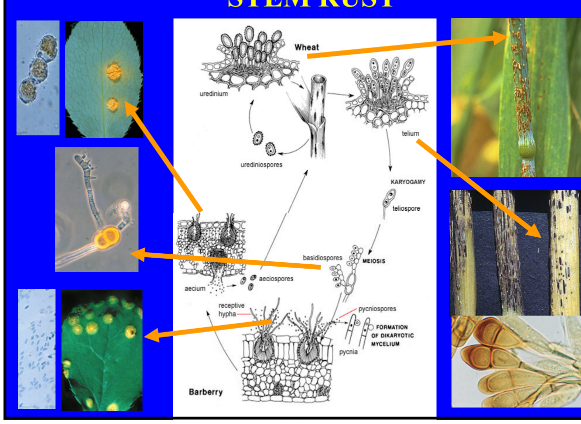
STEM RUST



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Wheat Stem Rust

Importance of alternate host
- once life cycle determined, control possible through removal of barberry host
- extensive eradication program initiated in 1918 in USA, continues today
- must be complete erdaication
- (e.g. in 1920, in the Mississippi Valley, a circular area of 10 miles of wheat was virtually destroyed. Agriculturalists searching the area found a *single* bush of barberry, which was responsible for the damage)

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Wheat Stem Rust

- Eradicate secondary host
  - removed source of inoculum
    - single barberry plant can produce as many as 64 billion aeciospores
  - also reduces genetic variation in fungal population
    - eliminates sexual cycle
    - only asexual urediniospores maintain fungus
    - fewer races of pathogens against which to breed resistance
- BUT spores can travel long distances (aerobiology)

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Aerobiology

- Long distance dispersal in air is important survival strategy
  - enables rapid colonisation of new territory
  - enables migration between summer and winter habitats
- Wind dispersal used in spread of plant pathogenic fungi and bacteria
  - Continental (e.g. wheat stem rust)
  - Global (e.g. coffee rust)
- Dispersal may be:
  - "Single step" – transport of spores over very long distances
    (e.g. cyclonic winds dispersed sugarcane rust from Cameroon to America in 1978)
    (cyclone introduced sugarcane smut to Ord River region in Australia from Indonesia)
  - "Gradual" – incremental expansion of range
    (e.g. creeping distribution of black sigatoka of bananas)

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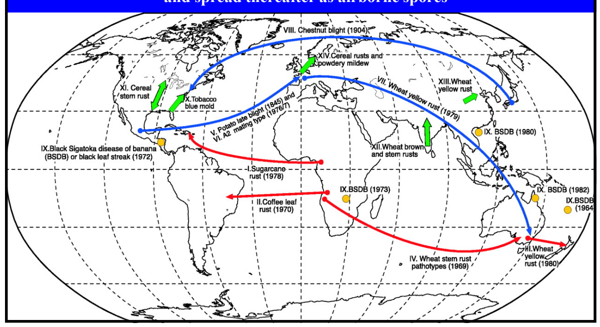
Aerobiology

Red arrows - dispersal by direct movement of airborne spores
Blue arrows - infected plants introduced to new territories by people and spread thereafter as airborne spores



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Wheat Stem Rust

- Understanding spore movement of *P. graminis*
  - sampling of atmosphere at 5,000 meters proved spores travelled the length of North America
  - continental epidemics still occurred even after intensive 'local' barberry eradication campaigns
    - spores found to move between Mexican, American and Canadian grain belts
    - barberry patches persisted in some areas
    - enough spores at right time to cause epidemics
  - control requires integrated multinational programmes (huge undertaking)

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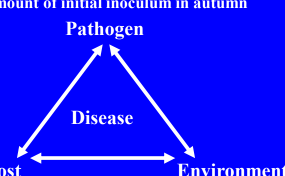
Ecology of Wheat Stem Rust

- Virulence of rust pathogen
- Amount of initial inoculum in autumn



Host
- Susceptibility
- Growth stage (planting date)

Environment
- Moisture
  - Rainfall, Dew
- Temperature in spring
- Wind

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Barley yellow dwarf disease

- Caused by group of viruses, collectively known as Barley Yellow Darf Viruses (BYDV)
- Worldwide distribution
- Infects >150 species of cultivated, lawn, weed, pasture and range grass species (*Gramineae*) including wheat, oats, rice, maize, rye and barley
- Oats are more susceptible than wheat; although tolerant cultivars are available
- Most destructive of viral diseases
- Grain yields may be reduced by 1/3rd

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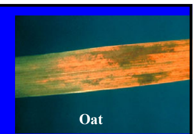
Barley yellow dwarf disease



- Most common signs are:
  - yellowing
    - loss of green colour in leaves (chlorosis)
    - begins 1-3 weeks after infection
  - dwarfism
    - stunting due to reduced internode length
    - mild-severe (heads may not emerge)
  - Severity dependent on:
    - host genotype, age, physiological condition
    - strain of virus
    - environmental conditions

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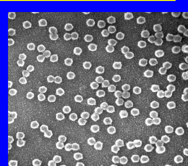
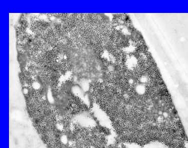
Barley yellow dwarf disease

