Agronomical handbook of methods

Organisation name of lead contractor for this deliverable: ISARA-Lyon.

Objectives of AGTEC-Org:

The overall objective of this project is to identify agronomical and food processing technologies that enhance the baking quality and the nutritional value of organic wheat and reduce mycotoxin contamination. Specific objectives are to:

• Evaluate the current practices for organic grain wheat production and flour-processing in Europe.
• Improve crop management strategies to enable bread-quality wheat to be produced on organic farms with and without livestock.
• Develop optimal post-harvest treatment to prevent mycotoxin contamination and enhance bread making quality and nutritional value.
• Generalise results from experiments in order to enhance farm management strategies in other climates and soil types.

The project is organized into five work packages and this deliverable deals with the WP2 (Field experiments).

Objectives and field experiments description of WP2:

WP2.1. Soil tillage management (ISARA, ESA, FIBL).

The effects of soil tillage and fertility managements will be assessed in three long-term field experiments. The trials represent various soil types and climatic conditions: Site 1 is located in SE France on a sandy loam soil; site 2 is in W France on a silty soil and site 3 is in NW Switzerland on a heavy loam soil. The experimental factors in France are (1) conventional tillage (mouldboard ploughing, 30 cm depth), (2) shallow ploughing (18 cm depth), (3) reduced tillage (15 cm depth without soil inversion) and (4) superficial tillage (5 cm depth without soil inversion). The fertilization management at both sites is similar in the four treatments. The experimental factors in Switzerland are (1) soil tillage management with conventional tillage (mouldboard plough followed by rotary harrow) versus reduced tillage system (chisel plough followed by rotary harrow), (2) fertilisation with slurry alone versus manure compost and slurry (both systems at a level of 1.4 Livestock Units ha-1) and (3) biodynamic preparations versus no biodynamic compost and field preparations. A 5-year crop-rotation survey set up in 2004 on 12 farm fields in SE and W France compares conventional tillage with reduced tillage. In the present project, an average of 3 organic wheat fields will be followed each year.

WP2.2. N fertilization (DIAS, FIBL, ART, ISARA).

An European database on organic fertilizers and amendments will provide information on (1) N, P, K and C contents and (2) N mineralization kinetics of the most frequent organic fertilizers and amendments used in organic wheat production in Europe (selected from the survey in WP1). Farmyard manures (fresh and composted), mixed composts and organic commercial fertilizers will be analysed for carbon content, nutrient content and N mineralization kinetics. The results will be used for the soil-crop modelling (see WP5).
The effects of animal manures and organic fertilizers and N availability will be assessed in longterm field experiments, such as the Organic Farming Crop Rotation in Denmark (since 1997; Olesen et al 2000). Grain of winter wheat will be collected at the three experimental sites in 2007-2009 from rotations with high/low proportion

of N-fixing crops, and with/without supply of animal slurry (110 kg N ha-1). In the DOK-Trial in Switzerland (since 1978; Mäder et al 2002), winter wheat is included in a 7-year crop rotation in biodynamic and organic systems with manure and slurry application at 0.7 and 1.4 livestock units ha-1 and in an unfertilized control. Data on wheat from 1978 to 2005 are available. Samples from 2006 and 2007 will be used for further quality analyses (see WP4).

WP2.3. Green Manure (DIAS, BOKU).

The influence of a legume green manure in a crop rotation will be investigated in the Organic Farming Crop Rotation in Denmark (Olesen et al 2000). Two soil types (loamy and sandy) and climates will be represented. The influence of legume green manure will be compared by collecting winter wheat grain from two crop rotations with and without inclusion of green manure. Grain of winter wheat will be sampled in 2007-2009.
A study of the influence of the removal of green manure for fodder use and its replacement with farmyard manure, simulating a livestock system (0.5 livestock units ha-1) in addition to stockless systems will be carried out in Austria in a long-term trial established in 2003 (Surböck et al 2006). Two 8-year rotations are running, one with green manure and straw being incorporated as in a stockless system, and one with removal of green manure and straw in turn to application of farmyard manure to winter wheat at 150 kg N ha-1. Grain of winter wheat will be sampled in 2008 and 2009. Interactions between type of green manure and time of incorporation will be investigated on a sandy loam at Askov in Denmark. In a field experiment initiated in 1981 (Thomsen and Christensen, 2004), three green manure treatments after spring barley were included in 2003: ryegrass, grass-clover and none. Half of each plot is ploughed in late autumn; the other half is ploughed in spring. In the growing season 2007/2008, winter wheat will be sown after the autumn ploughing and spring wheat after the spring ploughing. Grain of winter and spring wheat will be sampled in 2008.

