Example 2: the WHEATPEST model

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Poznan, 19 November 2008

The aim of WHEATPEST is to simulate wheat yield losses caused by an injury profile in a given production situation

Possible uses of WHEATPEST

⇨ Estimation of the yield losses caused by a range of pests or one specific pest

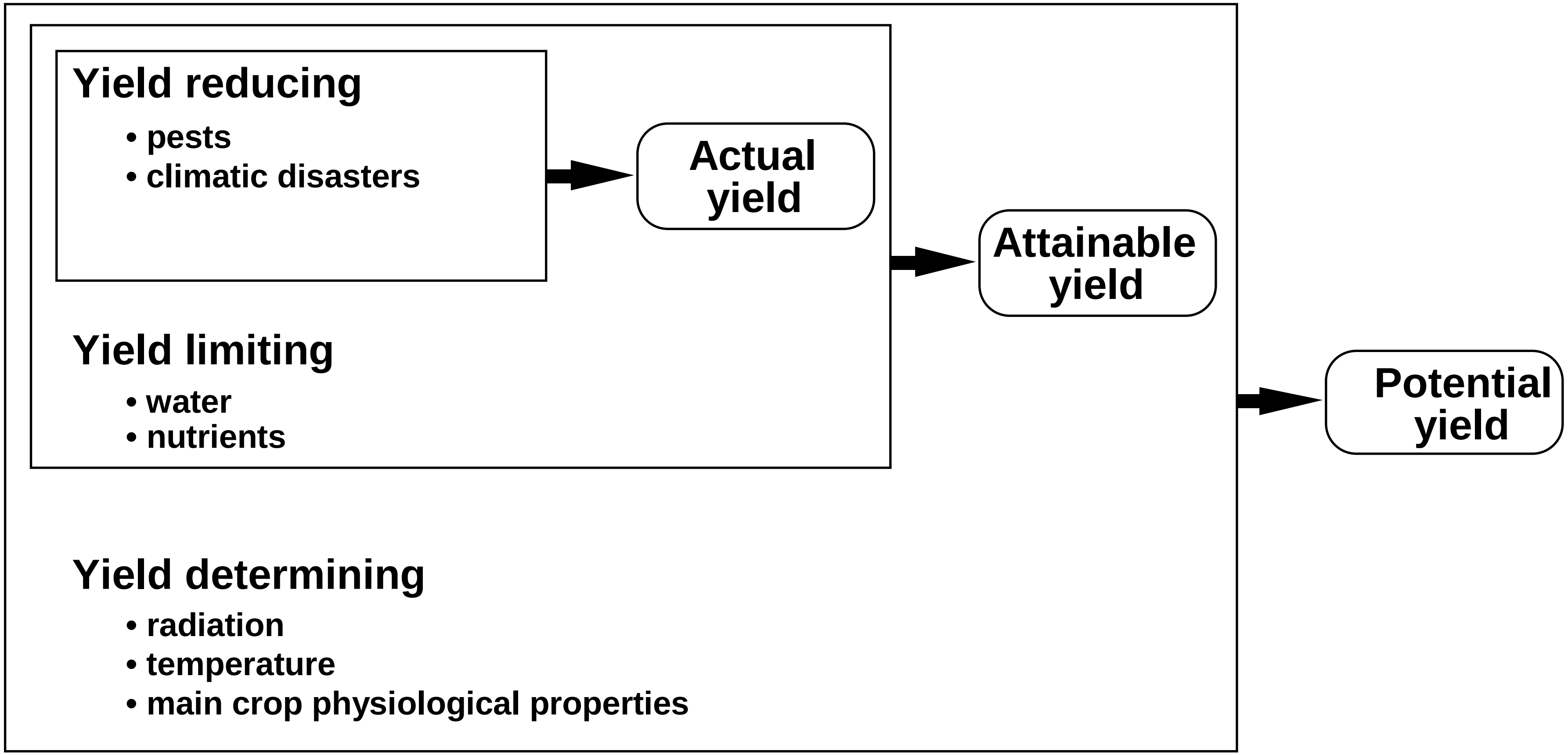
- → Hierarchy of importance of pests for a given Injury Profile (IP) * Production Situation (PS) combination
- → Guide research priorities for wheat pest management in Europe

⇨ Baseline to drive surveys on wheat health and management in Europe

- → Identify the main IP*SP in Europe
- → Build a map of a range of yield losses in Europe in interaction with their associated IP*SP

⇨ Pedagogical tool

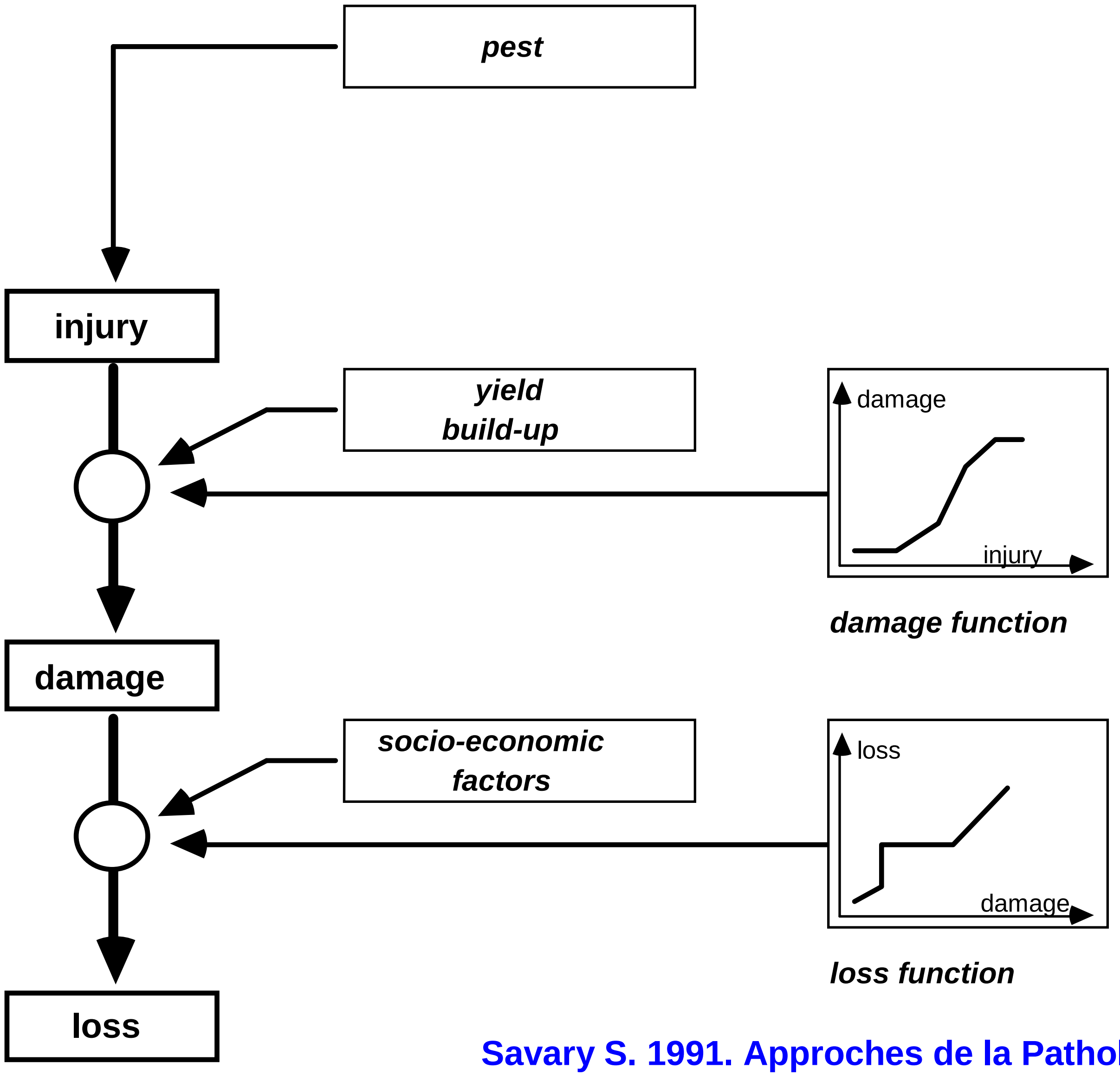
Yield defining factors



damage = attainable yield - actual yield

Zadoks, J.C., Schein, R.D., 1979. Epidemiology and Plant Disease Management. Oxford University Press, New York.

Rabbinge, R., 1993. The ecological background of food production. In: Chadwick D.J., Marsh, J. (Eds.), Crop Protection and Sustainable Agriculture. John Wiley and Sons, Chichester, UK, pp 2-29.



Savary S. 1991. Approches de la Pathologie des Cultures Tropicales. L'exemple de l'arachide en Afrique de l'Ouest. Karthala-ORSTOM, Montpellier, pp. 288.

Production situation 1 – theoretical definition

- A production situation (PS) is represented by the set of environmental (physical, biological) and socio-economic factors where the yield of a given crop is produced.

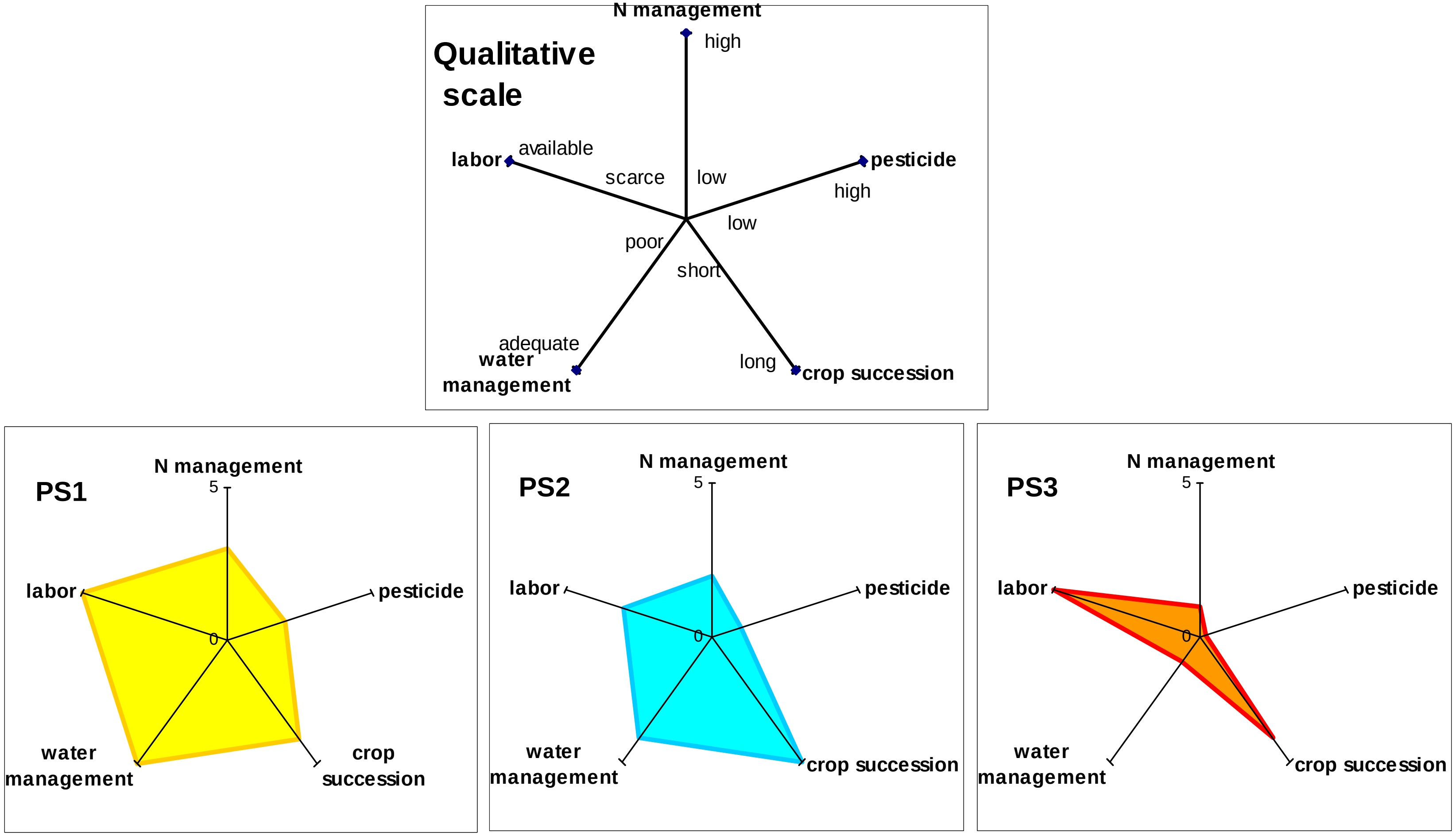
De Wit, C.T., Penning de Vries, W.W.T., 1982. L'analyse des systèmes de production primaire. In: La productivité des pâturages sahéliens. W.W.T. Penning de Vries, M.A. Djiteye, Eds. Agricultural Research Report 918. Pudoc, Wageningen. pp. 275-283.

