Clubroot (*Plasmodiophora brassicae*)

Agricultural & Biological Challenges

Prof. Geoffrey R Dixon

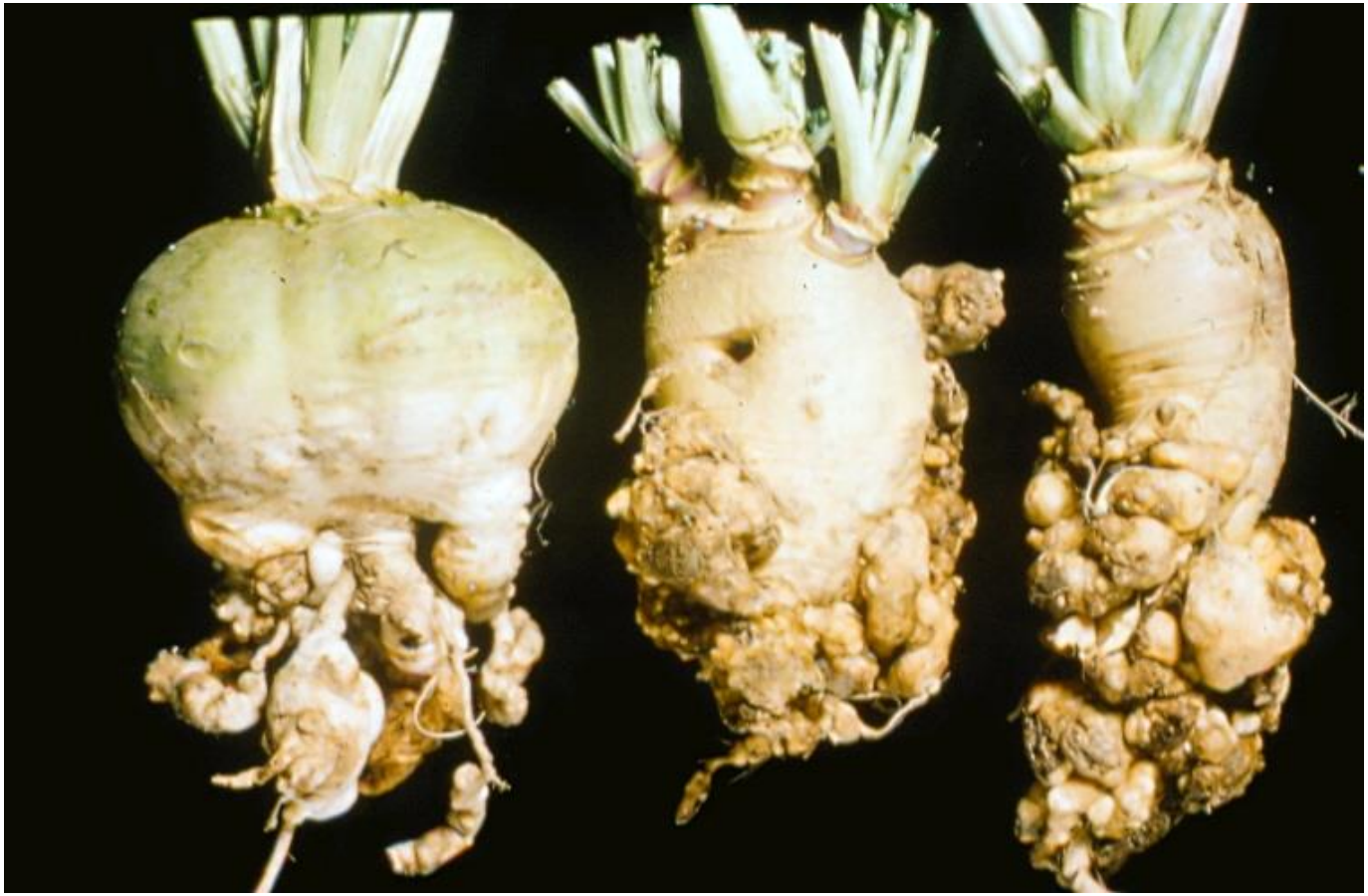
GreenGene International & University of Reading
Great Britain

THE FOE

GGI

Clubroot on Chinese cabbage

Clubroot on swede



Aims:-

1. Challenges – biological & agricultural;
2. Origins of this problem;
3. Science review, 1880s-1940s, 1940s-1970s, 1970s – current;
4. A brief review of “Why Lime”?

Challenges – biological

- **Soil borne**
  - **Exists amongst vast populations of microbes**
- **Host borne**
  - **Restricted to the family Brassicaceae**
- **Minute spores in soil**
  - **Well protected by layers of chitin & other carbohydrates**
- **Short free-living stage**
  - **Cannot be cultured except possibly in callus or hairy roots (ploidy problem)**
- **Hidden life cycle, root hairs & cortical & vascular tissues**
  - **Life cycle not fully understood**
- **Host metabolism disrupted & self-harming**
  - **? Able to switch on and off host genetic and cellular controls**
- **Released as resting spores**
- **Well fitted to the environments where *P. brassicae* exists**

Problems:-

Host

Soil

Environment

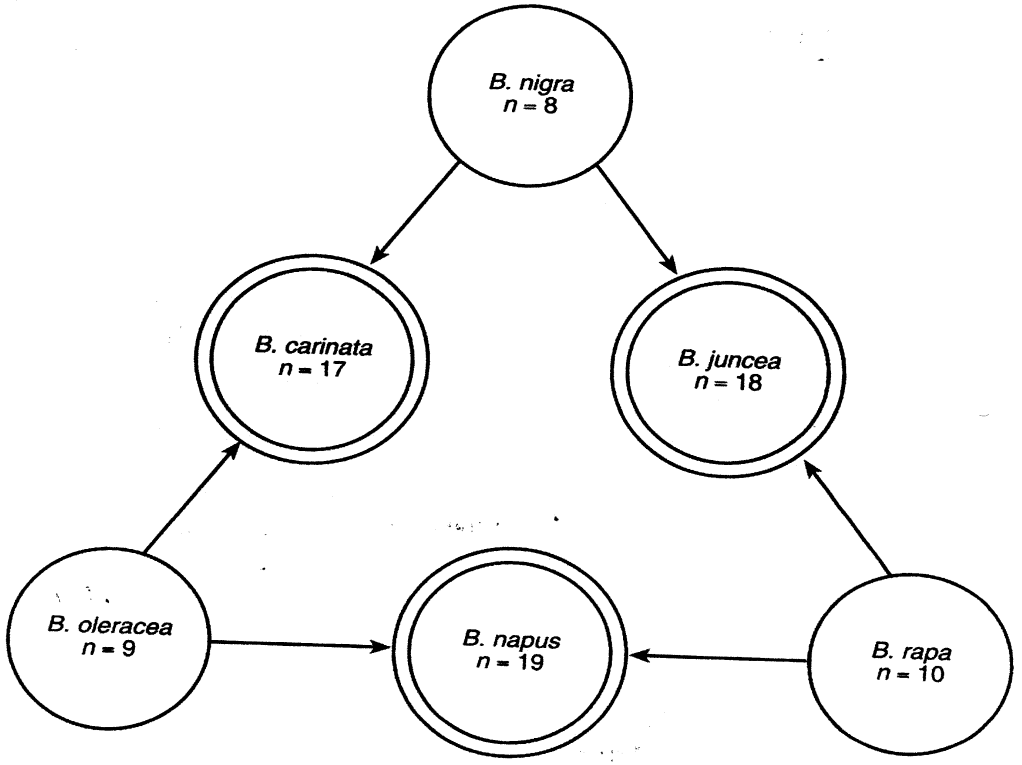


Fig. 1.2. Relationships between diploid and amphidiploid crop-founding *Brassica* species (the 'triangle of U'; U, 1935).

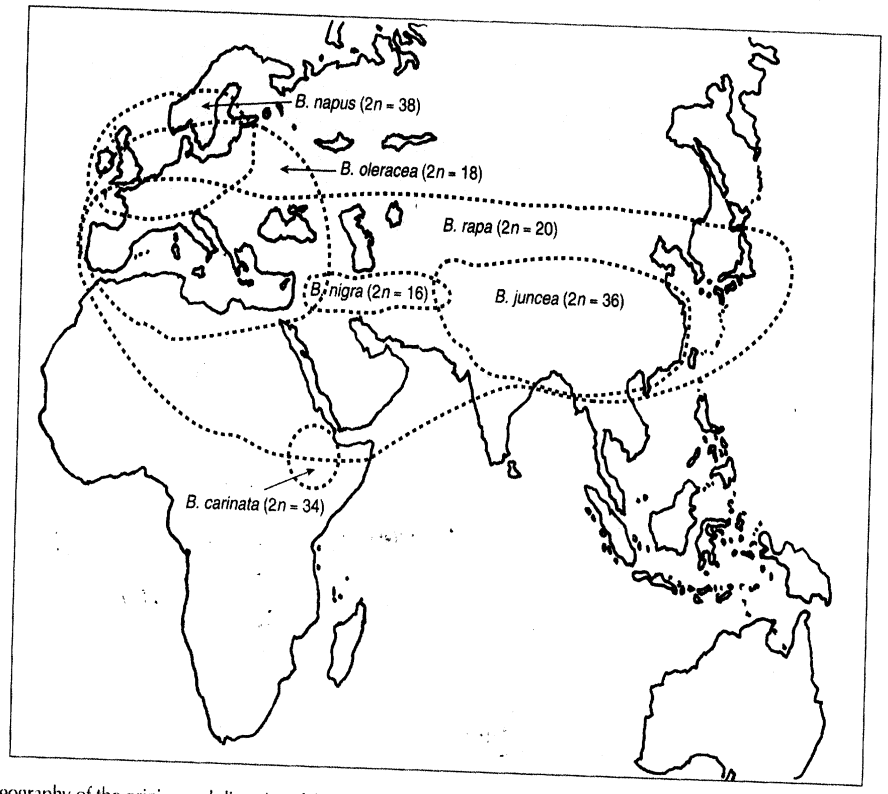


Fig. 1.1. Biogeography of the origins and diversity of the major crop-founding *Brassica* species (United Nations Food and Agriculture Organization, Rome).

