Cultivar and species mixture effect on wheat septoria tritici blotch spreading

V. Lebon, C. Gigot, M. Leconte, E. Pelzer, C. de Vallavieille-Pope, Sébastien Saint-Jean

Plant and Canopy Architecture Impact on Disease Epidemiology and Pest Development

International Conference
July 1-5, 2012 - Rennes, France

PROGRAMME

Sunday 1 July 2012

18:30-19:30 Registration
Poster hooking

19:30-21:00 Get-together and welcome cocktail

Presentations will be collected each morning before the beginning of the morning session (between 08:30 and 08:55) and during the morning and afternoon coffee breaks

Please, bring your USB flash drive or CD-ROM

Monday 2 July 2012

09:00-09:30 WELCOME ADDRESSES

- **Bernard Tivoli** (Scientific and Local Committees)
- **Grégoire Thomas** (Director of Agrocampus Ouest)
- **Patrick Herpin** (President of the INRA Rennes Center)

09:30-10:40 INTRODUCTIVE TALKS (Chair: Alain Baranger)

09:30-10:05 Keynote A: **Bernard Tivoli**, A. Calonnec, B. Ney and D. Andrivon: How do plant architectural traits modify the expression and development of epidemics? Consequences for reducing epidemic progress.

10:05-10:40 Keynote B: **Evelyne Costes**, P.E. Lauri, S. Simon and B. Andrieu: Introduction to plant architecture, its diversity and manipulation in agronomic conditions

10:40-11:10 Coffee break

11:10-13:00 SESSION 1 - Disease and pest epidemics in canopies with different architectures (Chair: Rebecca Grumet)

11:10-11:55 Keynote A: **Karsten Mody**: Relationship between plant architecture and plant infestation by arthropod herbivores

11:55-12:30 Keynote B: **Agnès Calonnec,** J.B. Burie, M. Langlais, S. Guyader, S. Saint-Jean, I. Sache and B. Tivoli: Impact of plant growth and architecture on pathogen processes and consequences for the epidemic behaviour

12:30-12:45 Angelena Syrovy, S. Banniza, and S. Shirtliffe: Inter-seeding semileafless with conventional leafed field pea alters canopy and *Mycosphaerella pinodes* blight development

12:45-13:00 Basudeb Dasgupta: Effect of crop canopy structure on the incidence of leaf rot and leaf spot of betelvine (*Piper betle* L.)

13:00-14:30 Lunch

14:30-17:30 SESSION 2.1: Effects of plant and canopy architecture on microclimatic variables and epidemiological processes (Chair: Harald Scherm)

14:30-15:15 Keynote A: **Sukumar Chakraborty** and I.B. Pangga: Climate change impacts on plant canopy architecture: implications for pest and disease management

15:15-15:30 Matthew Cromey, R.F. van Toor; S.L. Bithell; S. Keenan and S.F. Chang: Influences of host architecture in soil on multiplication and survival of take-all inoculum

15:30-15:45 Myriam Desanlis, E. Mestries, L. Lagarrigue, J.N. Aubertot and P. Debaeke: Effects of sunflower canopy on *Phomopsis helianthi* epidemics

15:45-16:00 Frédéric Bernard, I. Sache, F. Suffert and M. Chelle: Which temperature to simulate foliar epidemics × crop architecture interactions?

16:00-16:30 Coffee break

16:30-16:45 Benjamin Richard, F. Bussière, C. Langrume, F. Rouault, S. Jumel, R. Faivre and B. Tivoli: Pea canopy architecture affects microclimate and ascochyta blight development

16:45-17:00 Robin Caillon, S. Pincebourde and J. Casas: Thermal ecology of spider mites at the leaf surface

17:00-17:15 Sylvain Pincebourde and J. Casas: From global to micro-climate changes: Biophysics reveals buffering mechanisms at the canopy scale

17:15-17:30 Sébastien Guyader and F. Bussière: Comparing anthracnose dynamics and leaf wetness duration in staked and unstaked plots of water yam

17:30-19:30 Visit of Rennes historical centre (Departure by bus from Agrocampus-Ouest)
19:30-20:30 Reception in the Rennes city hall offered by Rennes Métropole (in the presence of Mrs. Isabelle Pellerin, Deputy mayor and Research delegate of Rennes Metropole)

Tuesday 3 July 2012

09:00-10:20 SESSION 2.2: Effects of plant and canopy architecture on microclimatic variables and epidemiological processes (Chair: Mary-Ruth Mac Donald)

09:00-09:35 Keynote B: **Michaël Chelle,** S. Pincebourde, I. Sache, M. Saudreau, S. Saint-Jean, F. Bussière, L. Huber, F. Bernard, A. Leca, R. Caillon and C. Gigot: Climate and plant pest dynamics: scales matter!

09:35-09:50 Guillaume Girardin, C. Gigot, C. Robert, C. de Vallavieille-Pope, F. Suffert and S. Saint-Jean: Effect of wheat canopy architecture and rain characteristics on *Septoria tritici* splash-borne spores

09:50-10:05 Claudine Pasco, B. Marquer, C. Langrume and D. Andrivon: How potato architecture affects microclimate and late blight epidemics

10:05-10:20 Louise Larissa May De Mio, C. Nunes Nesi, G. Alves, P.J. Ribeiro Junior: Spatial heterogeneity of peach rust in the canopy of peach trees

10:20-10:50 Coffee break

10:50-12:25 SESSION 3: Canopy architecture, crop physiology and disease impact on yield (Chair: Neil Paveley)

10:50-11:35 Keynote A: **Rebecca Grumet** and K. Ando: Modified plant architecture to enhance crop disease control via reduced contact with soil-borne pathogens: possible value of upright fruit position in cucumber

11:35-12:10 Keynote B: **Julie Smith**, M.O. Bancal, P. Bancal, I.J. Bingham, M.J. Foulkes, D. Gouache, B. Ney and N. Paveley : Crop Architecture and Crop tolerance to biotic stresses. Mechanisms to limit crop losses

12:10-12:25 Srikanta Das, P.S. Nath, A. Basu and B. Dasgupta: Altered plant canopy architecture of Safed musli (*Chlorophytum borivilianum*) on disease severity, growth and yield under field condition

12:30-14:00 Lunch

14:00-16:50 SESSION 4: Integrated modelling (Chair: Sukumar Chakraborty)

14:00-14:45 Keynote A: **Harald Scherm**, S.E. Everhart, A. Askew and L. Seymour: Disease distribution in complex three-dimensional canopies

14:45-15:20 Keynote B: **Pierre Casadebaig,** M. Langlais, C. Fournier and R. Faivre: Design steps of a generic model to simulate air-borne diseases as a function of crop architecture: case of the archidemio project

15:20-15:35 Romain Barillot, D. Combes, P. Huynh and A.J. Escobar-Gutiérrez: Ideotype construction from an architectural model of pea

15:35-15:50 Julie Caubel, M. Launay, F. Brun, F. Huard and N. Brisson: Using a coupled disease-crop model to quantify indirect effect of climate change on disease development

15:50-16:20 Coffee break

16:20-16:35 Catherine Abadie, C. Landry, F. Bonnot, V. Ravigné, J. Vaillant and J. Carlier: Evaluation of host partial resistance efficacy to a foliar disease using a simulation modelling approach: case of Mycosphaerella leaf spot diseases of banana

16:35-16:50 Alexandre Leca, M. Saudreau, L. Parisi, C. Gros and A. Lacointe: Spatial variability of wetness duration within a tree-crown

16:50-17:39 POSTER SESSION: short presentations (Chairs: Bertrand Ney & Didier Andrivon)

16:50-16:57 Lilian Amorim and G. Frare: The architecture of weed plants does not influence *Colletotrichum acutatum* survival

16:57-17:04 Corinne Robert, M. Abichou, B. Andrieu, M.O. Bancal, E. Barriuso, C. Bedos, P. Benoit, V. Bergheaud, M. Bidon, B. Bonicelli, C. Chambon, E. Cotteux, J. Da Costa, B. Durant, C. Fournier, N. Gagnaire, D. Gaudillat, C. Gigot, G. Girardin, D. Gouache, J. Jean Jacques, L. Mamy, B. Ney, N. Paveley, B. Perriot, S. Poidevin, V. Pot, C. Pradal, S. Saint-Jean, J. Salse, C. Sinfort, J. Smith, A. Ter Halle, E. Van Den Berg and A.S. Walker: ECHAP project: to reduce fungicide use by associating optimal treatment strategies and canopies promoting disease escape

17:04-17:11 Basudeb Dasgupta, S. Das, A. Basu and P.S. Nath: Impact of alteration in plant canopy architecture on disease incidence, growth, and yield of Sarpagandha (*Rauvolfia serpentine*)

17:11-17:18 Basudeb Dsagupta, S. Das, A. Basu and P.S. Nath: Reduction of incidence of Bud Necrosis Virus disease and increase of yield of Groundnut crop through manipulation of canopy growth

17:18-17:25 Valerian Lebon, C. Gigot, M. Leconte, E. Pelzer, C. de Vallavieille-Pope and S. Saint-Jean: Cultivar and species mixture effect on wheat *Septoria tritici* blotch spreading

17:25-17:32 Jean-Eric Chauvin, F. Esnault, A.M. Jacob, R. Pellé, R. Lecointe and J.P. Dantec: Study of a potato dihaploid mapping population to investigate the relationships between late blight resistance genes and plant architectural genes

17:32-17:40 Partha Sarathi Nath: Adjustment of Cultural Practices in Tomato to Manage the Canopy for reducing Tomato Leaf Curl Viruses in India

Wednesday 4 July 2012

09:00-10:20 SESSION 5: Genetic control of architectural traits involved in epidemic reduction (Chair: Karsten Mody)

09:00-09:45 Keynote A: **Phil Miklas**, J.D. Kelly and J.R. Myers: Genetic and phenotypic characterization of physiological resistance and avoidance to white mold disease in common bean

09:45-10:20 Keynote B: **Alain Baranger**, J.E. Chauvin, E. Costes, C. Giorgetti and P.E. Lauri: Genetic variability for architectural traits involved in disease/pest reduction

10:20-10:35 Stephen Jones, J. Foulkes, D. Sparkes and R. Ray: Identification of physiological traits in wheat conferring passive resistance to Fusarium head blight

10:35-11:00 Coffee break

11:00-11:15 Carole Giorgetti, G. Deniot, H. Miteul, F. Mohamadi, G. Morin, C. Morlet, C. Onfroy, M.L. Pilet-Nayel, J.P. Riviere, B. Tivoli and Baranger A: Stability of genetic factors controlling architectural traits and partial resistance likely to reduce ascochyta blight epidemics in pea

11:15-11:30 Peter Bokor: Reaction of sunflower hybrids to natural infection of the most important sunflower pathogens

11:45-13:00 Lunch
13:15-18:30 Visit of Mont Saint Michel
18:30-23:30 Conference dinner (Château d'Apigné)

Thursday 5 July 2012

09:00-11:45 Session 6: Integrated pest-disease management using canopy architecture (Chair: Phil Miklas)

09:00-09:45 Keynote A: **Mary-Ruth Mc Donald**, B.D. Gossen, C. Kora, M. Parker and G.J. Boland: Advances in control methods based on canopy modifications to manage plant diseases

09:45-10:20 Keynote B: **Didier Andrivon**, A. Baranger, A. Calonnec, P. Cartolaro, R. Faivre, C. Giorgetti, S. Guyader, P.E. Lauri, F. Lescourret, B. Ney, L. Parisi, I. Sache and B. Tivoli: Defining and designing architectural ideotypes to control epidemics?

10:20-10:35 Daniel Molitor, M. Behr, S. Fischer and D. Evers: Impact of cluster-zone leaf removal on grape (*Vitis vinifera*) bunch rot (*Botrytis cinerea*)

10:35-10:50 Amitava Basu: Management of Canopy structure to reduce the Severity of Anthracnose Disease of Grapes under Indian conditions

10:50-11:15 Coffee break

11:15-11:30 Christophe Gigot, S. Saint-Jean, L. Huber, M. Leconte, C. Maumené and C.de Vallavieille-Pope: Using wheat cultivar mixtures to reduce severity of *Septoria tritici* blotch, a rain-borne disease

11:30-11:45 François Bussière and S. Guyader: Can yam staking affect anthracnose epidemiology?

11:45-12:35 CONCLUSIVE TALK (Chair: Bernard Tivoli)

Keynote: **Neil Paveley**, M. Grimmer, J. Smith, J. Foulkes and C. Robert: Benefits and costs of disease escape, resistance and tolerance

Farewell address: Bernard Tivoli

12:35-14:00 Lunch
14:00 Departure

Plant and Canopy Architecture Impact on
Disease Epidemiology and Pest Development

CONTENTS

INTRODUCTIVE TALKS

CURRENT KNOWLEDGE ON PLANT/CANOPY ARCHITECTURAL TRAITS THAT REDUCE THE EXPRESSION AND DEVELOPMENT OF EPIDEMICS.

Bernard Tivoli[1], A. Calonnec[2], B. Ney[3] and D. Andrivon[1]

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[2] INRA, UMR1065 SAVE, Domaine de la Grande Ferrade 71 avenue Edouard Bourlaux, F-33883 Villenave d'Ornon, France.
[3] AgroParisTech INRA, Environnement et Grandes Cultures, F-78850 Thiverval-Grignon, France.

To reduce the use of pesticides, innovative studies have been developed to introduce the plant as the centre of the crop protection system. Although architectural features of plants and canopies to reduce disease development have been explored, their individual impact still remains insufficiently analysed. Using an integrated approach, the aim of this talk is to explain how architectural features of plants and canopies (Godin et al., 1999) induce a more or less severe epidemic and how they may be modified in order to reduce disease development. In particular, it focuses on three key questions: i) Which processes linked to epidemics can be influenced by architecture? ii) How can architectures be characterized relative to these modes of action? iii) How can these effects be explored and exploited? The roles of plant/canopy architecture on inoculum interception, on epidemic development via the microclimate and on tissue receptivity are discussed. In addition, the concepts of disease avoidance, canopy porosity and ideotype unfavourable for disease development are described. Two large fields have been covered by the scientists of the agronomy community. The first aims to relate the respective dynamics of plant development and of disease epidemics. For this purpose, the complementarities among scientists is now evident, and several groups, such as the EpiArch network in France reinforced by the ARCHIDEMIO project which studies the plant - pathogen interactions within host canopies in several pathosystems, are implementing this multidisciplinary strategy into joint research projects. The second field is to study the impact of these interactions on yield components and quality. Many authors do not hesitate to think of 'manipulating’ architecture to design agronomical solutions to control diseases, in both annual and perennial crops (Ando et al. 2007; Simon et al. 2006).This talk shows that many advances have already been made, but progress is still required in four main fields: microclimatology, mathematical modelling of plants, molecular genetics and ideotype conception. After having defined architecture in the context of plant disease epidemiology, and having identified the main characteristics that have to be known for disease and pest development, several aspects are detailed during this conference: i) How and why plant and canopy architecture can modify disease and pest development, ii) What can we expect from the modifications of canopy microclimate and the physiological status of the organs or the whole plant on disease and pest development t, iii) How the plant genetic can contribute to disease and pest reduction through the control of architectural traits contributing, iv) What impact has to expect of these modifications on yield losses and v) Can we imagine to combine the architectural traits and other disease control methods (resistance, cultural practices) to reduce the use of pesticides? Using an integrative strategy, a study has been initiated by a truly multidisciplinary team of scientists including plant pathologists, entomologists, geneticists, agronomists, microclimatologists and mathematical modellers to investigate the role of plant architecture in disease epidemics and pest development of plants.