Production situation 2 – operational definition

- PS can in turn be operationally determined on the basis of the combination of crop management practices occurring in a given field. This is because strategies and tactics for crop management are reflections of the physical (soil and climate), biological (genotypes, cultivars, and biotic environment), social and economical (e.g., markets) environment where a crop is grown.

Savary, S., Willocquet, L., Elazegui, F.A., Teng, P.S., Du, P.V., Zhu, D., Tang, Q., Lin, X., Singh, H.M., Srivastava, R.K., 2000a. Rice pest constraints in tropical Asia: characterization of injury profiles in relation to production situations. Plant Dis. 84, 341-56.

Example of representation of production situations

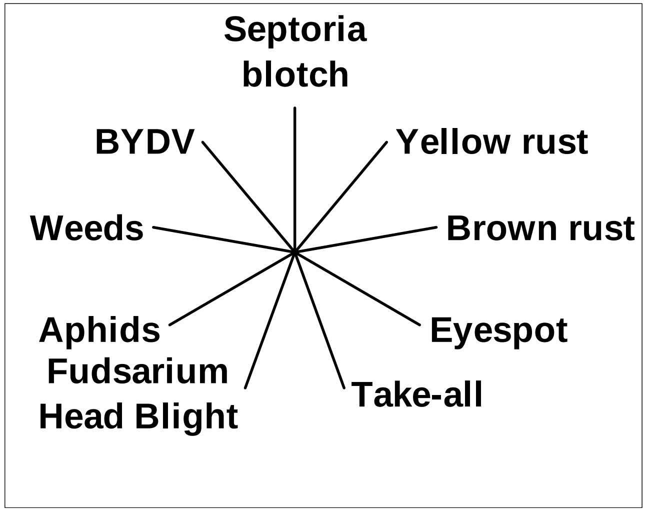


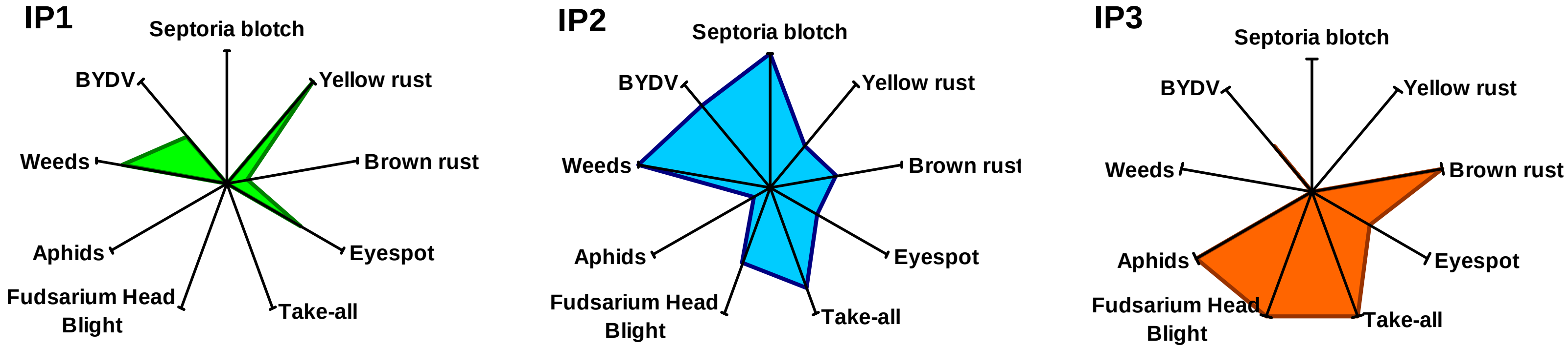
Injury profile

- An injury profile can be defined as the combination of injury levels caused by the multiple pests (pathogens, insects, weeds) that affect a crop during a growing cycle.

Savary, S., Willocquet, L., Elazegui, F.A., Teng, P.S., Du, P.V., Zhu, D., Tang, Q., Lin, X., Singh, H.M., Srivastava, R.K., 2000a. Rice pest constraints in tropical Asia: characterization of injury profiles in relation to production situations. Plant Dis. 84, 341-56.

Example of representation of injury profiles





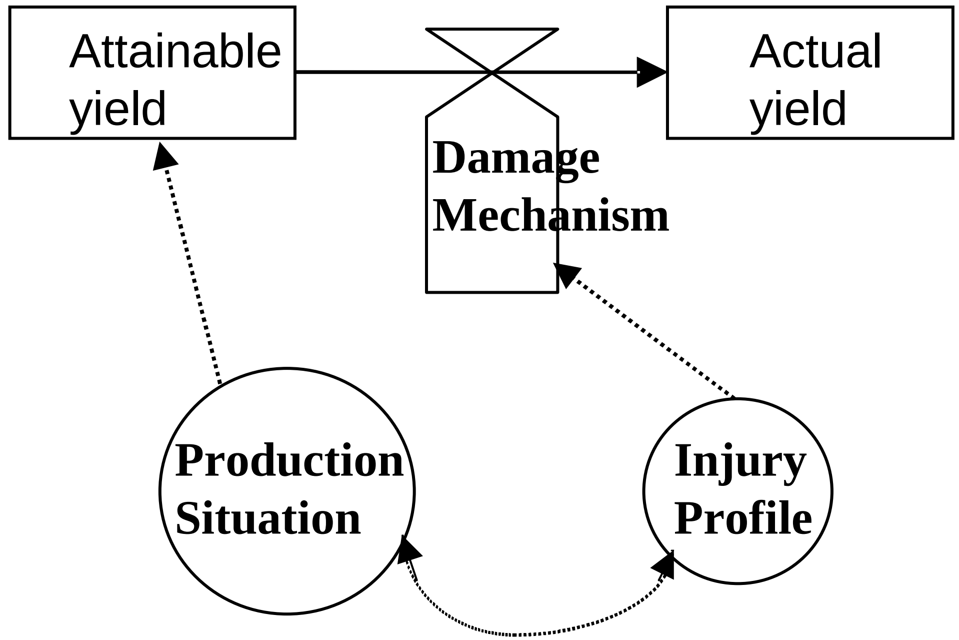
Summary of drivers for injuries in 3 clusters of injury profiles combined with 3 production systems

Injury profile	Crop management[a]	DVS[b]	Injury levels												
			WD[c]	TAK	EYS	SHY	FST	ST	SN	BR	YR	PM	APH	BYDV	FHB
A	C	0.8	1.16	0.70	3.07	0.94	1.30	0.48	0.06	0.01	0.02	0.22	0.00	1.14	1.99
A	C	1.6	3.00	3.50	30.70	9.40	13.00	4.81	0.64	0.76	0.12	0.67	0.58	1.14	1.99
A	I	0.8	4.23	0.70	3.07	0.94	1.30	0.24	0.03	0.01	0.02	0.45	0.00	1.14	1.99
A	I	1.6	11.00	3.50	30.70	9.40	13.00	2.41	0.32	0.76	0.12	1.34	1.37	1.14	1.99
A	O	0.8	6.15	0.14	0.77	0.94	1.30	0.12	0.02	0.08	0.00	0.06	0.00	1.14	1.99
A	O	1.6	16.00	0.70	7.68	9.40	13.00	1.20	0.16	7.60	0.02	0.17	4.25	1.14	1.99
B	C	0.8	1.16	0.95	0.73	0.63	0.96	0.16	0.18	0.00	0.01	1.22	0.00	1.14	0.86
B	C	1.6	3.00	4.75	7.28	6.32	9.64	1.64	1.83	0.25	0.06	3.66	0.71	1.14	0.86
B	I	0.8	4.23	0.95	0.72	0.63	0.96	0.08	0.09	0.00	0.01	2.44	0.00	1.14	0.86
B	I	1.6	11.00	4.75	7.28	6.32	9.64	0.82	0.92	0.25	0.06	7.32	1.75	1.14	0.86
B	O	0.8	6.15	0.11	0.18	0.63	0.96	0.04	0.05	0.03	0.00	0.31	0.00	1.14	0.86
B	O	1.6	16.00	0.95	1.82	6.32	9.64	0.41	0.46	2.50	0.01	0.92	7.03	1.14	0.86
C	C	0.8	1.16	1.20	1.62	1.08	3.77	0.24	0.26	0.00	0.02	0.29	0.00	1.14	1.16
C	C	1.6	3.00	6.00	16.20	10.80	37.70	2.39	2.63	0.29	0.13	0.87	0.65	1.14	1.16
C	I	0.8	4.23	1.2	1.62	1.08	3.77	0.12	0.13	0.00	0.02	0.58	0.00	1.14	1.16
C	I	1.6	11.00	6.00	16.20	10.80	37.70	1.20	1.32	0.29	0.13	1.74	1.55	1.14	1.16
C	O	0.8	6.15	0.24	0.40	1.08	3.77	0.06	0.07	0.03	0.00	0.07	0.00	1.14	1.16
C	O	1.6	16.00	1.20	4.05	10.80	37.70	0.60	0.66	2.90	0.02	0.22	5.35	1.14	1.16

Data are coming from farmers' field survey in England, Wales and the Netherlands (Polley and Thomas, 1991; Daamen et al (1990, 1991, 1992); Daamen and Stool (1990, 1992, 1994)

Production Situation and Injury profile relationships

- Strong link shown for multiple pathosystems of several crops
- Can be used as a framework to assess or model yield losses caused by multiple pests



Damage mechanisms

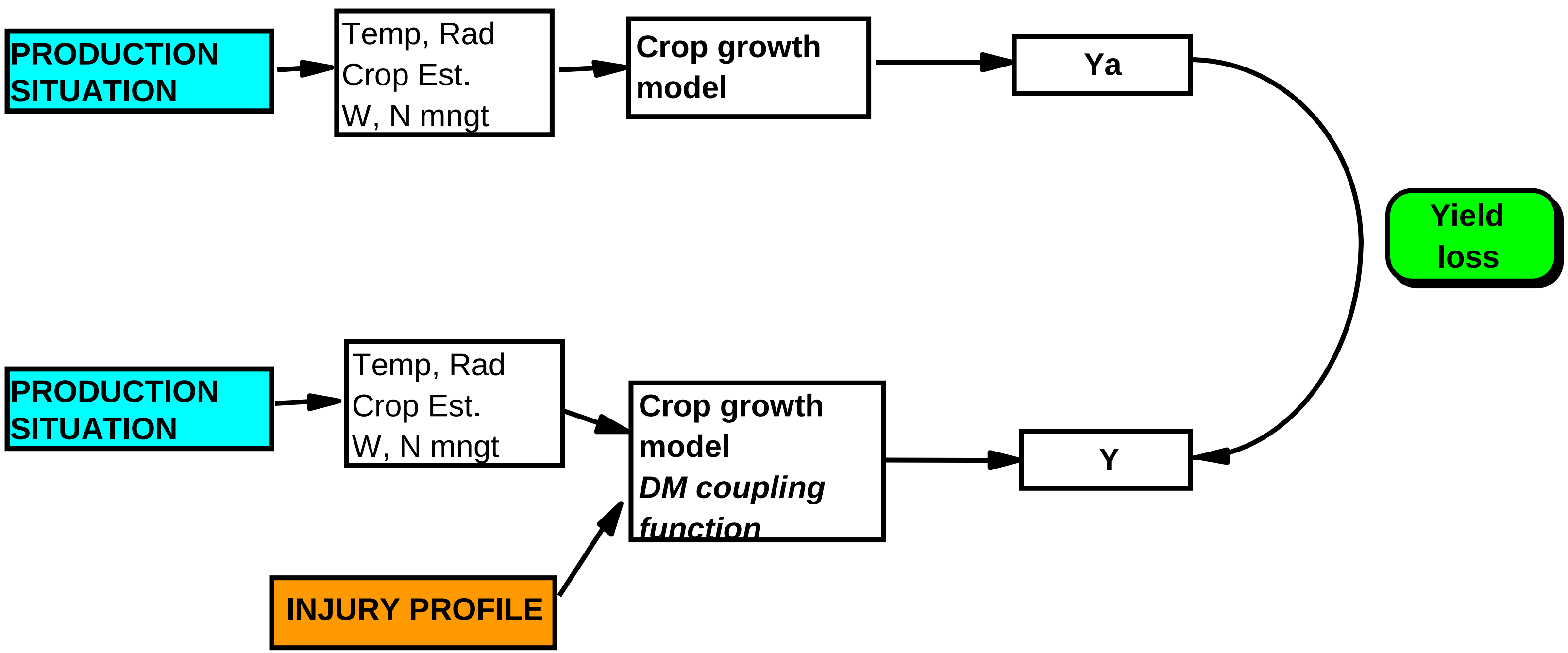
• Damage mechanism: physiological effect of injury on crop growth and yield. Can be incorporated in models to simulate yield losses.

Damage mechanism	**Physiological process/variable affected**	**Examples**
Assimilate sapper	Maintenance/pool of assimilates	Aphids, rusts, septoria blotch
Light stealer	Light interception/green LAI	Rusts, powdery mildew, septoria blotch
Assimilate rate reducer	Photosynthesis/RUE	Eyespot, sharp eyespot, fusarium stem rot, take-all, weeds, BYDV, aphids

Rabbinge, R., Vereijken, P.H., 1980. The effect of diseases or pests upon the host. Z. Pflkrankh. Pflschutz 87, 409-422.