Brassica

- **Wild origins – Sub-Saharan Africa**
- **Moved northwards, then east & west**
  - **Suited to dry, arid environments**
- **Biodiverse, biological flexible & plastic**
  - **Evolved environmental fitness**
- **Domestication**
  - **Huge range of crop types suited to cultivation**
- **Enormous economic & biological importance**

GGI

Calabrese – green broccoli – Fife, Scotland

GGI

- **Brassicas provide:**
- **Fresh and processed foods-health dividend;**
- **Animal fodder and forage;**
- **Condiments & flavourings;**
- **Vegetable oils & lubricants;**
- **Ornamental & amenity;**
- **Research models.**

Soil – Factors influencing *P. brassicae*

- **Physical – structure, texture, drainage;**
- **Meteorological – flooding, frosting, season;**
- **Chemical – pH, content & balance of macro- & micro-nutrients;**
- **Biological – presence & magnitude of antagonists**

Environment

- **Resting spore – germination triggers;**
- **Primary zoospore – free swimming, energy limited;**
- **Penetration, colonisation & multiplication in root hair;**
- **Secondary zoospore movement to cortical & vascular tissues (disruption of signalling, structure & functioning);**
- **Secondary multiplication & resting spore formation**
- **Passive release into soil.**

Agricultural Challenges

- **Ease of spread: animals, wind, water, infested plants & propagules, machinery;**
- **Longevity: economic limitations on rotation *versus* degradation of resting spores (>18yr);**
- **Husbandry: acidity *versus* alkalinity;**
- **Resistance: few major genes & complex minor genes – rapid erosion of effect by physiological variants of *P. brassicae*;**
- **Agrochemicals: few & geographical restrictions;**
- **Biological suppression & bio-control: indications of potential – more knowledge needed**

- **Where did *P. brassicae* come from?**
- **Probably a pathogen of cultivation**
- **Rarely seen on wild brassicas & real weeds**
- **Regularly found on weeds of cultivation**
- **Potentially an ancestral free living microbe came into association with ancestral cultivated hosts??**
- **Encouraged and evolved in lushly cultivated crop brassicas**

Weed host – penny cress

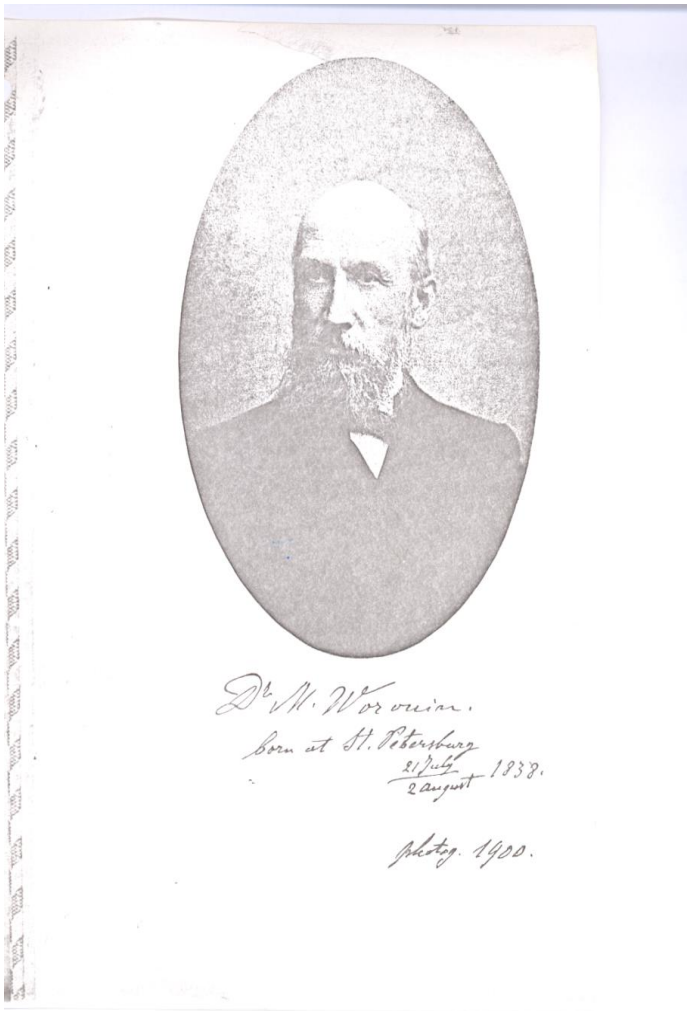
Descriptive records

- **Roman problem – *radices fungosae* associate with animal manure;**
- **13th century records in Spanish Low Countries (Belgium & The Netherlands);**
- **15th century records in Spain – syphilitic cabbage ;**
- **18th century – Agricultural Revolution increases swede growing especially in Britain;**
- **Exported to North America & Australasia on swede roots carried as animal fodder ;**
- **19th century – increasing problem on cabbage in northern Europe**


Brassica siluestris Crambe dicta.

Michael Woronin -Description of:

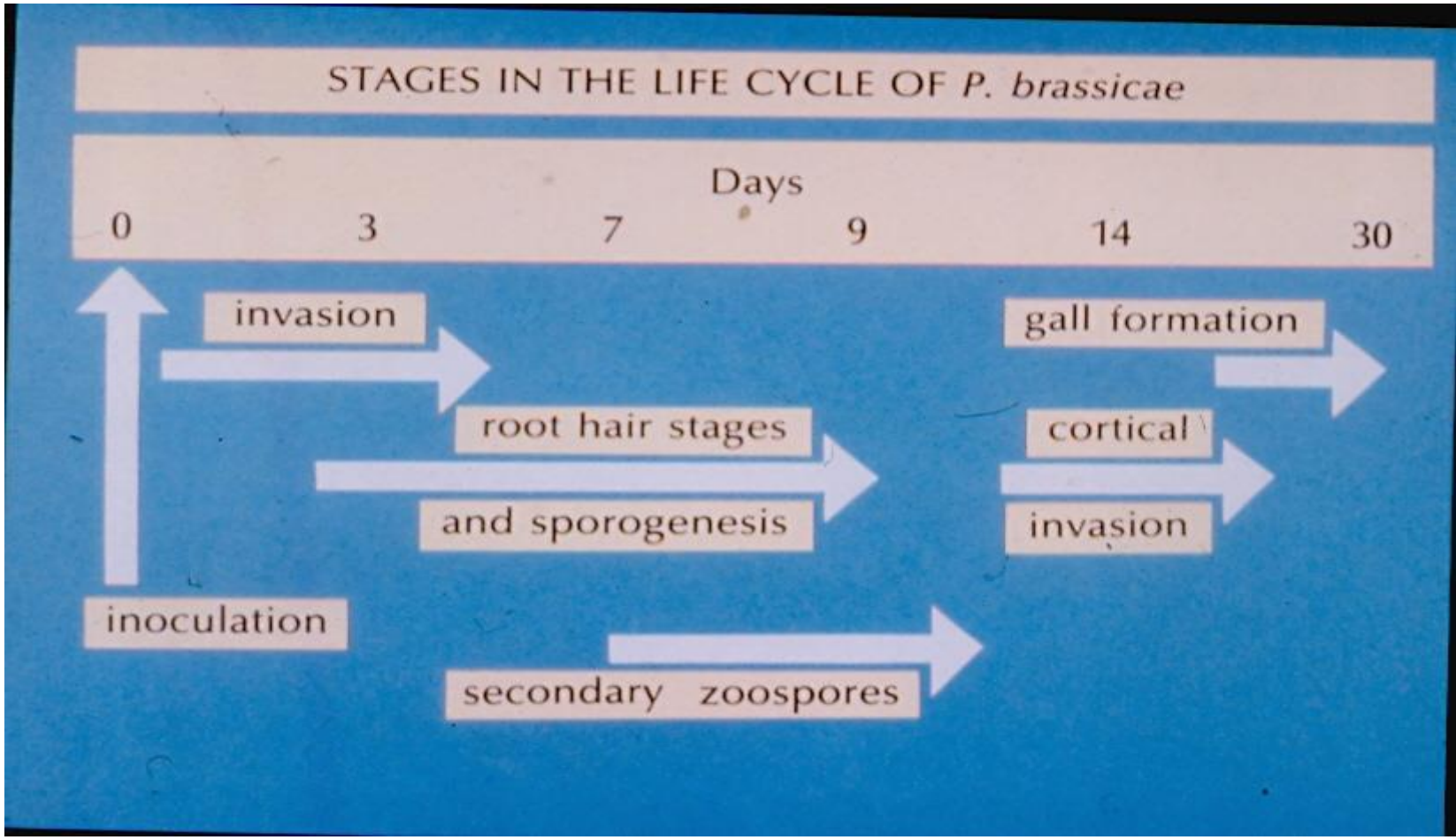
- **The pathogen (*Plasmodiophora brassicae*)**
- **Outline life cycle**
- **Association with clubroot symptoms**
- **Taxonomic relationships**
- **Suggestions for control = rotation, removal & burning of infected plants, application of soot**



Dr N. Voronin.
born at St. Petersburg
21 July
2 August 1938.

photog. 1900.

