Modelling for crop protection against diseases : fusarium species case study

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Modelling for crop protection against diseases: fusarium species case study

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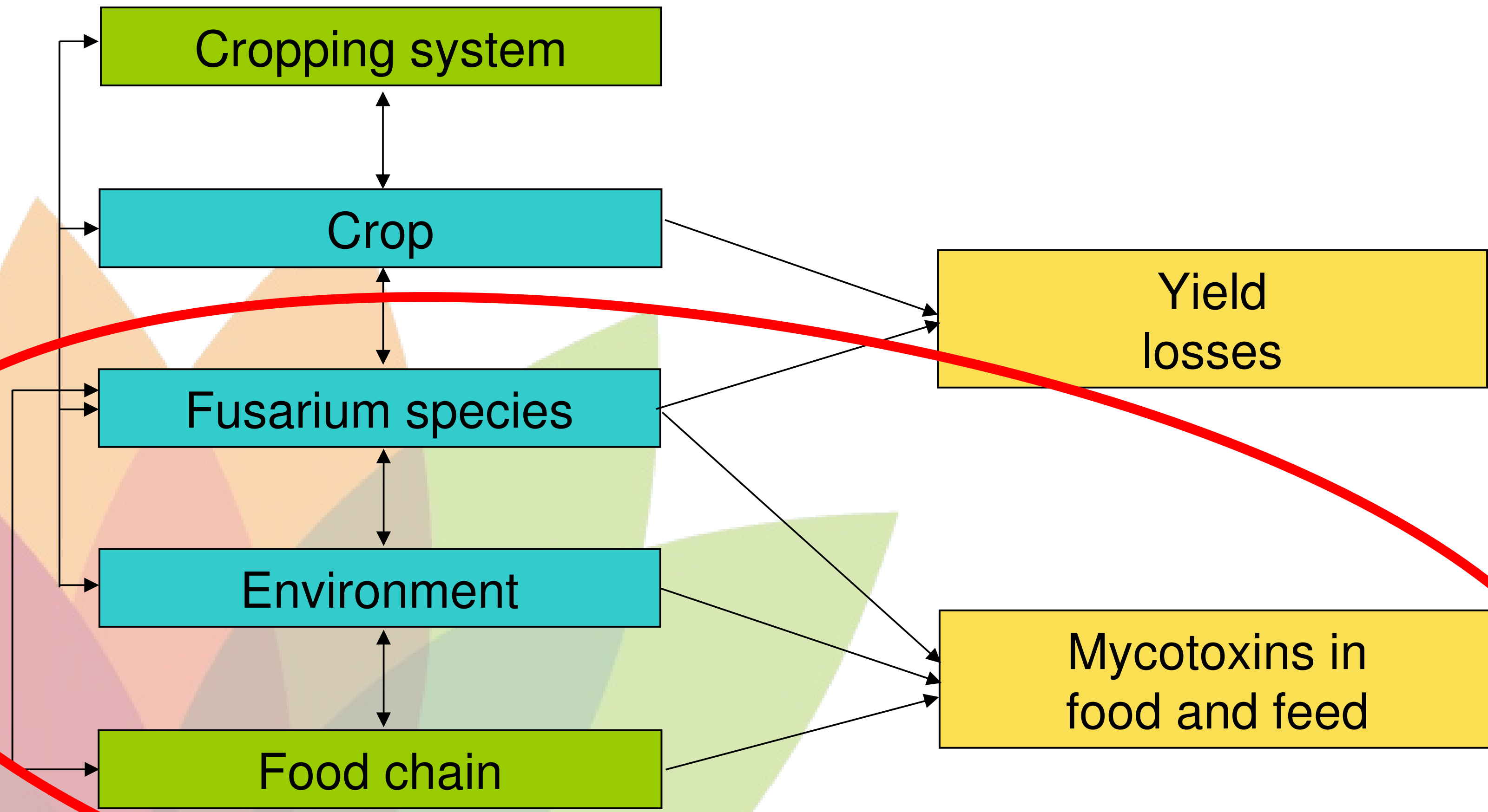
Overview of the general issues to address



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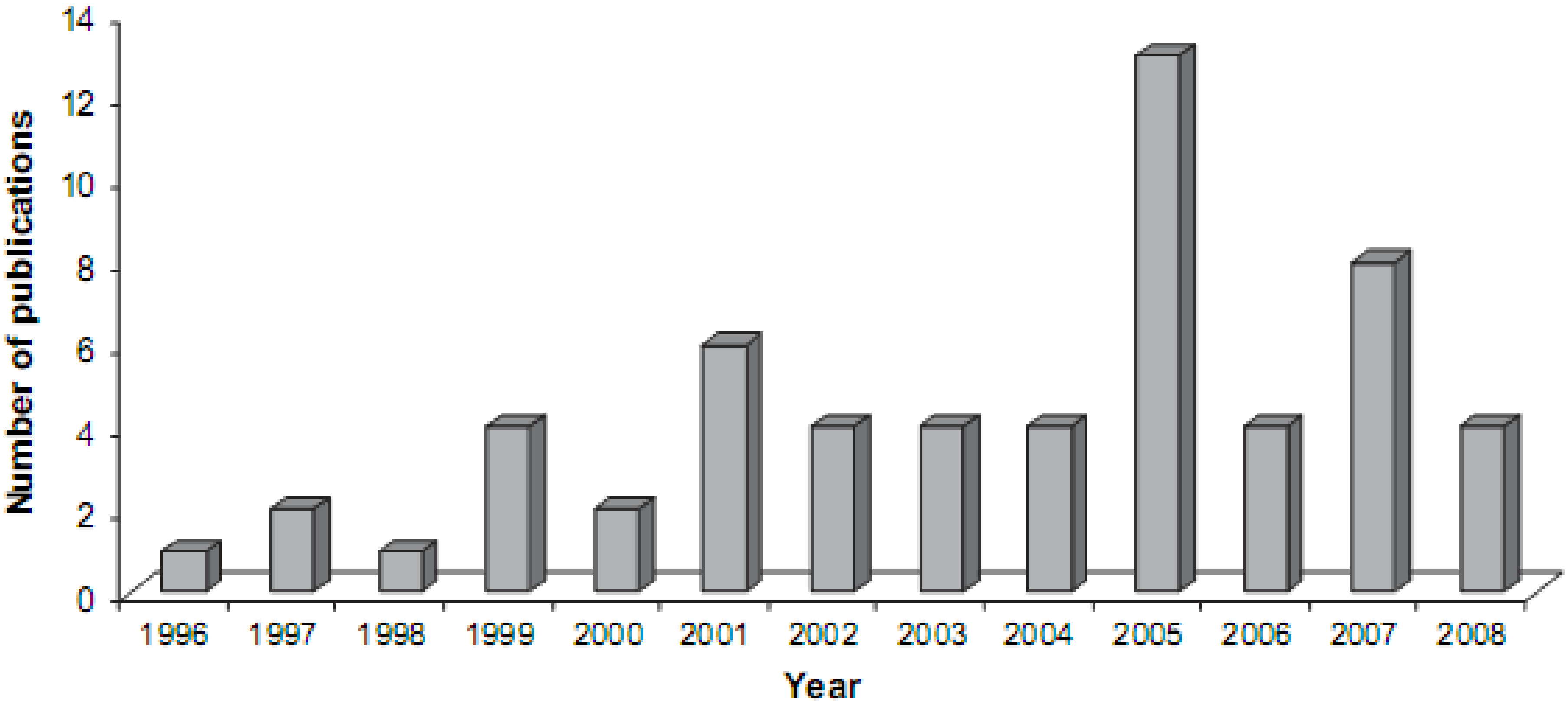
What has been done in terms of modelling of mycotoxins in food?

Publications on modelling of food-born mould growth in the last years (from Scopus database)



Garcia et al., 2009. Predicting mycotoxins in food: a review. Food microbiology 26 (2009) 757-769

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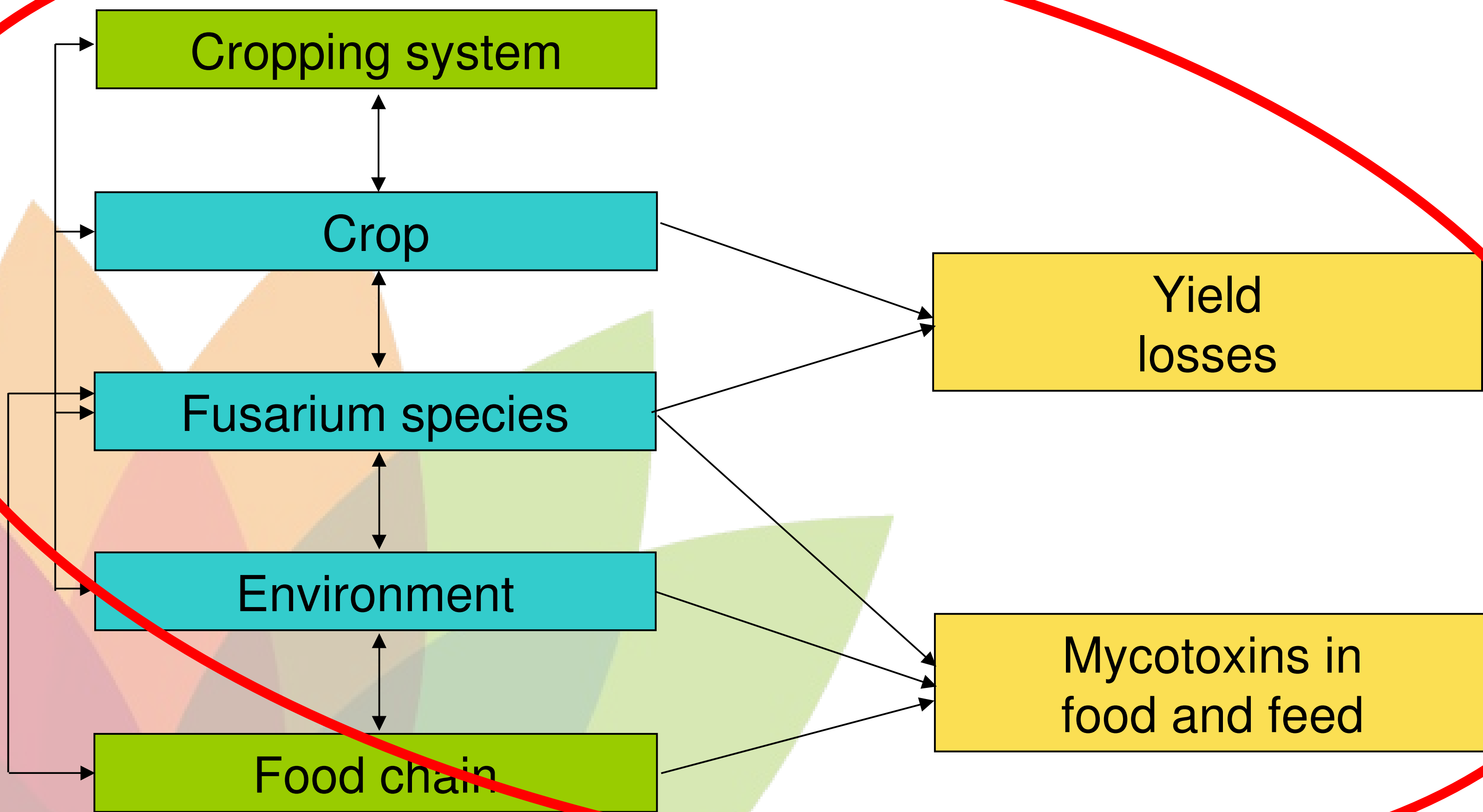