Boote, K.J., Jones, J.W., Mishoe, J.W., Berger, R.D., 1983. Coupling pests to crop growth simulators to predict yield reductions. Phytopathology 73, 1581-1587.

Simulation of yield losses caused by injury profiles according to production situations using a crop growth model

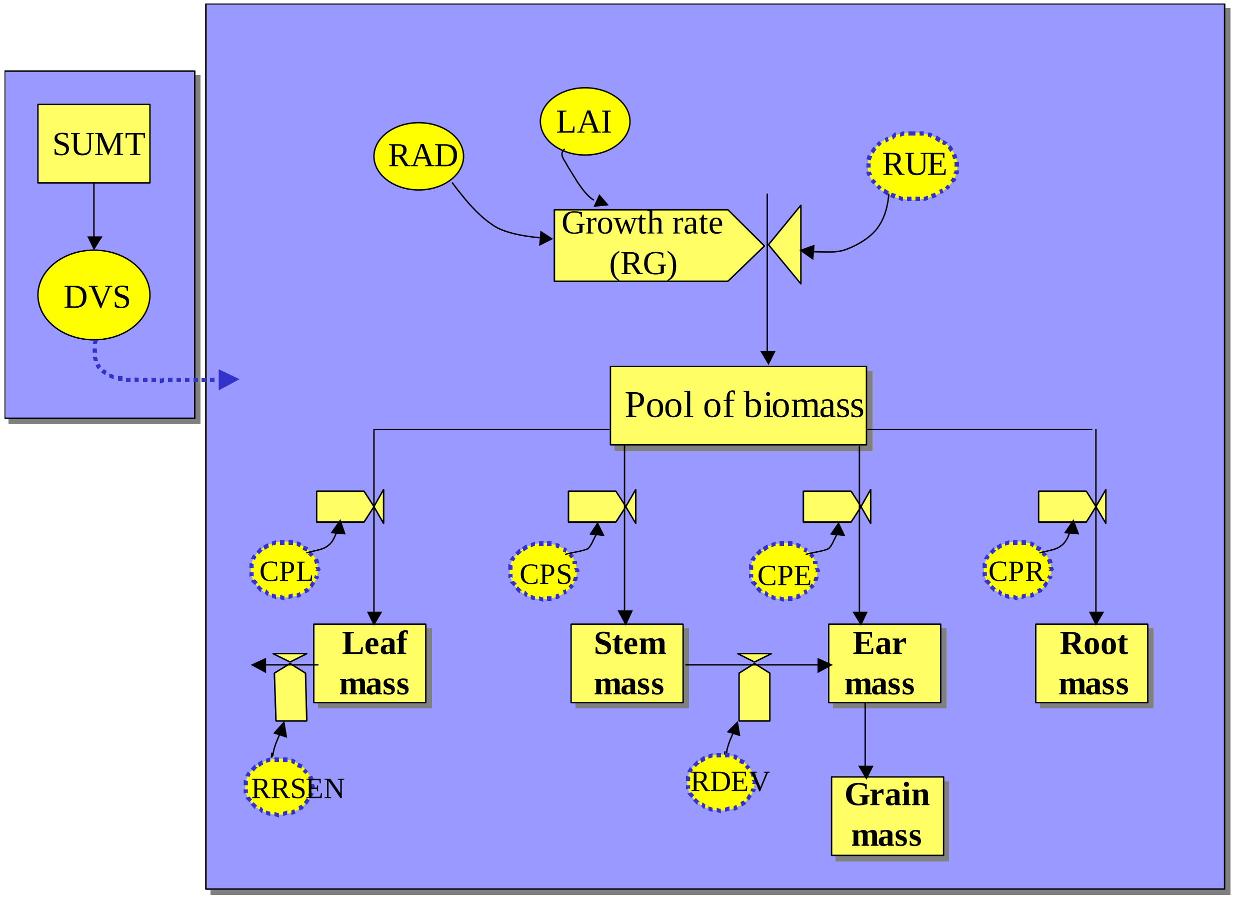


PS: production situation;
Ya: attainable yield;
Y: actual yield;
DM: damage mechanism;
W: water; N: nitrogen

Willocquet, L., Savary, S., Fernandez, L., Elazegui, F., Teng P.S., 1998. Simulation of yield losses caused by rice diseases, insects, and weeds in tropical Asia. IRRI Discussion Paper Series no 34. IRRI, Los Baños, Philippines, pp. 62.

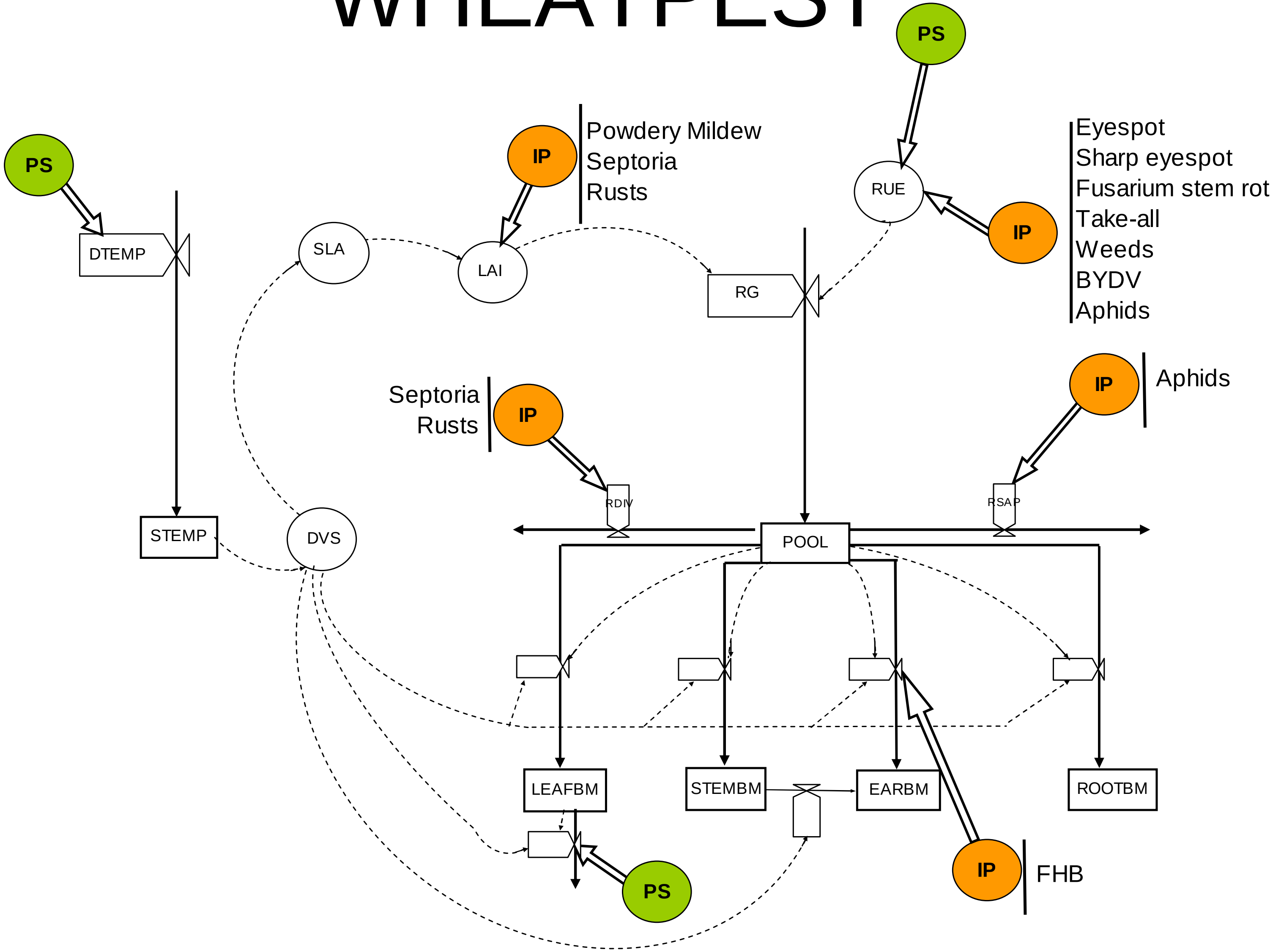
Schematic representation of the wheat growth and yield model **(simplified structure).**

1) Modelling YATT



parameter depending on DVS.

Incorporation of PS and IP in WHEATPEST



Biomass production

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

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

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

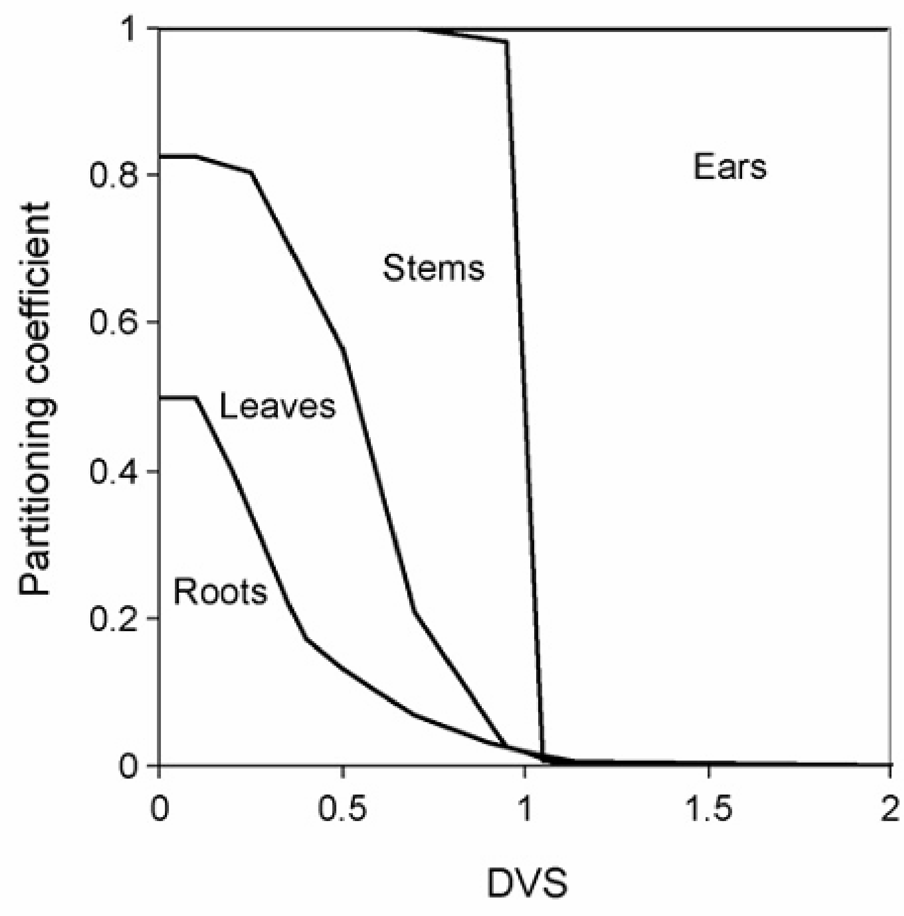
RUE: Radiation Use Efficiency ([RUE]=$T^{2}L^{-2}$)

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

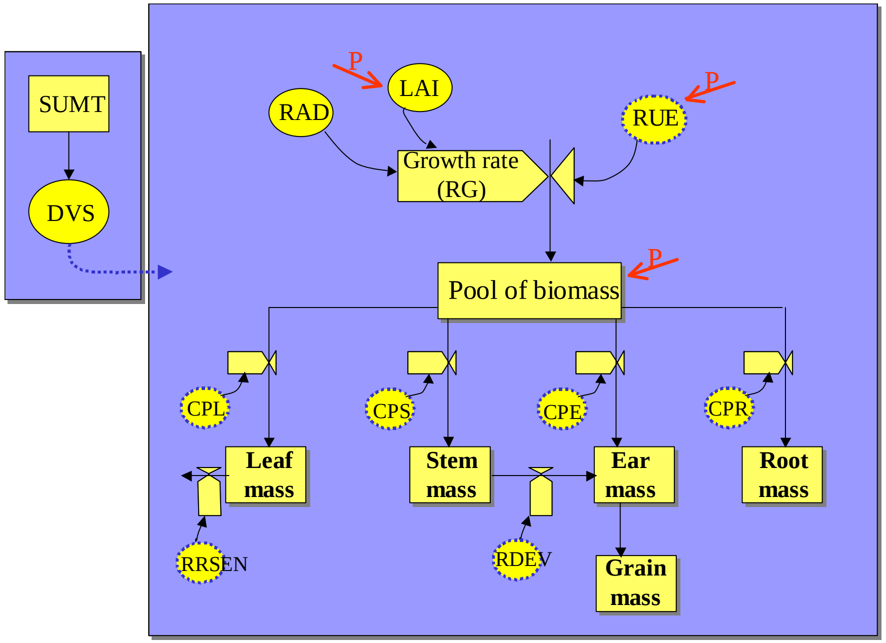
LAI: Leaf Area Index ([LAI]=1)

Partitioning of assimilates to wheat organs as a function of development stage (DVS)

Derived from Spitters et al (1989).