Rate of development



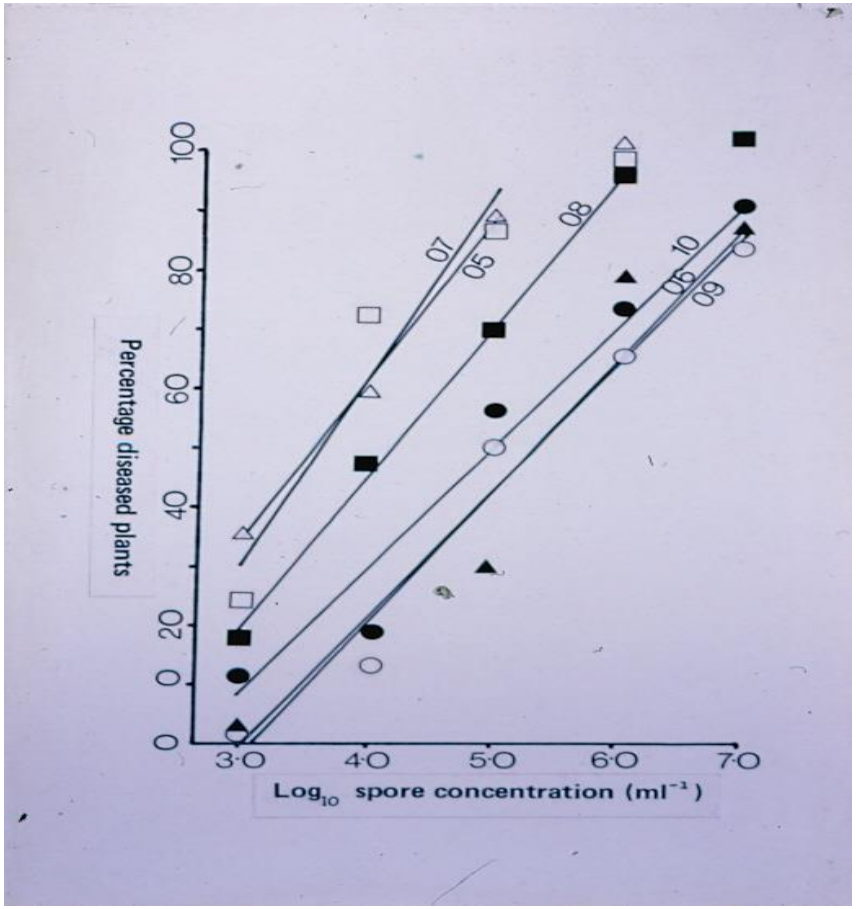
Science 1880s-1940s

- **Descriptions of the life cycle & colonisation processes;**
- **Conflicting analyses of taxonomy (fungus *versus* protista);**
- **Developing understanding of environmental impact – soil water, nutrient relationships**
- **Resistance breeding – Britain – swede, northern Europe & north America - cabbage**
- **Control – use of mercury**
- **Husbandry – pH manipulation (liming), application of calcium cyanamide**

Science 1940s – 1970s

- **Understanding of soil relationships;**
- **Knowledge of colonisation, life cycle, biochemistry of galling & host disruption;**
- **European Clubroot Differential (ECD) Series & relationship of host genotype to the distribution of physiological variants of *P. brassicae*;**
- **Search for “magic bullet” chemicals;**

Responses of ECD hosts to differing inoculum loads



Problems - “ignorance breeds contempt”- 1970s attitudes

1. **Field advisors recognised clubroot “easily”, then failed to make records of incidence and since it was either a “horticultural” problem (minor crops) or animal feed the advice was simply “don’t grow brassicas for 5 years” – end of story!;**
2. **some notable research “failures”;**
3. **Gained a reputation as “unsolvable and hence not worth funding”**
4. **Anyway – find a “magic bullet”**

- **Science 1980s onwards**
- **Developing as major agricultural problem in European spring sown oil rape and Asian human nutrition brassicas (Chinese cabbage and many variants);**
- **European crop stimulated by EU policies;**
- **Asian problem in part due to increasing intensity of production and removal of environmentally damaging agro-chemicals**

- **Molecular biology stimulated in understanding:**
- **Biology of *P. brassicae* and its hosts as a host-parasite combination**
- **Genetics and inheritance of resistance**
- **Pathogen virulence**
- **Relationships between soil environment, pathogen development & colonisation and host responses**
- **Environmentally sustainable controls**

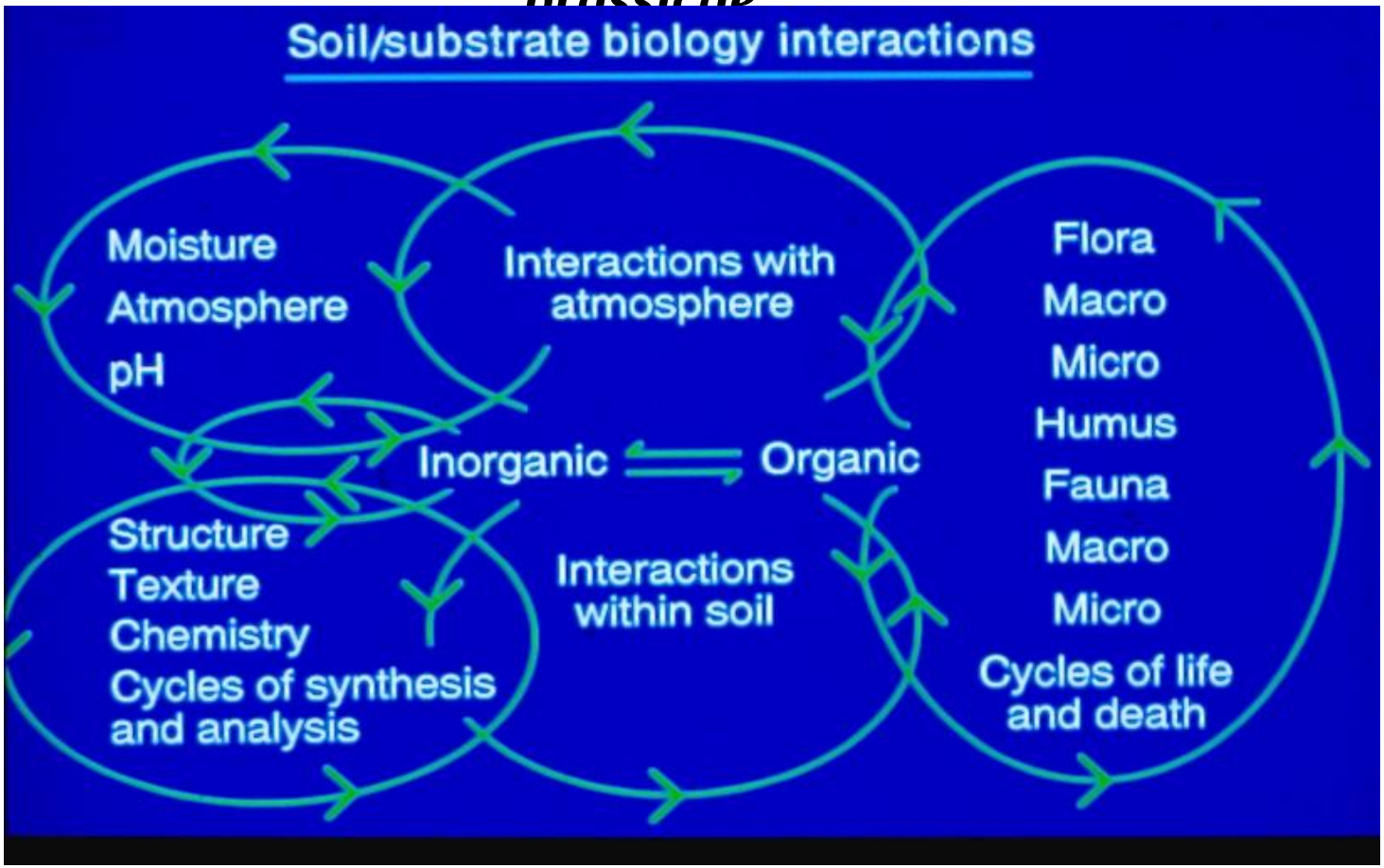
Why Lime?