WP2.4 Intercropping (ESA, ISARA, ART).

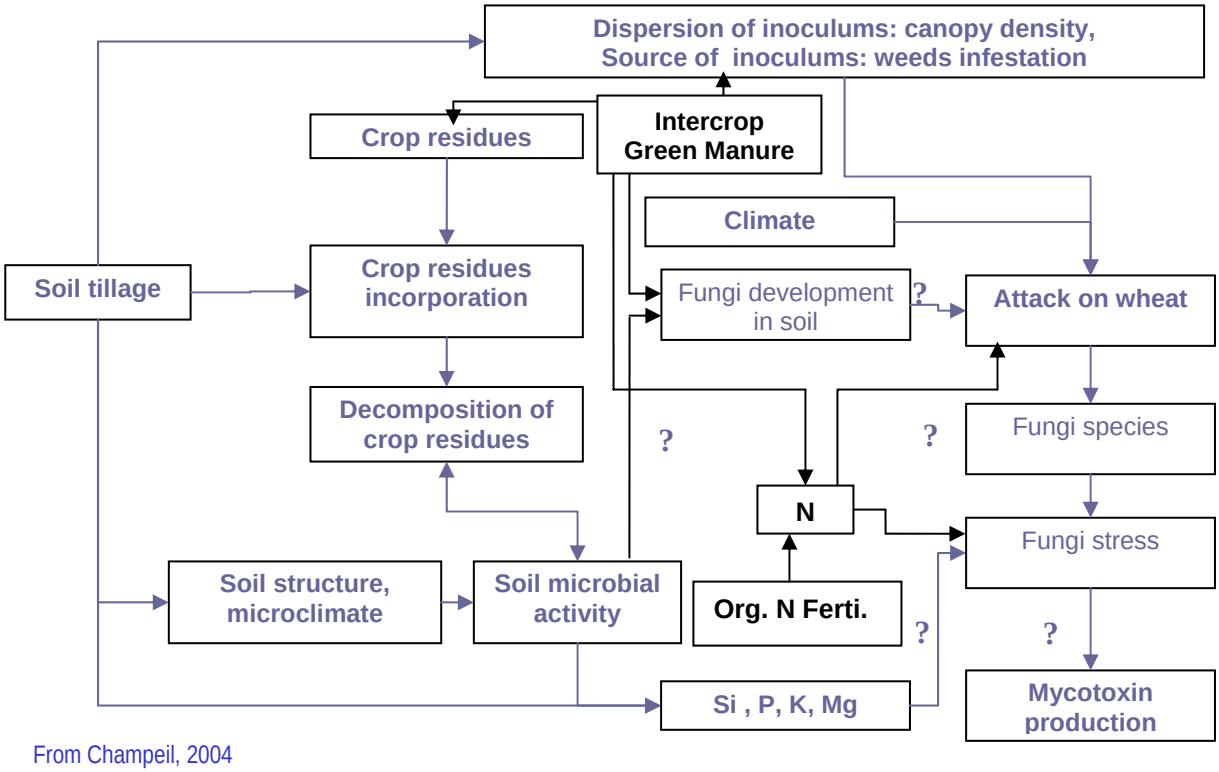
Experiments on winter wheat-pea intercrops are carried out by ESA at two sites (2 years). Wheat-pea is grown in either a 50/50 ratio of a monoculture seed rate (W50-P50) or 70/30 ratio (W70-P30) with three N fertilization strategies: no application (N0), late N application (a month before flowering) (N1), application at the same time as for wheat monoculture but proportional to wheat density (N2). Mixtures are compared with monoculture wheat without N fertilization (W100-N0) or with optimum (date and amount) N management (W100-N) based on N status decision tools (David et al 2005c). Experiments on wheat-clover mixtures are carried out by ISARA (2 sites) and ART (3 sites). Winter wheat is sown directly in white clover at a density of 300, 450 and 600 grains/m². In the control treatment, the winter wheat is established with the same density on a bare soil. Grain of winter wheat will be sampled in 2007-2009. For ART, grain analyses will be performed on experiments already conducted.