2) Modelling YACT

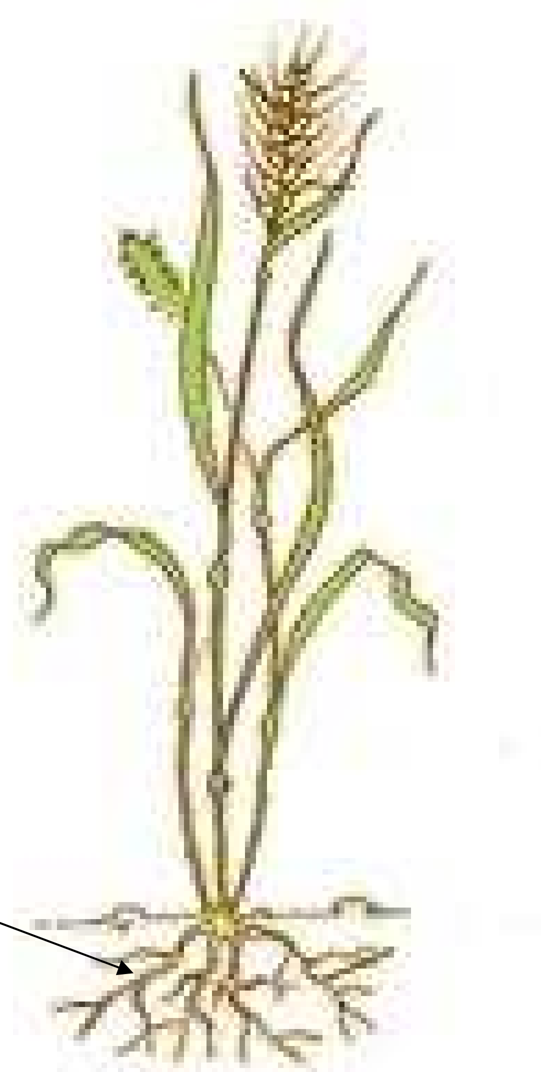


Disease	Injury localisation	Data input in the model
Take-all	Roots	Percentage of take-all disease on roots.
Fusarium Stem Rot	Roots, Stems	percentages of tillers with Fusarium stem rot symptoms.
Eyespot	Stems	percentages of tillers with eyespot
Sharp-eyespot	Stems	percentages of tillers with sharp eyespot symptoms
Septoria nodorum blotch	Leaves	Septoria nodorum blotch severity
Septoria tritici blotch	Leaves	Septoria tritici blotch severity
Brown rust	Leaves	Brown rust severity
Yellow rust	Leaves	Yellow rust severity
Powdery Mildew	Leaves	Powdery Mildew severity
Fusarium Head Blight	Ears	percentage of kernels with Fusarium head blight symptoms
Aphids	Affect overall performance	Number of aphids
Weeds	Affect overall performance	Dry biomass of weeds
Barley Yellow Dwarf Viruses	Affect overall performance	Percentages of plants with Barley Yellow dwarf Viruses symptoms

Root diseases

<u>Take-all</u>

• Blackened roots and stem bases on infected plants



Modelling damage mechanisms: take-all (Gaeumannomyces gramini var tritici)

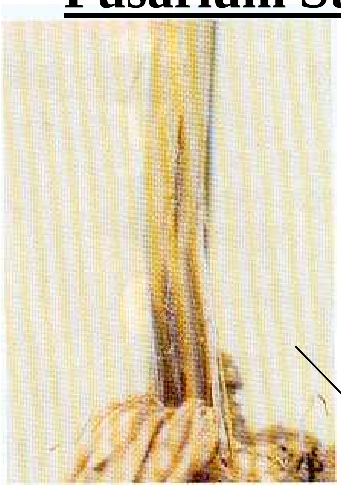
$$RF_{TAK} = 1 - TAK / 100$$

RF_{TAK}: reduction factor of RUE ([RF_{TAK}]=1)

TAK: root disease severity defined as the % of diseased root length ([TAK]=1)

Stem diseases

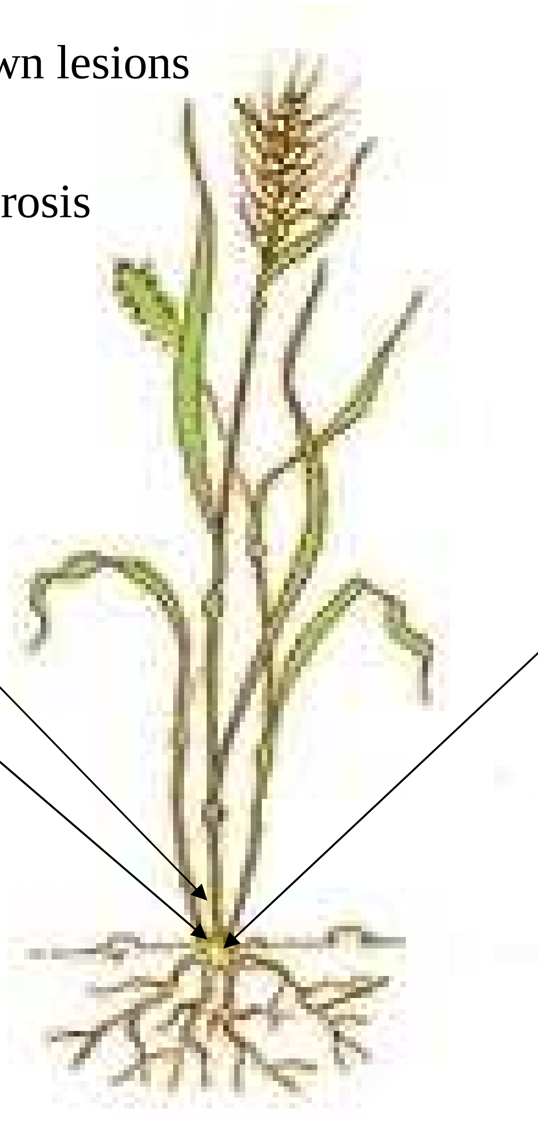
Fusarium Stem Rot



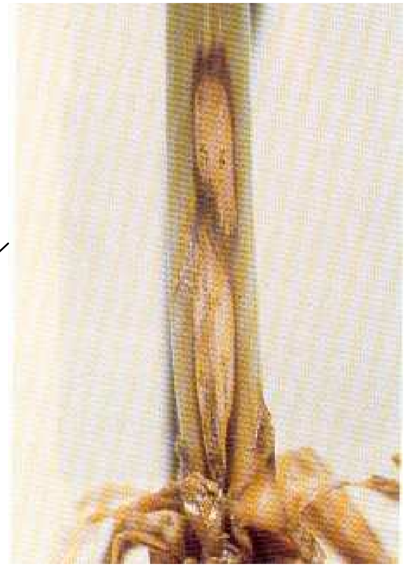
- linear and brown lesions
- no stroma
- superficial necrosis

Eyespot

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



Sharp Eyespot



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

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)

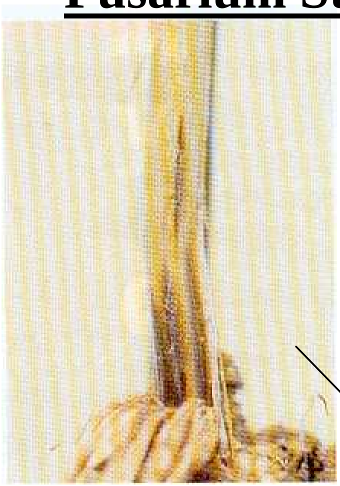
FST1: % of tillers with slight FST symptoms (browning up to second node [FST1]=1)

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)

Stem diseases

Fusarium Stem Rot



- linear and brown lesions
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Eyespot

- necrotic lesion ± limited
- stroma in the center
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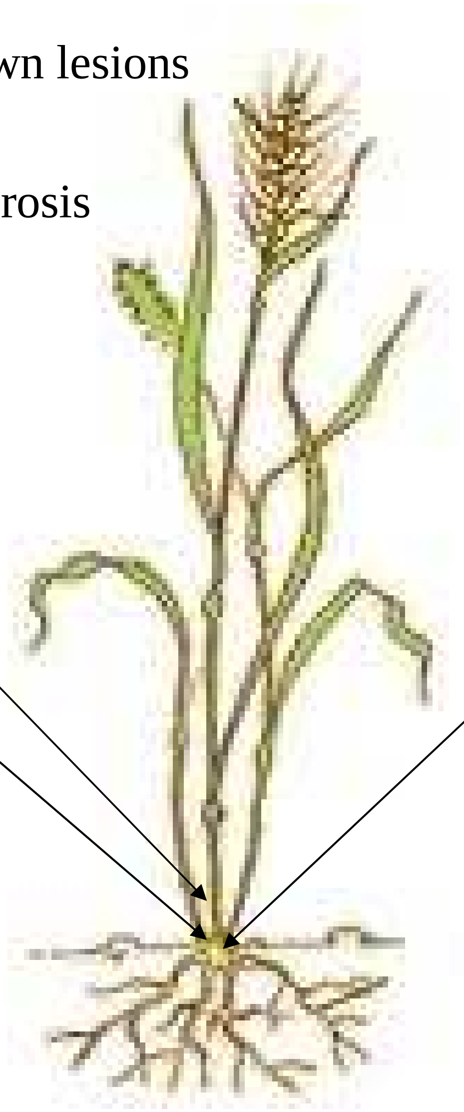
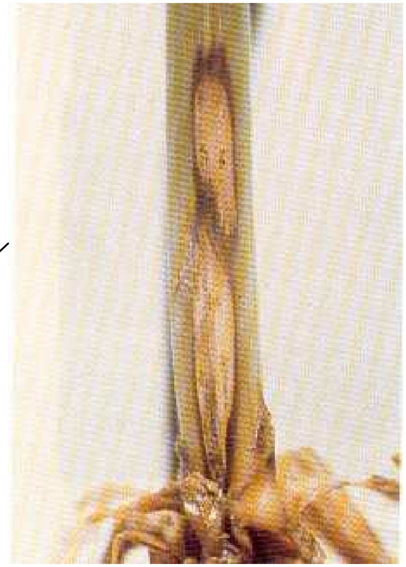


Sharp Eyespot



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

Modelling damage mechanisms: eyespot (Oculimacula yallundae, O acuformis)

$$RF_{EYS} = 1 - \left(aEYS1/100 + bEYS2/100 + cEYS3/100 \right)$$

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

EYS1: % of tillers with slight EYS symptoms (one or more lesions occupying in total less than half the circomference of the stem; [EYS1]=1)

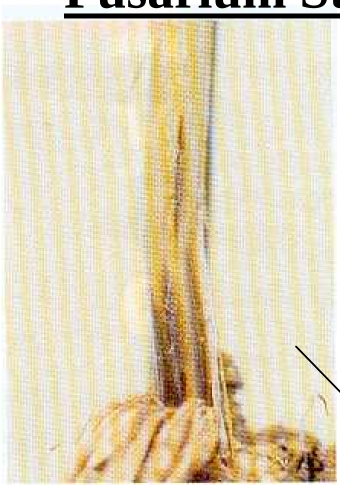
EYS2: % of tillers with moderate EYS symptoms (one or more lesions occupying in total more than half the circomference of the stem;[EYS2]=1)

EYS3: % of tillers with severe EYS symptoms (stem completely girdled by lesions, tissue softened; [EYS3]=1)

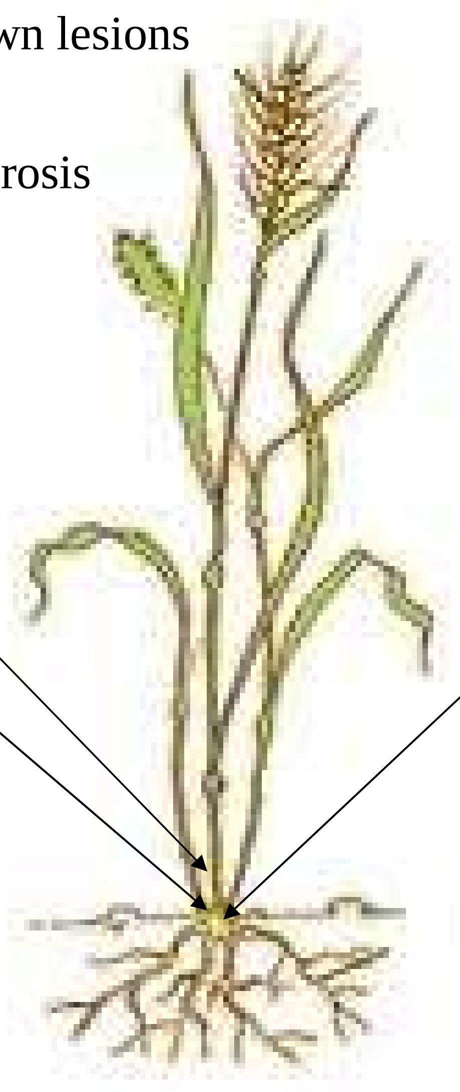
a, b, c : parameters derived from Clarkson et al. (1981) ([a]=[b] =[c]=1)

