Example 2: the WHEATPEST model

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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
Potential yield

Attainable yield

Actual yield

Yield defining factors

Yield reducing
- pests
- climatic disasters

Yield limiting
- water
- nutrients

Yield determining
- radiation
- temperature
- main crop physiological properties

Potential yield = attainable yield - actual yield


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.

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.

Example of representation of production situations

Qualitative scale

PS1

PS2

PS3
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.

Example of representation of injury profiles

- Septoria blotch
- BYDV
- Yellow rust
- Weeds
- Brown rust
- Aphids
- Eyespot
- Take-all
- Fusarium Head Blight
- IP1
- Septoria blotch
- BYDV
- Yellow rust
- Weeds
- Brown rust
- Aphids
- Eyespot
- Take-all
- Fusarium Head Blight
- IP2
- Septoria blotch
- BYDV
- Yellow rust
- Weeds
- Brown rust
- Aphids
- Eyespot
- Take-all
- Fusarium Head Blight
- IP3
- Septoria blotch
- BYDV
- Yellow rust
- Weeds
- Brown rust
- Aphids
- Eyespot
- Take-all
- Fusarium Head Blight
Summary of drivers for injuries in 3 clusters of injury profiles combined with 3 production systems

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.

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<th>Physiological process/variable affected</th>
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<td>Assimilate rate reducer</td>
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<td>Eyespot, sharp eyespot, fusarium stem rot, take-all, weeds, BYDV, aphids</td>
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</table>

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

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

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

1) Modelling $Y_{ATT}$

--- parameter depending on DVS.
Incorporation of PS and IP in WHEATPEST

- PS
- DTEMP
- STEM
- SLA
- LAI
- RG
- PS
- IP
- RUE
- IP
- IP
- IP
- FHB
- LEAFBM
- STEMBM
- EARBM
- ROOTBM

- Powdery Mildew
- Septoria
- Rusts

- Septoria
- Rusts

- Eyespot
- Sharp eyespot
- Fusarium stem rot
- Take-all
- Weeds
- BYDV
- Aphids
Biomass production

\[ RG = RAD \times RUE \times (1 - e^{-kLAI}) \]

- **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 \textit{YACT}

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<td>Septoria nodorum blotch severity</td>
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<td>Barley Yellow Dwarf Viruses</td>
<td>Affect overall performance</td>
<td>Percentages of plants with Barley Yellow dwarf Viruses symptoms</td>
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</table>
Root diseases

Take-all

• Blackened roots and stem bases on infected plants
Modelling damage mechanisms: take-all (Gaeumannomyces graminis var tritici)

\[ RF_{TAK} = 1 - \frac{TAK}{100} \]

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

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

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

**Fusarium Stem Rot**
- linear and brown lesions
- no stroma
- superficial necrosis

**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)

\[ RF_{FST} = 1 - \left( \frac{aFST1}{100} + \frac{bFST2}{100} \right) \]

\( RF_{FST} \): 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)
Eyespot
• necrotic lesion ± limited
• stroma in the center
• severe penetrating lesion can result

Fusarium Stem Rot
• linear and brown lesions
• no stroma
• superficial necrosis

Sharp Eyespot
• pale cream oval lesions with a dark brown margin
• superficial necrosis

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

\[ RF_{EYS} = 1 - \left( \frac{aEYS1}{100} + \frac{bEYS2}{100} + \frac{cEYS3}{100} \right) \]

- **RF<sub>EYS</sub>:** Reduction factor of RUE due to EYS ([RF<sub>EYS</sub>]=1)
- **EYS1:** % of tillers with slight EYS symptoms (one or more lesions occupying in total less than half the circumference of the stem; [EYS1]=1)
- **EYS2:** % of tillers with moderate EYS symptoms (one or more lesions occupying in total more than half the circumference 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)
**Eyespot**
- necrotic lesion ± limited
- stroma in the center
- severe penetrating lesion can result