References

Ando K., Grumet R., Terpstra K. & Kelly J.D. (2007). Manipulation of plant architecture to enhance crop disease control. CAB Reviews: Perspectives in Agriculture, Veterinary Science, Nutrition and Natural Resources 2, N° 26. http://www.cababstractsplus.org/cabreviews

Godin, C., Costes, E. & Sinoquet, H. (1999). A method for describing plant architecture which integrates topology and geometry. *Annals of Botany, 84,* 343-357.

Simon, S., Lauri, P. E., Brun, L., Defrance, H. & Sauphanor, B. (2006). Does manipulation of fruit-tree architecture affect the development of pests and pathogens? A case study in an organic apple orchard. *Journal of Horticultural Science & Biotechnology, 81,* 765-773.

Keywords :
Canopy, Disease avoidance, Ideotype, Leaf area density, Microclimate, Porosity

INTRODUCTION TO PLANT ARCHITECTURE, ITS DIVERSITY AND MANIPULATION IN AGRONOMIC CONDITIONS.

Evelyne Costes[1], P.E. Lauri[1], S. Simon[2] and B. Andrieu[3]

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[2] INRA, UE Recherche Intégrée, Domaine de Gotheron, 26320 Saint-Marcel-lès-Valence, France.
[3] INRA, UMR1091 EGC Environnement et Grandes Cultures, 78850 Thiverval-Grignon, France.

Plant architectural traits have been reported to impact pest and disease damages on several crops and to potentially provide alternative, although partly, solutions to limit the use of pesticides. In this paper, we introduce the major concepts of plant architecture analysis that can be used for investigating plant interactions with pests and pathogens. We briefly review how primary growth, branching and reiteration design the plants 3D structure, which properties may permit (or not) the plant to escape or survive to pests and pathogen attacks. This capability greatly depends on temporal aspect and "racing" between plant growth and pests or pathogens propagation. Different scales can be considered in the plant population:
(i) the organ which nature, tissular organisation, development stage, and shape may influence pathogen and pest attacks.
(ii) the individual plant form based on the relative positioning of its organs. In particular, the spatial distribution of leaves in space determines the within-plant micro-climate and the topological connections between shoots constraint pest and pathogen propagation.
(iii) The plant population which plantation density and layout may lead to different infection and infestation risks.
At individual scale, we show how growth, branching and flowering traits combine to confer to every plant species an intrinsic architectural model. However, these traits vary quantitatively throughout plant ontogeny and between genotypes within a same species. In addition, they can be modulated by environmental conditions, here considered *lato sensu*, i.e. including climatic conditions and manipulations by humans. Examples from different plant species and architectural types are provided to draw a comprehensive view of possible plant protection strategies which could benefit from plant architectural traits, their genetic variability as well as their plasticity to environmental conditions and agronomic manipulations. Associations, in a same plot, of species and/or genotypes having different susceptibility and architecture could also open new solutions to improve the tolerance to pests and diseases at whole plot scale. Eventually, modeling appears as an essential approach to integrate different processes and scales, and to cope with the complexity of interactions between plants and pests and pathogens.

Keywords :
Plant architecture, growth, branching, reiteration, topology, geometry, ontogeny, plasticity, manipulations, plant-host interactions, Functional-Structural Plant Models

SESSION 1

DISEASE AND PEST EPIDEMICS IN CANOPIES WITH DIFFERENT ARCHITECTURES

RELATIONSHIP BETWEEN PLANT ARCHITECTURE AND PLANT INFESTATION BY ARTHROPOD HERBIVORES.

Karsten Mody

Technische Universität Darmstadt, Schnittspahnstrasse 3, 64287 Darmstadt, Germany

Plant architecture may affect the distribution and abundance of plant-associated herbivorous and carnivorous arthropods. Understanding the differential effects of plant architecture on herbivores and on their antagonists can help to protect plants from herbivore damage, both via directly reducing herbivore feeding, reproduction or movement (bottom-up effects), or by indirectly enhancing the suppression of herbivores by their antagonists (top-down effects). In this introductory talk, I will present different aspects of the relationship between plant architecture and plant-associated arthropods. Considering bottom-up and top-down effects of plant architecture on plant infestation by arthropod herbivores, the state of the art shall be outlined as a basis for the possible application of plant architecture modification in crop protection from arthropod herbivores.

Keywords :
Plant architecture, Arthropod herbivores, Bottom-up control, Top-down control

IMPACT OF PLANT GROWTH AND ARCHITECTURE ON PATHOGEN PROCESSES AND CONSEQUENCES FOR EPIDEMIC BEHAVIOUR.

Agnès Calonnec[ab], JB. Burie[cd], M. Langlais[cd], S. Guyader[e], S. Saint-Jean[fg], I. Sache[hf], B. Tivoli[i]

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[b]Université de Bordeaux, ISVV, UMR SAVE, F-33883 Villenave d'Ornon, France.
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[e]INRA, UR1321 ASTRO Agrosystèmes tropicaux, F-97170 Petit-Bourg (Guadeloupe), France
[f]AgroParisTech, UMR Environnement et Grandes Cultures, F-78850 Thiverval-Grignon, France
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Epidemics are dynamical processes with variable rates of disease progress. How much of these changes in disease rate are triggered by the host population is still a pending issue. An epidemic is driven by its effective reproduction number: the product between the proportion of susceptible tissue, the rate of disease transmission, and the duration of the infectious period. Then, any modification in the host population, either quantitative or qualitative (distribution of plants or of susceptible organs) may have an impact on the epidemic dynamics. The growth of the host population is modified by architectural features or by cultural or agronomical practices. The production of new organs continuously modifies the porosity of the plant or of the canopy and its level of susceptibility if organ susceptibility changes with age (ontogenic resistance). Indirectly, plant growth modifies the micro-climatic environment inside the canopy, generating favourable or unfavourable conditions for pathogens. The organ susceptibility, or their susceptibility period, may also be modified by cultural practices disrupting the crop-pathogen synchronisation. These variations within host populations do impact disease incidence, severity or spread. However, they have rarely been explicitly taken into account in epidemiological models. Tracking back from the global dynamics of an epidemic the pathogen processes that are impacted and ranking the host traits involved in their modifications represents a challenge. In this paper, we will 1) review evidence of epidemic variations attributed to plant growth and architecture in main pathosystems, 2) list the pathogen processes impacted, and give some clue to identify and assess them in different epidemic contexts and 3) explore models able to measure and predict the effect of plant growth and architecture on epidemics.

Keywords :
Canopy structure, Disease transmission, Architectural traits, Micro-climate, Host-pathogen models

INTER-SEEDING SEMILEAFLESS WITH CONVENTIONAL LEAFED FIELD PEA ALTERS CANOPY AND MYCOSPHAERELLA PINODES BLIGHT DEVELOPMENT.

Angelena Syrovy, S. Banniza, and S. Shirtliffe

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Field studies have been initiated in Saskatchewan, Canada, to investigate the effect of intercropping semileafless and conventional leafed pea varieties on the microclimate of the canopy and the development of *Mycosphaerella pinodes*. Semileafless pea cultivar CDC Dakota and conventional cultivar CDC Sonata were sown at ratios of 0:100, 25:75, 50:50, 75:25, and 100:0, respectively, in a randomized complete block design with four replications. Parameters describing canopy growth, microclimate, and disease severity were measured at regular intervals. Significant differences were observed among growth parameters, relative humidity within the canopy, and disease severity in plots with different ratios of semileafless and conventional peas. Canopies dominated by the conventional leaf type were significantly taller, with fewer nodes, and increased lodging levels compared with canopies of 50% or more semileafless plants. During the period of epidemic development a higher number of days with 100% relative humidity was observed in canopies with 100%, 75%, and 50% of the conventional leafed variety compared with canopies of primarily semileafless pea plants. Disease severity increased at each scoring date, reaching an average of 35% necrosis in the pure stand of the conventional leafed variety, and 43% in the semileafless at the final assessment. Mycosphaerella blight severity was significantly higher in canopies with 50%, 75%, and 100% of the semileafless variety than in the two canopies of primarily conventional leaf type. Correlation analysis showed that higher disease severity was associated with higher number of nodes on the second to last scoring date ($r = 0.50$, $P = 0.02$), and with shorter, less lodged canopies on the last scoring date ($r = 0.56$ and 0.48, $P = 0.01$ and 0.03, respectively). Leaf area index was not associated with disease severity on any assessment dates ($r = -0.17$ to 0.29, $P = 0.21$ to 0.92) although canopies with more of the conventional leafed variety had higher leaf area indices than canopies dominated by semileafless plants. It is concluded that under moderate disease pressure in 2011, plant morphology may have played a greater role in the epidemic development than canopy microclimate.

Keywords :
Mycosphaerella pinodes, *Pisum sativum*, Cultivar mixtures, Microclimate, Canopy development

EFFECT OF CROP CANOPY STRUCTURE ON THE INCIDENCE OF LEAF ROT AND LEAF SPOT OF BETELVINE (PIPER BETLE L.).

Basudeb Dasgupta

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Betelvine (*Piper betle* L.) is a perennial dioecious creeper, belonging to the family Piperaceae usually grown under artificially erected structure known as baroj which provides high moist and humid condition favouring several diseases that in turn are prerequisites for good harvest. Betelvine suffers from many root and aerial diseases of which leaf rot caused by *Phytophthora parasitica* (Dastur) and leaf spot caused by *Colletotrichum capsici* Syd. (Butler and Bisby) are most important. The extent of losses may vary from 20 – 40% in case of leaf rot and 10-20% in case of leaf spot, leading to almost total crop failure (Dasgupta and Sen, 1999). As the betel leaf is directly chewed immediately after harvest, it is not feasible to apply any pesticides which may cause toxic hazards to human being. An experiment was conducted for two consecutive years (2009-10 and 2010-11) to study the effect of different crop canopy by maintaining three different plant to plant spacing (viz. 11.1 cm, 9.53 cm, and 8.3 cm) on leaf yield, disease incidence and keeping quality (days to 50% rotting) of betelvine. With the above plant to plant spacing and standard row to row spacing (60cm), the plant population was maintained as 1.50, 1.75 and 2.00 lakh ha^{-1}. The results reveal that when crop canopy was increased by reducing the plant to plant spacing from 11.1 cm to 8.3 cm there was significant increase in leaf rot disease 19.76% to 22.30% and 22.68% to 25.42% in case of leaf spot disease. Significant increase in yield (26.29 to 33.63 lakh $ha^{-1}year^{-1}$), decrease in fresh weight of 100 leaves (460.85g to 432.35g) and decrease in keeping quality of leaves (13.14 days to 10.28 days) were recorded when crop canopy was increased due to reduction in plant to plant spacing from 11.1 cm to 8.3 cm. From the results, it can be concluded that microclimate developed in increase of canopy by reducing the plant spacing helped in spread and infection of disease incidence.

References:

Dasgupta, B. and Sen, C. 1999. Assessment of *Phytophthora* root rot of betelvine and its management using chemicals. *J. Mycol. Plant Pathol.*, **29 :** 91-95.

Keywords:

Crop canopy, Betelvine, *Phytophthora parasitica*, *Colletotrichum capsici*

SESSION 2

EFFECTS OF PLANT AND CANOPY ARCHITECTURE ON MICROCLIMATIC VARIABLES AND EPIDEMIOLOGICAL PROCESSES

CLIMATE CHANGE IMPACTS ON PLANT CANOPY ARCHITECTURE IMPLICATONS FOR PEST AND DISEASE.

Sukumar Chakraborty[1] and I. B. Pangga[2]

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[2]Crop Protection Cluster, College of Agriculture, University of the Philippines Los Baños, College, Laguna, Philippines 4031.

Existing literature indicates that influences of climate change on pest and pathogens are mainly plant-mediated (Chakraborty *et al.*, 2012). Rising carbon dioxide and temperature and altered moisture modifies plant morphology, physiology, anatomy and resistance to influence the biology, life cycle and epidemiology of pests and pathogens and their interaction with the host plant. Elevated carbon dioxide also enhances plant growth and development causing an enlargement of the canopy. The altered size changes canopy density, microclimate and the quantity and availability of susceptible plant tissue to influence pest and disease development. A modified canopy influences pest and pathogen dispersal, the production and survival of inoculum, and the number of infection cycles to alter the nature and extent of damage to plants. Elevated carbon dioxide also increases fecundity of some pest and pathogens, and under favorable growing conditions in the canopy the boost in population can accelerate microevolution. Elevated temperature can also accelerate plant growth and developmental rates to modify canopy architecture and pest and disease development. Altered precipitation affects canopy architecture through either drought or flooding stress with corresponding effects on pest and diseases. But canopy-level interactions have largely been ignored in epidemiology models or in projecting the impacts of climate change on pest and disease management (Pangga *et al*., 2011). This is largely due to inconsistent and context-dependent findings in the limited literature. Capturing canopy level interactions to project epidemic risks due to climate change needs further studies on the interactive effects of climatic factors, especially for major food and industrial crops. Functional-structural plant growth modeling can be used to investigate canopy pest and disease development under climate change by coupling crop growth, microclimate and pest/disease sub-models. Nevertheless, there is evidence to show that climate change will influence the efficacy of biological, chemical and other disease management strategies. Using a review of relevant literature we will highlight key influences of climate change on plant canopy, and their implications for pests and pathogens and their management.

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Keywords

Climate change, Fecundity, Disease management, Crop canopy, Epidemiology

INFLUENCES OF HOST ARCHITECTURE IN SOIL ON MULTIPLICATION AND SURVIVAL OF TAKE ALL INOCULUM.