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How can modelling be useful to crop protection?

- Conceptual modelling:
  - helps organise knowledge
  - helps set up experiments
  - helps set up diagnosis in commercial fields
  - helps structure research programs
  - helps communicate

- Simulation modelling
  - helps understand epidemiological processes *sensu lato*
  - helps decision making with regard to tactical decisions
  - helps analyse crop losses
  - helps design crop management plans and/or cropping systems
  - helps design durable collective strategies preserving the efficacy of cultivar resistances

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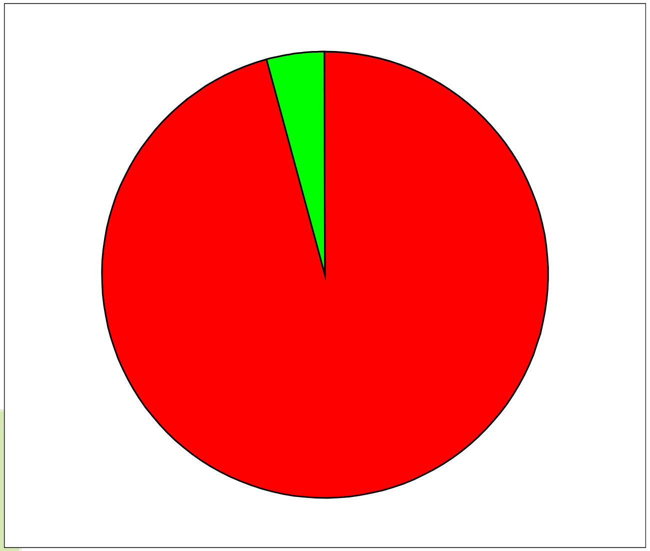
Proportion of communications dealing with modelling within the 11th European Fusarium seminar

Posters



Lectures

Without a modelling approach

With a modelling approach

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What has been done in terms of modelling for fusarium diseases?

Predictive models	Disease/ mycotoxin	Crop	Limits	References	Year
Argentina	FHB	Wheat	Site- and year-specific	Moschini & Fortugno	1996
				Fernandes et al.	2004
Belgium	FHB	Winter wheat	Instrumental (radar) availability	Detrixhe et al.	2003
				Dalla Marta et al.	2005
Canada	DON	Cereal grain	Do not consider: crop rotation, crop variety, tillage, fertilization, etc.	Hooker et al.	2002
				Hooker & Schaafsma	2003 & 2004
				Schaafsma & Hooker	2006
Italy	FHB, DON, ZEA	Wheat	Low accuracy for high TOX-risk	Rossi et al.	2003a & 2003b
The United States	FHB	Spring and winter wheat	Low accuracy	De Wolf et al.	2004
				Van Maanen & Xu	2003
				Xu	2003
				Madden et al.	2004
Italy	F. verticillioides	Maize	Aspect of dynamic cycle of fungi are needed	Rossi et al.	2003a; 2003b & 2006
Europe	P. verrucosum	Cereal grain	Lack of field and storage management effects	Pardo et al.	2006

Prandini et al. Review of predictive models for Fusarium Head Blight and related mycotoxin contamination in wheat. Food and chemical toxicology 47 (2009) 927-931

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Typology of models addressing Fusarium spp. epidemics and/or mycotoxins production: correlative approaches

- Correlation with climate (e.g. Schaafsma AW, Hooker DC. 2007. Climatic models to predict occurrence of Fusarium toxins in wheat and maize. International Journal of Food Microbiology 119: 116-125).
- Correlation with climate and other variables (e.g. de la Campa et al. 2005. Modeling effects of environment, insect damage, and Bt Genotypes on fumonisin in maize in Argentina and the Philippines. Mycopathologia 159: 539-552).
- Correlation between fungal complexes and climate (e.g. Xu XM et al. 2008.Relationship between the fungal complex causing Fusarium Head Blight of wheat and environmental conditions. Ecology and Epidemiology 98 (1): 69-78).
- Statistical relationship between ear and spiklets incidence (e.g. Xu XM et al. 2004. Relationship between the incidences of ear and spikelet infection of Fusarium ear blight in wheat. European Journal of Plant Pathology 110: 959-971).
- Statistical relationship symptoms and mycotoxin production (e.g. Paul PA et al. 2006. Meta-analysis of regression coefficients for the relationship between Fusarium Head Blight and Deoxynivalenol content of wheat. Ecology and Epidemiology 96 (9): 951-961).

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Typology of models addressing Fusarium spp. epidemics and/or mycotoxins production: mechanistic approaches

- Epidemiological modelling *in vitro* (e.g. Regalado et al. 1996. The origins of spatial heterogeneity in vegetative mycelia: a reaction-diffusion model. Mycological Research 100 (12) 1473-1480)
- Epidemiological modelling at the field level (e.g. Rekah et al. 1999. Spatial distribution and temporal development of Fusarium crown and root rot of tomato and pathogen dissemination in field soil. Phytopathology 89: 831-839).
- Spore production modelling (e.g. Rossi et al. 2009. Effect of environmental conditions on spore production by *Fusarium verticilloides*, the causal agent of maize ear root. European Journal of Plant Pathology 123: 159-169).
- Coupling crop and disease models (e.g. Del Ponte et al. 2009. A model-based assessment of the impacts of climate variability on Fusarium Head Blight seasonal risk in Southern Brazil. Journal of Phytopathology 157: 675-681).
- Economic modelling (e.g. Wu F, Munkvold. 2008. Mycotoxins in ethanol co-products: modeling economic impacts on the livestock industry and management strategy. Journal of Agricultural and food chemistry 56: 3900-3911)

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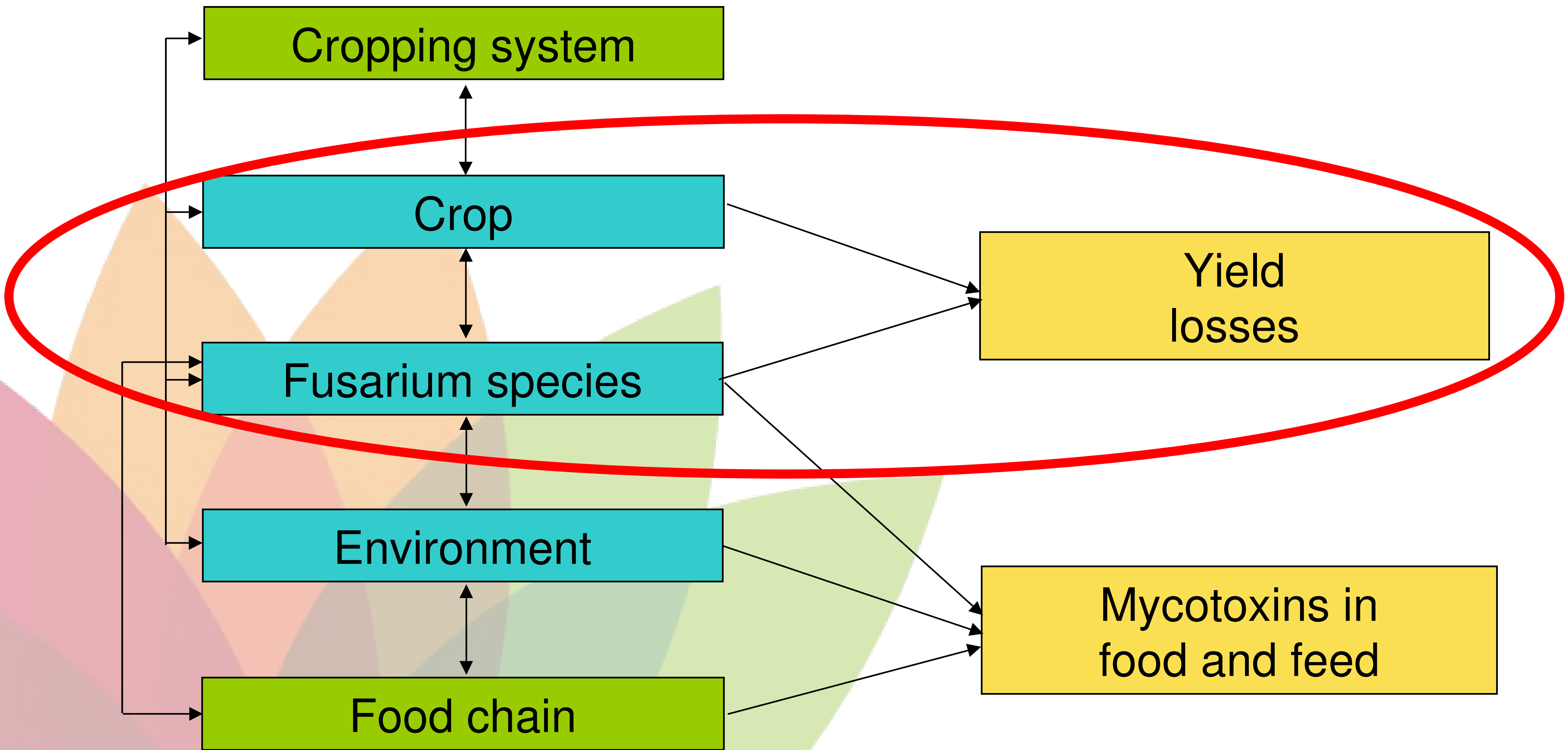
Overview of the general issues to address