**Fusarium Stem Rot**
- linear and brown lesions
- no stroma
- superficial necrosis

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

**Stem diseases**
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)

\[ \text{LAI}_{\text{dis}} = \text{LAI} \left(1 - \frac{x}{100}\right)^\beta \]

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

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

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

\(\beta=1\) (Scharen and Taylor, 1968; Rooney, 1989)
Modelling damage mechanisms: septoria nodorum blotch (septoria nodorum)

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

RDIVSN: daily rate of assimilate diversion ([RDIVSN]=MT\(^{-1}\)L\(^{-2}\))
\(\alpha\): parameter, derived from Scharen and Taylor (1968) ([\(\alpha\]=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

**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 tritici blotch (Mycosphaerella graminicola)

\[ \text{LAI}_{\text{dis}} = \text{LAI} \left(1 - \frac{x}{100}\right)^\beta \]

- \( \text{LAI}_{\text{dis}} \): reduced Leaf Area Index ([LAI_{\text{dis}}]=1)
- \( \text{LAI} \): Leaf Area Index ([LAI]=1)
- \( x \): severity of the disease expressed in % ([x]=1)
- \( \beta \): ratio of the virtual lesion area over the actual lesion area ([\beta]=1)

\( \beta = 1.25 \) (Robert et al, 2006)
Modelling damage mechanisms: septoria tritici blotch (Mycosphaerella graminicola)

\[ RDIVST = \alpha \cdot RG \cdot ST / 100 \]

RDIVST: daily rate of assimilate diversion ([RDIVST]=MT\(^{-1}\)L\(^{-2}\))
\(\alpha\): parameter, derived from Scharen and Taylor (1968) ([\(\alpha\]=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)

\[ \text{LAI}_{\text{dis}} = \text{LAI} \left(1 - \frac{x}{100}\right)^\beta \]

\(\text{LAI}_{\text{dis}}\): reduced Leaf Area Index ([LAI\(_{\text{dis}}\]=1)

\(\text{LAI}\): Leaf Area Index ([LAI]=1)

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

\(\beta\): 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)

\[ LAI_{\text{dis}} = LAI \left(1 - \frac{x}{100}\right)^\beta \]

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

\( \text{LAI} \): Leaf Area Index ([LAI]=1)

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

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

\( \beta=1.5 \) (Yang and Zeng, 1988)
Modelling damage mechanisms: yellow (stripe) rust (Puccinia striiformis)

\[ RDIVYR = \alpha \cdot NPUSYR \]

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

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

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

\[ NPUSYR = \left( \frac{YR}{100} \right) \cdot \left( \frac{LAI}{SURFYR} \right) \]

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

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

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

SURFYR=1.0 \(10^{-6}\) m²
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)

\[ \text{LAI}_{\text{dis}} = \text{LAI} (1 - \frac{x}{100})^\beta \]

- LAI_{dis}: reduced Leaf Area Index ([LAI_{dis}]=1)
- LAI: Leaf Area Index ([LAI]=1)
- x: severity of the disease expressed in % ([x]=1)
- \(\beta\): 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 
\textit{(Puccinia triticina)}

\[ RDIVBR = \alpha \cdot NPUSBR \]

RDIVBR: daily rate of assimilate diversion ([RDIVBR]=MT^{-1}L^{-2})
\(\alpha\): parameter, Savary et al (1990) \([\alpha]=1\)
NPUSBR: number of pustules of yellow rust per surface unit ([NPUSBR]=L^{-2})

\[ NPUSBR = \left( \frac{BR}{100} \right) \cdot \left( \frac{LAI}{SURFBR} \right) \]

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 \times 10^{-6} \text{ m}^2
Ear diseases

**Fusarium head blight**
- brownish spot + discoloration
- premature death or bleaching of cereal spikelets

**Septoria nodorum**
- purple-brown lesions

**Powdery mildew**
- white mould mainly on surface of glumes
Modelling damage mechanisms: Fusarium head blight (*Fusarium graminearum, F culmorum, F avenaceum, F poae, Microdochium nivale*)

\[ RF_{FHB} = 1 - \left( \frac{aFHB}{100} \right) \]