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Take-all, caused by *Gaeumannomyces graminis* var. *tritici* (*Ggt*), is an important root disease of wheat. Being a poor competitor in soil, *Ggt* requires the presence of hosts to multiply and host residues to survive. Host plant architecture strongly influences pathogen spatial and temporal spread as well as survival both during and between wheat cropping cycles.
Host spatial patterns in soil provide the means for *Ggt* to spread between roots of a plant via the crown. The distribution of hosts in a field affects plant to plant spread. Sowing a crop in discrete rows influences the distribution of roots and crowns in soil, resulting in post-harvest inoculum concentrations in the soil within rows being two to three times greater than those between the rows. Root architecture also influences the spread of *Ggt* between plants along rows. Take-all severity and inoculum concentrations decreased sharply along a row from a point source of primary inoculum when plants were spaced at approximately 8 cm. The average take-all severity was 80, 30, 10 and 2% and *Ggt* concentrations were 279500, 6200, 660 and 250 pg/g root respectively at the source of primary inoculum and the next three plants in a row. Differences in root architecture between host species also influence the multiplication of *Ggt*. For instance, rye is relatively resistant to take-all, but can result in high post-harvest *Ggt* concentrations in soil. The structure of the rye root system and its large root mass appear to enable efficient spread of mycelium along root surfaces during crop growth. This mycelium then colonises the root system during grain fill, resulting in two to ten times the post-harvest soil inoculum concentrations following rye than following wheat.
Inoculum concentrations decrease during a break crop, but the presence of volunteer wheat plants can reduce the effectiveness of the break. The density and distribution of volunteers is important in replenishment of inoculum lost during the breakdown of infected wheat residues of the primary crop. High volunteer densities increased soil *Ggt* concentrations, by enabling plant to plant spread of *Ggt* and widespread colonisation of soil. Lower densities resulted in only localised survival of *Ggt* probably because the spread of *Ggt* is hindered by the juxtaposition of host and non-host roots. The effectiveness of a break crop can also be reduced by the presence of the grass weed *Elytrigia repens*. *Ggt* causes small lesion on rhizomes of this host. The lateral spread of rhizomes can result in extensive colonisation of soil by *E. repens*, bringing it into contact with residue-borne *Ggt* and enabling *Ggt* to colonise the soil along with its host. When the herbicide glyphosate was applied, *Ggt* further colonised dying rhizomes, resulting in a rapid 8-fold increase in *Ggt* concentrations in soil and severe take-all in a subsequent wheat crop.

Keywords:
Roots, Rhizomes, *Gaeumannomyces graminis* var. *tritici*

EFFECTS OF SUNFLOWER CANOPY ON PHOMOPSIS HELIANTHI EPIDEMICS.

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Phomopsis stem canker (*Diaporthe/Phomopsis helianthi*), a major sunflower disease, decreases grain yield up to 15 q/ha and oil content up to 25% when conditions are favourable to leaf infection, plant wilting and lodging (Masirevic and Gulya. 1992. *Field Crops Research* 30: 271-300). With no change in soil, weather, variety or inoculum conditions, proportions of infected stems may range from 0 to 100% as a function of crop management (Debaeke *et al.* 2003. *Agronomie* 23(7): 581-592). This study analysed the fungus spreading within the canopy from spore projection to plant death. The objectives were to decompose the influence of crop management on stem attacks and understand why the same management can have opposite effects on the fungus with the growth stage.
A field experiment was set up near Toulouse (2011) using a criss-cross design, with irrigation (33 mm, July 7th) or not as the main plots, subdivided in two blocks with contrasting input levels (A: 150kg N/ha, 3.5 plants/m²; B: no N-fertilization, 7 plants/m²) applied to five genotypes (varying by their susceptibility to phomopsis) under reinforced inoculum. The position and fate of leaf symptoms were related to canopy development, microclimatic conditions and the timing of leaf infections.
Earlier and more severe attacks were observed in non-irrigated plots. Late contaminations predominantly occurred in irrigated plots. Indeed, canopy closure was more rapid in non-irrigated situations with plants having significantly higher leaf area index resulting in a microclimate more favourable for contaminations. Senescence began in early July and was more pronounced in non-irrigated situations which led to less potential sites for contaminations. Moreover, under wet conditions of July, contaminations were more numerous in less developed canopies probably due to higher levels of spore dispersal. Early attacks were mostly basal because relative humidity was more favourable. Those attacks did not result easily in stem lesions because of rapid senescence and/or *Phoma macdonaldii* competition that could prevent the leaf-to-stem passage. However, the lesions were more severe at this level due to their early development. Analysis of the disease incidence at the plant level would have hidden the complexity of the relationships between plants, pathogen and environment: situation A got more leaf contaminations but had less stem symptoms than situation B. Indeed, senescence began earlier and was more pronounced in situation B due to nitrogen deficiency. However, those B plants had smaller leaves and shorter petioles which shortened the distance to reach the stem resulting in more harmful stem lesions than in A. Among cultivars, discrepancies in contamination rates appeared to result from differences in intrinsic genotypic susceptibility and green tissue areas available for contaminations.
The final number of harmful stem lesions resulted from successive processes, each of them being differently affected by canopy structure and the resulting microclimate. Genotypes with long petioles and late canopy closure appeared to be less susceptible to stem symptoms.

Keywords:
Phomopsis helianthi, Sunflower, Crop management, Microclimate

WHICH TEMPERATURE TO SIMULATE FOLIAR EPIDEMICS x CROP ARCHITECTURE INTERACTIONS.

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Air temperature measured by weather stations is commonly used in epidemiological models to forecast the effect of temperature on the development of foliar fungal pathogens. However, leaf temperature is the temperature actually perceived by such pathogens. The leaf temperature depends on the leaf energy budget (*e.g.* air temperature, radiation, wind, transpiration, etc.), which itself strongly depends on the crop architecture (*e.g.* leaf position, leaf angle, leaf area density).
Consequently, differences between air and leaf temperatures vary spatially between canopies with contrasted architectures and between leaves within a given architecture, especially between leaf layers, as well as temporally throughout the course of the epidemic (seasonal variations). We already characterized the effect of leaf temperature on the latent period of the fungus *Mycosphaerella graminicola* infecting wheat leaves. In this simulation study, we aimed at estimating whether the use of either air or leaf temperature as input data influences the development of the infectious cycle of *M. graminicola* within contrasted wheat canopy architectures.
Various weather conditions were generated using actual weather data. For each leaf layer, leaf temperature was calculated using the one-dimensional Soil-Vegetation-Atmosphere Transfer model CUPID for different canopy architectures. From the thermal performance curves of the latent period established in the aforementioned study, the pathochron, defined as the number of leaves emerging per latent period, was calculated, using either air temperature or leaf temperature as input data.
At the leaf scale, the type of temperature used as input data modified the pathochron, which could generate various disease dynamics into the canopy. Our results highlighted the weather conditions for which it is necessary to take into account leaf temperature rather than air temperature to estimate accurately the development of *M. graminicola*.
Our simulation method could be applied to other foliar fungal pathogens. In a further step, we will use future climatic scenarios to explore the impact of climate change on disease dynamics. In a longer term, the integration of these findings to more elaborated epidemiological models is expected to improve their forecasting accuracy.

Keywords:
Leaf temperature, *Mycosphaerella graminicola*, Crop architecture, Foliar epidemics

PEA CANOPY ARCHITECTURE AFFECTS MICROCLIMATE AND ASCOCHYTA BLIGHT DEVELOPMENT.

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Ascochyta blight (*Mycosphaerella pinodes*) development on pea is affected by leaf wetness duration (LWD) and temperature (1). The aim of this study was to investigate the effects of canopy architecture and development on microclimate and on ascochyta blight development in pea canopies with contrasting architectures under field conditions.
A split-plot experiment was conducted at Le Rheu, France, in the spring of 2009 and 2010 with three pea cultivars (Athos, Antares and Gregor), each sown at two densities (80 and 40 seeds/m²) plus a third density in 2010 (30 seeds/m²). LWD and air temperature (Ta) were estimated respectively with leaf wetness sensors and thermocouples at the bottom and middle height of each canopy. Two mesoclimate parameters (LWD and Ta) were recorded with sensors placed at 1.50 m above the soil level. For each cropping season, microclimatic conditions prevailing during wetness episodes were compared according to the presence or absence of rainfall (rainfall and dry periods respectively).
Differences were observed between meso- and microclimate parameters only on LWD but not on Ta. During rainfall periods, LWD was longer inside the canopy than outside (more than 3 to 10h daily). Conversely, during dry periods, LWD became shorter inside the canopy after canopy closure (decreased of 1 to 7h daily). In the denser canopies, these differences appeared first at the bottom. During dry periods, LWD due to dew was longer in the middle than at the base of the canopy, with an average daily LWD of around 4h that decreased during canopy development. When the canopy was completely closed, no LWD was recorded at the base of the plants. Moreover, cultivar Gregor with the greatest leaf area index (LAI) provided lower LWD than the two other cultivars. A plant density effect was also observed in 2010 with longer LWD (more than 2 to 6h daily) in the canopies with the lowest density for each cultivar as soon as canopy was closed. During rainfall periods, no leaf wetness distribution patterns were observed inside the canopy whatever the cultivar or the plant density with an average daily LWD of around 15h. In 2009, longer LWD were observed at the base level for each cultivar sown at the greatest density from two weeks before canopy closure (more than 2 to 5h daily).
Regarding the effect of microclimate on disease development, we observed that during dry periods, temperatures were too low during wetness periods to favour disease development and correspondingly, a prediction model adapted from Magarey et al. (2) showed that infection periods occurred only during rainfall periods.
Denser canopies limit water evaporation and prevent dew formation on leaves while the lowest canopy densities favour dew formation. Therefore the microclimates of denser canopies are the more favourable to disease development and led to greatest disease severities.

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Keywords:
Leaf area index, Leaf wetness duration, Magarey model, *Mycosphaerella pinodes*, Plant density

THERMAL ECOLOGY OF SPIDER MITES AT LEAF SURFACE.

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Correlative studies demonstrated that recent climate change had impacted the ecophysiology and distribution of numerous organisms. At the moment, climate change studies need to integrate the microclimatic conditions that organisms actually experience in their microhabitat to fully understand the mechanisms behind the response of organisms to changing environmental conditions. The case of insect-plant relationships is particular because the microclimate used by insects results from the activity of another living organism, the plant. In this study, we were interested in characterizing the influence of the leaf thermal environment on the distribution of spider mites over single leaf surfaces. We first measured the spatial heterogeneity of the apple leaf surface temperature using thermometry in various conditions for air temperature and humidity in a controlled environment. The results indicated a clear effect of air temperature on both the configuration and the composition of pixel temperature at the leaf surface. Humidity influenced thermal heterogeneity to a lesser extent, and more humid conditions tended to increase temperature differences between the leaf and ambient air. Overall, the levels of leaf surface temperature heterogeneity suggest that spider mites can find very diverse, but structured thermal conditions over a single leaf surface by simply moving between leaf parts. Then, the upper lethal temperature threshold (ULT) was measured for the spider mite *Tetranychus urticae* as being the temperature causing 50% mortality when exposed for one hour. This spider mite species is highly thermo-tolerant as the ULT was found to be 46°C. Such temperature can be reached under relatively hot atmospheric conditions and/or under elevated level of incoming radiation. Finally, another experiment consisted in measuring simultaneously the leaf temperature surface heterogeneity (thermal imaging camera) and the distribution of the spider mites (digital camera) at the leaf surface under sub-lethal leaf temperature conditions compared to moderate conditions. We hypothesised that the spider mites would agglomerate in the colder portions of a leaf under extreme temperature conditions while their distribution is more likely to be homogeneous over the leaf surface under moderate conditions – a behaviour that should increase survival. Surprisingly, thermoregulation processes were found in the case of moderate conditions with the presence of spider mites in warmer areas where they can reach optimal temperature, but not in the case of extreme temperature conditions, due to the highly homogeneous environment. In the case of extreme temperatures (thermal chocks), the position of spider mites at the leaf surface tends to be a critical data to estimate the impact of temperature on survival.

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Keywords:

Biotic interactions, Microclimate, Thermal imaging, Spider mites

FROM GLOBAL TO MICRO CLIMATE CHANGES: BIOPHYSICS REVEALS BUFFERING MECHANISMS AT THE CANOPY SCALE.

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GCM models of climate change improve our understanding of the global mechanisms but very little is known on the effects of global warming on the microclimate of species. Here, we quantify the amplitude of the microclimate change following an increase in temperature during a heat wave event in a leafmining moth – apple tree system. We developed a nested model downscaling framework to spatially and functionally interconnect regional and microhabitat (leaf mine) scales. This mechanistic biophysical approach integrates heat budgets of organisms, physiology of the plant and the insect, behavior (thermoregulation), and physics of radiative transfer within canopy architectures. Various methodologies were used to parameterize and test the models: infrared gas analyzer to measure stomatal conductance, spectrometer to measure absorbance of mines, and electromagnetic digitizer to measure plant canopy geometry. The model predicts mine and body temperatures for a larva at a given position within a tree canopy from regional climatic variables canopy geometry. The model was found to predict temperature within leaf mines (~1cm² of leaf area) within 1°C. Tree geometry generated a high spatial heterogeneity of leaf mine temperature at the canopy scale. The comparison of predicted temperature increase during a moderately warm day and during the heat wave event shows that the amplitude of the mine microclimate warming does not equal that of the global temperature increase. Instead, the biophysical functioning of a mine partially buffers against overheating, which ameliorates survival of the leafminer. By confronting our results to the few other published works on climate change effects on microclimate and body temperature of species, we suggest that the buffering nature of species microclimate might be widespread if not the rule.

Keywords:
Global warming, Microclimate, Canopy geometry, Leafminer, Thermal ecology, Plant-insect interactions

COMPARING ANTRACHNOSE DYNAMICS AND LEAF WETNESS DURATION IN STAKED AND UNSTAKED PLOTS OF WATER YAM.

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Water yam (*Dioscorea alata*), an important root tuber crop in the tropics, is affected by anthracnose caused by *Colletotrichum gloeosporioides*. In order to reduce the impact of epidemics while reducing fungicide applications, the use of a combination of resistant yam cultivars and cultural practices is required. Among cultural practices, staking is traditionally used to grow yam vines in small fields, but is not in larger fields where mechanization is more widespread. In the literature, contradictory results have been obtained in the eighties by researchers when trying to assess the effect of staking on the dynamics of anthracnose.

We compared the disease dynamics in both staked and unstaked plots under natural infestation in humid pedoclimatic conditions, by measuring weekly severity indices across a 12x8 grid made of 1 m² units spaced by 1.5 m. Additionally, leaf wetness sensors were placed at several locations in both plots, and leaf wetness duration (LWD) as well as other climatic and microclimatic variables (*e.g.* relative humidity, air and canopy temperatures, wind speed and direction) were monitored every 15 minutes for 41 days.

Disease incidence (percentage of diseased units) could not be measured as all the units were diseased at the time of the first measurements; however severity indices suggest that the incidence was higher in the staked plot at a given time, and that the disease may have appeared earlier than in the unstaked plot. After fitting a 3-parameter logistic model to the data, we found that both the rate of increase of the disease and the time at the inflexion point were significantly different in both plots: the point of inflexion (time when 50% severity level is reached) occured on average at 154 ±1.9 and 165 ± 1.6 days after plantation for staked and unstaked plants, respectively), but the rate of increase was higher for unstaked than staked plots (11.22 ± 0.97 and 9.28 ± 0.76 dimensionless, respectively). Comparing the microclimate in staked and unstaked plots, cumulated LWDs were significantly longer in unstaked (491 ± 37 hours) than in staked plot (371 ± 70 hours). We observed that in the tropical conditions of the experiment, the high relative humidity of the air led to significant dew deposition during every clear night, and that dew was the main contributor to leaf wetness duration overall.