- **Over 150 year liming has been the major recommendation given to growers as a means of mitigating Clubroot Disease**
- **Variation in:**
- **Types of lime**
- **Rates of application**
- **Times of year**
- **Cropping systems**
- **Soil types**
- **Rotational strategies**
- **Statistical layout and analysis**
- **In many cases experiments / field trials had little or no scientific validity.**

Clubroot – traditional control = lime + grass

Soil:	Moisture, organic matter, temperature, aeration, chemical composition, active and reserve $[H^+]$ structure, texture
Pathogen:	Concentration, viability
Season:	Variations in weather patterns
Lime:	Types, quantities, time before cropping, past cropping history

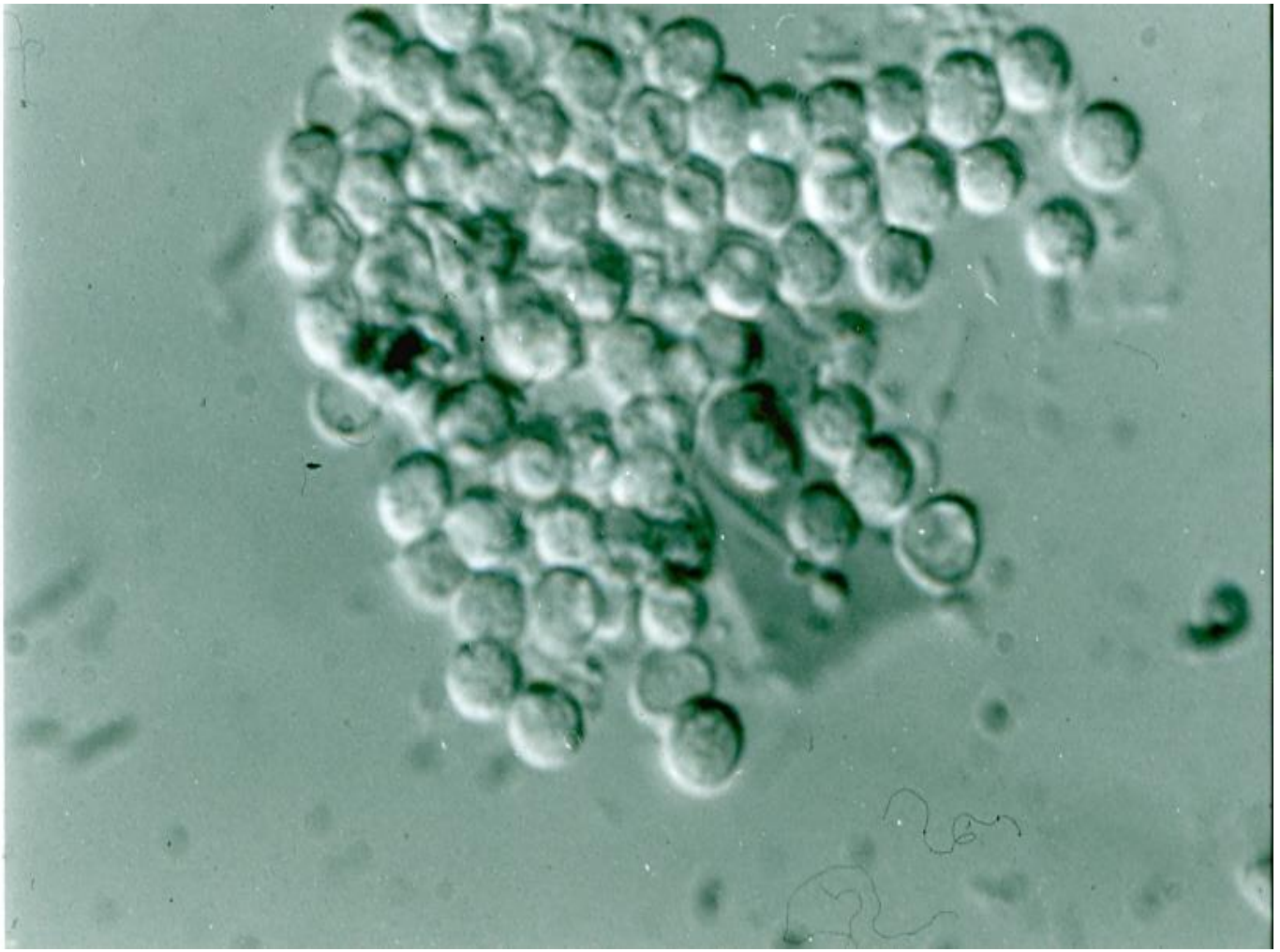
Complexities of the environment surrounding *P. brassicae*



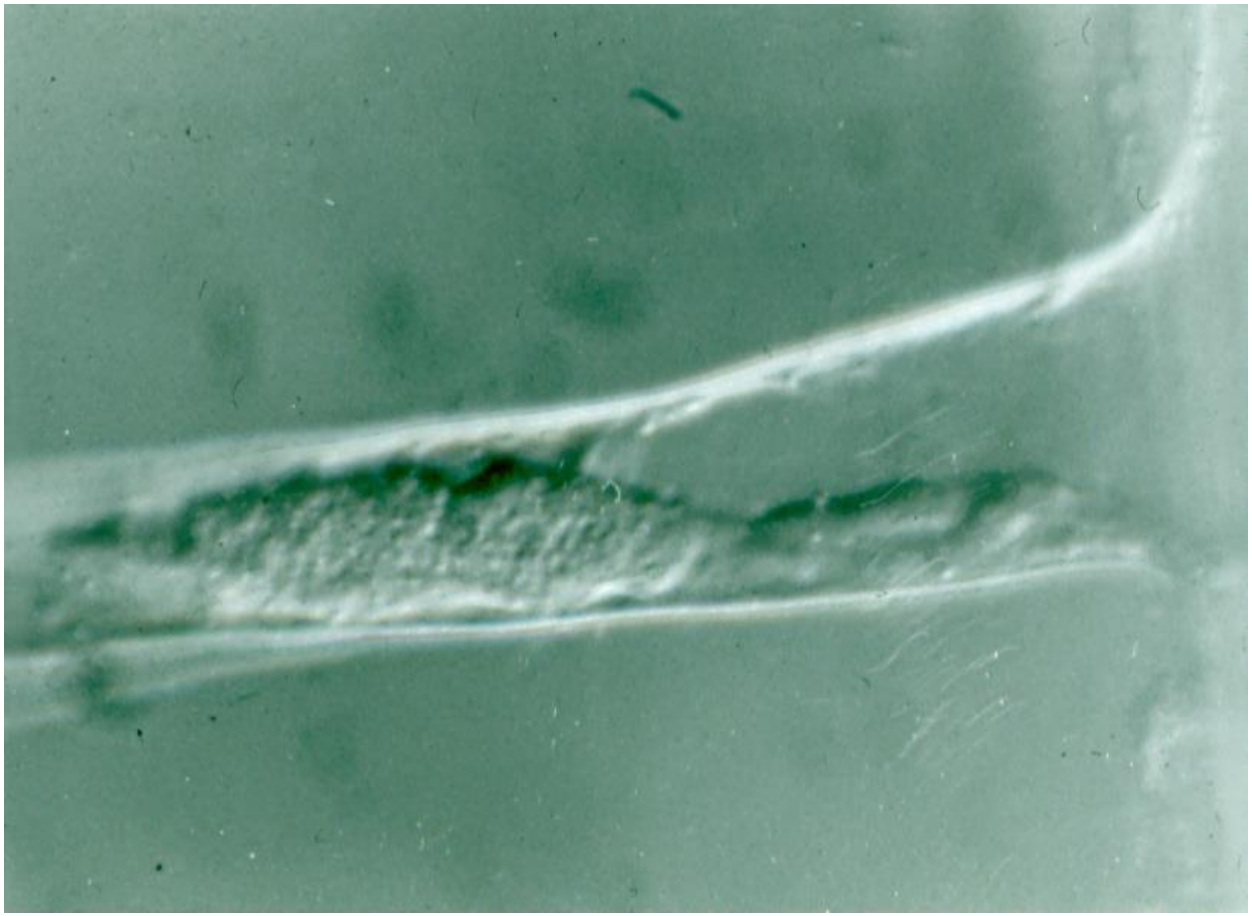
Summary

1. **Calcium, boron, nitrate-nitrogen & pH influence the growth & reproduction of *P. brassicae, and symptom expression;***
2. **The effects of each factor can be quantified separately;**
3. **The factors can be integrated providing cumulative effects;**
4. **Action commences with the germination of resting spores;**
5. **Greatest effects are apparent after root hair penetration;**
6. **Boron appears to be capable of influencing growth in the cortical tissue – possibly an effect resulting from its interaction with growth regulators;**
7. **Calcium interacts with host resistance and / or pathogen virulence;**
8. **Soil suppressiveness is encouraged by repeated use of calcium compounds**