\( RF_{FHB} \): 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*)

\[ \text{RSAP} = \text{RRSAP} \times \text{APHBM} \times \text{APH} \]

**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*)

\[ RF_{APH} = \text{MAX} \left( 1 - HONEY \times 0.015; 0.8 \right) \]

- \( RF_{APH} \): reduction of RUE caused by honeydew deposition (\([RF_{APH}]=1\))
- \( HONEY \): mass of accumulated honeydew per surface unit (\([HONEY]=\text{ML}^{-2}\))

\[ RHONEY = 0.35 \times RSAP \]

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

*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\(^2\)M\(^{-1}\))
aphids  
weeds  
viruses  
...
Modelling damage mechanism: Barley Yellow Dwarf Viruses

\[ RF_{BYDV} = 1 - a \times BYDV / 100 \]

RF\textsubscript{BYDV}: reduction factor of RUE due to BYDV ([RF\textsubscript{BYDV}]=1)

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

a=0.35: parameter (Perry et al., 2000; McKirdy et al, 2002) ([a]=1)
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 1m² of crop
- climatic data (RAD, TMIN, TMAX)

For a given Injury Profile:
- 1 or several pests (pathogen, insect, weeds)

For example:
- Brown rust
  - 0%
  - 4%
  - 8%
  - 74 134 194 Days
  - Diseased leaf area

- Aphids
  - 0
  - 1000
  - 2000
  - 3000
  - 74 134 194 Days
  - Density (nb/m²)

**OUTPUT**

Organ biomass

\[ Y_{LOSSES} = Y_{ATT} - Y_{ACT} \] (with IP)

YATT or YACT (with IP)
For those interested in more detailed information about WHEATPEST:

Using WHEATPEST …

The aim of the exercise is not to learn the FST (or the Fortran) language 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...

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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 execution)

**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 weather 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. \(Y=\text{INSW}(X, Y_1, Y_2)\) returns \(Y_1\) if \(X<0\) and \(Y_2\) if \(X\geq0\)

**INTGRL**: function Integral. \(Y=\text{INTGRL}(Y_1, Y_R)\), \(Y\) state variable, \(Y_I\) Initial value of \(Y\), \(Y_R\) 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?

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

Values at DVS 0 and DVS >2 have to be specified.
Answer the following questions, using:
- 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\(^{-1}\)

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 profile) 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.

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

| Injury profile | Crop Management | DWS (WEEDT) | TAK (SEVTAT) | EVS (FTE1T / FTE2T / FTE3T) | SHY (FSES1T / FSES2T / FSES3T) | FST (FBFR1T / FBFR2T) | ST (SIBT) | SN (SNBT) | BR (LRT) | YR (SRT) | PM (PMT) | APH (APHNBT) | BYDV (BYDVT) | FHB (FHB1) |
|---------------|----------------|-------------|--------------|----------------------------|--------------------------------|------------------------|----------|---------|---------|--------|--------|----------|-------------|------------|-----------|
| 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 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

![Graph showing biomass changes over Julian Day for different components: ROOTW, STEMW, LEAFW, and EARW.](chart.png)
• QUESTION 3

**Attainable yield**

- Conventional: 816 g.m\(^{-2}\)
- Integrated: 701 g.m\(^{-2}\)
- Organic: 582 g.m\(^{-2}\)