Disease dynamics differences observed between staked and unstaked plots could not be readily explained by LWD differences only, since one would have expected faster disease development in the unstaked plot than in the staked plot whereas the opposite was observed. It is likely that in the humid pedoclimatic conditions of the experiment, leaf wetness duration was not a limiting factor for disease development, and that other factors at disease onset (such as the source and density of primary inoculum) play a critical role.

Keywords:
Wetness duration, Severity, Epidemics, Staking, *Dioscorea alata*, *Colletotrichum gloeosporioides*.

CLIMATE AND PLANT PEST DYNAMICS SCALES MATTER.

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Ben Ari *et al*. (2011) stated that for "plague and climate, scales matter!" What about plant pest dynamics within canopies? Climate influences the micro-environment and the dispersal of plant pests within plant canopies, as determined by multiscale mass and energy fluxes. Climate influence has been studied following two approaches. First, correlative approaches, extensively used in disease forecasting, statistically link disease and climate variables, *e.g.* air temperature and humidity. These approaches lack robustness and sensitivity; they cannot satisfyingly explain how an epidemic actually interacts with climate within a canopy and how it would evolve with climate change. Second, mechanistic approaches study the interactions between pests and their physical environment at the individual's scale and integrate them from organ to canopy scale. Such interactions are described by the ecological concept of reaction norms, which relates performance, plasticity, and evolution (Angilletta *et al.,* 2003). Establishing such reaction norms requires the characterization of phylloclimate (Chelle, 2005), that is the climate actually perceived by individuals (pest, plant organ) involved in the plant-pest interactions. Phylloclimate is highly variable in time and space. This comes from the pest's energy budget, which non-linearly depends on microclimatic variables, and from the complex transfer of mass and energy from above the canopy to pest, mediated by canopy architecture. Top-canopy microclimate depends it-self on mesoclimate (1km^2) through the actions of elements such as hedges, neighboring forests, hills, lakes, roads, etc, which define the landscape architecture.
In addition to its downscaling function (from mesoclimate to phylloclimate), canopy architecture is an important component of the integration of many local pest-leaf-phylloclimate relationships, like the processes of infection, latency, lesion growth, and sporulation in fungi. The non-linearity of reaction norms to phylloclimate adds, however, great complexity to this integration. Thus, we will discuss questions raised by such integration, from a spatial and temporal point of view, little being known on the role of phylloclimate on the evolution and plasticity of pests and hosts.
Finally, we will list pending issues and show how multiscale interactions between climate and pests could provide innovative levers for pest management, from current climate to future one.

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Keywords:
Climate, scale, Epidemics, Plant pest, Phylloclimate, Canopy architecture, Reaction norms.

EFFECT OF WHEAT CANOPY ARCHITECTURE AND RAIN CHARACTERISTICS ON SEPTORIA TRITICI SPLASH BORNE SPORES.

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Canopy architecture and distances between organs of plants susceptible to fungal airborne diseases are two factors influencing disease epidemics. It has been shown that wheat architecture can affect the progression of septoria tritici blotch (STB) within the canopy. During the epidemic stage, STB progression is mainly due to rain splash, which induces upward vertical, and lateral transport of spores. We investigated, in controlled conditions, the effects of both plant architecture and rainfall characteristics on one dispersal cycle of conidia of *Mycosphaerella graminicola*, which are spores coming from the asexual reproduction of the pathogen fungus responsible of STB. The experiment was performed using a simulator of artificial rainfall on wheat micro-canopies (1 m^2), grown in a regulated temperature greenhouse. To avoid the influence of different varietal resistance genes on disease progression, two quasi-isogenic wheat lines of the cultivar Mercia, differing only by the RHT dwarf gene, were chosen (from the John Innes Centre). A linear inoculum source of conidia suspension (10^6 conidia per mL), located at the centre of the canopy was set up. Each canopy was exposed to two different rainfall events: a classical stratiform-like rain with distribution of raindrop diameters centred on 2.5 mm, and a (heavy) thunderstorm-like rain with distribution of raindrop diameters centred on 3.0 mm. Just before each rainfall event, some architecture components (internode lengths, wheat heights and leaf sizes) were assessed. During each rainfall event, splash droplets were collected at different locations within the canopy to quantify spore fluxes. Thereafter, canopies were incubated in a mist chamber for 4 days, and kept 3 weeks in a greenhouse at about 20°C during the symptomless phase (corresponding to the latency period). Disease progression resulting from rain splashes in the different leaves of the plants was precisely assessed, by measurements of diseased and non-green leaf areas. We observed a strong effect of the canopy structure on the spore dispersal. A 43% smaller (and denser) canopy had a higher level of disease severity: 10 and 7 times higher for stratiform-like and thunderstorm-like rains, respectively. The smallest canopy often concentrated disease symptom on a given foliar level and the percentages of non-green foliar areas were 2 times larger than for the other canopy. Such effects were amplified with thunderstorm-like rain. Our experiment allowed quantifying the effects of the canopy architecture and the kind of rainfall event in spore dispersal and identifying interaction between them.

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Keywords:
Wheat architecture, Splash dispersal, *Mycosphaerella graminicola*, *Septoria tritici* blotch.

HOW POTATO ARCHITECTURE AFFECTS MICROCLIMATE AND LATE BLIGHT EPIDEMICS.

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Plant and canopy architecture are known to modify the epidemic development of many aerial pathogens. One of the underlying hypotheses is that different host architectures generate different microclimatic or phylloclimatic conditions, and therefore change the duration of periods favorable for spore production, transportation, or penetration. However, experimental evidence for such indirect effects of plant architecture on epidemics are still lacking in many pathosystems, particularly those with highly explosive dynamics such as potato late blight. We therefore analysed simultaneously microclimatic sequences and late blight epidemic development in plots of two susceptible cultivars with contrasted foliage architecture.

Architecture affected wetness duration within the canopy in the absence of rainfall, but had no significant effect during rainy periods. Wetness duration within the canopy (consecutive to dew evaporation) was significantly longer, particularly towards the bottom parts of the canopy, in cv Bintje (with short internodes and large leaves) than in the more erect cv Monalisa. Epidemic development was significantly faster in Bintje than in Monalisa, suggesting that microclimate differences at the early stages of the epidemic could markedly modify subsequent disease spread. Interestingly, the defoliation of the plant by the pathogen at the later stages of the epidemic annihilated the differences in wetness duration recorded within the canopies.

These data show that host architecture can reduce or increase epidemic spread of late blight under conditions marginally favourable for the pathogen (dry spells where wetness comes exclusively from dew formation), and when inoculum pressure is still limited (early infections). These results suggest that architecture should be taken into account, together with partial resistance and sanitation measures, to design potato ideotypes able to cope with late blight attacks with minimal pesticide applications.

Key words:
Solanum tuberosum, *Phytophthora infestans*, Wetness duration, Epidemic development

SPATIAL HETEROGENEITY OF PEACH RUST IN THE CANOPY OF PEACH TREES.

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Peach rust, caused by *Tranzschelia discolor* (Fuckel) Tranzschel & Litvinov, is the most important foliar disease of peach and has caused severe damage in the different regions of Brazil (Alves et al. 2008, Alves et al., 2011). The epidemiology of this disease has not been subject of several studies, especially considering aspects related to spatio-temporal progress in peach tree canopies. This information in association of the knowledge of the survival and dispersion of the pathogen could improve the management recommendations. The aim of this study was to characterize onset and the temporal progress of peach rust at different positions of stems in the canopy of an orchard with Y central leader training system in subtropical region of Brazil. Incidence and severity of the disease were assessed each 15 days from end of spring to middle autumn in two consecutive cycles (2007/2008 and 2008/2009). The spatial development of the disease in the peach canopy was quantified in stems located at the lower, middle and higher position tree in two orchards, with and without use of fungicides. Evaluations were performed in competition experiments of 11 cultivars and the data analyzed by linear mixed-models, considering the height of the stem as fixed effects, cultivars and blocks as random effects. The incidence and severity reached respectively 80 and 1.5% in orchard with fungicides and 100 and 15% in orchards without fungicides. The area under the disease severity curve was higher in the upper stems comparing to lower but not always in relation to the stems located in the middle of the canopy. The initial inoculum for incidence and severity had the same behavior; however there were no differences between the rates of progress disease estimated by logistic and exponential models for incidence and severity, respectively. It was observed that from the second year of assessment the pathogen was surviving on stems and, the urediniospores of *T. discolor*, monitored inside and outside the experimental area, were detected primarily in the orchard, from late winter to early spring, indicating that auto-infection was prevalent in these experimental conditions.

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Keywords:
Tranzschelia discolor, Peach, Spatio-temporal progress.

SESSION 3

CANOPY ARCHITECTURE, CROP PHYSIOLOGY AND DISEASE IMPACT ON YIELD

MODIFIED PLANT ARCHITECTURE TO ENHANCE CROP DISEASE CONTROL VIA REDUCED CONTACT WITH SOIL BORNE PATHOGENS POSSIBLE VALUE OF UPRIGHT FRUIT POSITION IN CUCUMBER.

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In the absence of genetic sources of resistance, plant architectural features can facilitate disease control by creating an unfavorable environment for pathogen growth or limiting pathogen contact with the host. For soil borne pathogens, microclimate under the canopy and access of the pathogen to the susceptible plant organs can both be influenced by architectural structure. Traits such as reduced branching, tillering, or leaf surface area, or altered leaf angle can allow for more open canopies. Taller plants, upright growth habit, alternate leaf, flower, or fruit orientation can be used to reduce contact with the pathogen. In the case of infection of cucumber (*Cucumis sativus*) by the oomycete pathogen, *Phytopthora capsici*, the fruit, which typically lie in contact with the soil under the warm and moist conditions of a full leaf canopy, are in an ideal location for exposure to inoculum and disease development. We have shown that trellising, which modifies canopy microclimate and lifts fruit off the ground, can reduce disease occurrence. However, this labor intensive practice is not practical in many production systems. In contrast, increased row spacing and various architectures such as shorter vines, reduced branching, or smaller leaves that allowed for more open canopies and lower canopy temperatures, did not reduce infection rates. Screening of cucumber germplasm for alternate architecture traits identified an accession with short internodes and resulting upright fruit growth habit exhibited reduced disease occurrence in the field. Fruit of this accession were susceptible when directly inoculated with *P. capsici*, indicating that the reduced infection likely resulted from reduced contact with the soil. The upright trait is most pronounced when the fruit are smallest, which is also when they are most highly susceptible to infection by *P. capsici* (Ando et al., 2009). As they mature they develop an age-related resistance, indicating that it is most important to protect the fruit at the earliest stages of development. The upright fruit trait is controlled by a single recessive gene, compact (*cp*), however, like many architectural traits, it is also associated with pleiotropic effects, in this case, reduced soil emergence. Our studies indicate that the *cp* gene also interferes with normal apical hook formation in germinating seedlings, suggesting a possible hormone or developmental mutation regulating cell division or enlargement. Recent qTL analyses (Li et al., 2011) have localized the *cp* gene to a narrow region on the long arm of cucumber chromosome 4. Current efforts are examining expression levels of candidate genes in wild type and *cp* lines.

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Keywords

Phytopthora capsici, *Cucumis sativus*, Compact architecture, Fruit position, Apical hook

CROP ARCHITECTURE AND CROP TOLERANCE TO BIOTIC STRESSES. MECHANISMS TO LIMIT CROP LOSSES.

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Plant tolerance to biotic stresses (limited here to insects and diseases) is the ability of a plant to maintain performance, growth or a high quality characteristic in the presence of expressed disease. Tolerance is sometimes defined as a set of heritable traits and the determinants of its variability within a species may be considered as a means with which to control pests and diseases. Tolerance differs from resistance (the capacity of plants to eliminate or limit pests by genetic and molecular mechanisms) and avoidance (the ability of plants to reduce exposition of functional organs to pests and diseases) which both serve to reduce the incidence or severity of attacks. It is anticipated that tolerance will complement, rather than replace, resistance and avoidance traits.
Sources of tolerance to pests and diseases are multiple and express at scales from organ to population. For example, despite carbon assimilation being decreased by some fungi, photosynthesis of the green parts of an infected leaf may increase: the pathogen diverts assimilates and limits their negative feedback on photosynthesis. Similarly, when roots are attacked by soil pathogens the remaining healthy parts may increase their nitrate uptake per unit root surface, from a given level of severity.
Variations in canopy architecture and crop development may also be sources of tolerance. The contribution of organs to the capture and use of resources (light, nutrients etc) depends on canopy and root architecture so the respective locations of disease and plant organs within the canopy will have a strong effect on disease severity. Similarly, tolerance is increased when the period of crop sensitivity lies outside the period within which the pest is present. Candidate traits determining tolerance will differ between pathosystems, depending on the extent to which pests and diseases constrain yield through crop dry matter source or sink components. Improved disease management would be supported by a better knowledge of host x pest interactions at the crop level.
Finally, the ability of the plant to compensate for the reduced acquisition of resources by the production of new organs or by remobilization of reserves (sugars and nitrogenous compounds) may also mitigate biotic stress effects through increased tolerance. Numerous examples exist in the literature and are described in this article.
Quantification of tolerance remains difficult because of (i) the large number of mechanisms involved that stand within the canopy in a large range of resources levels (ii) different rates in the development of plants and pests (iii) various compensatory mechanisms such as recycling or organogenesis. Modeling is therefore a valuable tool to quantify losses that result from an attack, but also to prioritize the processes involved. An inventory of tolerance traits and the ways to manage them may lead to a better understanding of the behavior of plant varieties towards an attack. It may promote the use of overall tolerance through an optimal combination of these traits with complementary resistance and avoidance traits.

Keywords :
Tolerance, Damages, Modelling

ALTERED PLANT CANOPY ARCHITECTURE OF SAFED MUSCLI (*CHLOROPHYTUM BORIVILIANUM*) ON DISEASE SEVERITY, GROWTH AND YIELD UNDER FIELD CONDITION.