- BYDV pathogens
  - Luteoviridae
  - 2 genera
    - *Luteovirus* and *Polerovirus*
  - 25-28 nm in diameter
  - hexagonal in outline
  - composed of
    - two proteins (a major coat protein and a minor "readthrough" protein)
    - single-stranded ribonucleic acid (ssRNA) genome
  - restricted to phloem of host plants





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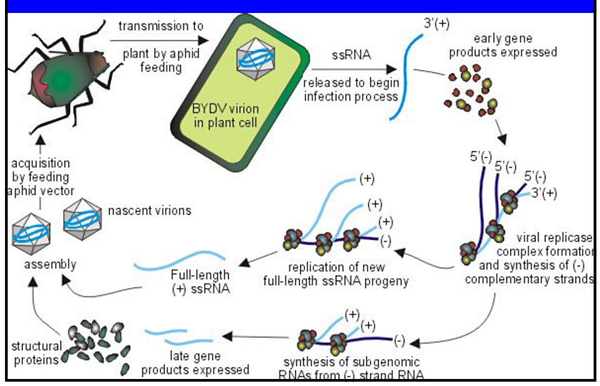
Barley yellow dwarf disease



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Barley yellow dwarf disease

- BYDV transmitted by ~25 species of aphids
  - viruses cannot be transmitted mechanically
  - viruses do not multiply in aphid vectors
  - viruses not present in new-borne aphids
- ⇒ aphids must acquire viruses by feeding on infected plants
- different BYD viruses transmitted more efficiently by different species of aphids
  - originally used to distinguish the viruses
  - e.g. BYDV-MAV efficiently transmitted by aphid *Sitobion* (syn. *Macrosiphum*) *avenae*
  - e.g. BYDV-RPV efficiently transmitted by aphid *Rhopalosiphum padi*

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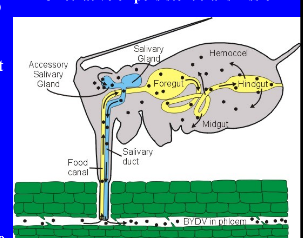
Barley yellow dwarf disease

- route of transmission in aphids
  - viruses ingested with phloem
  - travel through food canal into gut
  - pass into body cavity (haemocoel)
  - infect accessory salivary gland
  - pass into saliva
  - expelled into phloem of next plant
- short latent period (hours)
- transmission known as:
  - "circulative"
    (virus circulates in body)
  - "persistent"
    (virus persists for weeks)
- single viruliferous aphid can spread infection to many plants
- differences in vector transmission due to selective transport of different viruses across gut and salivary gland membranes

Circulative or persistent transmission



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Barley yellow dwarf disease

Aphid spread of disease

- Spread in field from initial foci
  - As non-winged (apterous) aphids crawl to and feed on new plants in a field, small patches of infected plants develop
- Long distance spread
  - Winged (alate) aphids often develop as host plants begin to deteriorate or when the aphid population is overcrowded
  - Circulative/persistent transmission allows alate aphids to carry BYDV over long distances as they migrate, seeking new hosts
  - Winged forms can move 80–300km non-stop

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Barley yellow dwarf disease

- Alternate hosts
  - Maize
    - symptomless carriers of virus
    - serve as reservoirs from which virus is carried by aphids to newly planted cereals
    - maize important in Mediterranean as summer crop
  - Common grasses
    - Fescue important in various US states
      - planted along highways
      - favourite host of common aphid vector

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Barley yellow dwarf disease

- Role of environment
  - High light intensity and cool temperatures 15-18ºC generally favour disease expression
    - leaf discoloration may attract aphid vectors to virus-infected plants
    - signs do not develop at temperatures above 30ºC
  - Reproduction rate of subsequent aphid populations is affected by environmental conditions
  - Efficiency with which aphids transmit viruses
    - transmission of BYDV-RMV by the inefficient vectors *R. padi* and *S. avenae* is dramatically increased at high temperatures (30ºC)

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Barley yellow dwarf disease

Role of man (Anthropogenic)

- After initial successes, resurgence after 1960
  - new cereal cultivars introduced
    - have higher yields but require heavy fertiliser use
  - ↑ in population of aphids and disease
    - correlates with increased use of fertilisers
      - nitrogen increases reproduction of aphids and stimulates conversion to winged forms

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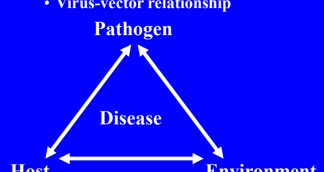
Barley yellow dwarf disease

- Virulence of virus
- Virus-vector relationship



Host:
- Susceptibility
- Presence of alternate hosts

Environment:
- Temperature
  - Vector-virus relationships
- Light intensity
- Use of high nitrogen fertilisers

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What's examinable?

Grain production
- major crops worldwide
- plant cultivars bred to:
  - maximize production
  - minimize disease susceptibility

Diseases
- plant mortality
- production-limitation
- contamination

Need to known pathogen
- life-cycles
  - heteroecious: involving second plant species
  - heteroxenous involving vector
- transmission
  - aerobiology: dissemination/dispersal
  - vector-borne: efficiency/distribution/abundance

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