FOOD QUALITY AND SAFETY



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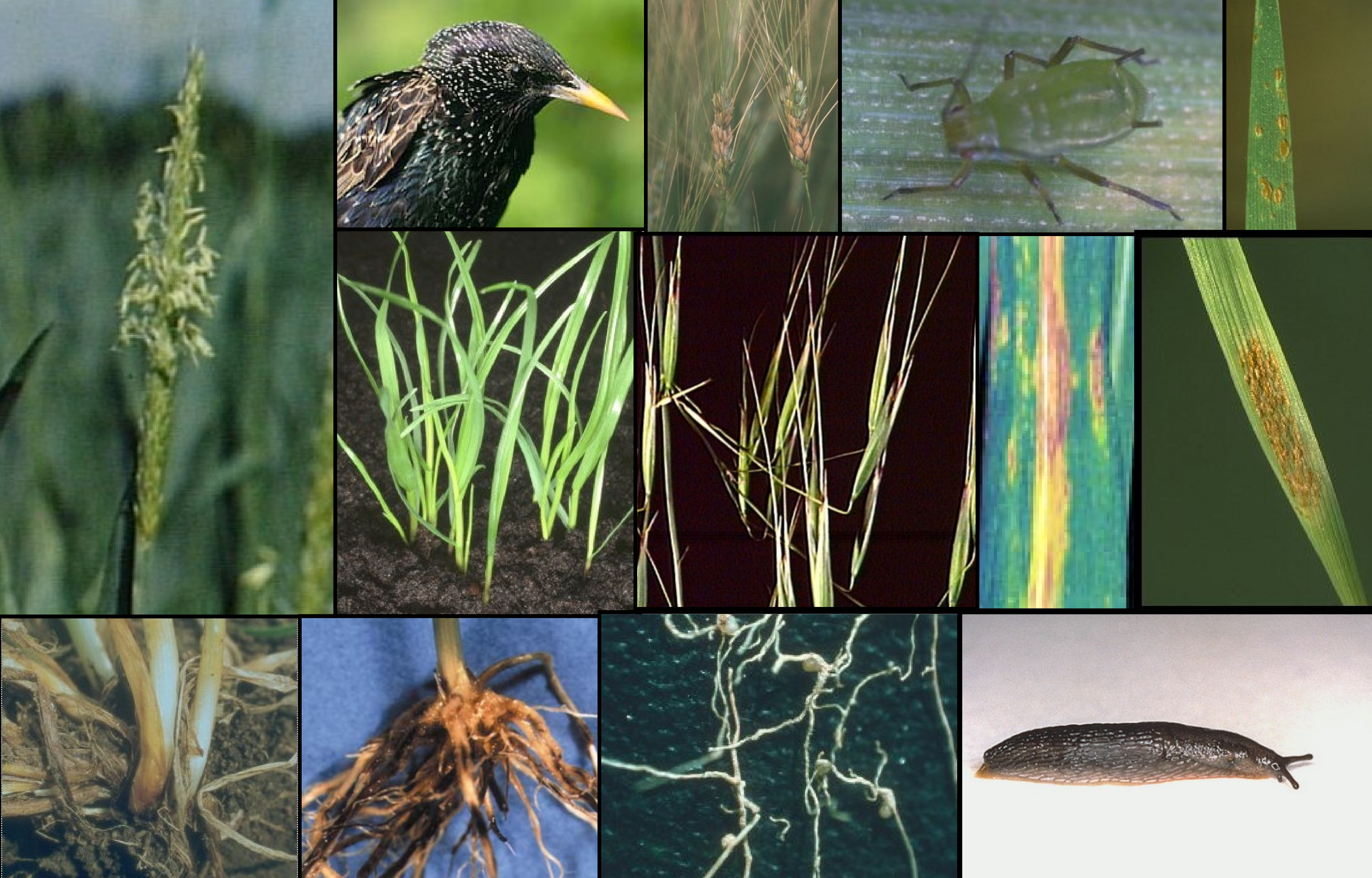

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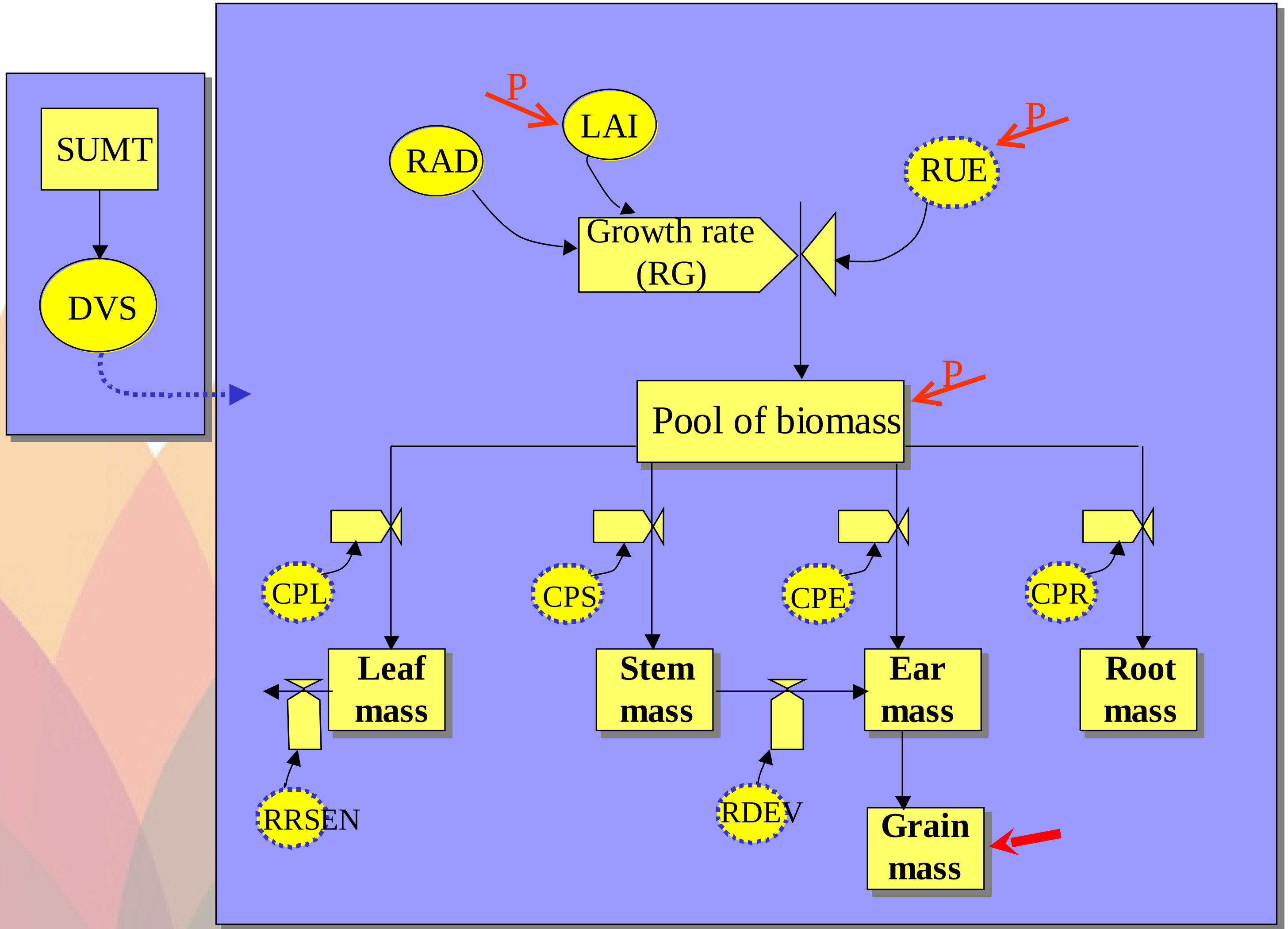
Simplified flow chart of WHEATPEST



Willocquet et al. Simulating multiple pest damage in varying winter wheat production situations (2008) Field Crops Research. 107 (1) : 12-28.