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Safed musli (*Chlorophytum borivilianum*) is an important medicinal plant of family Liliaceae. Its demand is increasing in India and annual requirement of it is 300-500 tons for its nutritive tonic and aphrodisiac value (Kothari, 2004). The plant is very much susceptible to rhizome rot caused by *Pythium aphanidermatum* due to moist and warm condition prevailed within the soil. The application of fungicide in soil to control this disease is very much cost effective and detrimental to soil health. An experiment was conducted at University Instructional Farm, Kalyani, West Bengal located at approximately 22° 39' N latitude, 89° E longitude and 9.75 meter altitude, during 2008-09 and 2009-10 to examine whether variations in plant architecture through different planting methods can influence the canopy structure to make condition less conducive for disease development and more favourable for rhizome yield. The four different planting methods viz. ridge and furrow, double row raised bed, triple row raised bed and quadrate row raised bed were used to study canopy growth, disease severity and rhizome yield of Safed musli. The results showed that in double row raised bed method the growth of the plant, rhizome yield and yield attributing characters were increased (20.14 leaves/clump, 470.80cm^2 leaf area / clump and 2.85 tons / ha root yield, 11.90 roots/ clump, 25.10g root weight / clump) significantly than other planting methods. The disease severity was also low (10.15% rhizome rot) in comparison with other planting methods (30.25% in ridge and furrow method, 25.15% in triple row raised bed and 20.15% in quadrate row raised bed).

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Kothari,S.K.(2004). Safed musli (*Chlorophytum borivilianum*) revisited. *Journal of Medicinal and Aromatic plant Sciences*. 26: 60-3.

Keywords:
Safed musli, *Chlorophytum borivilianum*, Disease severity, Crop canopy

SESSION 4

INTEGRATIVE MODELLING

DISEASE DISTRIBUTION IN COMPLEX THREE DIMENSIONAL CANOPIES.

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Analysis of spatial patterns of disease and of the genetic structure of pathogen populations can shed light on important epidemiological processes in plant pathosystems. Most such work has been conducted at the field scale, with limited data available at the canopy level. Here, we report on the spatio-temporal dynamics of brown rot disease and the fine-scale population structure of its causal agent, *Monilinia fructicola*, in individual, intensively mapped peach tree canopies.

Across 3 years, a total of 12 trees was monitored for brown rot development throughout the season, tagging each individual symptom (blossom blight, green fruit rot, preharvest fruit rot, and twig cankers) and mapping it in three dimensions using a magnetic digitizer (1). In addition, *M. fructicola* was isolated from each of the mapped symptoms. To characterize disease aggregation within canopies, nearest-neighbor distances among symptomatic fruit were calculated and compared with simulations where symptomatic fruit were assigned randomly to the positions of all fruit mapped within each tree. A total of 718 single-conidial isolates representing all isolates obtained from a subset of six trees was evaluated with 20 polymorphic SSR markers developed previously, calculating haploid diversity and spatial autocorrelation among genetic distances of isolates within each canopy (2).

The twelve test trees had between 126 and 739 fruit total, with a final preharvest fruit rot incidence of 12.3 to 78.2%. Median nearest-neighbor distances among all fruit ranged from 4.4 to 14.7 cm. The index of disease aggregation was negatively correlated with disease incidence ($r = -0.756$, $P < 0.0001$), i.e., the lower the disease incidence, the greater the degree of aggregation of affected fruit. Thus far, one tree has been analyzed completely for fine-scale genetic structure of *M. fructicola*. In this tree, haploid diversity for early-season blossom blight isolates was higher than for isolates from mid-season green fruit rot and late-season preharvest fruit rot epidemics ($h = 0.522$, 0.355, 0.393, respectively). No spatial genetic structure was detected for early- or mid-season periods, whereas significant autocorrelation among genetic distances was observed at spatial distances up to 1.5 m during the preharvest interval.

The system presented here for monitoring, mapping, and analyzing phenotypic (disease aggregation) and genotypic (fine-scale genetic structure) three-dimensional patterns will be applicable to a wide range of studies in canopy ecology. Our results on aggregation patterns of brown rot in three dimensional canopies are consistent with epidemiological theory developed for two dimensions (field scale). Spatial genetic autocorrelation among isolates within canopies indicates the increasing importance of localized within-tree inoculum sources as the season progresses.

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Keywords

Spatial analysis, Population genetics, Epidemiology, Canopy ecology

DESIGN STEPS OF A GENERIC MODEL TO SIMULATE AIR BORNE DISEASES AS A FUNCTION OF CROP ARCHITECTURE PROJECT.

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In a context of reduced use of pesticides, alternatives to a chemical-based crop protection are interesting to lessen the severity of epidemics. In this sense, the crop and the plant architecture could be considered as levers to control the disease outbreak by affecting local climate or pathogen transmission.
It is hypothesised that modelling and simulation could play an important role to help grasping the functioning of such systems where direct observation is non-trivial. Such modelling should gather concepts from ecophysiology and epidemiology to define structures and functions that describe a wide range of disease epidemics.
The canopy architecture, a complex and dynamic structure which mediates the external environment is a key object involved in modelling host-pathogens systems.
The representation of this object can range from a detailed level, where organs, their geometry and topology are explicitly represented (3D virtual plants) to a broader level, where the canopy is discretised into homogeneous elements of variable scale (phytomers, plant, population). Choosing a point of view depends not only on the knowledge of underlying physiological processes but also on the purpose of the model (e.g understanding, integrating, teaching, ...).
This work highlights the design steps and mathematical formalisms chosen during the development of an epidemiological model integrating structural canopy effects in various crop-pathogen systems. This model was developed during the Archidemio ANR project and its design was based on a summary representation of canopy architecture that suited for 4 diverse crop-pathogen systems: pea - aschochyta blight, yam - anthracnose, vine - powdery mildew, potato - late blight. Additionally, for the model to be used as a research and teaching tool to promote discussions about epidemic management in cropping systems, the design should minimise computing time by both limiting the complexity and setting an efficient software implementation.
The point of view adopted in this case is then compared to more detailed approaches and discussed on the basis of different design criterion: the depth of architectural details, the model finality, the ease of model parameterization and numeric exploration and the model adaptability to represent new pathosystems.

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Keywords:
Epidemiology, Modelling, Canopy architecture.

IDEOTYPE CONSTRUCTION FROM AN ARCHITECTURAL MODEL OF PEA.

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There is an increasing need for growing legume species in Europe in order to reduce dependency on imported vegetable proteins. Currently, pea (*Pisum sativum*) is the principle source of vegetable proteins. However, the productivity rate of pea crop is still under its potential mainly due to fungal foliar diseases. The most damaging ones are caused by *Ascochyta pisi, Mycosphaerella pinodes and Phoma medicaginis*.
Dynamics of such diseases have been shown to depend on plant architecture *e.g.* Leaf Area Index (LAI), plant height, internode length (Le May *et al.*, 2009). Virtual models of canopy architecture therefore appear as suitable tools for studying and modelling plant–pathogen interactions and diseases dispersal.
We have developed a 3D architectural model of pea growth based on the L-system formalism and developed on the L-Py platform (Boudon *et al.*, 2010). Initial parameters were based on data from a field-grown crop of winter pea *cv* Lucy. The above ground architecture is represented as a succession of phytomers emitted by main stems and branches. Phytomers are considered as a collection of organs encoded as modules that support their state *i.e.* age, length, topology and geometry. The rate of phytomer emission was set for main stems and branches. The number of branches and their time of emergence are attributes of each node of stems.
Coupled with epidemiologic models, this simulator can be used as a conceptual framework for studying the effects of pea architectural parameters on disease development and dispersal. Indeed, the present model is able to build contrasted canopies of ideotypes with regard to LAI and its spatial distribution (plant density, phytomer number, branching ability, axis orientation, leaf growth), plant height (internode growth), foliage orientation (leaf geometry) and dynamics of growth (rate of phytomers and branch emission, organ growth kinetics). Moreover, the formalism chosen in the present study also allows to assess the benefits of intercropping systems, comprising pea-wheat mixtures, towards disease pressure such as the wheat/*Septoria tritici* pathosystem (Robert *et al.*, 2008).

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Keywords:
Architectural model, Ideotype, L-System, LPy, *Pisum sativum*

USING A COUPLED DISEASE CROP MODEL TO QUANTIFY INDIRECT EFFECT OF CLIMATE CHANGE ON DISEASE DEVELOPMENT.

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Climate change influences the development of crop diseases through direct effects on the pathogens but also indirect effects via the host plant (Chakraborty and Newton, 2011). A simulation model of development of crop diseases coupled with a process-based crop model is an interesting tool to take into account the relationship between both plant and pathogen development and to quantify the direct and indirect effects of climate change on crop diseases. We propose to study the impacts of climate change on two important pathosystems: the brown rust of durum wheat and the downy mildew of grapevine by coupling a generic model of development of aerial crop diseases, MDMA, to a generic crop model, STICS.
MDMA simulates successive epidemiological cycles at the crop level with a daily time step. For each module, corresponding to the simulated epidemiological processes, several responses functions are proposed that correspond to the different pathogenic responses to climate, microclimate inside the crop canopy, plant growth and development and plant trophic status variables (Caubel et al., 2012 submitted). The coupled disease-crop model MDMA-STICS was adapted and accurately calibrated (on disease severity) for the two pathosystems according to literature, available observed severity data on various place and year in France and using the durum wheat and grapevine versions of the STICS crop model. The climate change impacts were studied for three representative location (Bordeaux, Avignon and Dijon), with climatic data from the ARPEGE general circulation model (climatic scenario A1B) and downscaled with the Quantil-Quantil method (Brisson and Levrault, 2010). The temporal evolution of some variables of interest were analyzed and statistically compared between the 1970-2000, the 2020-2050 and the 2070-2100 periods.
According to the hypothesis on climate change, on plant and disease development, we may expect the following results. “Brown rust” severity is expected to increase, mainly due to rising temperatures favorable to shorter epidemiological cycles (shorter latency period) and higher spore production by lesions. Additionally, the rise in atmospheric CO_2 concentration will increase the plant radiation use efficiency; consequently wheat foliar surface in winter will increase in the future. This will result in a higher spore deposit, the deposit in MDMA being dependent on the available surface of the target organ. “Downy mildew” severity is expected to decrease because of lower rainfall affecting the infection and spore production processes. However, whereas the grapevine bud break will be earlier in the future, the period of availability of the first infectious spores (after the maturation and germination process of the survival form) will remain unchanged in the future. This ensures a more frequent presence of a physical support for the first downy mildew infections. In conclusion, this study confirmed the value of the consideration of plant development and growth on the epidemic development.

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Keywords
Climate change, Disease development, Generic model, Impacts study, Wheat brown rust, Grapevine downy mildew.

EVALUATION OF HOST PARTIAL RESISTANCE EFFICACY TO A FOLIAR DISEASE USING A SIMULATION MODELLING APPROACH CASE OF MYCOSPHAERELLA LEAF SPOT DISEASES OF BANANA.

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Black leaf streak disease (BLSD) due to the ascomycete *Mycosphaerella fijiensis* is considered as the most destructive foliar disease of bananas. It has just invaded the French Indies banana production area. The current control strategy requires frequent aerial fungicide applications on intensive production plots because of the cultivation of high-yield but BLSD susceptible varieties. The use of resistant varieties appears as the most durable and appropriate control. As none commercial resistant varieties are available for producers, CIRAD has set up a banana breeding program to create BLSD resistant varieties.
As the evaluation of BLSD resistance efficacy of new hybrids created by CIRAD is both time- and space-consuming, a disease simulation model has been developed. It will allow to select resistant hybrids and to identify efficient resistance components.
The model SiBatoKa is a mechanistic and discrete simulation model of *Mycosphaerella* leaf spot diseases. It describes, at a banana plant scale, the establishment and development of BLSD epidemics under optimal climatic conditions during several banana cycles (two years).
It is built into two sub-models describing (i) the banana growth and (ii) the epidemics development. The banana-sub model simulating leaves growth is determinist. The disease-sub model simulates the complete infectious cycle including spore dispersal (at plant scale), the creation of lesions, their growth and the asexual and sexual sporulation stages.
Available data on lesions (counts and surface) and sporulation collected under natural and artificial were used to calibrate the model. Parameters of the disease-sub-model are estimated with a Bayesian approach using the MCMC (Markov Chain of Monte Carlo) technics. Then a posteriori distributions of all parameters and residual variance are obtained. The inference of parameters and the results from the first simulations will be presented and discussed.

Keywords:
Mycosphaerella sp., Banana, Foliar disease, Simulation model, Bayesian parameter estimation

SPATIAL VARIABILITY OF WETNESS DURATION WITHIN A TREE CROWN.

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Cryptogamic disease infection risk in fruit trees is strongly dependent on the climatic conditions in the orchard and on the microclimate within the tree. The Leaf Wetness Duration (LWD), *i.e.* the time that liquid water deposited on leaves takes to evaporate, is for many fungi species the significant parameter linking the epidemic risk to environment humidity. LWD results from two processes: water deposition (rain or dew) and water evaporation, and both are known to be strongly related to microclimate variables. Those include air and leaf temperature, relative humidity, irradiation and wind which are known to spatially change within a tree crown in relation to the tree foliage distribution (Sinoquet *et al.*, 2001). Several studies have shown spatial variability of LWD within a tree does exist, yet none of them was able to fully correlate such spatial variations with tree structure parameters (Batzer *et al.*, 2008). The work presented here proposes a novel approach to understand the origin of LWD spatial variability. Wetness Duration (WD) sensors were installed in apple trees in different spatial positions. These positions and the trees structures were digitized to make a 3D mock up. Knowing the position of sensor and foliage in a 3D space allows to compute the cover ratio of each sensor (Sinoquet & Rivet, 1997), which can be related to the radiation received and emitted by each sensor. Our study did not comprehend the values of air and sensor temperature and relative humidity. However, comparing the spatial variability of WD to cover ratio showed that WD was significantly correlated to the latter for dew events and for the evaporation part. Moreover, the use of virtual 3D plants enables the description of other mechanisms occurring in leaf wetness duration, such as the amount of water distribution in the tree crown function of the cover ratio, and enables to compare tree structures related to their ability to enhance or decrease LWD.

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Keywords:
Leaf Wetness Duration, Apple Scab, Digitized Plant, Microclimate, Spatial Variability.

SHORT POSTER PRESENTATIONS

THE ARCHITECTURE OF WEED PLANTS DOES NOT INFLUENCE *COLLETOTRICHUM ACUTATUM* SURVIVAL.