P. brassicae – resting spores

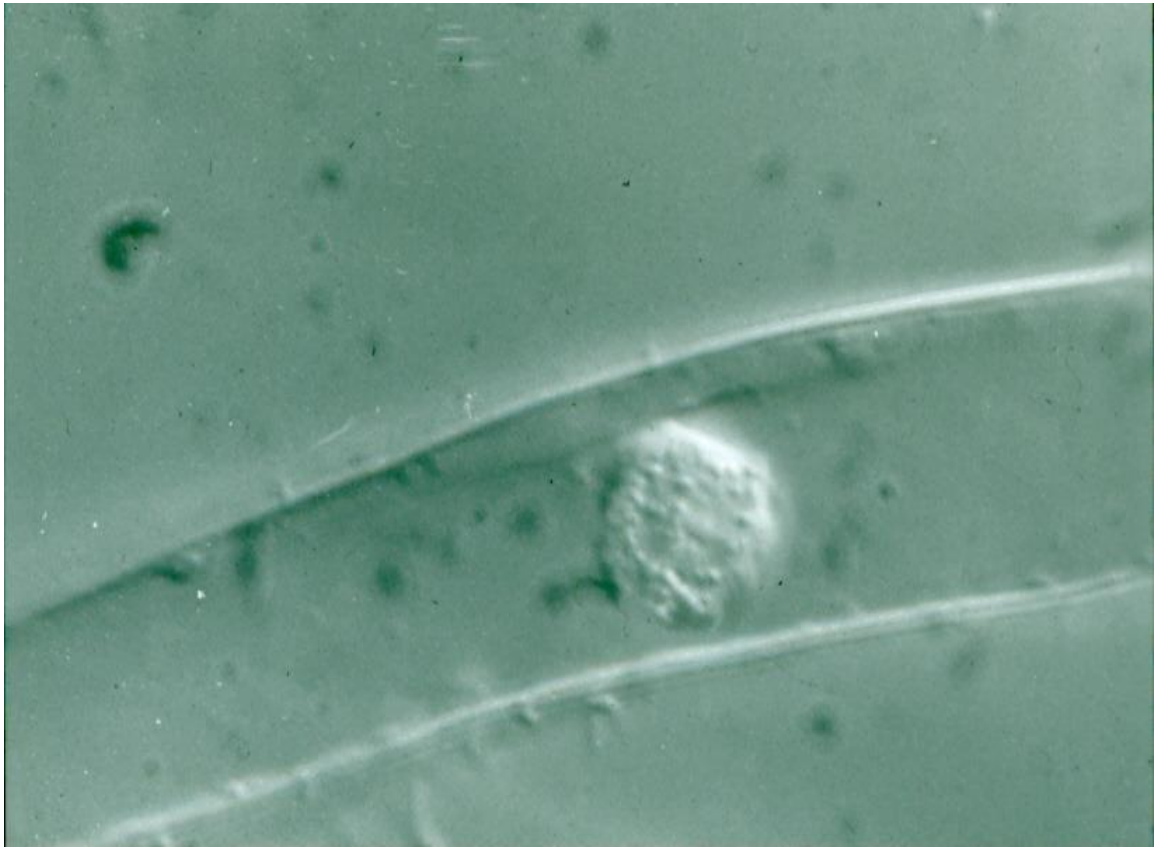


P. brassicae - plasmodium



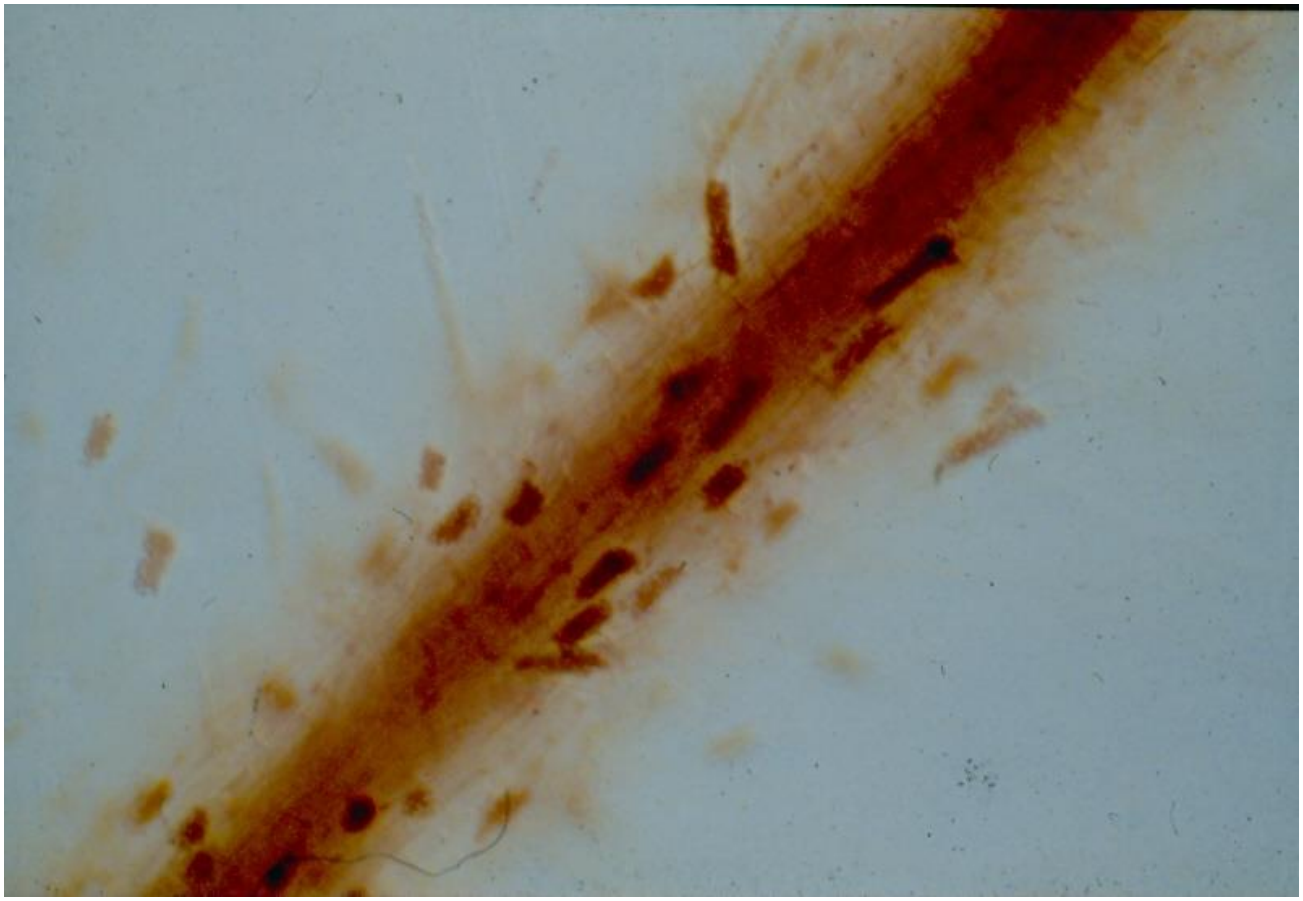
ggi

Zoosporangium *P. brasscicae*



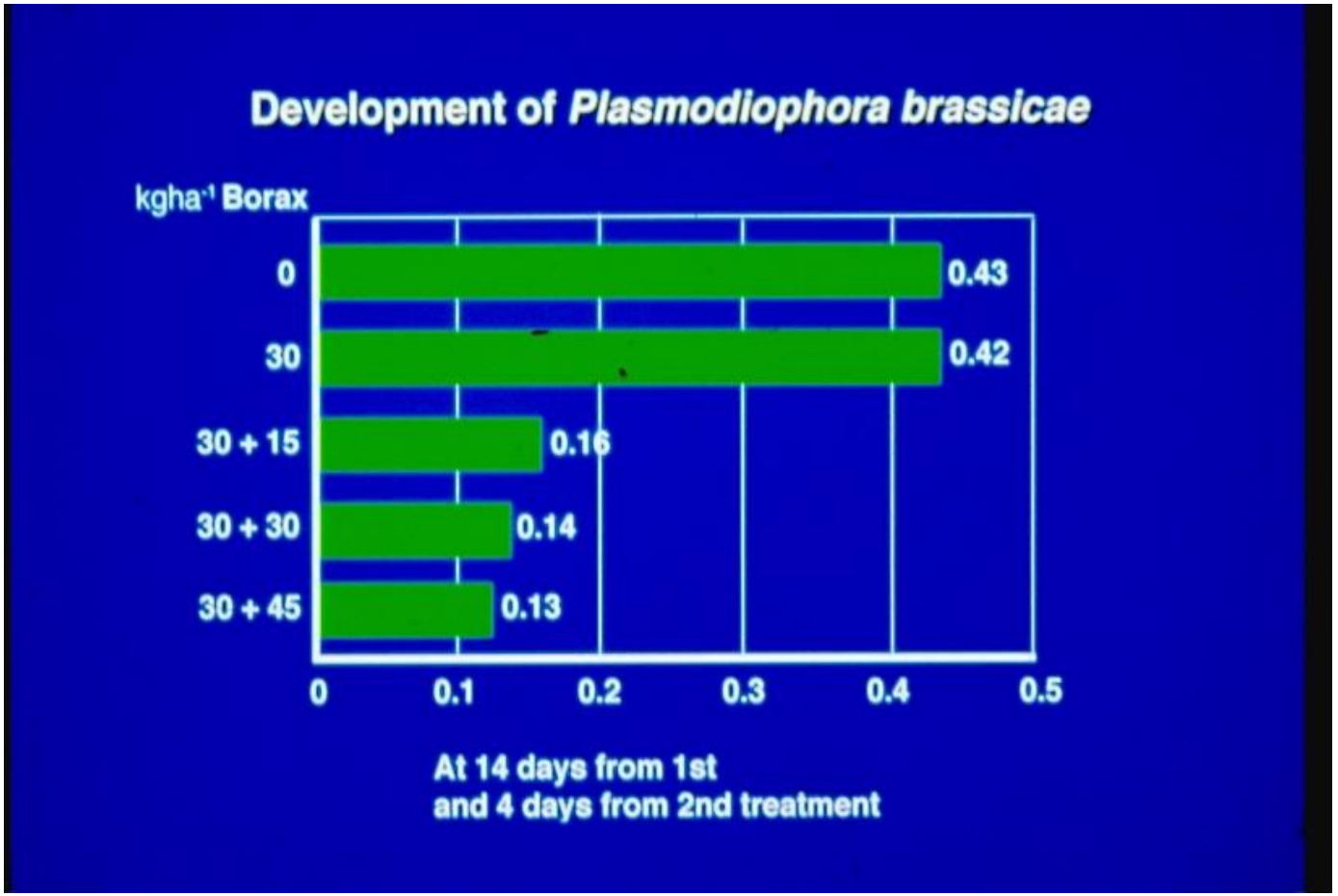
Root hair loaded with zoosporangia