Stem diseases

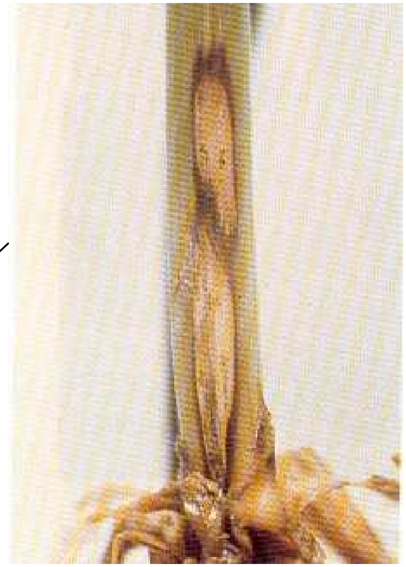
Fusarium Stem Rot



- 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

Modelling damage mechanisms: sharp eyespot (Rhizoctonia cerealis)

$$RF_{SHY} = 1 - \left(aSHY1/100 + bSHY2/100 + cSHY3/100 \right)$$

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

SHY1: % of tillers with slight SHY symptoms ([SHY1]=1)

SHY2: % of tillers with moderate SHY symptoms ([SHY2]=1)

SHY3: % of tillers with severe SHY symptoms ([SHY3]=1)

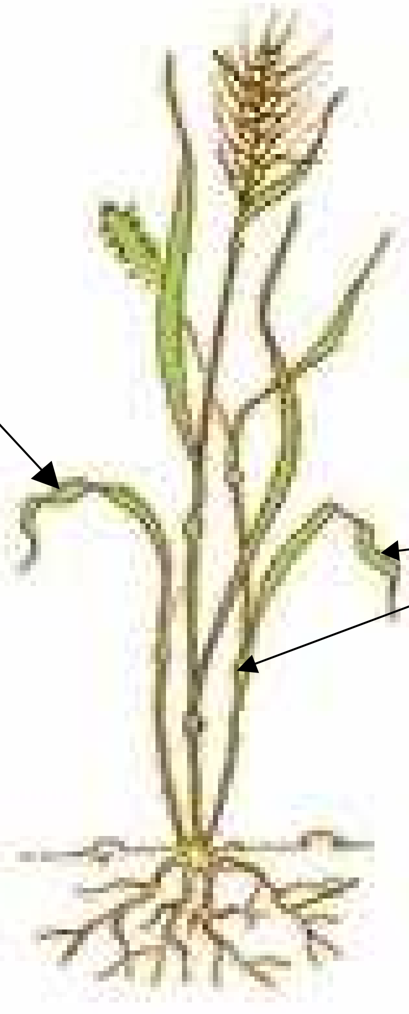
a, b, c : parameters derived from Clarkson and Cook (1983) ([a]=[b] =[c]=1)

Leaf and Stem diseases

Septoria tritici, S nodorum

• elongate ovals lesions, running parallel to leaf veins +chlorotic halo around the lesions.

• black pycnidia (spore cases) in mature lesions.



Powdery mildew

• white fluffy mildew pustule + black spores at the end of vegetation

Modelling damage mechanisms: septoria nodorum blotch (septoria nodorum)

$$LAI_{dis} = LAI\left(1 - x/100\right)^{\beta}$$

LAI_{dis}: reduced Leaf Area Index ($[LAI_{dis}]=1$)

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

x: severity of the disease expressed in % ([x]=1)

β: ratio of the virtual lesion area over the actual lesion area ([β]=1)

β=1 (Scharen and Taylor, 1968; Rooney, 1989)

Modelling damage mechanisms: septoria nodorum blotch (septoria nodorum)

$$RDIVSN = \alpha.RG.SN / 100$$

RDIVSN: daily rate of assimilate diversion ([RDIVSN]=$MT^{-1}L^{-2}$)

α: parameter, derived from Scharen and Taylor (1968) ([α]=1)

RG: rate of crop growth ([RG]=$MT^{-1}L^{-2}$)

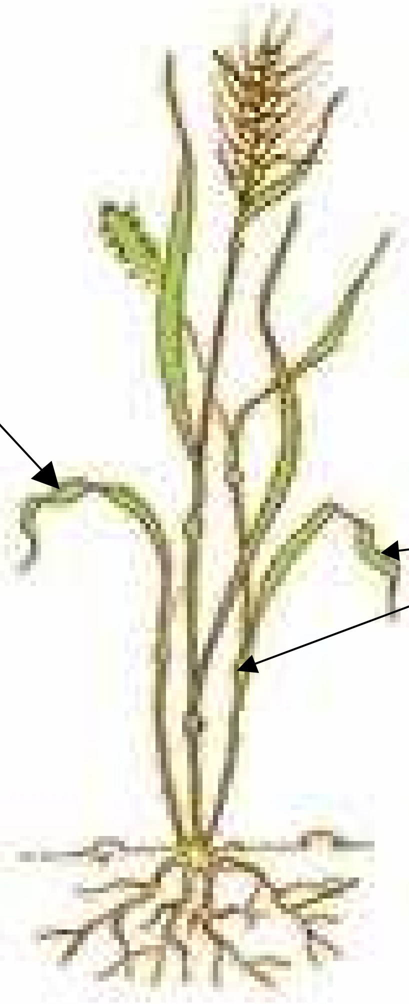
SN: severity of septoria nodorum blotch expressed in % ([SN]=1)

Leaf and Stem diseases

<u>Septoria tritici, S nodorum</u>

• elongate ovals lesions, running parallel to leaf veins +chlorotic halo around the lesions.

• black pycnidia (spore cases) in mature lesions.



<u>Powdery mildew</u>

• white fluffy mildew pustule + black spores at the end of vegetation

Modelling damage mechanisms: septoria tritici blotch (Mycosphaerella graminicola)

$$LAI_{dis} = LAI\left(1 - x/100\right)^{\beta}$$

LAI_{dis}: reduced Leaf Area Index ($[LAI_{dis}]=1$)

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

x: severity of the disease expressed in % ([x]=1)

β: ratio of the virtual lesion area over the actual lesion area ($[\beta]=1$)

β=1.25 (Robert et al, 2006)

Modelling damage mechanisms: septoria tritici blotch (Mycosphaerella graminicola)

$$RDIVST = \alpha.RG.ST / 100$$

RDIVST: daily rate of assimilate diversion ([RDIVST]=$MT^{-1}L^{-2}$)

α: parameter, derived from Scharen and Taylor (1968) ([α]=1)

RG: rate of crop growth ([RG]=$MT^{-1}L^{-2}$)

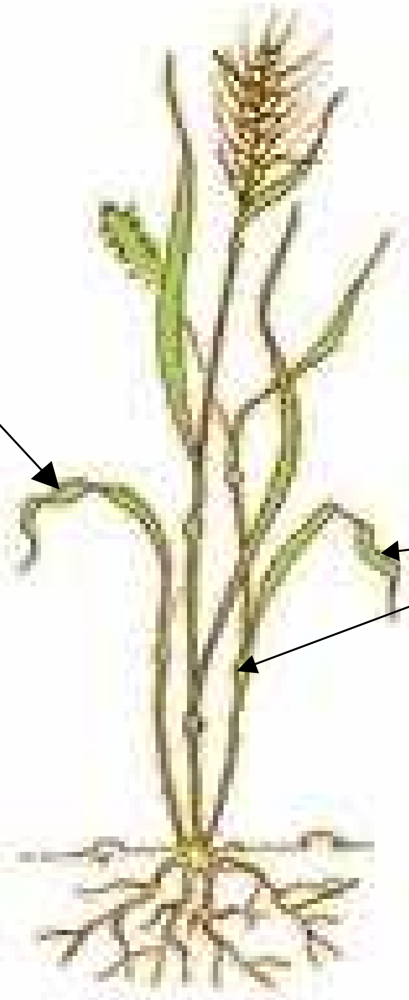
ST: severity of septoria tritici blotch expressed in % ([ST]=1)

Leaf and Stem diseases

Septoria tritici, S nodorum

• elongate ovals lesions, running parallel to leaf veins +chlorotic halo around the lesions.

• black pycnidia (spore cases) in mature lesions.



Powdery mildew

• white fluffy mildew pustule + black spores at the end of vegetation

Modelling damage mechanisms: powdery mildew (Blumeria graminis)

$$LAI_{dis} = LAI\left(1 - x/100\right)^{\beta}$$

LAI_{dis}: reduced Leaf Area Index ($[LAI_{dis}]=1$)

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

x: severity of the disease expressed in % ([x]=1)

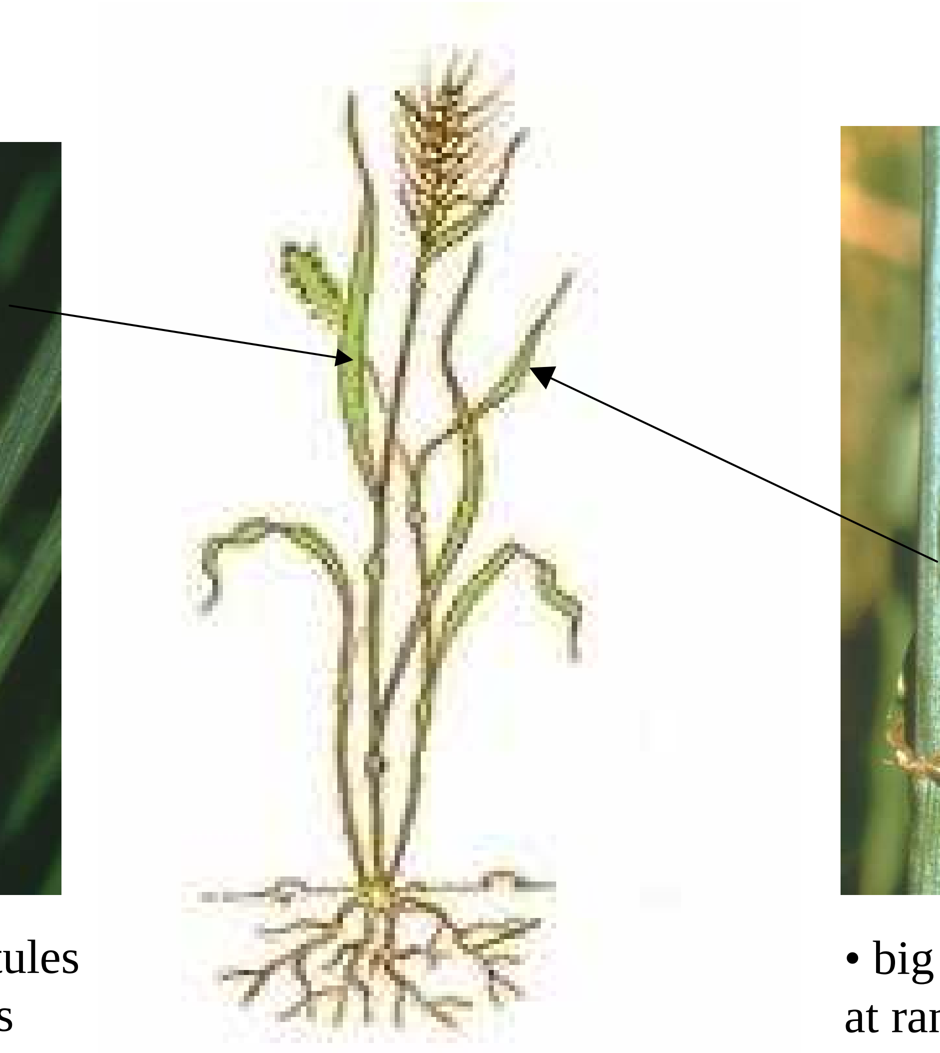
β: ratio of the virtual lesion area over the actual lesion area ($[\beta]=1$)

$\beta=2.5$ (Rabbinge et al, 1985)

Leaf and Stem diseases

Yellow rust

• yellow and small pustules between veins in stripes



Brown rust

• big pustules scattered at random

Modelling damage mechanisms: yellow (stripe) rust (Puccinia striiformis)

$$LAI_{dis} = LAI\left(1 - x/100\right)^{\beta}$$

LAI_{dis}: reduced Leaf Area Index ([LAI_{dis}]=1)

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

x: severity of the disease expressed in % ([x]=1)

β: ratio of the virtual lesion area over the actual lesion area ([β]=1)

β=1.5 (Yang and Zeng, 1988)

Modelling damage mechanisms: yellow (stripe) rust (Puccinia striiformis)

$$RDIVYR = \alpha.NPUSYR$$

RDIVYR: daily rate of assimilate diversion ([RDIVYR]=$MT^{-1}L^{-2}$)

α: parameter, Savary et al (1990) ([α]=1)

NPUSYR: number of pustules of yellow rust per surface unit ([NPUSYR]=L^{-2})

$$NPUSYR = \left(YR/100\right).\left(LAI/SURFYR\right)$$

YR: severity of yellow rust expressed in % ([YR]=1)