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Post bloom fruit drop, caused by *Colletotrichum acutatum*, is an important citrus disease in Brazil. The symptoms are restricted to citrus flowers where the pathogen causes orange to brown necrotic lesions. After flowering, fruitlets abscise at the base of the ovary, leaving the calyx and peduncle attached to the tree branches. The pathogen survival between two blooming and its introduction in a new orange grove have not yet been determined. It has been demonstrated that *C. acutatum* can survive as an epiphyte over citrus leaves for one month, but no information is available for longer periods (Zulfiqar et al., 1996). Weeds can be sources of inoculum for anthracnose on tomato, caused by *Colletotrichum coccodes* (Raid & Pennypacker, 1987), and for anthracnose on strawberry, caused by *Colletotrichum acutatum* (Freeman et al., 1991). The objective of this work was to verify if different species of weeds, with different canopy architecture can act as sources of inoculum of *C. acutatum*, the causal agent of post bloom fruit drop. Leaves of seven weed species commonly found in citrus orchards – *Brachiaria decumbens*, *Brachiaria plantaginea*, *Bidens pilosa*, *Cenchrus echinatus*, *Commelina benghalensis*, *Digitaria insularis*, and *Panicum maximum* – were inoculated with a conidial suspension (10^5 conidia mL^{-1}) of an isolate of *C. acutatum* which causes citrus post bloom fruit drop. After inoculation the weeds were incubated in a humid chamber for 36 hours. By the end of the humid chamber period, samples of all weeds were collected and observed in optical microscope to verify the conidial germination and appressoria formation. Isolations of *C. acutatum* from inoculated leaves were performed one, two, and three months after inoculation. At the end of the experiment, all isolates were inoculated on citrus flowers to verify their pathogenicity. Conidial germination and appressoria formation were observed in all inoculated weeds. No symptom was observed on weeds inoculated leaves and the pathogen survived in all weeds for at least two months. All isolates caused lesions on citrus petals. The architecture of the weeds did not influence the survival period of *C. acutatum*.

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Keywords:
Alternative host, Survival

ECHAP PROJECT TO REDUCE FUNGICIDE USE BY ASSOCIATING OPTIMAL TREATMENT STRATEGIES AND CANOPIES PROMOTING DISEASE ESCAPE.

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This poster presents ECHAP project objectives and methods. The ECHAP project is part of the « Evaluation et réduction des risques liés à l'utilisation des pesticides » program of Ministère de l'Ecologie et du Développement Durable.
Canopy architecture may influence crop disease epidemics by inducing disease escape. Architecture also influences pesticide interception and hence the efficiency and fate of the applied fungicide. The project aims to evaluate the scope for fungicide reduction by optimising crop architecture via promoting disease escape and fungicide interception. The project also addresses the question of the evaluation of the fungicide strategies. Currently, strategies are mainly evaluated for their effects on epidemic and yield. We propose to develop a multicriteria evaluation including epidemics control, yield gain, environmental impact (fungicide losses in the different compartments) and fungicide lifespan decrease due to pathogen resistance. To evaluate the scope for fungicide reduction on canopies that induce disease escape and that increase fungicide interception two lines of research are developed. (A) The methodological objective of the project is to develop modelling tools for multicriteria evaluation of fungicide treatments for varied crop architectures. A simulation model integrating plant/fungicide/pathogen interactions is being developed on the OpenAlea platform. The model will simulate the consequences of fungicide strategies by taking into account crop canopy effects. The three submodels are (i) the effect of architecture on epidemics (the Septo3D model), (ii) the interception and persistence of fungicide on the leaf, and (iii) the effect of fungicides on the infection cycle. The project will be developed on the "wheat – septoria tritici" pathosystem, but the approach could be applied to a range of pathosystems. (B) We also aim to test the feasibility of fungicide reduction in the field. For this a field experiment will be repeated 3 years in Boigneville (France) with crossed treatments of varied architectures x fungicide strategies (date, quantity and mode). Innovative wheat lines from the John Innes Centre (UK) and INRA Clermont Ferrand are used. Canopy architecture, microclimate, epidemics, fungicide interception, pathogen resistance and yield are assessed in the experiment. The complementarity of partners makes it possible to address and integrate the numerous facets of the addressed question.

Keywords:
Architecture, Fungicide, *Septoria tritici*, Interception, Resistance, Evaluation.

IMPACT OF ALTERATION IN PLANT CANOPY ARCHITECTURE ON DISEASE INCIDENCE, GROWTH, AND YIELD OF SARPAGANDHA (*RAUVOLFIA SERPENTINE*).

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Sarpagandha (*Rauvolfia serpentina*) is an important medicinal plant of family Apocynaceae. It is used in the treatment of conditions like hypertension, nervousness and insomnia. Sarpagandha suffers from many aerial diseases of which target leaf spot caused by *Corynespora cassicola* is most important and causing 30- 40% losses in yield (Elvera, 2010). Application of fungicides for the management of this disease is not recommended due to residual toxicity of fungicides which in turn causes toxic hazards to human being. An experiment was conducted during 2008-09 and 2009-10 at University Instructional Farm, Kalyani, West Bengal located close to tropic of cancer at $22^{0}39^{/}$N latitude,89^{0}E longitude and 9.75m altitude, to study the variations in plant architecture through management of different plant spacing that influence canopy structure to make condition less disease development and more root yield which is used for medicinal purpose. Five plant spacings viz. 30 x 30 cm, 30 x 45 cm, 45 x 30 cm and 45 x 45 cm were used to study disease incidence, growth and yield of Sarpagandha. In the above plant spacing, the plant population was maintained as 1.10, 0.74, 0.74 and 0.5 lakh ha^{-1}.The results revealed that significantly maximum plant height (43.25 cm), Yield in fresh wt. of plant (524.19 g / sq.m), Yield in dry wt. of plant (141.41 g / sq.m), Yield in fresh wt. of root (54.38 g / sq.m) and Yield in dry wt. of root (11.46 g / sq.m) were recorded when plant canopy was increased remarkably by increasing the plant spacing to 45 x 30 cm than other plant spacing. However, minimum disease incidence was recorded (11.79%) when plant canopy was increased maximum with the increase of plant spacing (45 x 45 cm). The results thus conclude that, alteration in plant canopy structure by increasing the plant spacing not only increases the growth and yield but also reduces the disease incidence, which was recorded minimum with the increase in plant canopy by changing the microclimate in the plant canopy.

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Keywords:
Sarpagandha, *Corynespora cassicola*, Disease incidence, Plant canopy

REDUCTION OF INCIDENCE OF BUD NECROSIS VIRUS DISEASE AND INCREASE OF YIELD OF GROUNDNUT CROP THROUGH MANIPULATION OF CANOPY GROWTH.

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Peanut Bud Necrosis Virus disease (BND) is the most threatening viral disease of peanut (groundnut) in India. India is the largest producer of groundnut in the world (32% of world production). There has been appreciable increase in the area (68.5%) and production (163%) of the crop between 1950-51 and 1998-1999 (www.preservearticles.com). The BND can cause severe yield reductions resulting in large monitory losses for farmers (Tillman et al. 2006). The infection is associated with migrant thrips and secondary spread is unimportant (Nirmal & Mali 1988). Application of dimethoate during thrips migration can substantially reduce the disease. But insecticides are generally not effective in reducing the BND incidence unless continuously applied throughout the growing period. Continuous application of insecticides results in environmental pollution, for this reason the present study was conducted to reduce the incidence and increase the yield by modifying crop canopy structure. The experiment was laid out in the University farm of Bidhan Chandra Krishi Viswavidyalaya, West Bengal, India, located close to tropic of cancer at $22^{0}39^{/}$N latitude,89^{0}E longitude and 9.75m altitude, during the year of 2010 and 2011. The experimental design was RBD with eight treatments. The treatments consisted of different plant to plant and row to row spacing. Significantly, lowest BND incidence (12.4%) and highest yield (1.85 q/ha) was recorded at 30cm x 5cm spacing. From the above findings, it may be concluded that, cultural management through manipulation of seedling density is the important factor for managing BND. Incidence of BND was decreased as plant density was increased. Yield was significantly increased, when plant density and crop canopy was increased. Increased rate of canopy growth in groundnut due to higher plant density may affect the ability of thrips to locate the host.

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Keywords:
Peanut, Bud necrosis disease, Plant density, Yield.

CULTIVAR AND SPECIES MIXTURE EFFECT ON WHEAT SEPTORIA TRITICI BLOTCH SPREADING.

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Within the framework of pesticide reduction policy, it is necessary to find alternative practices to control wheat diseases. For air-borne diseases such as rusts and powdery mildew, cultivar and species mixtures can reduce severity by 40 to 80% compared to the mean of the pure stands. However, for rain-borne diseases such as septoria tritici blotch (STB), caused by the pathogenic fungus *Mycosphaerella graminicola*, severity may be reduced by only 6 to 27% (de Vallavieille-Pope, 2004). The benefits of cultivar and species mixtures (such as disease management and agronomic performance) rely on combinations of disease pressure, cultural practices (*e.g.* fertilization), and mixture proportions. The main factors involved in the reduction of disease severity in mixtures are the proportion of susceptible/resistant host leading to the genetic barrier effect, and the induced resistance (Finckh *et al.*, 2000). In the case of foliar fungal disease dispersed by rain splash, a physical barrier to the transfer of splash droplets carrying the spores also contributes to the reduction of the disease severity (Saint-Jean *et al.*, 2008). Thus, in order to control STB epidemics, it is necessary to study the fungus dispersal within mixtures. For the particular case of species mixtures such as cereals/legumes there are nitrogen exchanges between the two components, which leads us to investigate the effects of the nitrogen quantity and origin on the STB development.
An experiment was set up at Grignon for several years. Different proportions of a susceptible and a resistant wheat cultivars were tested. Mixtures with the susceptible wheat cultivar and pea were also tested. Two levels of nitrogen supply were applied on each mixture. Diseased surfaces, emergence of necrotic surface, were assessed weekly. Meteorological and spore fluxes were also assessed during the epidemic seasons. Depending on the disease pressure and the direct and indirect nitrogen supply, our findings show that the emergence of leaf necrotic (diseased) surfaces can be reduced by 60% in cultivar mixtures compared to the pure stands.

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Keywords:
Cultivar mixture, Splash dispersal, *Mycosphaerella graminicola*, *Septoria tritici* blotch, Canopy architecture, Nitrogen supply.

STUDY OF A POTATO DIHAPLOID MAPPING POPULATION TO INVESTIGATE THE RELATIONSHIPS BETWEEN LATE BLIGHT RESISTANCE GENES AND PLANT ARCHITECTURAL GENES.

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Plant architecture and plant dynamics of growth are important factors affecting pathogen development in the case of aerial diseases. Concerning potato, several studies showed that plant or canopy architecture had strong effects on the development of foliar late blight disease. Indeed, levels of partial resistance are significantly and positively correlated with plant maturity. This association results from the colocalization of resistance and lateness QTLs (Visker *et al*, 2005). The understanding of the relationship between partial resistance and plant growth is therefore an important issue to orientate the construction of resistant ideotypes. The UMR IGEPP team is involved in a project named ARCHIDEMIO, funded by ANR Systerra, which aims at identifying the relative part of intrinsic resistance, architectural traits and growth characteristics in the late blight partial resistance in order to combine genetic resistance components with favorable architectural alleles in new cultivars.
A dihaploid population including 251 genotypes was obtained by crossing a tetraploid late blight resistant genotype 92T.118.5 with the parthenogenesis inductor *S. phureja* IVP48. The resistant parent combines monogenic and partial resistance. The evaluation of the progeny for late blight resistance in field conditions and for different architectural traits (plant height, leaf number, foliage coverage, length/width ratio of the leaflets, leaflet number, stem number) showed that these traits are strongly segregating in the population. Correlations between phenotypic traits were calculated and phenotypic variability was estimated in the population and proved to be high for almost all studied traits. This population is thus appropriate to determine, among the genetic components that are involved in late blight resistance, those which result from intrinsic resistance only and those which cosegregate with maturity and/or plant architectural traits.
A genetic map of the tetraploid resistant parent is currently under construction using SSR markers. A set of 287 markers, evenly distributed in the potato genome, was tested in order to select the markers that show more than 2 different alleles in the tetraploid parent and that segregate in the dihaploid population. The poster will present results from analysis performed on the phenotypic traits and from the development of the genetic map.

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Keywords:
Potato, Late blight, Plant canopy, Genetic resistance

ADJUSTMENT OF CULTURAL PRACTICES IN TOMATO TO MANAGE THE CANOPY FOR REDUCING TOMATO LEAF CURL VIRUSES IN INDIA.

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In India tomato is grown in 0.458 million hectare with 7.277 million tons production and 15.9 metric tons/hectare productivity (NCPAH). Tomato leaf curl virus (TLCV) is one of the major constraints which causes up to 100% yield losses (Friedmann et al. 1998). Farmers have to apply huge quantity of pesticides for controlling the insect White fly (*Bemisia tabacci*), which is the only vector to transmit the disease. Excessive use of pesticides results in environmental pollution as well as the reduction of quality of fruit. Therefore, present study was conducted to reduce the use of pesticides and also to minimize the disease severity and increase the fruit yield. The field trial was carried out during 2009 and 2010 at the University farm of Bidhan Chandra Krishi Viswavidyalaya, West Bengal State of India. The variety taken was Pusa Ruby which is susceptible to TLCV. The percent disease index was measured by adopting 0-9 scale (Friedmann et al. 1998). The design of the experiment was Randomized block design (RBD) with seven treatments. Treatments consisted of manipulation of plant to plant spacing along with standard row to row spacing (75cm) Significant lowest disease incidence (3.77%) was recorded at 50cm plant to plant spacing and it was statistically at par with 55cm(4.54%)& 60cm (4.23%). Significant highest yield was also recorded in 50 cm (253.31 q/ha), the yield was statistically at per with 55cm (242.06q/ha). The population of white fly vector was found to be lowest (2-6 white flies per five plants) in 50 cm and 60cm. Therefore, from the above findings it may be concluded that when the crop canopy is decreased by increasing the plant to plant spacing from 30cm to 50cm and 55cm there was significant decrease in severity of TLCV and also significant increase in yield of tomato fruit. Population of white fly was also significantly lower when higher plant spacing (50cm & 55cm) was adopted.

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Keywords:
Cultural practices, Tomato, Tomato leaf curl viruses

SESSION 5

GENETIC CONTROL OF ARCHITECTURAL TRAITS INVOLVED IN EPIDEMIC REDUCTION

GENETIC AND PHENOTYPIC CHARACTERIZATION OF PHYSIOLOGICAL RESISTANCE AND AVOIDANCE TO WHITE MOLD DISEASE IN COMMON BEAN.

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White mold disease caused by *Sclerotinia sclerotiorum* limits common bean (*Phaseolus vulgaris*) yield and quality across Europe, North America, and South America. Integrated disease control is necessary and includes host resistance and avoidance, cultural practices, and fungicide applications. Expression of physiological resistance and avoidance are confounded in the field making it difficult to discern the separate affect of each trait. Recent QTL studies have helped to distinguish mechanisms, as more than 40 QTL conditioning host response have been identified. These QTL, the relative importance of avoidance versus physiological resistance mechanisms, and effect these mechanisms have on yield and fungicide efficacy in common bean will be examined.

Keywords:
QTL, Genomics, Marker-assisted breeding, Dry bean, Snap bean

GENETIC VARIABILITY FOR ARCHITECTURAL TRAITS INVOLVED IN DISEASE PEST REDUCTION.