P. brassicae – root hair sporangial stages

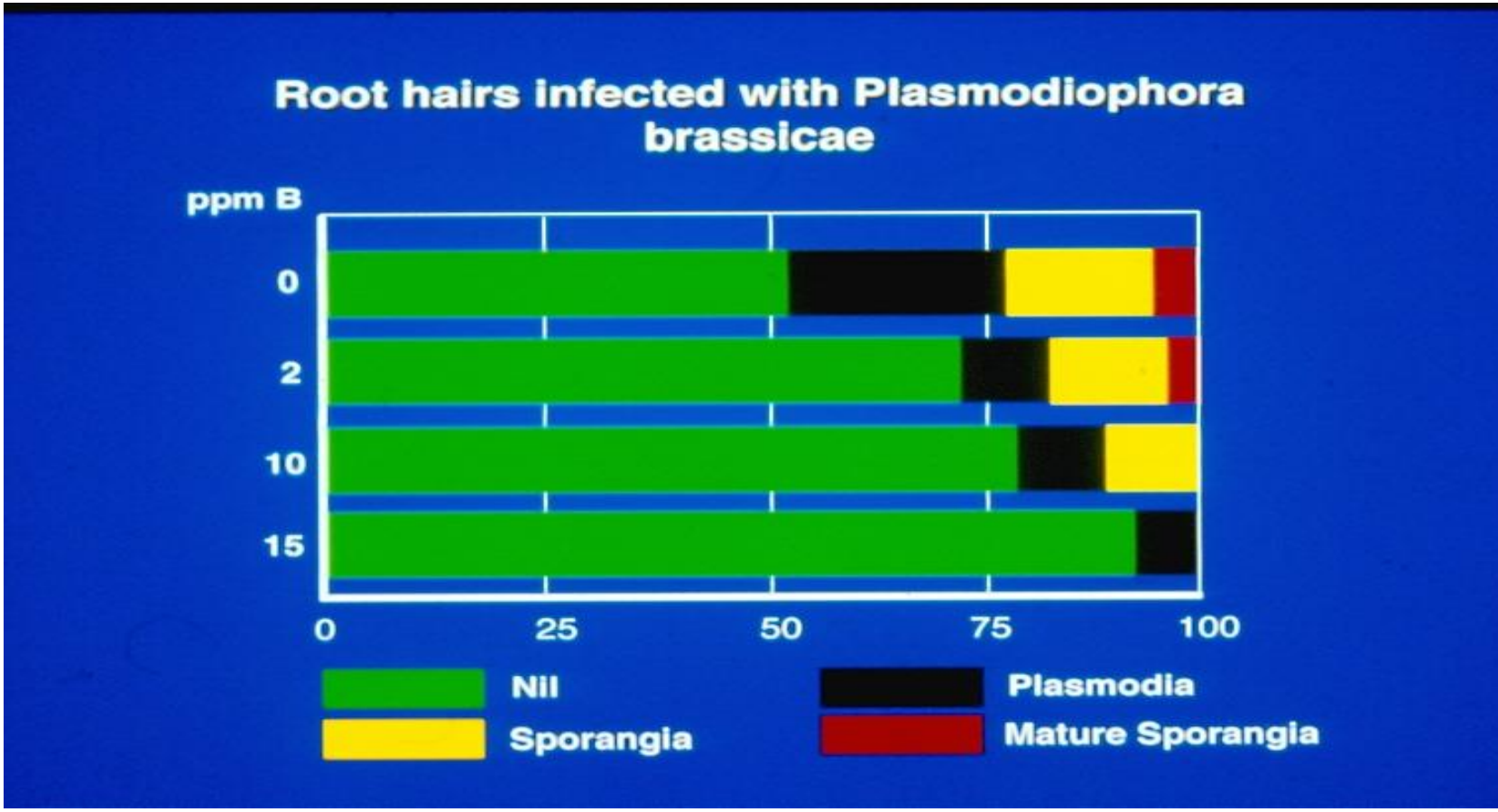


Root hair & sporangia

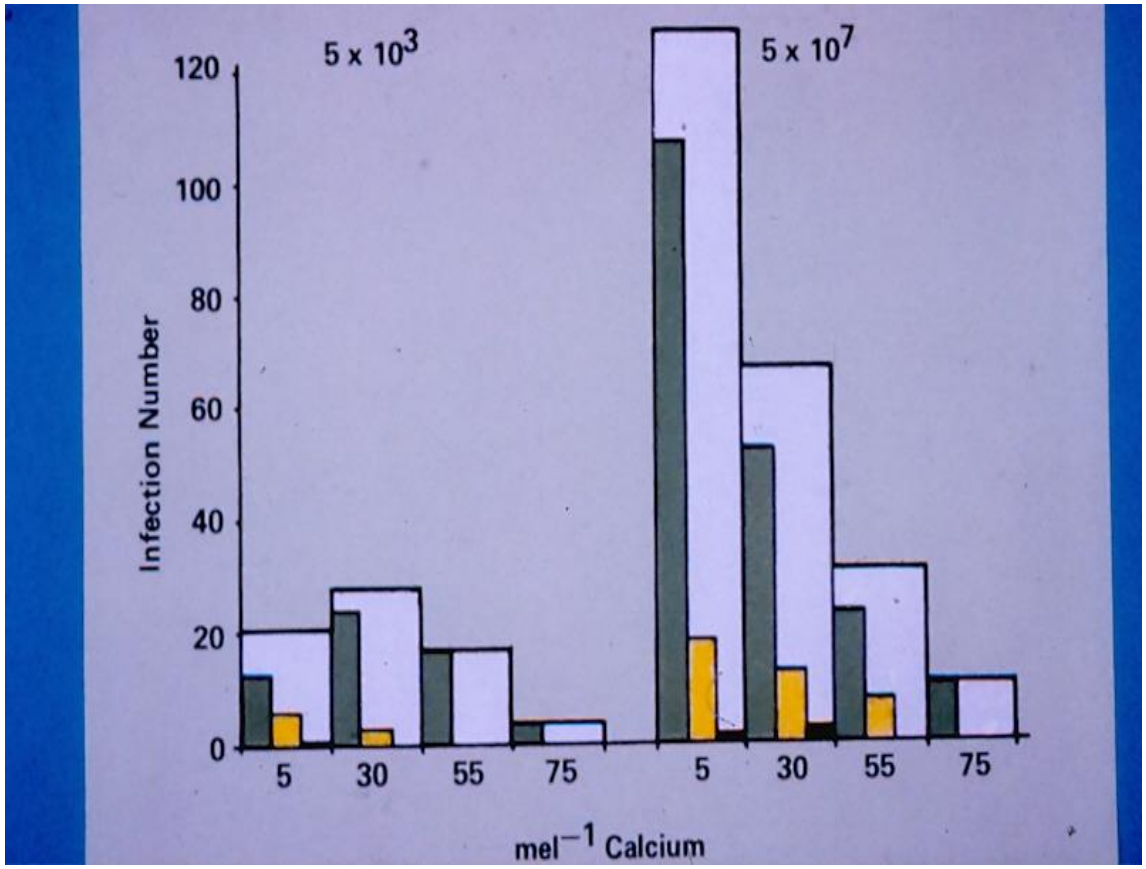
Boron x root hair development



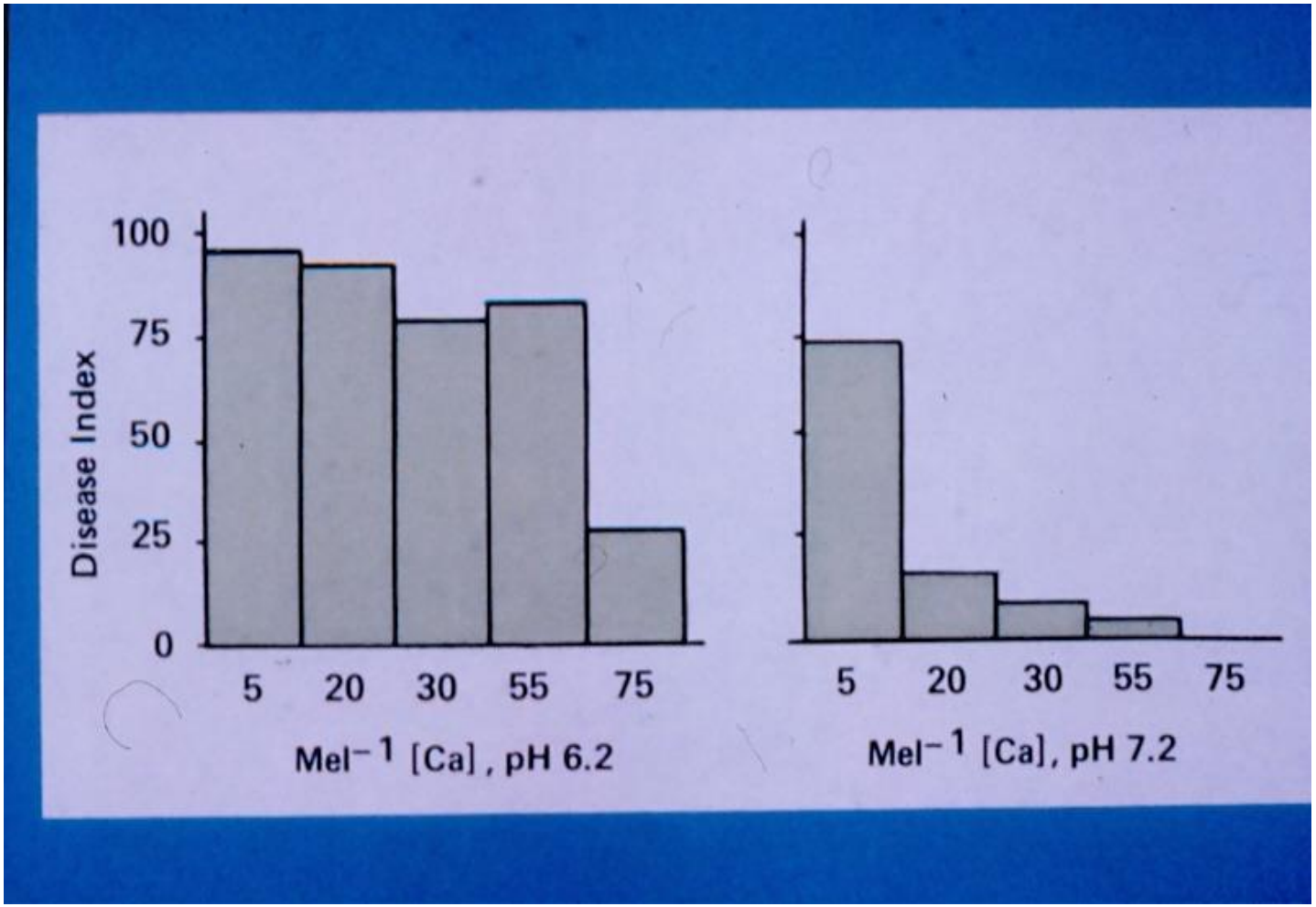
GGI


Root hairs infected with Plasmodiophora brassicae