Biomass production

$$RG = RAD * RUE * (1 - e^{-kLAI})$$

RG: Rate of Growth ($[RG]=MT^{-1}L^{-2}$)

RAD: global RADiation ($[RAD]=MT^{-3}$)

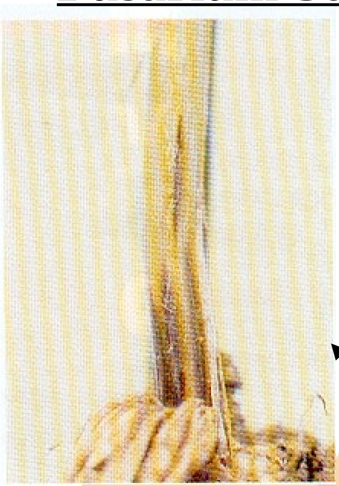
RUE: Radiation Use Efficiency ($[RUE]=T^{2}L^{-2}$)

k: coefficient of light extinction ([k]=1)

LAI: Leaf Area Index ([LAI]=1)

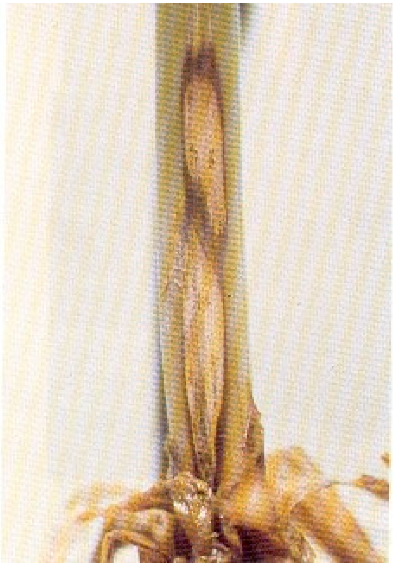
Stem diseases

Fusarium Stem Rot



- linear and brown lesions
- no stroma
- superficial necrosis

Sharp Eyespot



- pale cream oval lesions with a dark brown margin
- superficial necrosis

Eyespot

- necrotic lesion ± limited
- stroma in the center
- severe penetrating lesion can result

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Fusarium Stem Rot

- Modelling damage mechanisms: Fusarium Stem Rot (*Fusarium graminearum*, *F culmorum*, *Microdochium nivale*)

$$RF_{FST} = 1 - \left(aFST1/100 + bFST2/100 \right)$$

RF_{FST}: reduction factor of RUE due to FST ($[RF_{FST}]=1$)

FST1: % of tillers with slight FST symptoms (browning up to second node [FST1]=1)

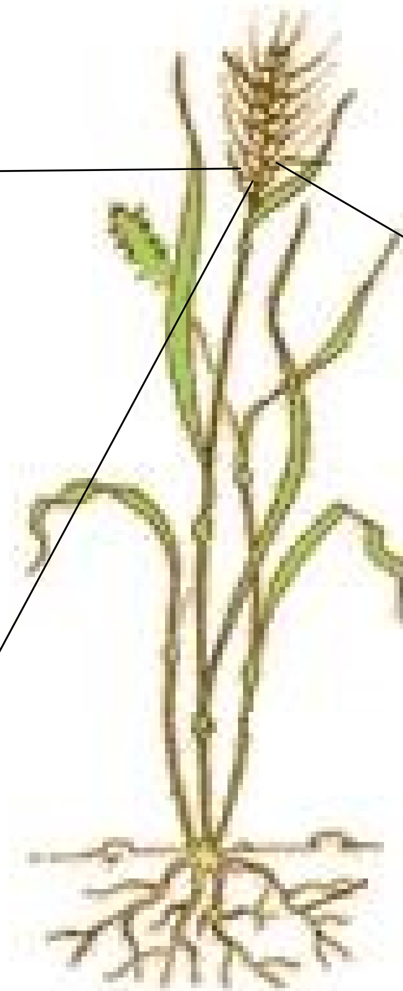
FST2: % of tillers with severe FST symptoms (browning up to third node or above [FST2]=1)

a and b: parameters derived from Smiley et al. (2005) ([a]=[b]=1)

Ear diseases

Fusarium head blight

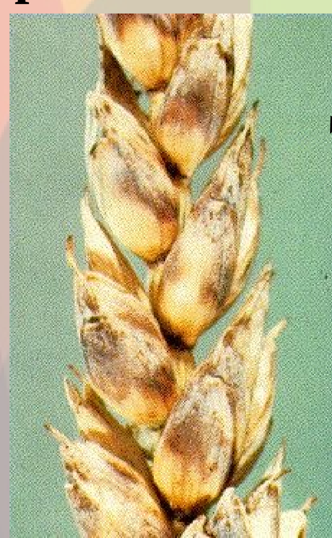
- brownish spot + discoloration
- premature death or bleaching of cereal spikelets



Powdery mildew

- white mould mainly on surface of glumes

Septoria nodorum



- purple-brown lesions

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Fusarium Head Blight

FOOD QUALITY AND SAFETY

- Modelling damage mechanisms:
  Fusarium head blight (*Fusarium graminearum, F culmorum, F avenaceum, F poae, Microdochium nivale*)

$$RF_{FHB} = 1 - \left(aFHB / 100 \right)$$

RF_{FHB}: reduction factor of grain biomass due to FHB ($[RF_{HB}]=1$)

FHB: percentage of disease kernels ([FHB]=1)

a=1.1 : parameter derived from Mesterhazy et al. (2003, 2005) ([a]=1)

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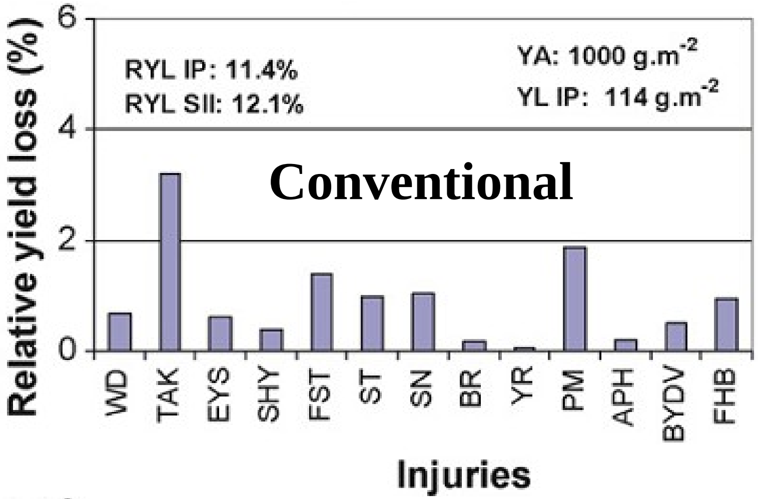
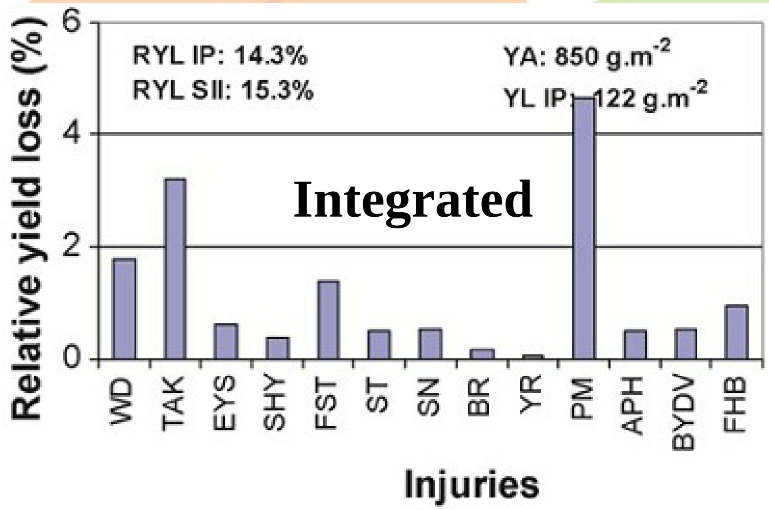
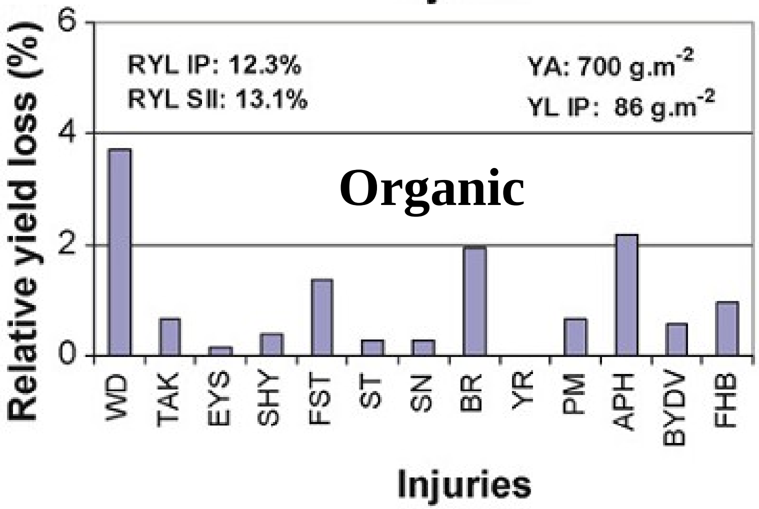
Output variables of WHEATPEST

- Attainable yied
- Actual yield
- Relative yield losses caused by individual pests
- Relative yield loss caused by the injury profile







FOOD QUALITY AND SAFETY

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A 2 year field experiment in Central Europe on spring wheat (IHAR)

ENDURE RA2.1: Preventing pest damage at the cropping system level.