Specific objective of this handbook:

This handbook is a working tool for scientists involved in WP 2. It contains the methods used for data collection on WP 2. Description of the field experiments are detailed in appendix 2.

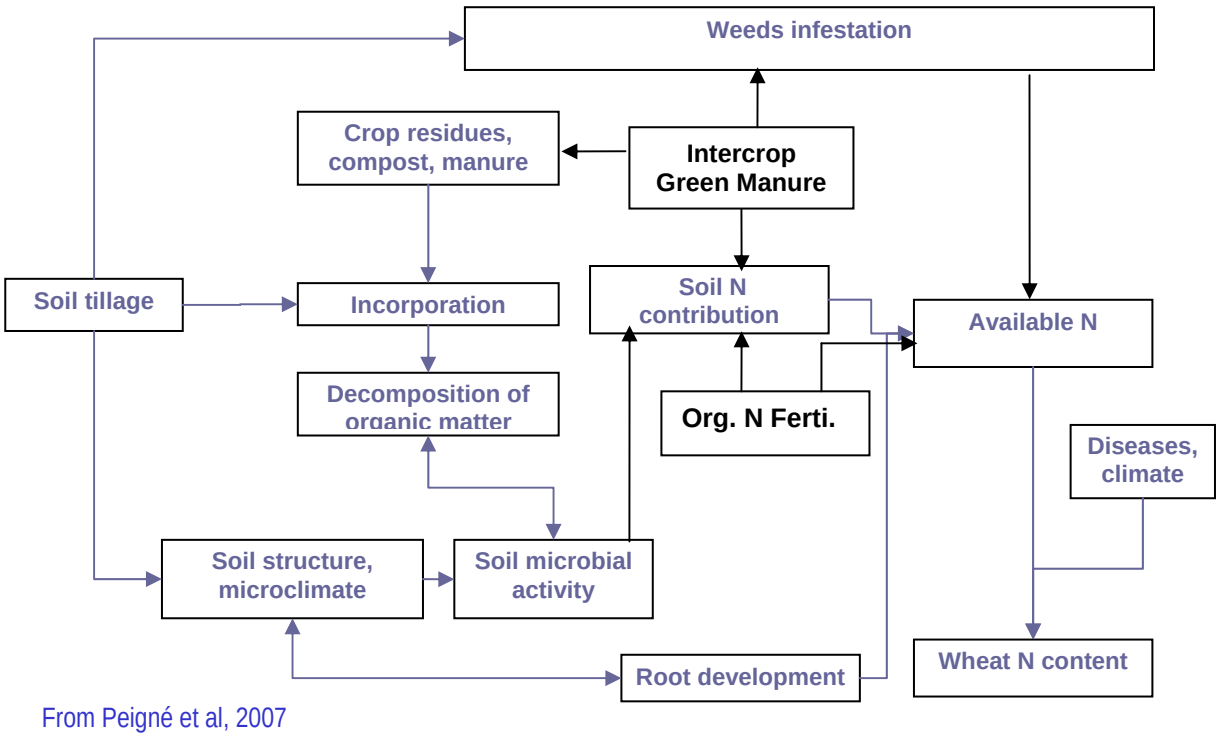
Figures 1 and 2 illustrate the effects of technics (soil tillage management, fertilization, intercropping) on mycotoxin and wheat N content in order to select parameters to measure (in bold).

Figure 1: Effects of soil tillage on fusarium head blight and mycotoxin



From Champeil, 2004

Figure 2: Effect of N contribution



From Peigné et al, 2007

Planning

Note: the list of measured parameters will be modified according to your comments. Sheets may be modified or completed with your comments.