ppm B
0
2
10
15
0
25
50
75
100
Nil
Plasmodia
Sporangia
Mature Sporangia

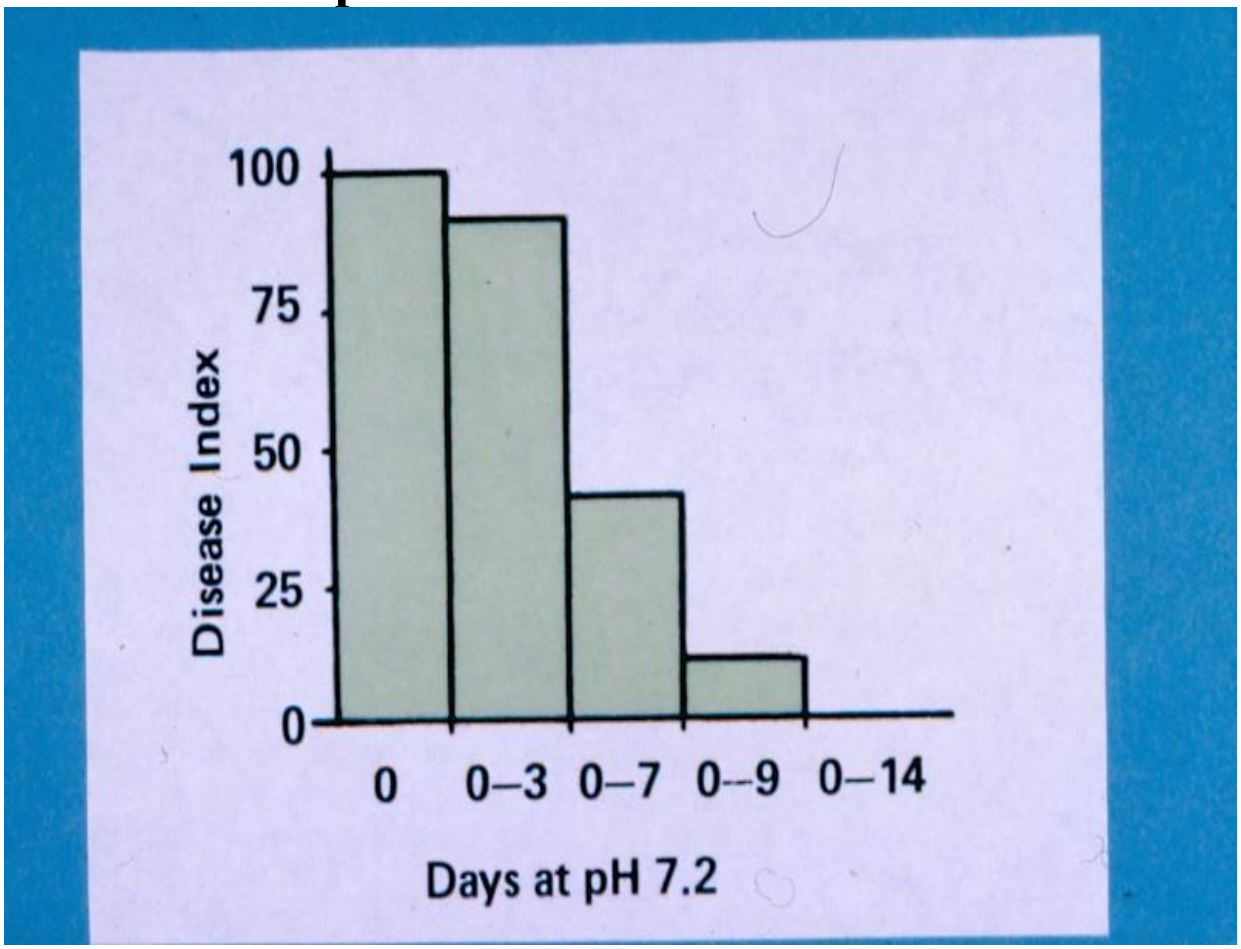
P. brassicae spores x calcium conc x root hair dev



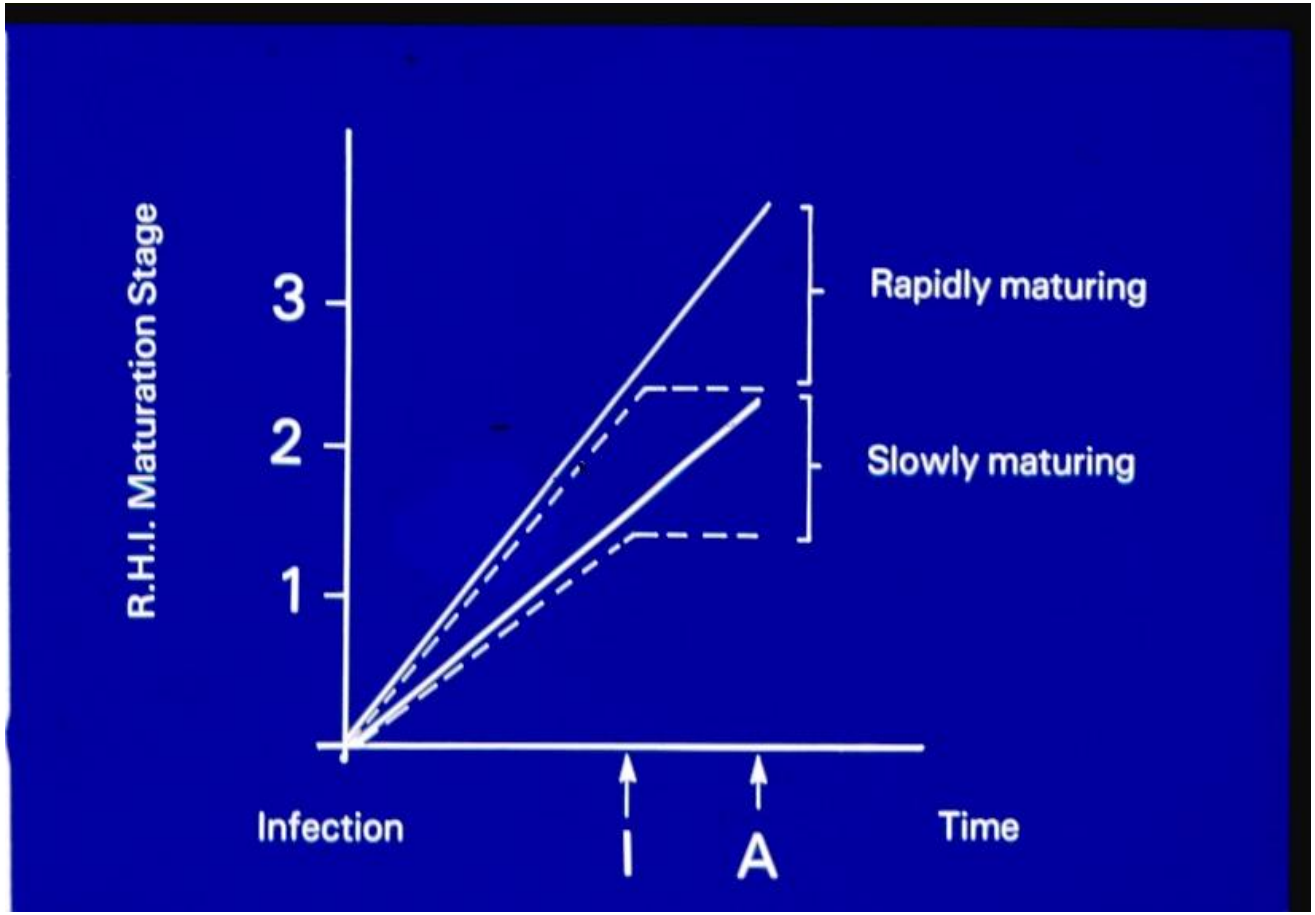
Clubroot disease index x pH x calcium concentration