**Production situation**
QUESTION 4

**Conventional**

<table>
<thead>
<tr>
<th>Injuries</th>
<th>Relative yield loss (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>WD</td>
<td>0.6</td>
</tr>
<tr>
<td>TAK</td>
<td>3.0</td>
</tr>
<tr>
<td>ET5</td>
<td>0.7</td>
</tr>
<tr>
<td>FY6</td>
<td>0.5</td>
</tr>
<tr>
<td>BT5</td>
<td>0.7</td>
</tr>
<tr>
<td>ST</td>
<td>0.7</td>
</tr>
<tr>
<td>SN</td>
<td>0.1</td>
</tr>
<tr>
<td>BR</td>
<td>0.2</td>
</tr>
<tr>
<td>YR</td>
<td>0.4</td>
</tr>
<tr>
<td>PM</td>
<td>0.4</td>
</tr>
<tr>
<td>APH</td>
<td>0.0</td>
</tr>
<tr>
<td>BYDV</td>
<td>0.4</td>
</tr>
<tr>
<td>FHB</td>
<td>0.9</td>
</tr>
</tbody>
</table>

**Integrated**

<table>
<thead>
<tr>
<th>Injuries</th>
<th>Relative yield loss (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>WD</td>
<td>2.3</td>
</tr>
<tr>
<td>TAK</td>
<td>3.0</td>
</tr>
<tr>
<td>ET5</td>
<td>0.7</td>
</tr>
<tr>
<td>FY6</td>
<td>0.5</td>
</tr>
<tr>
<td>BT5</td>
<td>1.9</td>
</tr>
<tr>
<td>ST</td>
<td>0.4</td>
</tr>
<tr>
<td>SN</td>
<td>0.1</td>
</tr>
<tr>
<td>BR</td>
<td>0.2</td>
</tr>
<tr>
<td>YR</td>
<td>1.4</td>
</tr>
<tr>
<td>PM</td>
<td>0.0</td>
</tr>
<tr>
<td>APH</td>
<td>0.4</td>
</tr>
<tr>
<td>BYDV</td>
<td>0.9</td>
</tr>
</tbody>
</table>

**Organic**

<table>
<thead>
<tr>
<th>Injuries</th>
<th>Relative yield loss (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>WD</td>
<td>3.3</td>
</tr>
<tr>
<td>TAK</td>
<td>0.8</td>
</tr>
<tr>
<td>ET5</td>
<td>0.2</td>
</tr>
<tr>
<td>FY6</td>
<td>0.5</td>
</tr>
<tr>
<td>BT5</td>
<td>0.2</td>
</tr>
<tr>
<td>ST</td>
<td>0.2</td>
</tr>
<tr>
<td>SN</td>
<td>0.0</td>
</tr>
<tr>
<td>BR</td>
<td>0.2</td>
</tr>
<tr>
<td>YR</td>
<td>0.2</td>
</tr>
<tr>
<td>PM</td>
<td>0.0</td>
</tr>
<tr>
<td>APH</td>
<td>0.0</td>
</tr>
<tr>
<td>BYDV</td>
<td>0.0</td>
</tr>
<tr>
<td>FHB</td>
<td>0.9</td>
</tr>
</tbody>
</table>

**Relative yield loss caused by the injury profile**

<table>
<thead>
<tr>
<th>Injuries</th>
<th>Relative yield loss (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional</td>
<td>9.8</td>
</tr>
<tr>
<td>Integrated</td>
<td>11.6</td>
</tr>
<tr>
<td>Organic</td>
<td>8.3</td>
</tr>
</tbody>
</table>

Injuries: WD, TAK, ET5, FY6, BT5, ST, SN, BR, YR, PM, APH, BYDV, FHB.
Weeds. Indeed, weeds are difficult to control in organic and integrated cropping systems.
• QUESTION 6

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


**QUESTION 7**

<table>
<thead>
<tr>
<th>Relative yield loss (%)</th>
<th>Conventional</th>
<th>Integrated</th>
<th>Organic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Injury profile</td>
<td>9,8</td>
<td>11,6</td>
<td>8,3</td>
</tr>
<tr>
<td>Sum of individual losses</td>
<td>10,2</td>
<td>12,3</td>
<td>8,6</td>
</tr>
</tbody>
</table>

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 addresses 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
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