Sheet n°	Methods	WP 2.1 Soil tillage	WP 2.2 N fertilisation	WP 2.3 Green manure	WP 2.4 Intercropping
Climate (daily data)					
1	Temperature	×	×	×	×
1	Rainfall	×	×	×	×
1	Radiation	×	×	×	×
Soil microclimate					
2	Soil water content	×	×	×	×
2	Soil temperature	×	×	×	×
Soil structure					
3	Soil assessment	×	**(×)**	**(×)**	**(×)**
4	Soil bulk density	×	×	×	×
Soil chemistry					
5	Texture, pH, CEC	×	×	×	×
5	Soil C org, N tot	×	×	×	×
6	Soil NO_3, NH_4	×	×	×	×
5	Soil Available P and K	×	×	×	×
Soil biology					
7	Soil microbial biomass	×	**(×)**	**(×)**	**(×)**
7	C min and N min	×	×	×	×
Crop residues					
8		×		×	×
Weeds					
9	Density	×	×	×	×
9	Cover rate	**x**	**x**	**x**	**x**
9	Biomass	×	×	×	×
Wheat yield build-up					
6	Wheat initial conditions	**x**	**x**	**x**	**x**
10	Foliar, root and ear diseases	×	×	×	×
11	Yields and N content	×	×	×	×
Cash crop or intercrop build-up					
12	Associated crops			**x**	**x**

Sheet n°1

1. Climate data monitoring

2. Work Packages: WP 2.1; 2.2; 2.3 and 2.4.

3. Objective: Collect climate data-set recorded nearby each experiment.

4. Literature:

5. Procedure:

When?	Procedure
Daily	• Daily climatic variables will be collected in a climate station nearby the experimental field and representative of the inter-field climate. • Meteorological data monitored are: – Mean daily temperature (°C) – Total daily rainfall (mm) – Global radiation ($J.cm^{-2}$)

Sheet n°2

1. Soil water content and temperature

2. Work Packages: WP 2.1; 2.2; 2.3 and 2.4.

3. Objective: Characterise the soil water content and temperature and indirectly the conditions of fungi development and of nitrogen mineralization.

4. Literature:

5. Procedure:

5.1 Soil water content

When?	Procedure
Feekes 2.0 (Tillering) Feekes 10.5.1 (beginning of flowering) Feekes 15.3 (Harvest)	• Soil water content will be measured gravimetrically (g of water/g of soil) or directly on field with TDR method (cm^3 of water/cm^3 of soil). • <u>For TDR method:</u> - Soil layers monitored depending of tillage practices: 0-0.05m; 0.05-0.2m; 0.2-0.3 (or 0.4)m - Number of replicates: 4 per soil layer per block • <u>For gravimetrically method:</u> - idem than TDR method - but each replicate is a composite of 3 soil samples. Each soil sample is dried at 105°C during 48h.

5.2 Soil temperature

When?	Procedure
Feekes 2.0 (Tillering) Feekes 10.5.1 (beginning of flowering) Feekes 15.3 (Harvest)	• 4 replicates are realised per soil layer and per experimental plot

Sheet n°3

1. Soil profile, root development and crop residues

2. Work Packages: WP 2.1; (optional for 2.2; 2.3 and 2.4)

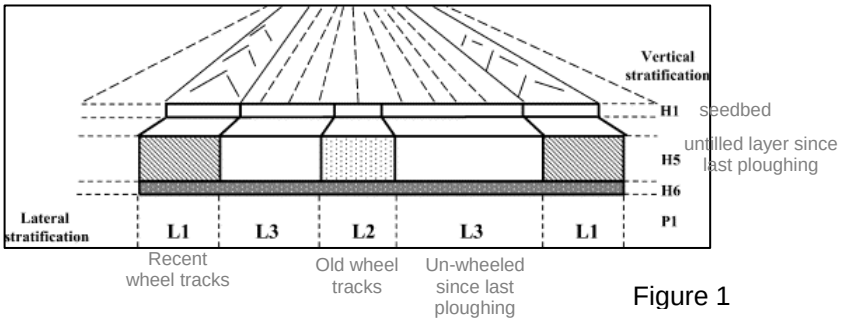
3. Objective: Characterise the soil structure, observe the root development and the distribution of crop residues in the soil profile.

4. Literature:

Roger-Estrade, J., G. Richard, J. Caneill, H. Boizard, Y. Coquet, P. Defossez, and H. Manichon. 2004. Morphological characterisation of soil structure in tilled fields: from a diagnosis method to the modelling of structural changes over time. Soil & Tillage Research. 79: 33-49.