- O Domeradzka, J Czembor, E Czembor

Objectives:

- to quantify agronomic, socio-economic, and environmental performances of various spring wheat cropping practices in Central European conditions

- to quantify the predictive quality of WHEATPEST for spring wheat in Central European conditions

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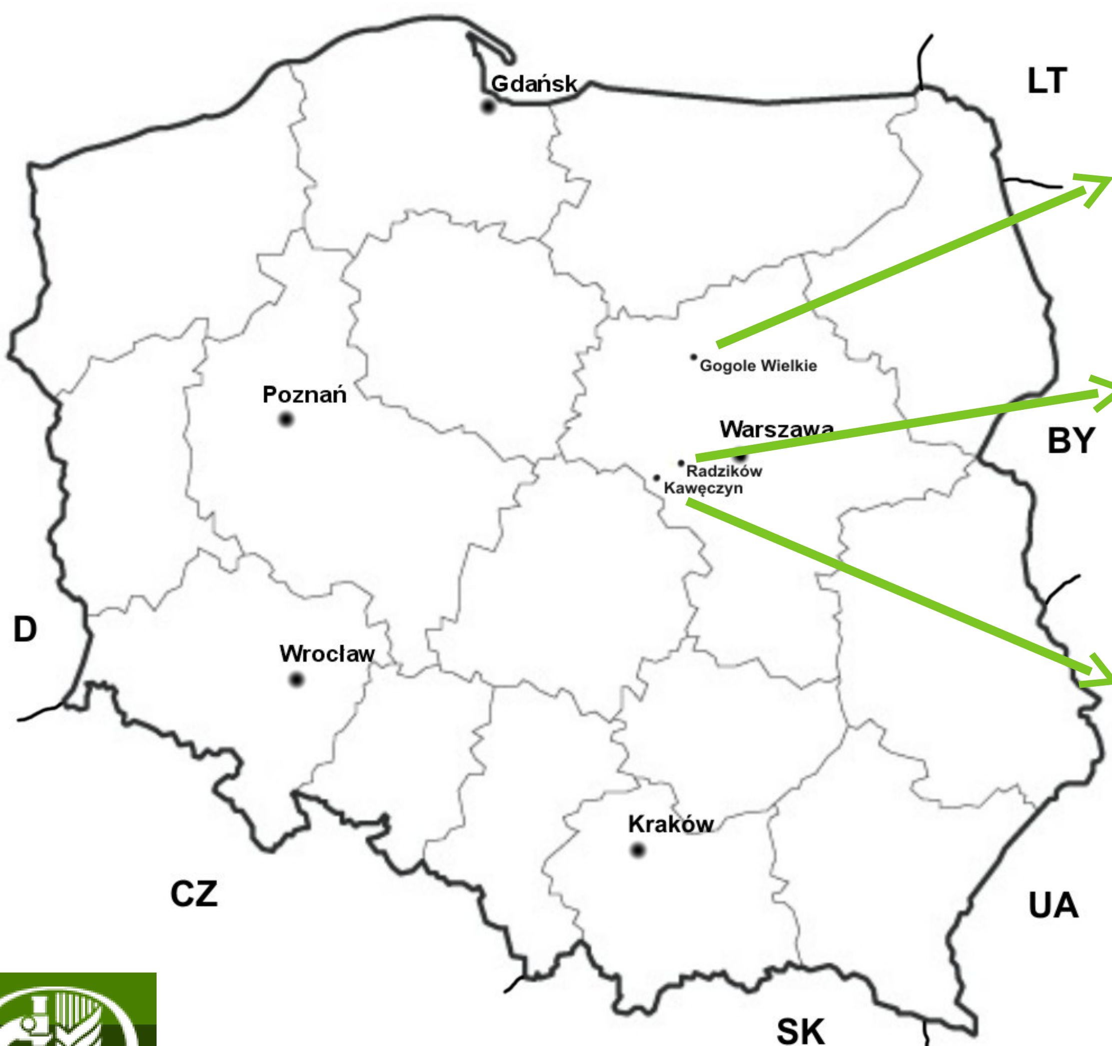
Management plans

FOOD QUALITY AND SAFETY



Organic management

Intensive and Integrated management with no chemicals

Integrated management with possible use of chemicals

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Management plans

Variety: Raweta

Soil class: 4b

Area: 0,5 ha

- Integrated management with no chemicals, Radzikow

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Management plans

Variety: Grywa

Soil class: 3b

Area: 6,3 ha

- Integrated management with possible use of chemicals, Kaweczyn

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Management plans

Variety: Raweta

Soil class: 4a

Area: 20 ha

- Intensive management, Radzikow

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Management plans

Variety: Nawra

Soil class: 4a

Area: 3,3 ha

- Organic management (in an organic certified farm), Gogole Wielkie

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Data collection

- Cropping practices
- Climate
- Crop status
- Injury profile

Powdery mildew

Leaf rust

Cereal Leaf Bettle

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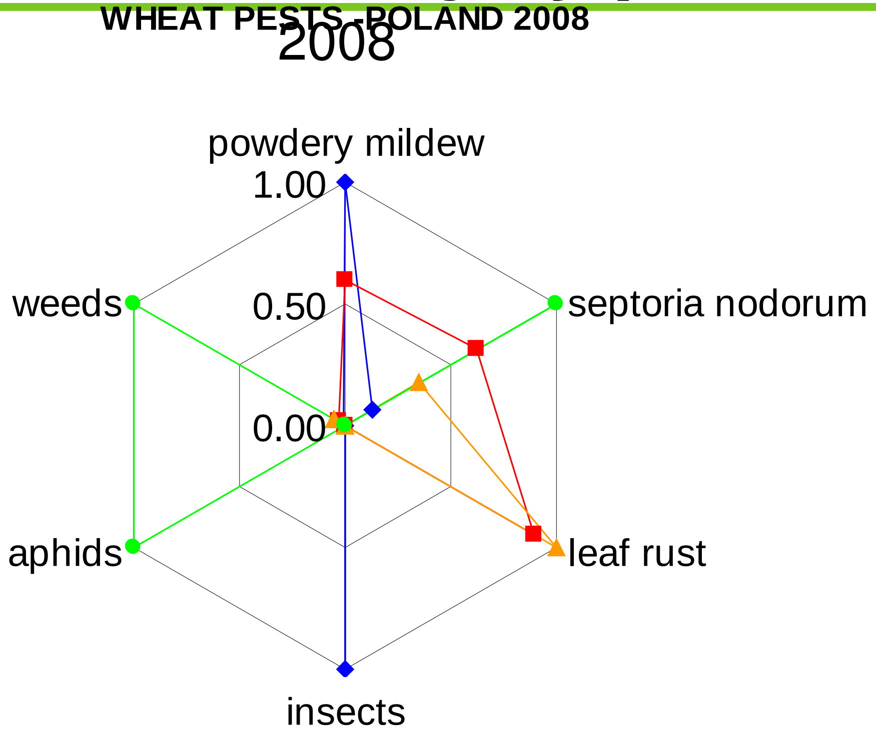
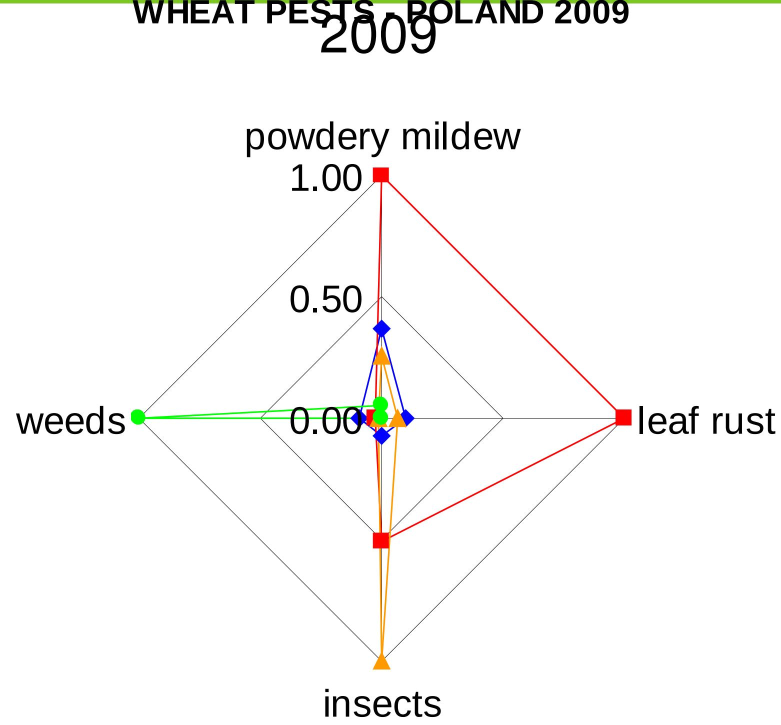
Observed injury profiles





integr.possible use of chem
intensive
integr.no chemicals
organic

Ratio of AUDPC for the 4 situations (maximum value observed among the 4 production situation as denominator)