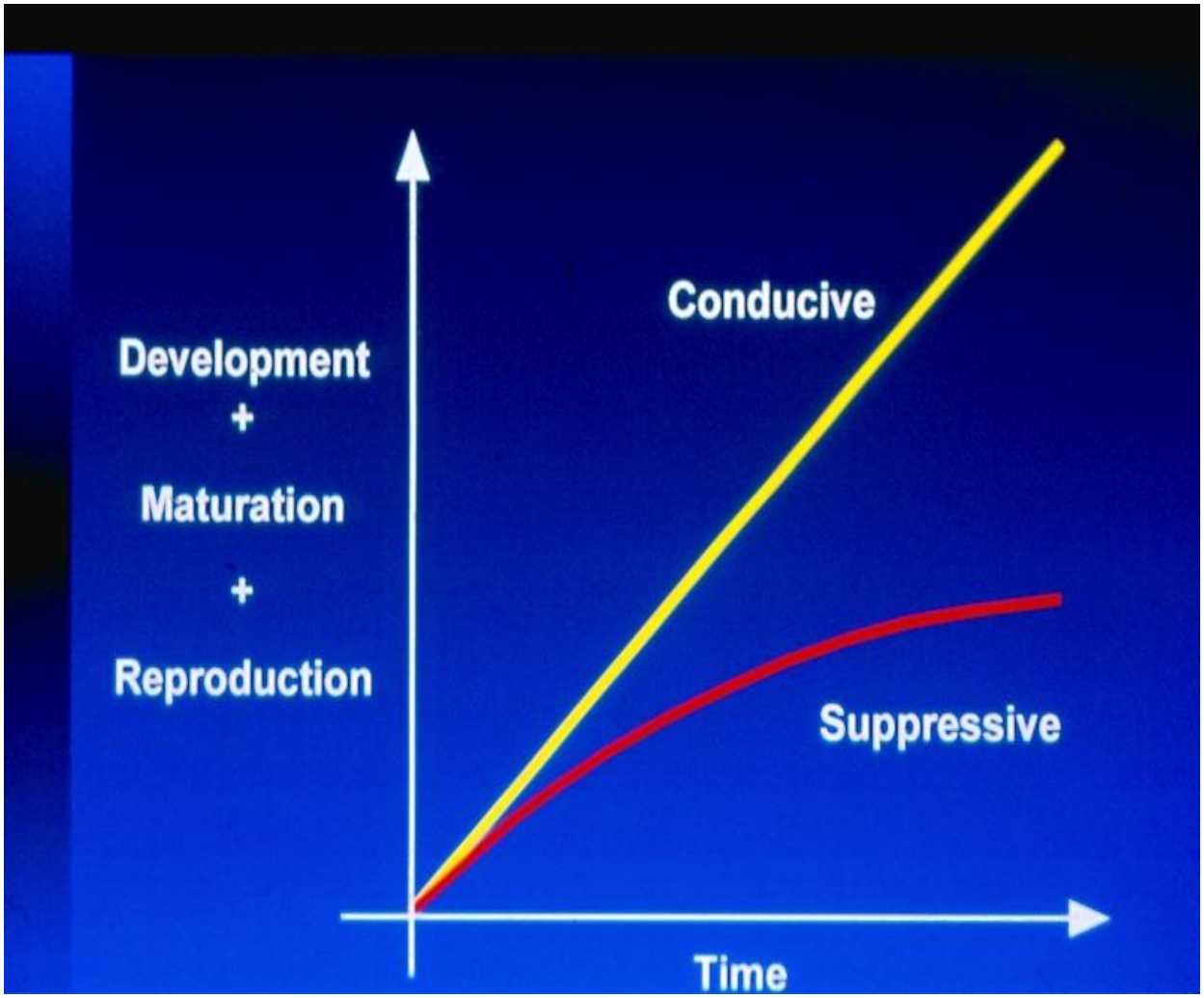


Clubroot expression following exposure to pH=7.2 for time periods

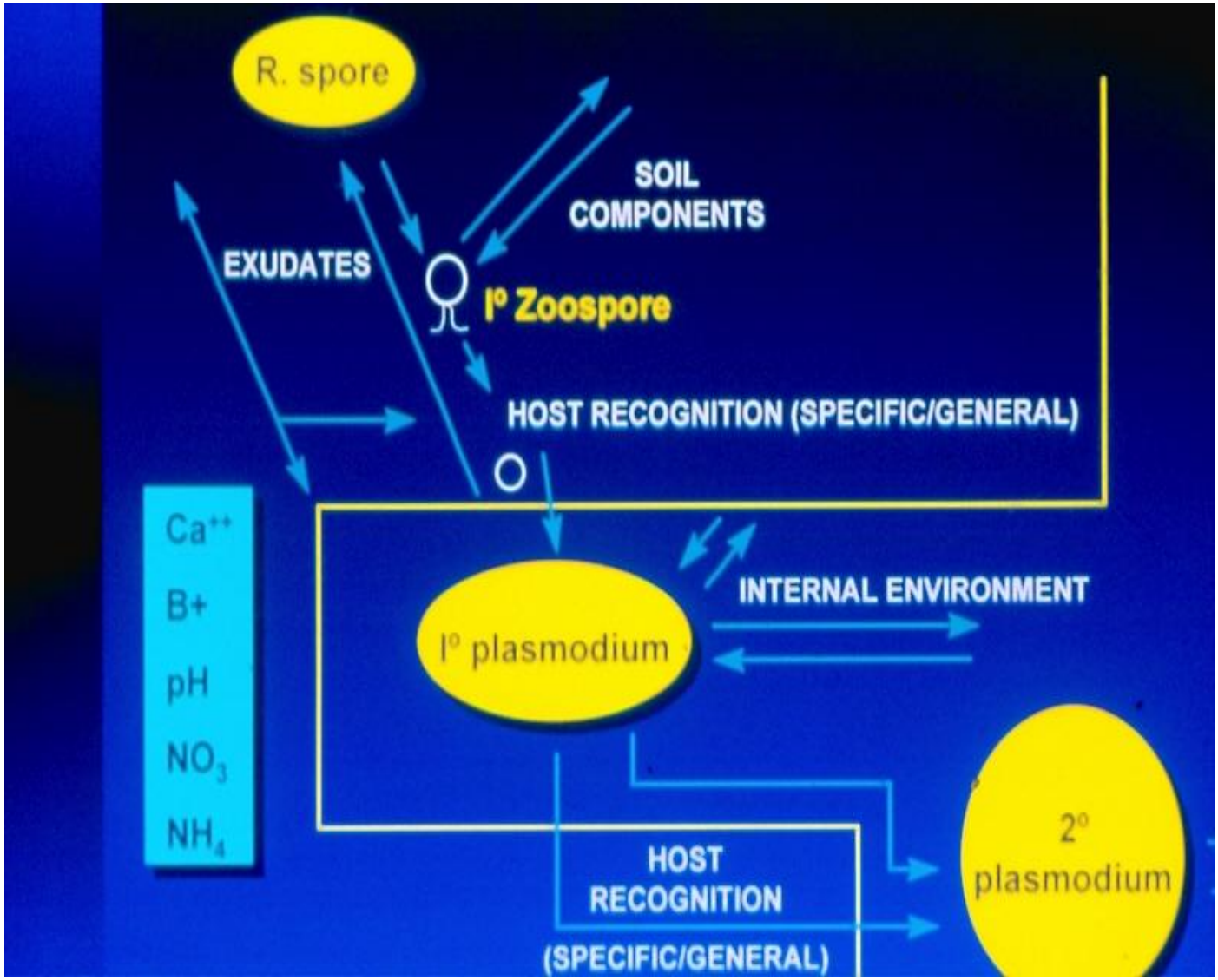


Suppressive environments resulting in rapid and slow maturation




Development
+
Maturation
+
Reproduction
Conducive
Suppressive
Time

ggi


R. spore
SOIL
COMPONENTS
EXUDATES
I° Zoospore
HOST RECOGNITION (SPECIFIC/GENERAL)
Ca++
B+
pH
NO3
NH4
I° plasmodium
INTERNAL ENVIRONMENT
2°
plasmodium
HOST
RECOGNITION
(SPECIFIC/GENERAL)

Acknowledgements

- **Postgrads, Post-docs & research assistants: David Jones, Ann Webster, Lisa Page, Mark Craig, David Kenyon, Sally Withers, Tracy Price; Taka Naiki, Seiya, Joan Aves, Ian Wright, Fred Wilson, Karen Anderson, Karen Coulshed, Jan Morton, Lynn Baird, George Bryden,**
- **Industry friends: Paul Corfield, Tore Frogner**
- **Clubrooters: Denis Garrett, Ian MacFarlane, Betty Gray, John Colhoun, David Ingram, Paul Williams, Peter Mattusch, Hille Toxopeus plus all current members of the International Clubroot Working Group (ICWG)**

This is the largest ever gathering of "Clubrooters"

Very grateful thanks are due to the Organising Committee for making this event happen

Please enjoy and profit from the next couple of days

THANK YOU FOR LISTENING