5. Procedure:

Soil structure will be characterised on a morphological basis, on the observation face of a pit (100 cm depth x 300 cm width). We will also observe in the soil pit the location of crop residues (burying depth) and the lateral and vertical repartition of roots.

When?	Procedure
Feekes 2.0 (Tillering)	**Soil structure (Optional):** 1 - Pits are placed on each plot perpendicularly to the tillage operations. 2 - The macroscopic description of their observation faces is performed in two steps: A – Localisation of wheel tracks and soil layers delimited by the working depth (Figure 1) B - Soil structure description in every compartment according to compaction degree: classification (%) of the clods > 2 cm according to loose structure, exhibiting a clearly visible structural porosity (called clods) and the compacted clods without any visible structural porosity (called clods) C – Classification of the whole profile according to a scale of compaction.  Figure 1 **Root development and crop residues** In the pit previously described, or in a smaller pit, lateral and vertical roots developments are counted in each mesh (2 cm * 2 cm) of a roasting (70 cm width). Location of crop residues in the soil profile (depth) is also noted.

Sheet n°4

1. Soil bulk density

2. Work Packages: WP 2.1; 2.2; 2.3 and 2.4

3. Objective: Characterise the soil structure. This measurement will also permit to determine the total porosity and the saturation of this porosity, thanks to the soil water content measured at the same time.

4. Literature:

5. Procedure:

When?	Procedure
Feekes 10.5.1 (beginning of flowering)	• Soil sampling: Soil bulk density (BD) is estimated from undisturbed soil cores (5x5 cm2) taken on each plot. 4 replicates per soil layer (0-0.05m; 0.05-0.2m; 0.2-0.3 (or 0.4)m) per plot and per block are sampled. • Measurement: Soil core is oven dried (105°C during 48h) and then weighted. BD is obtained dividing the soil sample weight by its known volume.

Sheet n°5

1. Soil texture, pH (H20), CEC, Corg, Ntot and available P and K

2. Work Packages: WP 2.1; 2.2; 2.3 and 2.4.

3. Objective: Characterise the mean physical and chemical soil properties and how the different studied practices affect them.

4. Literature:

5. Procedure:

When?	Procedure
Feekes 1.5 (beginning of tillering)	• Soil sampling: Each soil sample is a composite of a minimum of 16 soil cores, randomly distributed over the field plot and blocks: margins and compacted tractor tracks are left unsampled. Each sample is of about 500g. 0-0.2 m soil layer is sampled • Measurement: For each soil sample, soil texture, pH_{water}, CEC, Corg, Ntot, available P and K are measured according to standard methods (ISO and NF).

Sheet n°6

1. Soil N03 and NH4 and initial wheat biomass

2. Work Packages: WP 2.1; 2.2; 2.3 and 2.4.

3. Objective: Characterise the initial wheat development and the initial soil inorganic nitrogen content for the modelling of the system (WP 5.1).

4. Literature:

5. Procedure:

5.1 Soil inorganic nitrogen content

When?	Procedure
Feekes 2.0 (Tillering) Feekes 10.5.1 (beginning of flowering) Feekes 15.3 (Harvest)	• Soil sampling: Same as sheet n°5 Soil samples are realised for soil layers 0-0.3 m, 0.3-0.6 m and 0.6-0.9 m depth. • Measurement: For each soil sample, soil water, N-NH4 and N-NO3 contents are measured with the KCl extraction method (gas chromatographic analysis).

5.2 Wheat initial biomass

When?	Procedure
Feekes 1.5 (beginning of tillering)	• Sampling: The wheat initial biomass is measured on 4 samples quadrants of 0.25 m² randomly chosen in each plot and block. • Measurements: Wheat biomass is measured (oven dry basis, 105°C during 48 h)

Sheet n°7

1. Soil microbial biomass, C and N mineralization

2. Work Packages: WP 2.1 (optional 2.2; 2.3 and 2.4).

3. Objective: Characterise how the various studied practices make change the soil microbial biomass and the C and N associated mineralization.

4. Literature:

Wu, J., R.G. Joergensen, B. Pommerening, R. Chaussod, and P.C. Brookes. 1990. Measurement of soil microbial biomass C by fumigation-extraction-an automated procedure. Soil Biology & Biochemistry. 22(8): 1167-1169.