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

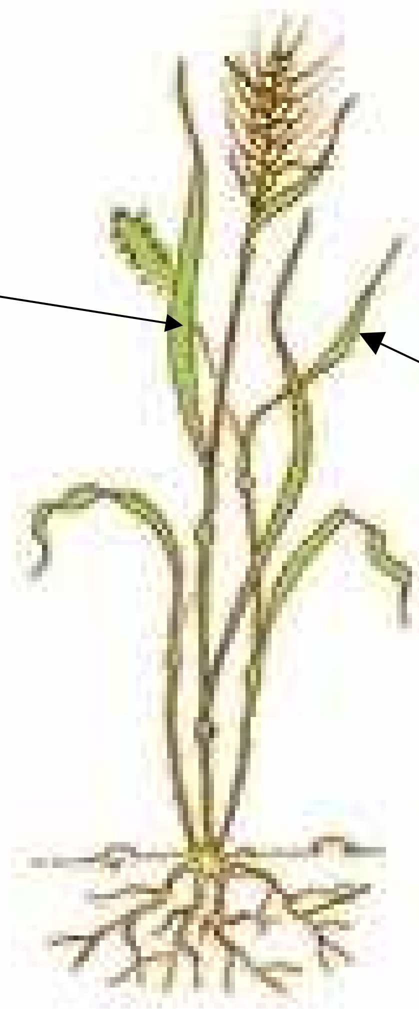
SURFYR: area of a pustule of a leaf rust ([SURFYR]=L^2)

SURFYR=1.0 10^{-6} m^2

Leaf and Stem diseases

Yellow rust

• yellow and small pustules between veins in stripes



Brown rust

• big pustules scattered at random

Modelling damage mechanisms: brown rust (Puccinia triticina)

$$LAI_{dis} = LAI\left(1 - x/100\right)^{\beta}$$

LAI_{dis}: reduced Leaf Area Index ($[LAI_{dis}]=1$)

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

x: severity of the disease expressed in % ([x]=1)

β: ratio of the virtual lesion area over the actual lesion area ($[\beta]=1$)

$\beta=1$ (Spitters et al, 1990; Robert et al, 2005)

Modelling damage mechanisms: brown rust (*Puccinia triticina*)

$$RDIVBR = \alpha.NPUSBR$$

RDIVBR: daily rate of assimilate diversion ($[RDIVBR]=MT^{-1}L^{-2}$)

α: parameter, Savary et al (1990) ($[\alpha]=1$)

NPUSBR: number of pustules of yellow rust per surface unit ($[NPUSBR]=L^{-2}$)

$$NPUSBR = \left(BR/100\right).\left(LAI/SURFBR\right)$$

BR: severity of brown rust expressed in % ([BR]=1)

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

SURFBR: area of a pustule of a leaf rust ($[SURFBR]=L^2$)

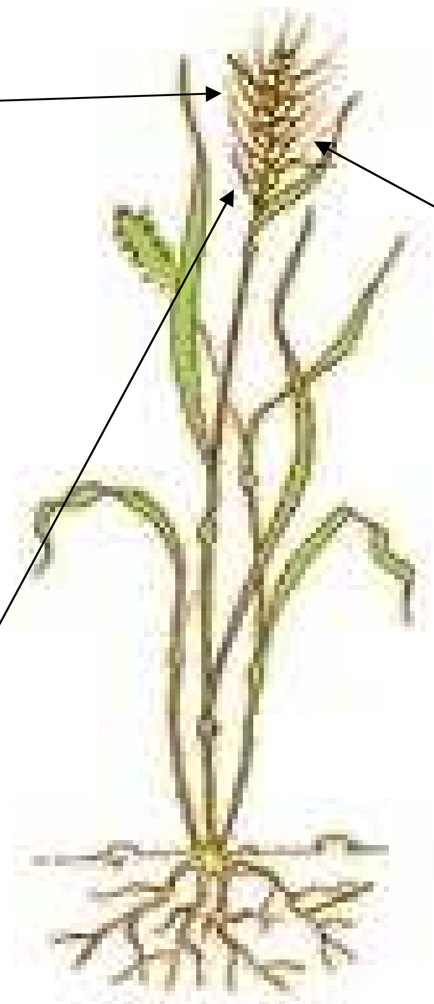
$SURFBR=1.0\ 10^{-6}\ m^2$

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

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)

...
aphids
weeds
viruses
...

Modelling damage mechanism: aphids (*Sitobion avenae*)

$$RSAP = RRSAP * APHBM * APH$$

RSAP: daily rate of assimilate sapping by aphids ($[RSAP]=MT^{-1}L^{-2}$)

RRSAP: relative feeding rate ($[RRSAP]=T^{-1}$)

APHBM: fresh biomass of an individual aphid ($[APHBM]=M$)

APH: number of aphids per surface unit ($[APH]=L^{-2}$)

Modelling damage mechanism: aphid example (*Sitobion avenae*)

$$RF_{APH} = MAX(1 - HONEY * 0.015; 0.8)$$

RF_{APH}: reduction of RUE caused by honeydew deposition ($[RF_{APH}]=1$)

HONEY: mass of accumulated honeydew per surface unit ($[HONEY]=ML^{-2}$)

$$RHONEY = 0.35 * RSAP$$

RHONEY: daily rate of honeydew accumulation ($[RHONEY]=MT^{-1}L^{-2}$)

Parameters from Mantel et al. (1982) and Rossing (1991)

...
aphids
weeds
viruses
...

Modelling damage mechanism: weeds

$$RF_{WD} = e^{-\alpha WD}$$

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

WD: dry biomass of weeds per surface unit ($[WD]=ML^{-2}$)

$\alpha=0.003$: parameter (Willocquet et al, 2000) ($[\alpha]=L^2M^{-1}$)

…

aphids

weeds

viruses

…

Modelling damage mechanism: Barley Yellow Dwarf Viruses

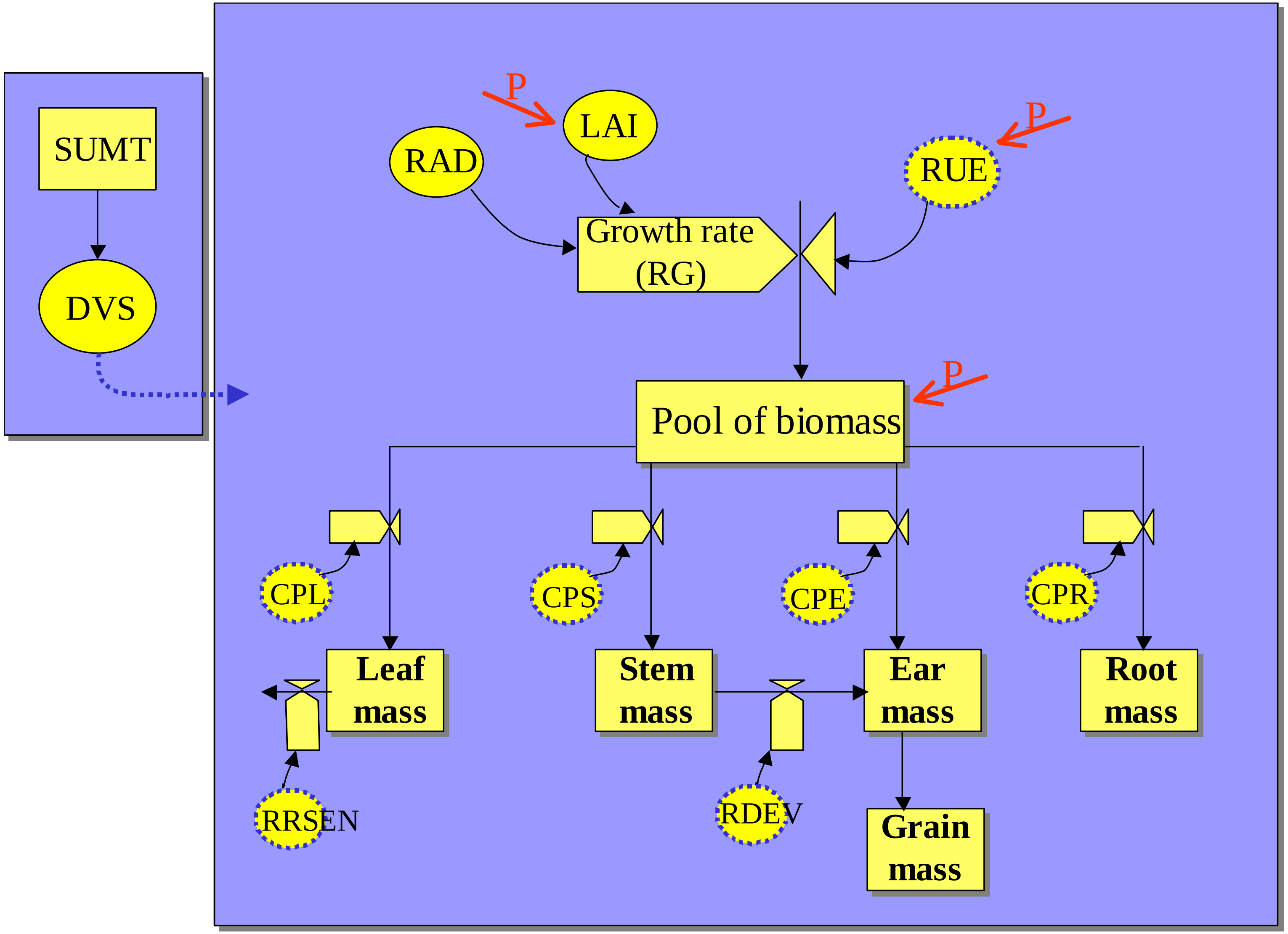
$$RF_{BYDV} = 1 - aBYDV / 100$$

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

BYDV: % of diseased plants ([BYDV]=1)

a=0.35: parameter (Perry et al., 2000; McKirdy et al, 2002) ([a]=1)

Simplified flow chart of WHEATPEST



WHEATPEST : A crop growth model for wheat (roots, stems, leaves, ears biomass) which incorporates damage mechanisms caused by a variety of pests.

INPUT

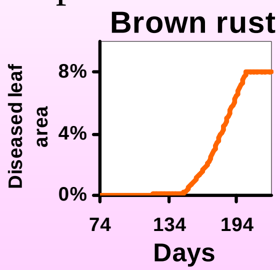
for a given Production Situation :

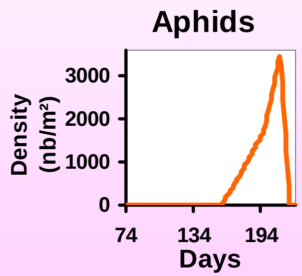
- **driving functions (parameterisation)**
- **date of key development stage**
- **initial dry biomass of plants in $1m^2$ of crop**
- **climatic data (RAD, TMIN, TMAX)**

for a given Injury Profile :

- **1 or several pests (pathogen, insect, weeds)**

For example:





DVS0 = seedling emergence

DVS1 = flowering

DVS2 = grain maturity

OUTPUT

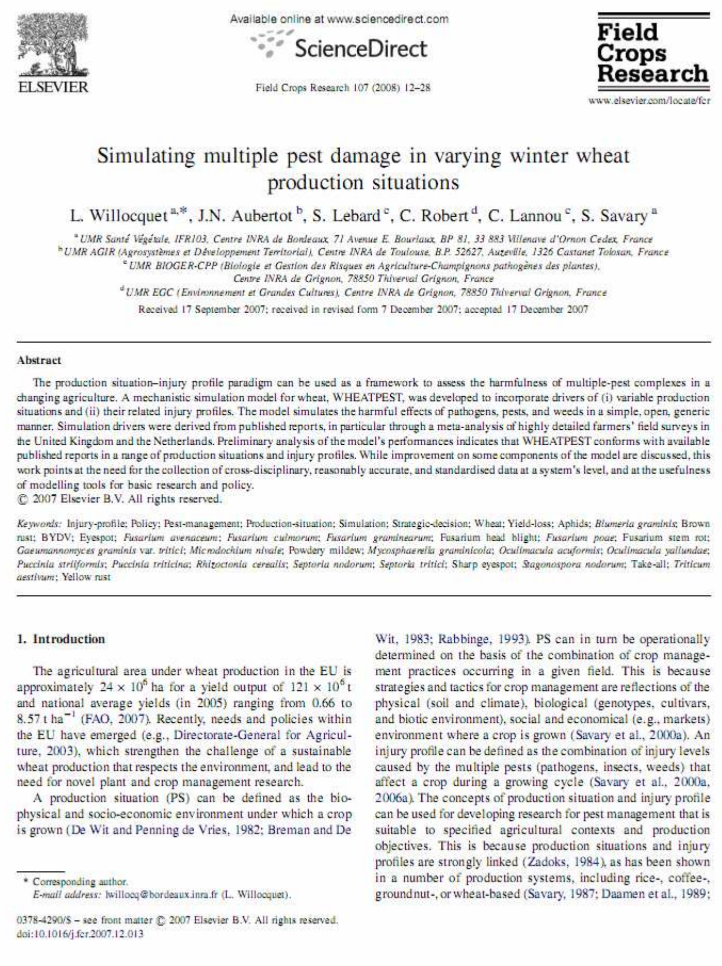
Organ biomass

YATT or YACT (with IP)

YLOSSES = YATT-YACT

For those interested in more detailed information about WHEATPEST:

Willocquet L, Aubertot JN, Lebard S, Robert C, Lannou C, Savary S. 2008. Simulating multiple pest damage in varying winter wheat production situations. Field Crops Research, 107 (1), p.12-28.