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Plant and canopy architecture involves the integration of topology, geometry and dynamic growth of the plant and canopy (1). Architectural traits of the plant and/or the canopy are believed to be partially efficient for controlling pathogen epidemics or pest infestations, either through creating a microclimate unfavorable to pathogen or pest development, the reduction of pathogen or pest dispersal efficiency, or through creating a plant or organ reduced receptivity (2). Plant and canopy architecture are determined by architectural structure of the plant species, intraspecific plasticity, which depends mainly on environmental conditions, and by intraspecific variability, which is mainly controlled by genetic effects (also interacting with environmental conditions) (3). The purpose of this review paper is to consider how the genetic control of architectural traits in plants is likely to open ways to the reduction of pathogen epidemics and/or pest infestations.

A number of genetically controlled architectural traits have been shown to be potentially involved in the control of pathogens or pests in various plant species. These include (i) architectural traits *stricto sensu* at the plant scale, such as leaf shape and area, branching, plant height, root diameter, number of adventitious roots (ii) developmental traits such as vegetative, blooming and maturity stages (iii) the dynamics of architecture development, the speed of growth patterns being a primary factor for the success of infection or infestation. Finally, a number of the former traits control the ageing of some organs or of the whole plant that can lead to differential receptivity to the pathogen or pest.

Variability for these traits and potential impact on reducing pathogen or pest development can be either identified or created using different strategies, including the screening of already existing cultivar or genetic resources collections, of segregating populations or mutant phenotypes for architectural traits. Conversely, allelic variability at known genes controlling architecture can be searched for at the sequence level within genetic resources (ecotilling) or mutant (tilling) collections in order to identify new phenotypes for this trait. In these processes, key issues are (i) the way architectural traits are phenotyped spatially (shape, height), temporally (timing of development) and at what scale (organ, plant, canopy) (ii) the potential genetic x environment effects on the trait.

The creation of new architectural ideotypes controlling pathogen epidemics or pest infestations raises a number of intriguing issues : (i) the potential use of architectural traits may depend on a balance between pathogen or pest reduction benefits and possible drawbacks on other agronomic characters (quality, yield). (ii) architectural traits can be complementary or redundant with partial resistance, tolerance and escape effects on epidemics or infestation (this may be specific to each patho or pests system). Frequent colocalisations between genetic factors controlling architectural traits and genetic factors controlling partial resistance can be due to linkage disequilibrium between genes in these genomic regions, or pleiotropic effects of a single gene on both architecture and partial resistance. (iii) using architectural traits as potential pathogen and pest control means raises the issue of pathogen or pest populations evolution to face this new challenge, and therefore questioning the durability of this new control mean.

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Keywords:
Plant variability ; Epidemics, Resistance, Escape, Colocalisations, Durability.

IDENTIFICATION OF PHYSIOLOGICAL TRAITS IN WHEAT CONFERRING PASSIVE RESISTANCE TO FUSARIUM HEAD BLIGHT.

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Fusarium head blight (FHB) is a devastating fungal disease of wheat and other cereals worldwide, caused by a complex of *Fusarium* and *Microdochium* species. Infection of the wheat head occurs during anthesis and leads to reductions of grain yield, grain quality and the increased production of harmful mycotoxins. Methods available for the control of FHB include crop rotations, deep cultivations and fungicide applications. Whilst these methods have been shown to partially control the disease, the development of cultivars with improved FHB resistance is considered the essential step towards reducing the impact of this disease and ensuring future food security. A number of FHB resistance genes have been identified within the wheat genome, however the potential contribution of passive resistance to disease control has generally been overlooked.

This study aims to identify and quantify canopy and ear traits in wheat conferring passive resistance to FHB through disease escape strategies. A field experiment was carried out in 2010/2011 using 5 UK winter wheat varieties and 10 doubled-haploid lines derived from a cross between a spring wheat advanced line of large-ear phenotype from CIMMYT, Mexico and the UK winter wheat variety, Rialto. All 15 wheat genotypes were ground inoculated using infected oat grains with a mixture of *Fusarium graminearum, F. culmorum, F. avenaceum, F. langsethiae, F. poae*, *Microdochium majus* and *M. nivale* at GS30. Canopy and ear traits of the wheat genotypes were assessed at GS39 and GS65. Visual disease symptoms were scored at regular intervals from mid-anthesis and used to calculate the area under the disease progress curve (AUDPC) for each wheat genotype. Mature grain from each wheat genotype was milled to fine flour which underwent DNA extraction and quantification of individual *Fusarium, Microdochium* species and Tri5 DNA using Real-Time PCR.

Five of the CIMMYT/Rialto lines had a similar AUDPC compared to the control lines, while the other five doubled haploid lines showed a significantly higher AUDPC to that of the controls. Overall, in descending order, the predominant species found at harvest were *F. poae*, *F. culmorum* and *F. langsethiae*. Multiple linear regression ($P<0.001$) accounted for 50% of the AUDPC variance and showed that Y (AUDPC) = 19.7 – 0.0814 x_1 (GS65 total plot fresh weight) – 0.2302 x_2 (GS65 Average ear height) + 1.605 x_3 (GS65 Flag leaf length) + 152.4 x_4 (*F. poae* DNA). Tri5 DNA, quantified in grain flour was positively correlated with AUDPC ($P=0.003$) and was significantly related to the individual DNA of *F. poae* and *F. langsethiae*.

Work is continuing on the simultaneous quantification of multiple Fusarium mycotoxins in wheat flour. This additional information will assist in building a more complete picture of the resistance of the experimental lines used in this study.

Keywords
Fusarium, Passive, Resistance.

STABILITY OF GENETIC FACTORS CONTROLLING ARCHITECTURAL TRAITS AND PARTIAL RESISTANCE LIKELY TO REDUCE ASCHYTA BLIGHT EPIDEMICS IN PEA.

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Mycosphaerella pinodes is the causal agent of ascochyta blight, one of the most damaging foliar diseases in pea. Only partial resistance to this pathogen is available and the underlying mechanisms of partial resistance are still unknown. Previous work has shown the effect of plant and canopy architectural traits on epidemics development, such as plant height and leaf area index (1). Moreover QTL mapping studies showed co-localizations between QTL of partial resistance and QTL controlling earliness (2, 3), plant height (3) and aerial biomass (2). Our main objective is to study the potential link between architectural traits and partial resistance genetic control.
A QTL analysis of several architectural traits (plant height, stipule size, number of branches and number of internodes) under controlled and field conditions was conducted in three recombinant inbred line populations previously used for QTL analysis of partial resistance to ascochyta blight. We also selected and mapped genes known to control earliness, ramification, plant height, senescence and foliar characteristics in pea.
We identified two common major genomic regions of co-localizations on linkage groups V and VI between QTL controlling partial resistance to *M. pinodes* and QTL involved in stipule size, that could correspond to the ones observed previously (2,3). We also identified three genomic regions of co-localizations between QTL controlling partial resistance and major genes controlling architectural traits: the first one on LGIII included the *Hr* locus controlling photoperiod sensitivity, the second one on the distal part of LGIII including the *Le* locus controlling plant height and the last one on LGVI carrying the *Ago1* locus associated with numerous traits, including stipule size. Depending on the segregation of architectural genes in these three populations, co-localizations were stable or not across them. Linkage between genes controlling partial resistance and architectural traits in regions showing co-localizations is currently tested to evaluate the potential complementary use of architectural and partial resistance genetic factors to control ascochyta blight epidemics.
Our results will contribute to provide new insights for the development of pea breeding strategies for ascochyta blight epidemics control, by using allelic variability at architectural genes.

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Keywords:
Mycosphaerelle pinodes, *Pisum sativum*, Plant architecture, Partial resistance, QTL, Co-localizations, Candidate gene

REACTION OF SUNFLOWER HYBRIDS TO NATURAL INFECTION OF THE MOST IMPORTANT SUNFLOWER PATHOGENS.

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The aim of the research was to evaluate the differences in tolerance of sunflower hybrids to diseases caused by pathogens *Sclerotinia sclerotiorum*, *Diaporthe helianthi* and *Phoma mcdonaldii*.
Resistance of 13 sunflower hybrids to fungal pathogens *S. sclerotiorum*, *D. helianthi*, *P. mcdonaldii* was studied at 4 localities in Slovakia during three years. At each locality there were evaluated the plants after flowering during July and August. Four localities from south-western Slovakia were selected for observations (Kalná nad Hronom /N 48°11´ E 18°30´/, Bučany /N 48°25´ E 17°42´/, Čakajovce /N 48°22´ E 18°02´/ and Macov /N 48°01´ E 17°25´/).
Over three years the number of plants infected by *S. sclerotiorum* varied depending on weather factors and the susceptibility or the tolerance of hybrids. The highest infection of plants was found on hybrids NK Brio, NK Kondi, Sambasol and the lowest on hybrids MH 3307, Nutrasol, Alexandra, Rumbasol Pikasol. The most tolerant sunflower hybrids to *D. helianthi* were MH 4316, NK Kondi, Pikasol, Rumbasol, and those the most susceptible were Aurasol, PR 63 A82, Nutrasol, respectively. The highest numbers of sunflower plants during three years of observation were infected by the pathogen *P. mcdonaldii*. Number of infected plants regularly exceeded 60% at localities Macov and Čakajovce. The most tolerant hybrids were Flexisol, Sambasol and the most susceptible hybrids were Arena PR and Pikasol.
It was found that the number of infected plants by all pathogens significantly depended on locality, year and sunflower hybrid. Plant height, head size, form and position of the head on the stem as important plant architecture features did not significantly influence the level of plant infection.
Based on the experiment it was concluded that the level of plant infection caused by important sunflower pathogens (*S. sclerotiorum, D. helianthi* and *P. mcdonaldii*) is influenced by sunflower hybrids and climate conditions.

Keywords :
Sunflower hybrids, *Sclerotinia sclerotiorum*, *Diaporthe helianthi*.

SESSION 6

INTEGRATED PEST-DISEASE MANAGEMENT USING CANOPY ARCHITECTURE

ADVANCES IN CONTROL METHODS BASED ON CANOPY MODIFICATIONS TO MANAGE PLANT DISEASES.

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There are several examples where modifying the plant canopy has been used to successfully manage plant diseases in vegetable and field crops. Recent research has established that trimming the carrot canopy can suppress sclerotinia rot of carrot (SRC, caused by *Sclerotinia sclerotiorum).* Lateral trimming of the canopy by 30- 40% just after the crop canopy closes can effectively reduce SRC to zero under moderate disease pressure, with no decrease in yield. Trimming reduces relative humidity, and increases air and soil temperature, within the carrot canopy, which inhibits the formation of apothecia on the sclerotia of *S. sclerotiorum* (1). Trimming also severs infected petioles, preventing the progression of infection to the carrot crown. When trimming was combined with applications of a fungicide (boscalid) or biofungicide (chitosan), trimming alone reduced SRC, but the combination of trimming and sprays was even more effective. Trimming also reduced carrot leaf blights (caused by *Alternaria dauci* and *Cercospora carotae)* in one of three years when disease pressure was low. There was no advantage of combining trimming and fungicide sprays for leaf blight control (2).
Canopy modification also plays a role in disease suppression in legume crops. In soybean, selection of varieties with reduced height, lodging and/or maturity resulted in up to a 74% reduction in apothecia of *S. sclerotiorum*, and up to an 88% reduction in incidence of white mold at harvest. As with carrots, this strategy is associated with reduced relative humidity and soil moisture within the crop, and has been a recommended practice in some areas for more than 20 years. Over the last 20 years, the field pea (*Pisum sativum*) crop in western Canada has switched from fully-leaved cultivars to leafless and semi-leafless cultivars. The result is reduced lodging and a more open canopy, which allows more air movement. This reduces the severity of foliar disease caused by *Mycosphaerella pinodes* (3) and others. Similarly in chickpea (*Cicer arietinum*), opening up the canopy using variations in seed row spacing increased deposition of fungicides within the canopy, reducing both the severity of ascochyta blight (*Ascochyta rabiei*) and the number of fungicide applications required to manage this important disease.
In conclusion, there are a number of different crops where canopy modification can be used to manage diseases without the use of additional fungicides, or where this approach sometimes improves the efficacy of crop protection materials.

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Keywords:
Carrots, Trimming, Sclerotinia, Soybean, Chickpea.

DEFINING AND DESIGNING ARCHITECTURAL IDEAOTYPES TO CONTROL EPIDEMICS?

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Ideotypes are a popular concept for plant breeders, who designate as such the ideal combinations of traits in a particular genotype. This historical, genetic view of ideotypes can (and has) been more recently extended to cover the design of plant genotypes for specific cropping systems (the 'agronomic' view), or even the ideal combination of parameters, identified from simulation modeling, to a specific agronomic problem (the 'mathematical' view).
Designing an ideotype requires first to precisely bind the purpose the ideotype is supposed to meet. This imposes not only the definition of the agronomic problem itself, the action possibilities available (genetic variability in the plant, human interventions during crop husbandry, etc…), but also of the production system considered. Whether ideotypes should remain virtual objects (i.e., cultivar blueprints) or can be real varieties is still an open debate.
The different forms of ideotypes in turn induce different strategies for breeding plants. This paper will therefore briefly describe, analyse and discuss the application of these modes of ideotype conception and design in the specific case of architectural traits of plant and plant canopies to limit the epidemic development of pests and diseases in crops.

Keywords:
Ideotype, Model

IMPACT OF CLUSTER ZONE LEAF REMOVAL ON GRAPE (VITIS VINIFERA) BUNCH ROT (BOTRYTIS CINEREA).

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Grey mould or bunch rot caused by *Botrytis cinerea* is able to reduce grape yield as well as quality. Leaf removal in the cluster-zone has proved to be an efficient option to reduce grey mould infestation on grape clusters under different climatic conditions. However, in practical viticulture the timing of leaf removal varies. Hence, the aim of the present work was to determine the optimal timing of this crop cultural measure. Field trials were conducted in the years 2009 and 2010 in Remich/Luxembourg in the white varieties Sauvignon blanc (2009), Auxerrois (2009), Pinot gris (2010) and Riesling (2010). Manual leaf removal in the cluster-zone was carried out on the northeast exposed side of the canopy at six different time points between pre-bloom (BBCH 57) and veraison (BBCH 81). Leaf removal conducted between early bloom (BBCH 63) and beginning of berries touching (BBCH 71) consistently led to a better grape sun and wind exposure (point quadrat analysis) as well as to reduced cluster compactness (density index). Consequently, the speed of the bunch rot epidemic was reduced and the final disease severity of *B. cinerea* clearly decreased. Pre-bloom and late (at veraison) leaf removal turned out to be less efficient. In conclusion, leaf removal between early bloom and berries touching proved to be a valuable tool to control bunch rot due to (i) the improved microclimatic conditions related to better sun and wind exposure in the cluster zone and (ii) the disaggregation of the cluster structure. The period in which leaf removal provided a significant reduction of the bunch rot infestation on a consistent efficacy level was relatively long (around 30 days). Cluster-zone leaf removal can be recommended as a sustainable tool in integrated as well as organic viticulture providing excellent options to maximize wine quality in two ways; (i) in terms of a reduction of fungal contamination of the crop and/or (ii) an improvement of grape maturity through a potential prolongation of the ripening period without any input of chemical substances into the environment.