5. Procedure:

When?	Procedure
Feekes 1.5 (beginning of tillering)	• Soil sampling: Soil layers are monitored in relation with the tillage practices (0-0.05 m; 0.05-0.2 m and 0.2-0.4 m depth). For each soil layer in each plot and block, 4 soil samples are collected. • Measurement: Soil microbial biomass (SMB) will be measured by Fumigation-Extraction (Wu et al, 1990). Potential C and N mineralization will be measured by incubating soil samples during 28 days at 28°C *Optional: microbial respiration rate could be measured (BOKU? Methods?)*

Sheet n°8

1. Crop residues assessment

2. Work Packages: WP 2.1; 2.3 and 2.4.

3. Objective: Quantitative and qualitative assessment of previous crop residues

4. Literature:

Champeil, A., 2004. Contribution à la compréhension des effets des systèmes de culture sur l'infection des cultures de blé tendre d'hiver par la fusariose et la contamination des grains par les mycotoxines associées. Thèse de doctorat. Ecole Doctorale ABIES. INRA-INAPG. 132 p.

5. Procedure:

<table>
<tr><th>When?</th><th>Procedure</th></tr>
<tr><td>Feekes 1.0
(emergence)</td><td>

Sampling:
Residues is assessed from 4 samples quadrants of 0.5 m2 randomly located in each plot and block
Measurement:
The number of residues (greater than 1 cm) will be counted, classified (level of crop residues left at soil surface) and then weighed (in dry matter).

<table>
<tr><th>Number of crop residues / 0.5 m^2</th><th>Classes</th></tr>
<tr><td>0-1</td><td>1</td></tr>
<tr><td>2-10</td><td>2</td></tr>
<tr><td>11-30</td><td>3</td></tr>
<tr><td>31-60</td><td>4</td></tr>
<tr><td>61-100</td><td>5</td></tr>
<tr><td>> 100</td><td>6</td></tr>
</table>
</td></tr>
</table>

Sheet n°9

1. Weed density, diversity and biomass

2. Work Packages: WP 2.1; 2.2; 2.3 and 2.4.

3. Objective: To assess the weed population and competition.

4. Literature:

5. Procedure:

When?	Procedure
Feekes 1.5 (beginning of tillering) Feekes 4.0 (first node visible) Feekes 10.5.1 (beginning of flowering)	<u>Density and diversity</u> • Sampling: The weed population (counting each specy) is assessed at different stages from 4 samples quadrants of 0.25 m² fixed in each plot and block. • Measurements: Weed cover rate is estimated by a global visual observation realised on each sample quadrant (see appendix 3) Shannon index is calculated as: $H = \sum_{i=1}^{n} p_i.Ln(p_i)$ With n: the number of weed species p_i: the rate of the individual specie in the total weed population
Feekes 1.5 (beginning of tillering) Feekes 10.5.1 (beginning of flowering) Feekes 11.0 (Harvesting)	<u>Abundance</u> • Sampling: The weed biomass is measured on the same 4 samples quadrants of 0.25 m² fixed in each plot and block. • Measurements: Weed biomass is measured (oven dry basis, 105°C during 48 h)

Sheet n°10

1. Foliar, root and ear diseases

2. Work Packages: WP 2.1; 2.2; 2.3 and 2.4.

3. Objective: Identify the root, ear, stalk and foliar diseases severity.

4. Literature:

Schoeny, A., M.H. Jeuffroy, and P. Lucas. 2001. Influence of take-all epidemics on winter wheat yield formation and yield loss. Phytopathology. 91:694-701.