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Simulating multiple pest damage in varying winter wheat production situations

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Abstract

The production situation–injury profile paradigm can be used as a framework to assess the harmfulness of multiple-pest complexes in a changing agriculture. A mechanistic simulation model for wheat, WHEATPEST, was developed to incorporate drivers of (i) variable production situations and (ii) their related injury profiles. The model simulates the harmful effects of pathogens, pests, and weeds in a simple, open, generic manner. Simulation drivers were derived from published reports, in particular through a meta-analysis of highly detailed farmers' field surveys in the United Kingdom and the Netherlands. Preliminary analysis of the model's performances indicates that WHEATPEST conforms with available published reports in a range of production situations and injury profiles. While improvement on some components of the model are discussed, this work points at the need for the collection of cross-disciplinary, reasonably accurate, and standardised data at a system's level, and at the usefulness of modelling tools for basic research and policy.

Keywords: Injury-profile; Policy; Pest-management; Production-situation; Simulation; Strategic-decision; Wheat; Yield-loss; Aphids; *Blumeria graminis*; Brown rust; BYDV; Eyespot; *Fusarium avenaceum*; *Fusarium culmorum*; *Fusarium graminearum*; Fusarium head blight; *Fusarium poae*; Fusarium stem rot; *Gaeumannomyces graminis* var. *tritici*; *Microdochium nivale*; Powdery mildew; *Mycosphaerella graminicola*; *Oculimacula acuformis*; *Oculimacula yallundae*; *Puccinia striiformis*; *Puccinia triticina*; *Rhizoctonia cerealis*; *Septoria nodorum*; *Septoria tritici*; Sharp eyespot; *Stagonospora nodorum*; Take-all; *Triticum aestivum*; Yellow rust

1. Introduction

The agricultural area under wheat production in the EU is approximately 24×10^6 ha for a yield output of 121×10^6 t and national average yields (in 2005) ranging from 0.66 to 8.57 t ha^{-1} (FAO, 2007). Recently, needs and policies within the EU have emerged (e.g., Directorate-General for Agriculture, 2003), which strengthen the challenge of a sustainable wheat production that respects the environment, and lead to the need for novel plant and crop management research.

A production situation (PS) can be defined as the bio-physical and socio-economic environment under which a crop is grown (De Wit and Penning de Vries, 1982; Breman and De Wit, 1983; Rabbinge, 1993). PS can in turn be operationally determined on the basis of the combination of crop management practices occurring in a given field. This is because strategies and tactics for crop management are reflections of the physical (soil and climate), biological (genotypes, cultivars, and biotic environment), social and economical (e.g., markets) environment where a crop is grown (Savary et al., 2000a). An injury profile can be defined as the combination of injury levels caused by the multiple pests (pathogens, insects, weeds) that affect a crop during a growing cycle (Savary et al., 2000a, 2006a). The concepts of production situation and injury profile can be used for developing research for pest management that is suitable to specified agricultural contexts and production objectives. This is because production situations and injury profiles are strongly linked (Zadoks, 1984), as has been shown in a number of production systems, including rice-, coffee-, groundnut-, or wheat-based (Savary, 1987; Daamen et al., 1989;

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Using WHEATPEST …

The aim of the exercice is not to learn the FST (or the Fortran) langage but rather to understand how WHEATPEST works.

1) Open the «C:\fstmodel » folder and open the file named « FILES » to understand the general purpose of the various files in this folder (don't hesitate to open these files to better understand their role!).

2) Start FST (use the FSTS dos command)

3) Open the WPEST.fst file

4) Read the code in order to get a general overview of the program's structure

A little French lesson…

Fichier: Plik
- Nouveau: Nowy
- Ouvrir: Otwierać
- Enregistrer: Zapisać
- Enregistrer sous: Zapisać jako
- Fermer: Zamykać
- Imprimer: Wydrukować
- Annuler: Anulować
- Nom du fichier: Nazwa (pliku)
- Répertoire: Katalog
- Quitter: Zakończ
- Aide: Pomoc

Edition: Wydanie
- Couper: Ciać
- Copier: Kopiować
- Coller: Nakleić
- Effacer: Zmazać

Affichage: Wyświetlanie
- Séparer fenêtre: Oddzielny okno
- Dimensionner fenêtre: Wymiar okno
- Fermer fenêtre: Zamykać okno

Recherche: Wyszukiwanie
- Rechercher: Poszukiwać
- Poursuivre la recherche: Kontynuować wyszukiwanie
- Remplacer: Zmieniać

Options: Opcje
- Paramètres: Parametr
- Couleurs: Gama kolorów

?: ?
- Commandes: Kontrola
- A propos de: przyim

A little FST lesson…

*****: start of a comment line

TITLE: keyword containing a short identification of the program (written in the output file)

MODEL: the model section describes the actual model by means of calculation statements, input statements, output statements and simulation control statements

INITIAL: one of the three sections (INITIAL-DYNAMIC-TERMINAL). These keywords indicate that the computations must be performed before, during and after a simulation run, respectively. INITIAL is optional. It can be used to specify input data (initial conditions and parameters) and the time variables

DYNAMIC: section that contains the complete description of the model dynamics and any other computation required during the simulation

TERMINAL: optional. It can be used for computation and specific output that is only available at the end of the simulation run. As INITIAL section, the computations are executed only once

END: end of a section

PARAM: statement to define parameters (quantities that should be constant during the model exécution)

INCON: statement to define initial constants (that specify the start values of state variables)

FUNCTION: keyword to define a variable which varies in time or which depends on some other model variable

FINISH: keyword to define when the simulation must finish (if the model doesn't need to be run until FINTIM but until a variable reach a certain value)

TIMER: statement to give information about time (start time (STTIME), finish time (FINTIM), time step of integration (DELT), time interval between outputs (PRDEL))

TRANSLATION GENERAL: keyword that specifies that a model routine that can run under a general simulation driver is used

DRIVER=‘EURDRIV’: scheme that has to be specified when TRANSLATION GENERAL is chosen (EURDRIV: fixed time step integration method of Euler)

WEATHER: keyword to define which wheather file has to be taken (path…)

AFGEN: function (Arbitrary Function GENerator) for linear interpolation (this function can be used with a variable defined as FUNCTION)

INSW: function Input switch. Y=INSW(X, Y1, Y2) returns Y1 if X <0 and Y2 if X>=0

INTGRL: function Integral. Y=INTGRL(Y1, YR), Y state variable, YI Initial value of Y, YR rate of change

MAX-MIN: functions taking the maximum or minimum of a set of variables

How to define a driver using a function under FST ?

Value of the driving function at a given DVS

FUNCTION APHNBT= 0.,0.,0.5,0.25,1.2,0.75,1.5,0.3,2.1,0.

DVS

Values at DVS 0 and DVS >2 have to be specified

Answer the following questions, using:
- <u>the injury profile B</u> of the dataset coming from the farmers' field survey in England, Wales and the Netherlands (Polley and Thomas, 1991; Daamen et al (1990, 1991, 1992); Daamen and Stool (1990, 1992, 1994)
- the generic weather embedded within WHEATPEST
- the following values of RUE (without any pest) for 3 different production situations at the vegetative and the reproductive stage respectively:
RUE1: 1.70 and 1.60 $g.MJ^{-1}$
RUE2: 1.45 and 1.40 $g.MJ^{-1}$
RUE3: 1.32 and 1.15 $g.MJ^{-1}$

TIP: don't forget to adapt the definition of the runs and the prints at the end of the file!

---

1) Associate logically RUE1, RUE2, and RUE3 with the 3 production situations: Conventional, Integrated and Organic.
2) For the conventional situation, plot the graph of root, stem, leaf and ear biomasses (impacted by the whole injury profil) as a function of time. Do these curves look consistent?
3) Calculate the attainable yield for each of the 3 production situations
4) Calculate individual relative yield losses and the total relative losses caused by the injury profiles for each of the 3 production situations (you can make histograms with Excel)
5) What is the pest responsible for the highest damage in the organic system ? Is it consistent with your own experience?
6) How would you explain the differences observed for the damage caused by powdery mildew in the 3 systems?
7) Calculate the differences between the sum of individual yield losses and the total yield loss. Are these differences different from 0? If it is so, briefly explain why.

Data derived from Polley and Thomas (1991) ; Daamen et al (1990, 1991, 1992) ; Daamen and Stool (1990, 1992, 1994)

Injury profile	Crop Management	DVS	WD (WEEDT)	TAK (SEVTAT)	EYS (FTES1T / FTES2T / FTES3T)	SHY (FSES1T / FSES2T / FSES3T)	FST (FBFR1T / FBFR2T)	ST (STBT)	SN (SNBT)	BR (LRT)	YR (SRT)	PM (PMT)	APH (APHNBT)	BYDV (BYDVT)	FHB (FHBT)
B	C	0.8	1.2	0.010	0.0047 / 0.0018 / 0.0007	0.0041 / 0.0016 / 0.0006	0.0077 / 0.0019	0.002	0.002	0.000	0.000	0.012	0	0.011	0.009
B	C	1.6	3.0	0.048	0.0473 / 0.0182 / 0.0073	0.0411 / 0.0158 / 0.0063	0.0771 / 0.0193	0.016	0.018	0.003	0.001	0.037	0.71	0.011	0.009
B	I	0.8	4.2	0.010	0.0047 / 0.0018 / 0.0007	0.0041 / 0.0016 / 0.0006	0.0077 / 0.0019	0.001	0.001	0.000	0.000	0.024	0	0.011	0.009
B	I	1.6	11.0	0.048	0.0473 / 0.0182 / 0.0073	0.0411 / 0.0158 / 0.0063	0.0771 / 0.0193	0.008	0.009	0.003	0.001	0.073	1.75	0.011	0.009
B	O	0.8	6.2	0.001	0.0012 / 0.0005 / 0.0002	0.0041 / 0.0016 / 0.0006	0.0077 / 0.0019	0.000	0.001	0.000	0.000	0.003	0	0.011	0.009
B	O	1.6	16.0	0.010	0.0118 / 0.0046 / 0.0018	0.0411 / 0.0158 / 0.0063	0.0771 / 0.0193	0.004	0.005	0.025	0.000	0.009	7.32	0.011	0.009