Intensive

Integrated with possible use of chemicals

Integrated with no chemicals

Organic

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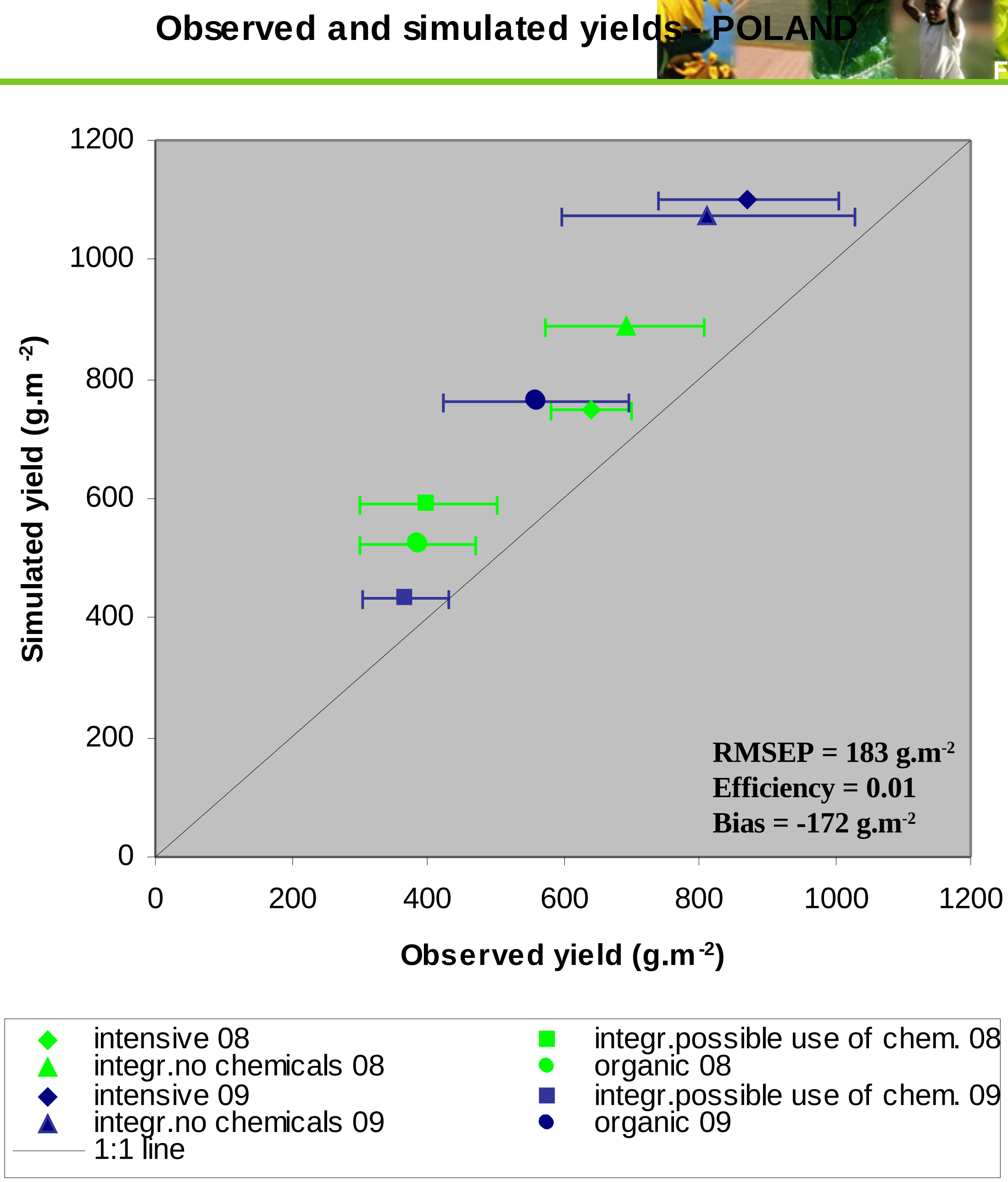
Observed and simulated yields



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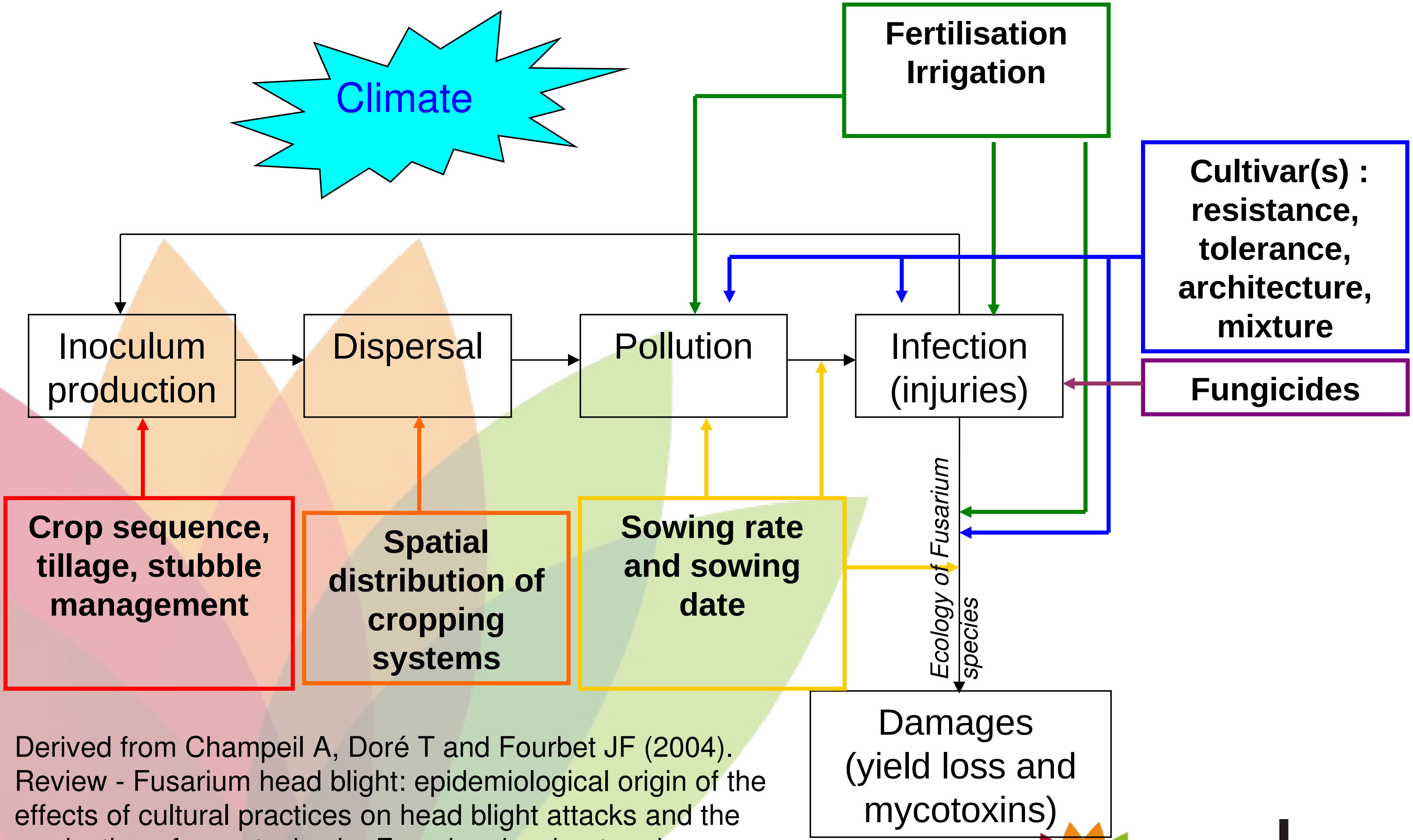
Proposal of a simplified conceptual framework for a model to design IPM strategies against damages caused by Fusarium species



Derived from Champeil A, Doré T and Fourbet JF (2004). Review - Fusarium head blight: epidemiological origin of the effects of cultural practices on head blight attacks and the production of mycotoxins by Fusarium in wheat grains. Plant Science 166(6): 1389-1415.

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CONCLUSION

- The control of Fusarium species on various crops remains a major challenge for many research teams worldwide
- The level of complexity to cope with mycotoxin production requires significant modelling efforts
- Specific data collections are required to develop efficient control methods, not only at the cropping system level, but also at the food chain level
- This requires better integration of the disciplines aiming at analysing and developing control methods to reduce damages caused by Fusarium species.

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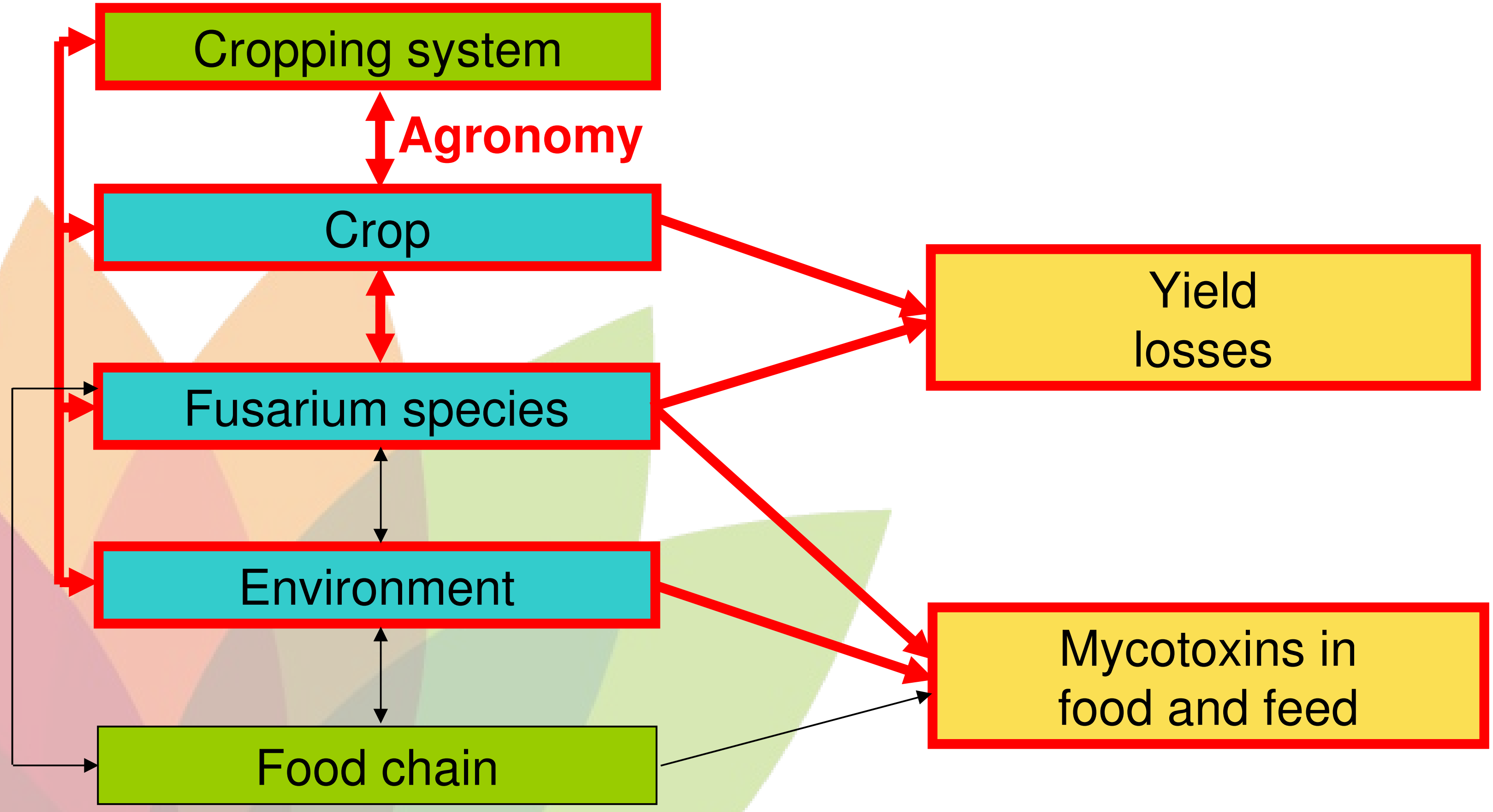
Towards a common modelling plateform for more interdisciplinarity?