5. Procedure:

When?	Procedure
Feekes 4.0 (first node visible)	Root diseases + shoot basis + leaves • Sampling: 15 plants are randomly sampled per plot and per block • Measurements: - The number of plant affected by root disease is counted - The necrosis rate at shoot basis is evaluated - The incidence of leaf diseases (Septoria tritici and nodorum principally) is assessed on the upper three leaves
Feekes 11.2 (Sough-dough stage)	Leaf diseases • Sampling: 20 plants are randomly sampled for each experimental plot and block. • Measurements: The incidence of leaf diseases (brown rust, yellow rust, Septoria tritici and nodorum, Fusarium spp) are assessed on the upper two leaves. The proportion of leaf area affected by foliar disease estimated by global visual observation (see appendix 3) as the number of plant affected.
Feekes 11.2 (Sough-dough stage)	Ear diseases • Sampling: 50 ears are randomly sampled for each experimental plot and block. • Measurements: The % of attacked spikelet and area of spikelet envelope infested (according to classification) is evaluated. (it is necessary to distinguish *Septoria spp.*, *Fusarium spp*. from for example *Microdochium nivale* and *Fusarium graminearum* (because of the link with mycotoxins)

Sheet n°11

1. Wheat yield components and N content

2. Work Packages: WP 2.1; 2.2; 2.3 and 2.4.

3. Objective: Determine yield build-up and identify the limiting factors. This allows them to be used as criteria to identify the phase of occurrence of the limiting factors.

4. Literature:

Brancourt-Hulmel, M., C ; Lecomte, and J.M. Meynard. 1999. A diagnosis of yield limiting factors on probe genotypes for characterizing environments in winter wheat trials. Crop Science. 39: 1798-1808.

Meynard, J.M., and G. David. 1992. Diagnostic de l'élaboration du rendement des cultures. Cahiers Agricultures. 1: 9-19.

5. Procedure:

When?	Procedure
Feekes 1.0 (emergence)	• Sampling: 4 quadrant samples of 0.25 m² per plot and per block • Measurements: Determination of the number of wheat per m²
Feekes 10.5.1 (Flowering)	• Sampling: 4 quadrant samples of 0.25 m² per plot and per block • Measurements: - Determination of the number of spike per m² - Evaluation of wheat biomass (oven dry basis at 65°C during 48 h). - N content of one sample per replication, previously oven dried (65°C during 48h), weighed and pound, is determined by the Dumas method (gas chromatography analysis).
Feekes 11.0 (Harvesting)	• Sampling: 4 samples of 0.25 m² per plot and per block • Measurements: - Total aboveground biomass - Determination of the yield components (total grain weight at 15% moisture, number of grain per m²) - Grain yield and thousand-kernel weight is measured at 15% moisture content. Dry thousand kernel weight (TKW) is measured using 200 kernels per sample. - The kernel number (KN) is calculated as the ratio between the grain yield and the dry thousand-kernel weight. - N content of one sample per replication, previously oven dried (65°C during 48h), weighed and pound, is determined by the Dumas method (gas chromatography analysis).

Sheet n°12

1. Associated crops

2. Work Packages: WP 2.3 and 2.4.

3. Objective: Evaluate the competition and facilitation for resources (light and nitrogen) between the two associated species. Identify the disease attacks related to intercropping. Evaluate the increase of productivity obtained with this association (Land Equivalent Ratio).

4. Literature:

Amarger N, Mariotti A, Mariotti F, Dürr JC, Bourguignon C and Lagacherie B 1979 Estimate of symbiotically fixed nitrogen in field grown soybeans using variations in 15N natural abundance. Plant & Soil 52, 269-280.

Cantot, P., 1986. Quantification des populations de Sitonal lineatus L. et de leurs attaques sur pois protéagineux (Pisum sativum L.). Agronomie 6, 481-486.

5. Procedure:

When?	Procedure
Feekes 1.5 (beginning of tillering)	• Sampling: 1. 4 quadrant samples of 0.25 m² per plot and per block 2. 20 plants (pea or other associated crop to wheat) are randomly sampled for each plot and block. • Measurements: 1. On each quadrant, the initial biomass of associated crops is measured (for modelling). 2. On the 20 plants, attacks of pea weevil (Sitona lineatus) on leaves is estimated using a scale of 0-3 (Cantot, 1986)
Feekes 10.5.1 (Flowering)	• Sampling: 4 quadrant samples of 0.25 m² per plot and per block • Measurements: - Determination of the biomass of associated crops (oven dry basis at 65°C during 48 h). - Height of each species in the canopy to appreciate the competition for light in each quadrant. - N content and 15N content (15N natural abundance method (Amarger et al, 1979) in legume and wheat intercropped and in wheat sole crop* to determine the contribution of N2 fixation to legume N nutrition and perhaps to wheat N nutrition ** for this method, wheat sole crop and wheat-legume intercrop should receive the same N fertilization (same amount and dates)*