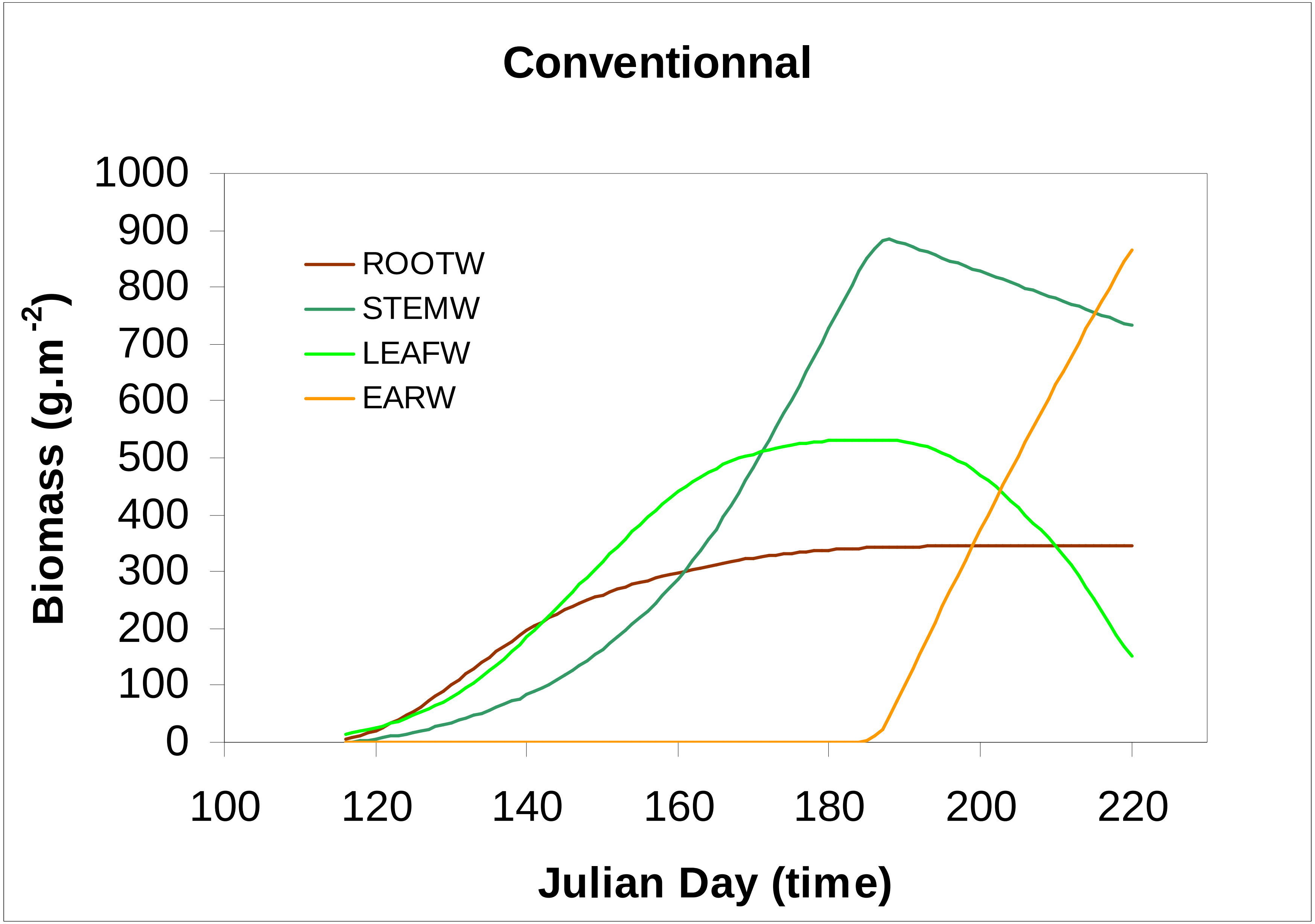
- QUESTION 1

RUE 1 → CONVENTIONAL

RUE 2 → INTEGRATED

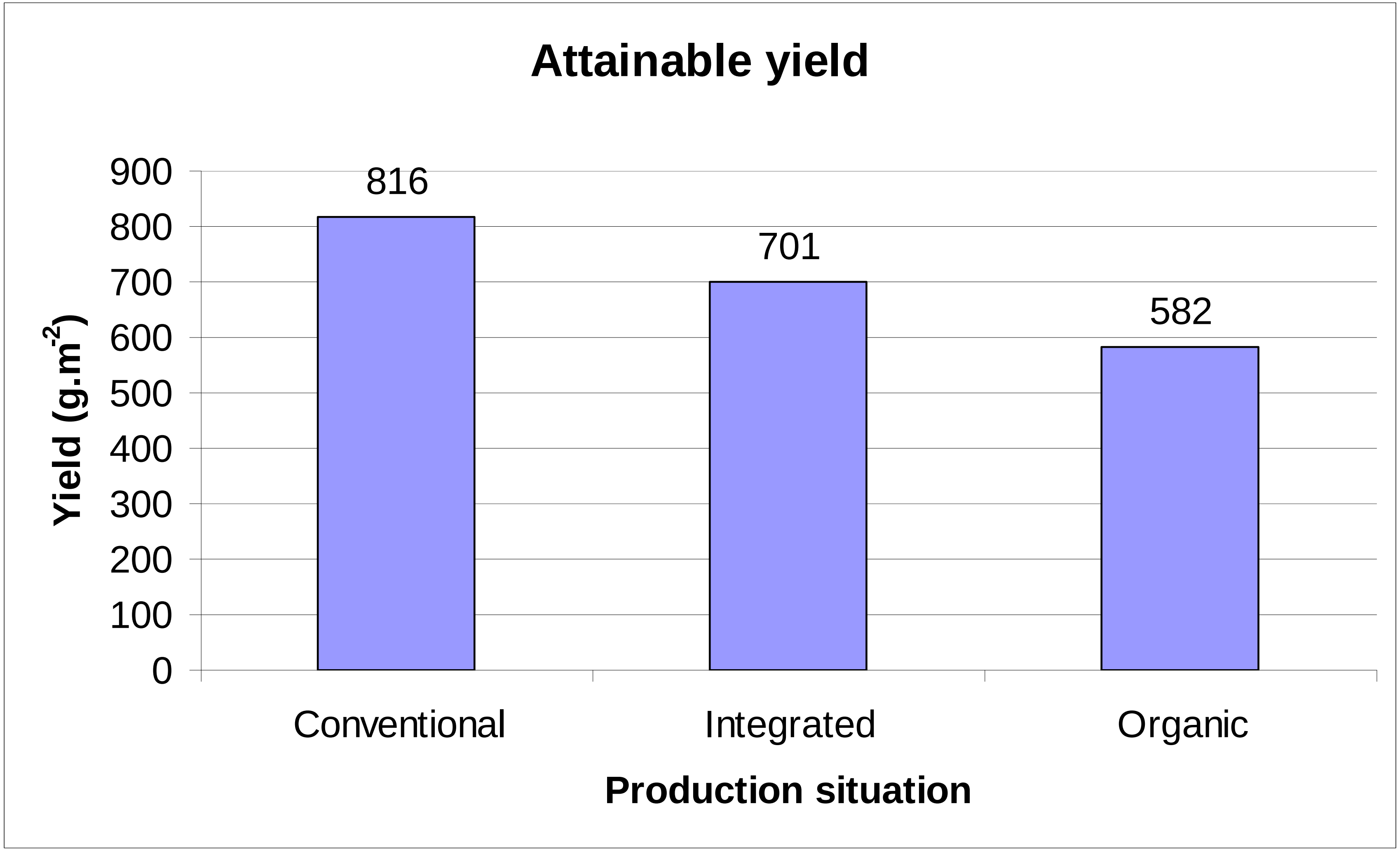
RUE 3 → ORGANIC

• QUESTION 2



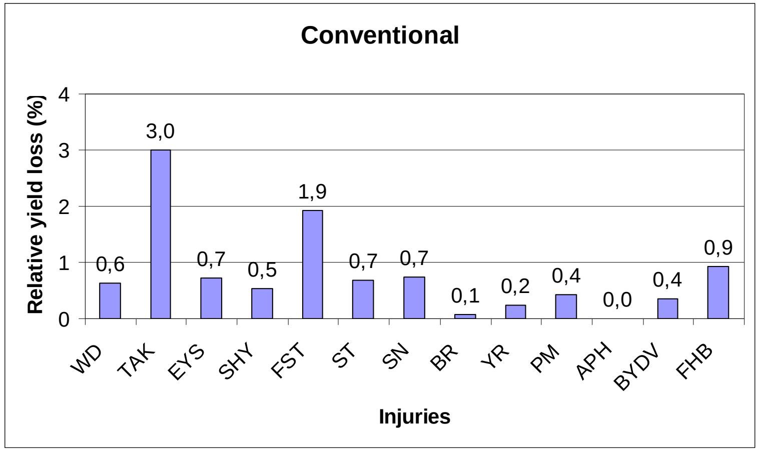
Conventionnal
1000
900
800
700
600
500
400
300
200
100
0
100
120
140
160
180
200
220
Biomass (g.m -2)
Julian Day (time)
ROOTW
STEMW
LEAFW
EARW

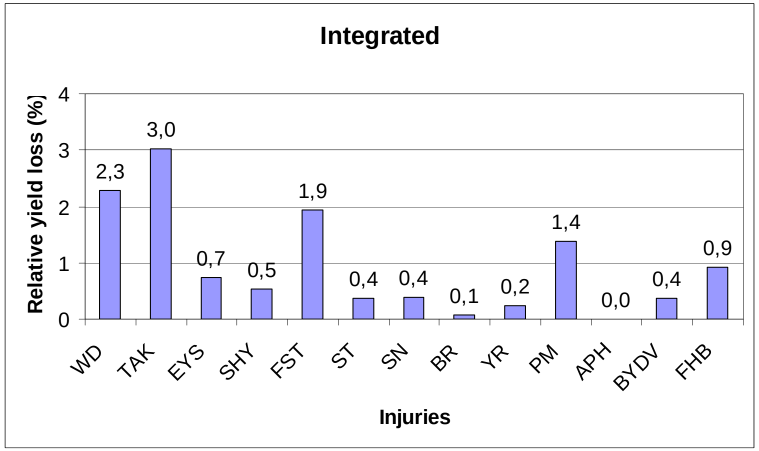
- QUESTION 3

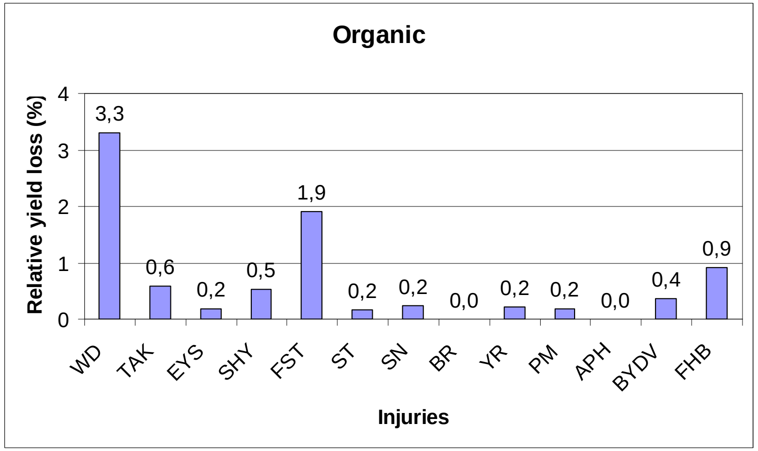


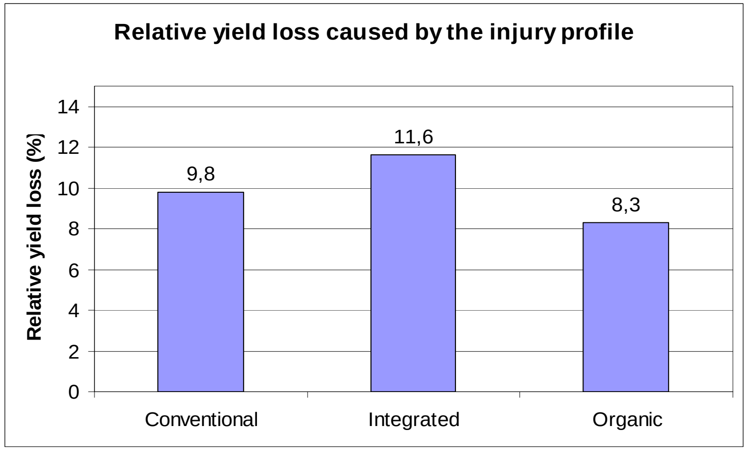
Attainable yield
900
800
700
600
500
400
300
200
100
0
Yield (g.m-2)
816
701
582
Conventional
Integrated
Organic
Production situation

• QUESTION 4


Conventional
Relative yield loss (%)
4
3
2
1
0
0,6
3,0
0,7
0,5
1,9
0,7
0,7
0,1
0,2
0,4
0,0
0,4
0,9
WD
TAK
EYS
SHY
FST
ST
SN
BR
YR
PM
APH
BYDV
FHB
Injuries


Integrated
Relative yield loss (%)
4
3
2
1
0
2,3
3,0
0,7
0,5
1,9
0,4
0,4
0,1
0,2
1,4
0,0
0,4
0,9
WD
TAK
EYS
SHY
FST
ST
SN
BR
YR
PM
APH
BYDV
FHB
Injuries


Organic
Relative yield loss (%)
4
3
2
1
0
3,3
0,6
0,2
0,5
1,9
0,2
0,2
0,0
0,2
0,2
0,0
0,4
0,9
WD
TAK
EYS
SHY
FST
ST
SN
BR
YR
PM
APH
BYDV
FHB
Injuries


Relative yield loss caused by the injury profile
Relative yield loss (%)
14
12
10
8
6
4
2
0
9,8
11,6
8,3
Conventional
Integrated
Organic

- QUESTION 5

Weeds. Indeed, weeds are difficult to control in organic and integrated cropping systems.

- QUESTION 6

Powdery mildew was controled by fungicides in the conventional crop management and by cultivar resistance in the organic crop management.

- QUESTION 7

	Relative yield loss (%)		
	Conventional	Integrated	Organic
Injury profile	9,8	11,6	8,3
Sum of individual losses	10,2	12,3	8,6

Losses are less than additive in WHEATPEST. This is because a damage caused by a given pest will affect the crop development, which, in turn, will affect damages caused by other pests.

CONCLUSION

⇨ **WHEATPEST permits to analyse yield losses for diverse production situations**

⇨ **WHEATPEST is an integrative tool for various scientific disciplines**

⇨ **The development of WHEATPEST is unique for several reasons:**

- it is based only on published data,

- it adresses the complexity of injury profiles,

- it follows the KISS approach.

Perspectives

- evaluation of the predictive quality of WHEATPEST
- sensitivity analysis of WHEATPEST
- test of WHEATPEST for spring wheat (Central Europe)

Experiment set up to test WHEATPEST in Central Europe (IHAR, Poland)

Objectives:

- quantify agronomic, socio-economic, and environmental performances of various spring wheat management plans in Central European conditions

- quantify the predictive quality of WHEATPEST for spring wheat

Experimental fields

Integrated management 1
(as little chemicals as possible)

Integrated management 2
(supervised chemical control)

Organic management (in an organic certified farm, Ciechanow)

Intensive management

Perspectives

- evaluation of the predictive quality of WHEATPEST
- sensitivity analysis of WHEATPEST
- test of WHEATPEST for spring wheat (Central Europe)
- use of WHEATPEST's structure to simulate yield losses caused by multiple pests on banana