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Keywords:
Leaf removal, Grapevine, *Vitis vinifera*, Cluster structure, Bunch rot, *Botrytis cinerea*.

MANAGEMENT OF CANOPY STRUCTURE TO REDUCE THE SEVERITY OF ANTHRACNOSE DISEASE OF GRAPES UNDER INDIAN CONDITIONS.

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Anthracnose caused by *Elsinoe ampelina* (de Bary) Shear, is one of the important foliar diseases of grapes (*Vitis vinifera L.*) in India. Gupta et al (1981) reported that, 50% yield losses were resulted, when all the aerial plant parts including inflorescence and berries were attacked by the pathogen. In West Bengal, Pusa Navrang cultivar is heavily infested in every season due to its dense canopy, tight berry cluster and harboured on Bower system. Present trial was conducted through effective canopy management practices during 2011 and 2012 to reduce the injudicious use of pesticides and also to minimize the yield losses due to Anthracnose. A susceptible cultivar, Pusa Navrang was selected in a 10 years old vine at University farm of BCKV, West Bengal, India, The disease severity was measured following 0-5 scale scoring system (Nargund et al, 2007). The replicated plots were established in split plot design. Treatments consisted of leaf removal, shoot tip removal and untreated control. Leaf removal at cluster zone showed significant reduction in disease incidence (13.5%) and severity (1.9%) as compared to control. Shoot tip removal not only showed significant increase in lateral shoot development but also reduced the incidence (20.85%) and severity (8.91%). Yield components i.e, Berry weight(g), Number of berries per cluster, Cluster weight(g) and yield (Kg/vine) showed significant responses due to canopy management. The berry weight was remarkably increased in leaf removal and shoot tip removal treatment. Number of berries per cluster was also enhanced due to leaf removal (97.5) and shoot tip removal (96.0). Significant increment due to leaf removal and shoot tip removal was noticed in cluster weight ((215.4g and 226.6g respectively). Total yield was also significantly increased in leaf removal (7.9kg/vine) and shoot tip removal (8.25kg/vine) than control(5.5kg/vine). Hence, it can be concluded that, canopy management practices in the form of leaf and shoot removal significantly reduced the crop losses caused by Anthracnose disease and also remarkably increased the yield of grape.

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Keywords

Grape, Anthracnose, Leaf removal, Shoot tip removal, Yield.

USING WHEAT CULTIVAR MIXTURES TO REDUCE SEVERITY OF SEPTORIA TRITICI BLOTCH, A RAIN BORNE DISEASE.

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Increasing plant diversity using cultivar mixtures is a worthwhile strategy that has been shown as a way of reducing wind-borne disease severity on crops and prolonging the efficacy period of plant resistance genes. The relevancy of this cultural practice remains to be assessed in the case of rain-borne diseases, such as septoria tritici blotch. This last one, due to the pathogen fungus *Mycosphaerella graminicola*, is a predominant foliar disease on wheat crops, able to cause substantial yield losses (up to 40%). Field experiments were conducted on a binary wheat mixture, with a 1:3 susceptible:moderately high resistant ratio, at Grignon (Yvelines, France) every year since 2008. The results showed a consistent decrease of septoria tritici blotch severity on the more susceptible cultivar (on average, 42% less pycnidial leaf area on the three upper leaves), without significantly affecting the more resistant cultivar, comparatively to their respective pure stands. In addition, a mechanistic-stochastic model is specifically developed to describe the progression of septoria tritici blotch within a heterogeneous virtual 3D-canopy. This theoretical approach combines physics and epidemiology, firstly, to compute the raindrop interceptions with the plant organs and the trajectories of the rain-splash droplets within the canopy, and secondly, to take into account the cultivar resistance levels and the polycyclic nature of the pathogen agent. This model will be first compared with the experimental results, and then, it will be aimed to extend our findings to other cultivar mixture conditions such as cultivar proportions or cultivar spatial distributions.

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Keywords
Cultivar mixture, Splash dispersal, *Mycosphaerella graminicola*, *Septoria tritici* blotch, Modeling

CAN YAM STAKING AFFECT ANTHRACNOSE EPIDEMIOLOGY?

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Many cultivars of water yam (*Dioscorea alata*) are affected by anthracnose epidemics due to *Colletotrichum gloeosporioides*. While there is neither authorized nor advisable pesticide treatment, the only way to limit disease impact is to use combination of partial plant resistances and cultural practices limiting fungi dispersion and development. Staking was traditionally used to grow yam on small plots but was no longer used in larger mechanized yam plots.

In order to evaluate the role of staking in anthracnose epidemiology, we designed in 2011 an experiment to compare the disease dynamics and the microclimate within staked and unstaked yam plots. We recorded microclimatic variables (Radiation budget, wind speed, air temperature and relative humidity) 2 m above ground outside the plots and 1 m above ground into the plots between rows of 2m high stakes. Leaf temperature (LT) and leaf wetness duration (LWD) were recorded by appropriate sensors placed in vegetation at the bottom and the top of the stakes near the ground in unstaked plants.

LWD was always recorded by all sensors when rainfall was greater than 1mm in a 15 minute time step. For a given rainfall, LWDs were longer in unstaked that in staked crop (up to 8 h LWD in unstaked plot, for 2 h LWD in staked plot). During clear nights with no rain, dew was deposited and measured LWDs were longer at the bottom than at the top of the stakes. Consistent differences of LT in the three canopy conditions were observed and confirmed by latent heat fluxes calculated from microclimatic data. The data recorded along the experiment were used to calibrate LWD models for the three canopy conditions. Simulations of LWD with data from two weather stations in contrasted climatic conditions of Guadeloupe, showed that staking may be efficient to limit periods favourable for disease development in drier climate, but not in regions where rainfalls are more frequent and intense.

While traditional staking provides dense vegetation mound, trellising is increasingly used for yam. This practice leading to new vegetation spatial distribution may exhibit antagonist effect on fungi development and dispersion and should be investigated.

Keywords:
Microclimate, Staking, Canopy architecture, *Dioscorea alata*, *Colletotrichum gloeosporioides*

CONCLUSIVE TALK

BENEFITS AND COSTS OF DISEASE ESCAPE, RESISTANCE AND TOLERANCE.

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Crop production in NW Europe is highly dependent on fungicide treatment. The degree of fungicide dependence can be quantified, as it relates to the economic optimum total fungicide dose, which varies with disease severity and yield loss per unit severity. The former can be reduced by disease escape or resistance and the latter by improving tolerance. This paper compares the advantages and disadvantages of constraining crop losses to disease through disease escape, resistance and tolerance, and hence the extent to which it is feasible that one or more of these control methods might reduce the current intense use of fungicides. Control of foliar diseases in winter wheat is used as an example case. In this context, escape is defined here as reduced efficiency of inoculum transfer to the upper crop canopy, resistance is the reduction of pathogen growth or symptom severity per unit of inoculum arriving on the upper canopy, and tolerance is the reduction of yield loss per unit of pathogen growth or symptom severity. We restrict the analysis to heritable variation which can be exploited through plant breeding. ‘Benefits’ are quantified as the efficacy and spectrum of disease control and the likely durability of that control. ‘Costs’ are taken here to include any physiological cost to the plant which results in reduction in yield or quality. Escape, resistance and tolerance are complementary in their effect on reducing fungicide requirement; escape displaces epidemics later in time, resistance reduces the relative epidemic growth rate and tolerance reduces the yield loss resulting from symptoms which occur despite the first two mechanisms. Considering each method of control in turn: Escape is moderately effective against a range of splash-dispersed pathogens and should be highly durable. The most influential validated escape trait in wheat is height and increasing height causes costs related either to increased lodging risk, or increased structural stem dry matter requirement (and consequent reduction in harvest index) to maintain the same lodging risk despite increased leverage resulting from increased height. Race-specific host resistance is highly effective, usually against a single pathogen species, but often ephemeral. Partial host resistance is moderately effective, but tends to be more durable. Breeding for disease resistance may have deleterious effects on yield, caused: (i) indirectly (heavy selection for resistant phenotypes in the early generations of breeding programmes reduces the number of lines from which to select for yield in later generations), (ii) via linkage between resistance genes and deleterious alleles, (iii) by deleterious effects from segments of alien chromosome, (iv) by a pleiotropic increase in susceptibility to pathogens of a different trophic group, or (v) directly, by a physiological cost of the resistance gene to the plant. Such yield effects are difficult to measure and there is conflicting evidence in the literature, but evidence is accumulating that such costs are common. Tolerance is covered in more detail in another paper in this volume. In summary, the range of heritable variation in tolerance in adapted germplasm has not been fully explored in order to assess efficacy. There is some evidence for tolerance being ‘broad-spectrum’ in its effects across foliar pathogens. In general, there is an association between high yield and poor disease tolerance, but there is preliminary evidence that this association is not inevitable. The loss of effective fungicides, due to stringent legislation and the evolution of insensitivity, increases the need for wheat cultivars which combine good disease escape, resistance and tolerance with high yields and good agronomic characteristics. Progress towards breeding such cultivars will be more rapid if informed by understanding of the physiological mechanisms driving the associations between the benefits and costs outlined above.

Plant and Canopy Architecture Impact on Disease Epidemiology and Pest Development

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Bernard Tivoli is senior scientist in Plant Pathology at INRA in Rennes.
He leads the research team working on epidemiology of pulses diseases and on disease resistance (ascochyta blight and root rot diseases on pea).
He supervises research consortia studying the effects of canopy architecture on disease epidemiology (ARCHIDEMIO project and EpiArch network)
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Didier Andrivon is a senior plant pathologist at INRA.
He leads a research groupworking on the epidemiology an population genetics of aerial plant pathogens (primarily *Phytophthora infestans* on potato) and on the design of management strategies of host resistance according to the evolution of population structures of these pathogens.
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Alain Baranger is a geneticist in UMR APBV laboratory at INRA Rennes. He leads a research group focusing on quantitative resistance to pathogens in legumes, including ascochyta blight resistance in pea, using standard as well as molecular-based methods. One of the considered issues is the relative and potential complementary role of plant architecture and plant resistance genetic factors to reduce disease severity and effects.
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Agnès Calonnec is a plant pathologist at INRA in Bordeaux. She is an epidemiologistworking on spatio-temporal disease progression mostly on powdery mildew of grapevine. She is closely working with mathematicians to develop statistical and deterministic models to characterise disease progression and to grade factors favourable to it. Since 2003, her major research area concerns the use of host development and grapevine conduct to decrease the risk of disease invasion. Agnès Calonnec is convenor of the IOBC WG “Integrated Protection in Viticulture” since 2007.
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Sukumar Chakraborty is a plant disease epidemiologist with extensive research publications on the diversity and adaptation in necrotrophic pathogens at a global scale and environmental influence on plant diseases including the impacts of climate change. His research exploits weakness in biology, epidemiology and pathogenesis mechanisms to develop management strategies for necrotrophic pathogens under current and future climates. Research is focused on Fusarium pathogens causing crown rot and head blight of wheat.
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Michaël Chelle is a bioclimatologist at INRA Grignon. He has conducted his research at the interface between the plant ecophysiology and physics, developing the notion of *phylloclimate*, the climate perceived by individual plant organs, and mainly relying on a modeling approach. He is currently studying the interaction between phylloclimate and fungal epidemics (wheat x Mycosphaerella graminicola) in collaboration with plant pathologists.
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Mary Ruth McDonald is a professor at the University of Guelph, Ontario, Canada. Her research focuses on integrated pest management and disease management of vegetables crops and related field crops. The approaches to disease management includes the evaluation of biological controls, fungicides and cultural practices such as modifying the crop canopy Her work on modifying plant canopies to manage plant disease includes trimming of carrot foliage to reduce Sclerotinia rot of carrot.

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Robert Faivre is a statistician/biometrician at INRA in Toulouse. He is involved in generic modelling to analyse the role of plant architecture in the epidemiological process. He is responsible of the MEXICO network dedicated to computer experiments and sensitivity analysis of model outputs.
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Rebecca Grumet is plant geneticist at Michigan State University, USA. She leads a research group investigating host-pathogen interactions and reproductive development in cucumber and melon. Her studies of *Phytophthora capsici* infection of cucumber fruit include the role of age related resistance and plant architecture on disease development.
Michigan State University, East Lansing, MI, USA.

Phil Miklas conducts genetic research and breeding in support of common bean (*Phaseolus vulgaris*) germplasm enhancement for improved resistance and tolerance to major bacterial, fungal, and viral induced diseases. Current focus is on use of architectural avoidance in combination with partial physiological resistance to combat Sclerotinia white mold in dry bean.
Agricultural Research Service (ARS), Prosser, WA, USA.

Karsten Mody is an ecologist and applied entomologist at ETH Zurich, Switzerland. A focus of his research is on herbivore-plant interactions in apple trees, tropical (timber) trees and stressed herbaceous plants. He studies the genetic as well as environmental basis of plant resistance to insect herbivores. A major goal of his studies is to reduce herbivore damage to plants by understanding the effects of abiotic and biotic stress, plant architecture and plant association on herbivore-plant interactions.
Swiss Federal Institute of Technology (ETH), Zurich, Switzerland.

Bertrand Ney, Professor at AgroParisTech, is a plant ecophysiologist scientist. After work on grain legumes modelling, he specialized on diseases x plants interaction in canopies with special emphasis on using Function x Structure Plant Models. Our team aim to explain how pathosystems (mainly focused on wheat diseases) are working in various environmental conditions, moreover nitrogen and temperature. The models are used to identify main plant traits involved in tolerance and escape to pathogens for integrated pest management and

breeding.
Paris Institute of Technology for life, food and environmental sciences (AgroParisTech), Grignon, France.

Neil Paveley leads the ADAS crop pathology research group in the UK, which works on fungal pathogens of cereals, oilseeds, pulses and potatoes. Areas of interest (in collaboration with Rothamsted, University of Nottingham, the John Innes Centre and SAC) include the integration of disease control through host resistance, disease escape, tolerance and fungicides, to ensure sustainable control, and slow pathogen evolution towards virulence and fungicide insensitivity. The group is part of the ECHAP project, led by INRA, modelling the effects of canopy architecture on epidemics and control of Mycosphaeralla graminicola in wheat.
Agricultural Development and Advisory Service (ADAS), Malton, North Yorkshire, UK

Harald Scherm is a plant pathologist at the University of Georgia with research interests in theoretical and applied epidemiology. He and his students and collaborators are studying the three-dimensional distribution of plant pathogens and their associated symptoms in fruit tree canopies with the goal of providing deeper insights into sources of inoculum, mechanisms of dissemination, and reproductive strategies of the pathogen population.
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