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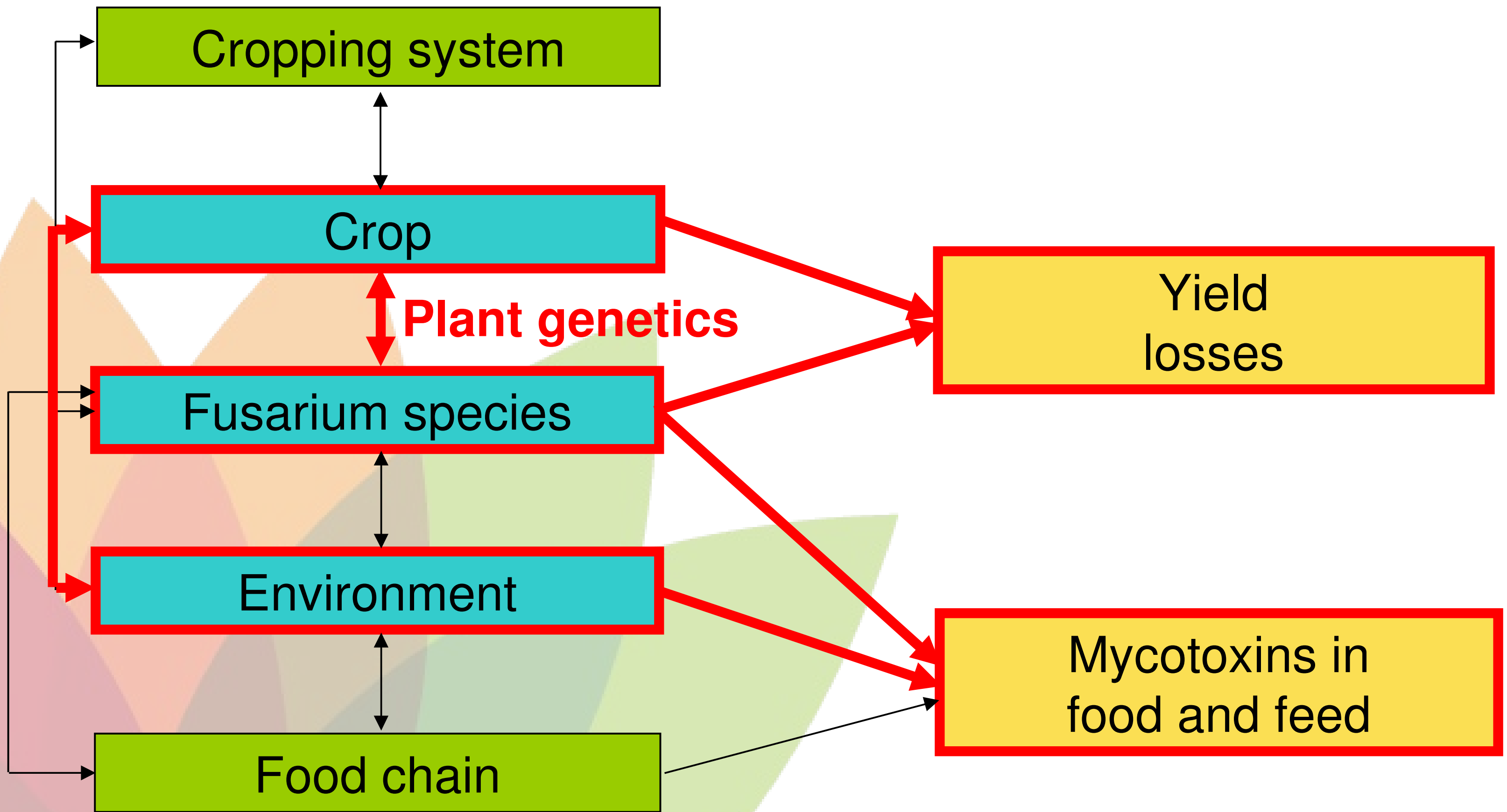

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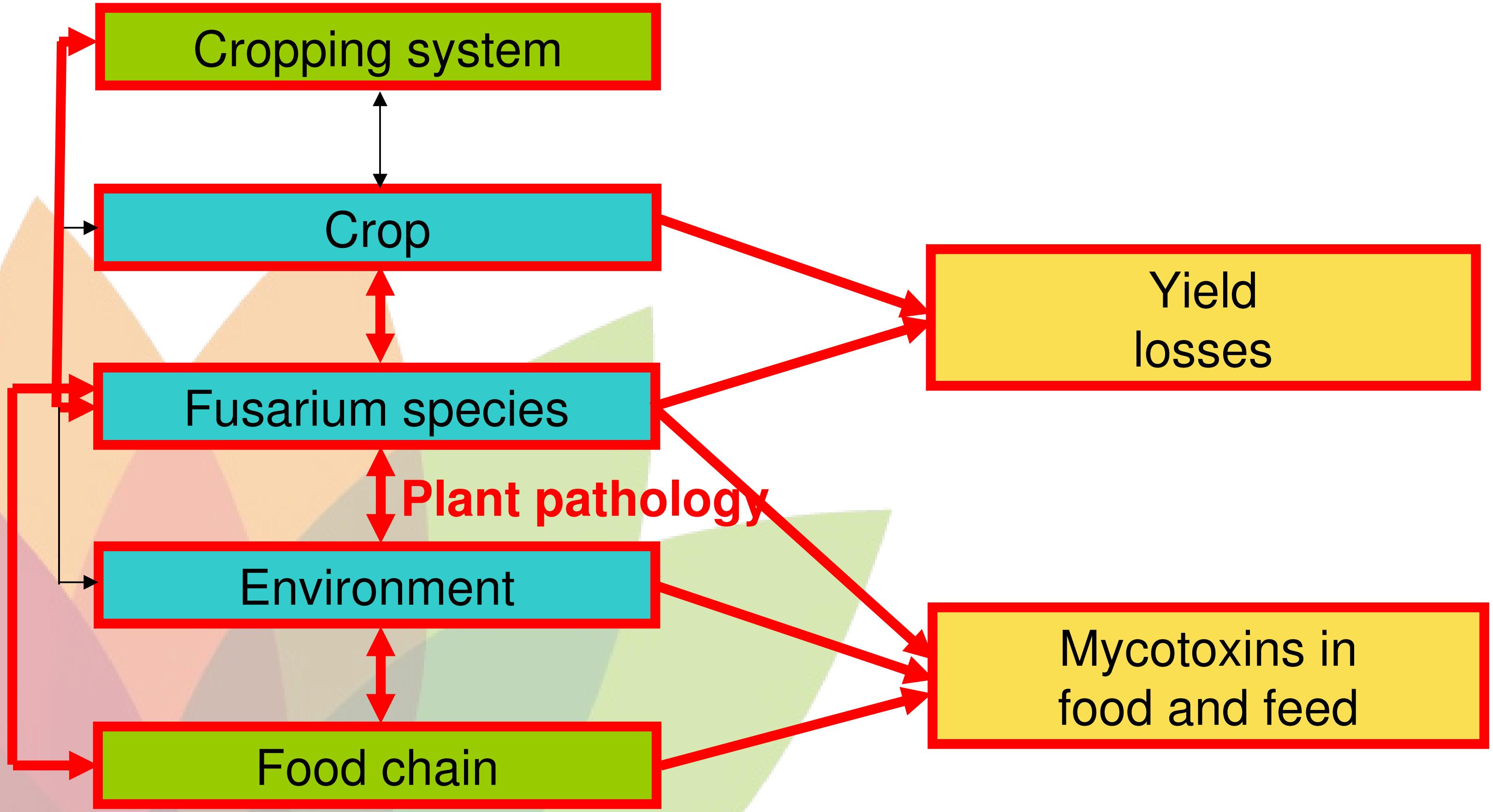
FOOD QUALITY AND SAFETY