Feekes 11.0 (Harvesting)	• Sampling: 1. 4 quadrant samples of 0.25 m² per plot and per block 2. 20 plants (pea or other associated crop to wheat) are randomly sampled for each plot and block. • Measurements: 1. Height of each specie present in the canopy to appreciate lodging. For associated crops which do not reach maturity: 1. Biomass of associated crop (oven dry basis at 80°C during 48 h) 1. N and 15N content in intercropped legume and wheat and in wheat sole crop to determine the contribution of N2 fixation to legume N nutrition and perhaps to wheat N nutrition over the crop cycle For associated crops which reaching maturity (pea…): 1. Determination of the yield components (total grain weight at 15% moisture, number of grain per m²) 1. N and 15N content of grain and straw in intercropped legume and wheat and in wheat sole crop to determine the contribution of N2 fixation to legume N nutrition and perhaps to wheat N nutrition over the crop cycle 2. The incidence of Ascochyta blight (Mycosphaerella pinodes) (brown rust, mildew, Septoria tritici, Fusarium spp) is assessed on pods (Tivoli, 1994).

Appendix 1: References

Amarger N, Mariotti A, Mariotti F, Dürr JC, Bourguignon C and Lagacherie B 1979 Estimate of symbiotically fixed nitrogen in field grown soybeans using variations in 15N natural abundance. Plant & Soil 52, 269-280.

Brancourt-Hulmel, M., C ; Lecomte, and J.M. Meynard. 1999. A diagnosis of yield limiting factors on probe genotypes for characterizing environments in winter wheat trials. Crop Science. 39: 1798-1808.

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Champeil, A., 2004. Contribution à la compréhension des effets des systèmes de culture sur l'infection des cultures de blé tendre d'hiver par la fusariose et la contamination des grains par les mycotoxines associées. Thèse de doctorat. Ecole Doctorale ABIES. INRA-INAPG. 132 p.

David, C. M.H. Jeuffroy, J. Henning and J.M. Meynard. 2005. Yield variation in organic winter wheat: a diagnostic study in the Southeast of France. Agronomy for Sustainable Development. 25(2) : 213-223.

Meynard, J.M., and G. David. 1992. Diagnostic de l'élaboration du rendement des cultures. Cahiers Agricultures. 1: 9-19.

Olesen, J.E., Askegaard M. and Rasmussen I.A. 2000. Design of an organic farming crop-rotation experiment. Acta Agriculturae Scandinavica. Section B, Soil and Plant Science 50 (1) : 13-21.

Peigné, J., B.C. Ball, J. Roger-Estrade and C. David, 2007. Is conservation tillage suitable for organic farming? A review. Soil Use and Management. 23(2): 129-144.

Roger-Estrade, J., G. Richard, J. Caneill, H. Boizard, Y. Coquet, P. Defossez, and H. Manichon. 2004. Morphological characterisation of soil structure in tilled fields: from a diagnosis method to the modelling of structural changes over time. Soil & Tillage Research. 79: 33-49.

Schoeny, A., M.H. Jeuffroy, and P. Lucas. 2001. Influence of take-all epidemics on winter wheat yield formation and yield loss. Phytopathology. 91:694-701.

Sürbock, A., J.K. Friedel, M. Heinzinger, and B. Freyer. 2006. Long-term monitoring of different management systems within organic farming and their effects on arable land and landscape. Phase I: Monitoring of the conversion to organic farming. *In*. J. Raupp, C. Pekrun, M. Oltmanns, and U. Kopke (Eds). Long-term field experiments in organic farming: pp. 183-198. Verlag - Berlin-Germany.

Thomsen, I.K., and B.T. Christensen. 2004. Yields of wheat and soil carbon and nitrogen contents following long-term incorporation of barley straw and ryegrass catch crops. Soil Use and Management. 20(4):432-438.

Wu, J., R.G. Joergensen, B. Pommerening, R. Chaussod, and P.C. Brookes. 1990. Measurement of soil microbial biomass C by fumigation-extraction-an automated procedure. Soil Biology & Biochemistry. 22(8): 1167-1169.