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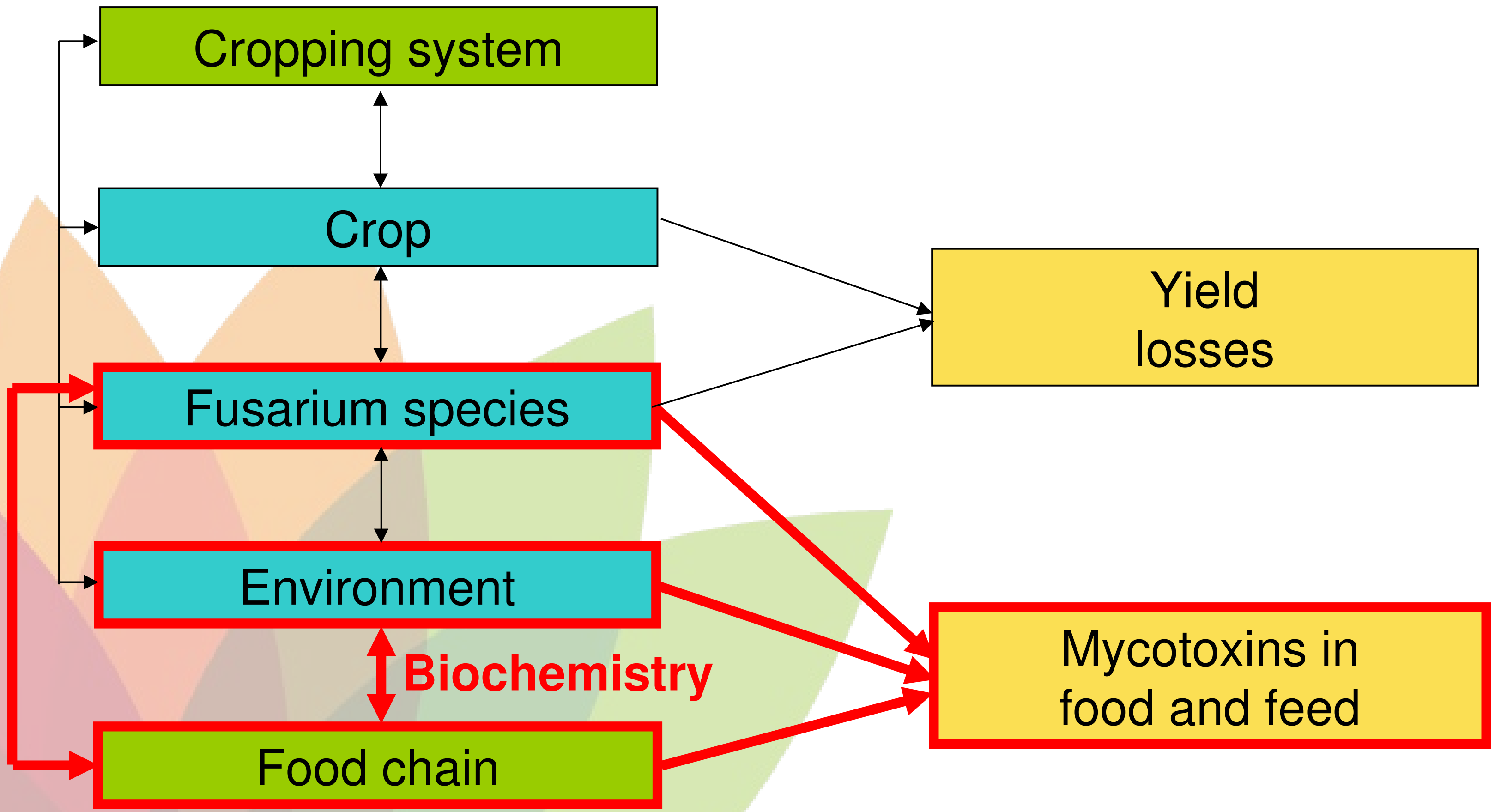

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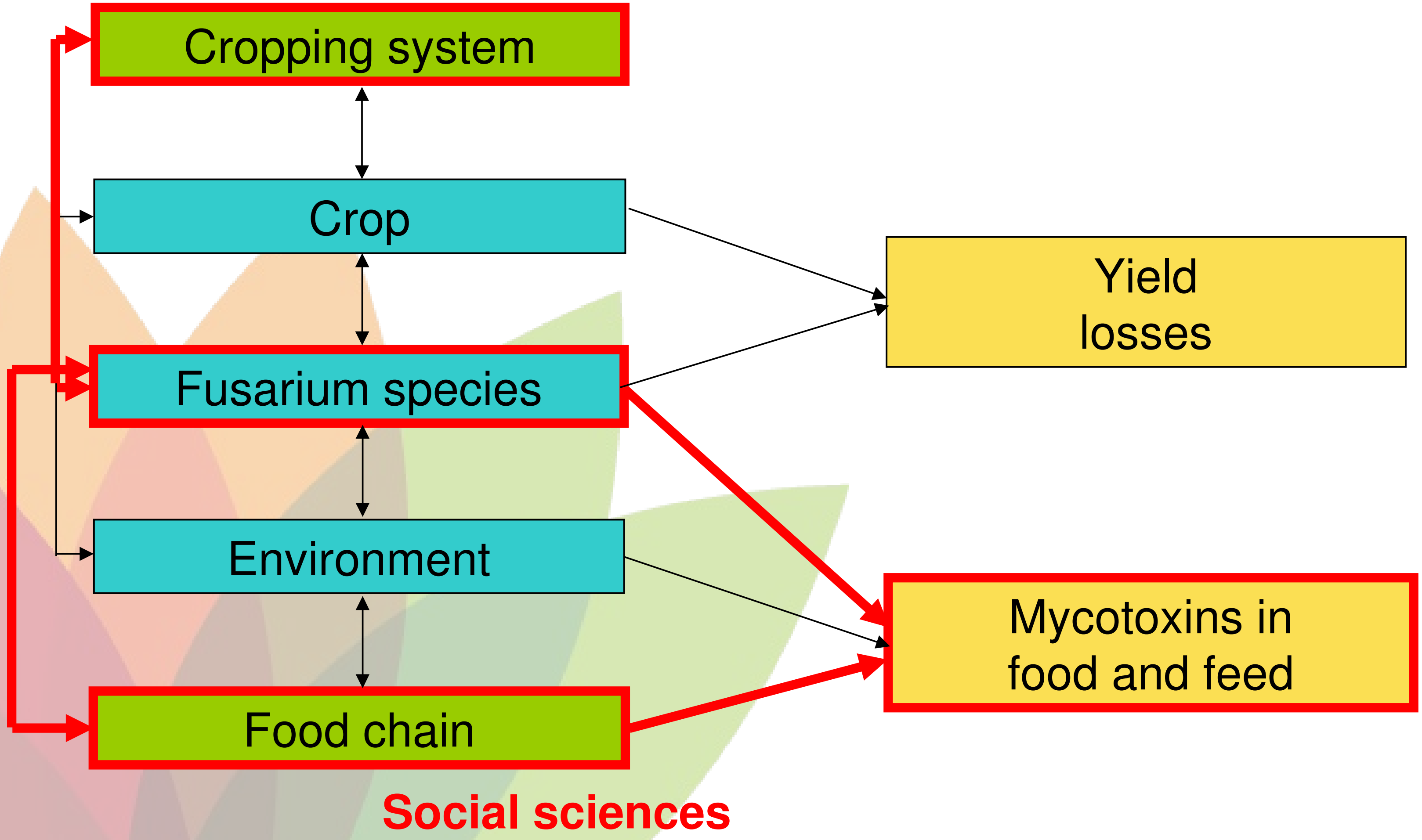

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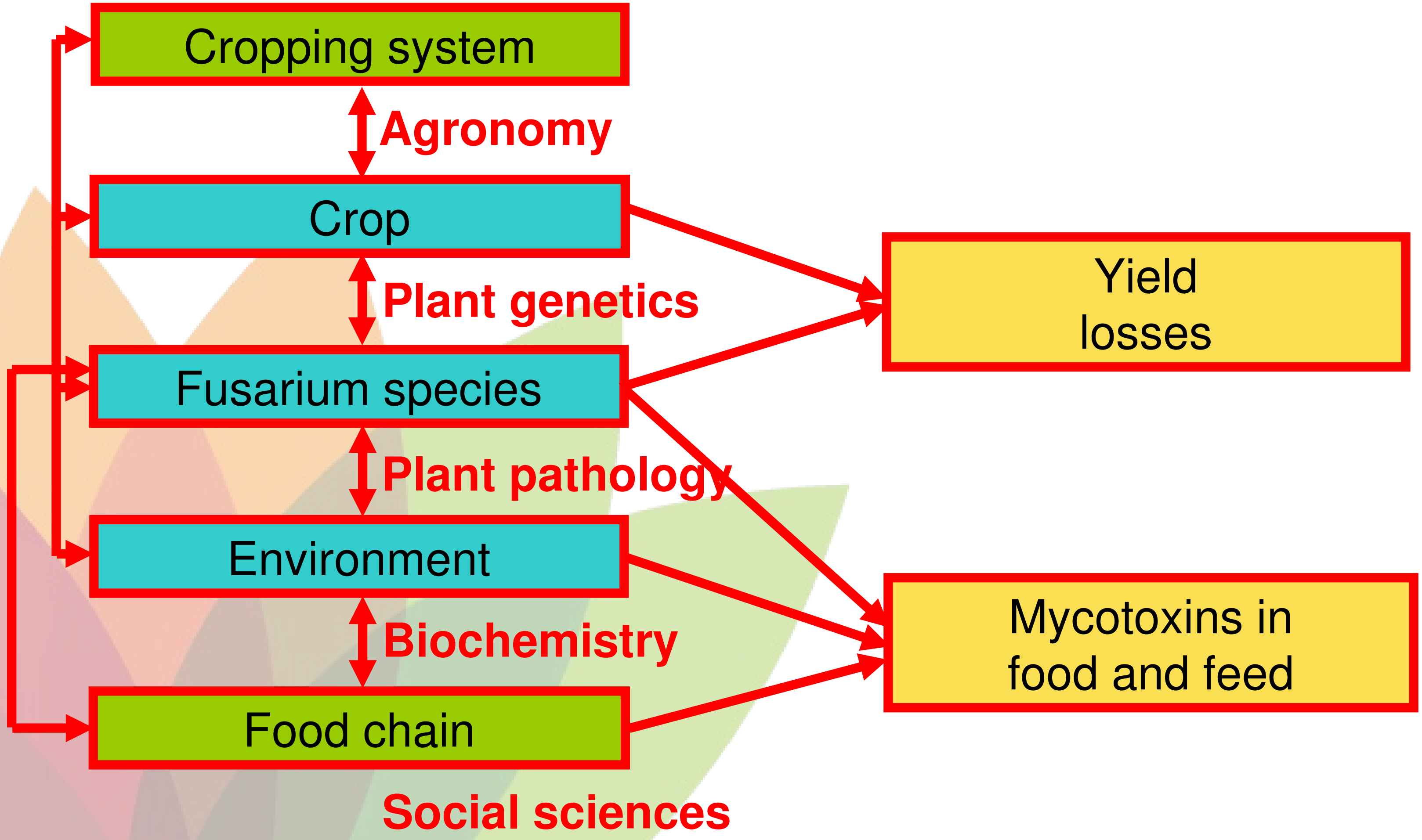

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