On-farm evaluation of integrated cropping systems

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ABSTRACT

On-farm research on IAFS (Integrated arable farming system) and EAFS (Ecological arable farming system) are of high priority in the Netherlands, these systems are supposed to solve the problems of agricultural pollutions. To improve results of the tested systems, this study has for aim to make an agronomical diagnosis on wheat in order to identify yield limiting factors. A methodology of diagnosis, adapted to on-farm research especially based on pilot-group study is elaborated and tested.

This 1993 survey was done both on ecological farms and integrated ones, what allows comparisons between these two systems. Yield formation was precisely observed, as well as environmental factors (water, lodging, soil structure, nitrogen supply...).

A strong yield variability is observed within each system; integrated farming has on average 30% more yield than ecological one. Yield seems closely related to grain number and nitrogen status at flowering. Nitrogen nutrition is not limited at tillering, but stress can occur during the shooting; almost all ecological fields have important nitrogen stress at flowering. The first stage (before tillering) and last one (filling period) are of minor importance in their contribution to yield elaboration.

Nitrogen supply is very well correlated to grain number. The relatively low quantity of Nitrogen input in ecological farming system is a first reason of lower grain number/m^2. But there was also a lower absorption of the available nitrogen in compacted soils; both factors lead to strong Nitrogen shortage in ecological farming. Soil compaction could be related to late harvest of the previous crop in relation to climatic conditions during harvest (rains). Cropping system improvement are therefore proposed.

Concerning methodology, it is of major importance to know the potential 1000 grain weight of each variety, in order to use correctly yield component. Choice of some couple of fields in the sample has strongly improved the analysis. Use of a Crop Simulation Model (SUCROS in this study) for diagnosis has brought some interesting informations, but further investigations are needed to improve its use for diagnosis.

INTRODUCTION

The high level of intensification and specialisation of the dutch agriculture has led to a growing public concern for the development of a less pollutive agriculture. Consequently, the government has decided to lead agriculture in a more sustainable way, amongst others by a research on Integrated and Ecological Farming System (IFS and EFS), in a near-practice conditions (Spiertz, 1991). On-farm research of a pilot group is considered as a good way (Vereijken, 1992).

Presently, there are 2 pilot projects in Dutch arable farming. A pilot project with 35 farmers is aimed at testing and improving regions-specific prototypes of Integrated Arable Farming System (IAFS) (Wijnands and Vereijken, 1992). This project should stimulate the main group of Dutch arable farmers to meet the policy aim of reducing pesticide inputs by 50% (2000 compared to 1985-1990). The second pilot project has the more strategic aim to upgrade organic farming as a pacemaker of sustainable development (Vereijken and Kloen, 1993). In this project, prototypes of Ecological Arable Farming Systems (EAFS) are developed.

There is a strong yield variation within a pilot group, how can we nevertheless evaluate the tested farming prototypes systems ?

Meynard (1985) has shown the efficacity of an agronomic diagnosis to make this evaluation: the identification and hierarchization of the yield limiting factors are relatively easy for several arable crops. This diagnosis can be the basis of a critical analysis of the crop management.

In the EAFS pilot group led by P.Vereijken, we have tried the french approach to analyse wheat yield formation and variation. Our first goal is to propose targeted improvements of wheat cropping in the EAFS.

Since on-farm evaluation in a pilot group is new, we have as a second goal to adapt the methods used in common agronomic diagnosis, for example by simulating the potential yield according to actual climatic data with a crop simulation model: SUCROS.

I / CROP DIAGNOSIS IN PILOT FARMS

I.1/.DEVELOPMENT OF SUSTAINABLE FARMING SYSTEM IN THE NETHERLANDS

I.1.1/ Development of Integrated Arable Farming Systems (IAFS)

The Netherlands are probably the first country in the EC to feel the negative side-effects of an intensive agriculture. The high level of pollution by nitrate (NO3⁻), phosphates and pesticides has led the dutch ministry of agriculture to consider as soon as 1971 (Spiertz and Vereijken, 1993) the methods used in organic agriculture. It has been decided in 1979 to test new farming system in experimental farms. The general objectives of agricultural policy is to promote competitive, safe and sustainable farming (Spiertz, 1991). The government has formulated some ambitious goals concerning the reduction in the use of crop protection agents and fertilizers.: -50% in 2000 (compared to 1980) and especially -80% for soil fumigants.

Three steps have been defined:

* First step: technical feasability and economic viability of IAFS are tested in experimental farms (Nagele, 1979). Three objectives are pursued with these experimentations (Spiertz and Vereijken, 1993):

- the development: a coherent system has to be conceived, based on available analytical knowledge,
- the comparison: three systems of references are often compared on the same place: integrated, ecological and conventionnal,
- the evaluation of these systems with a technical, economic and environmental points of view.

Results seem to be encourageous (Wijnands and Vereijken, 1992). Nevertheless, these experimental farms do not reflect very well the real conditions, especially the technical feasibility.

* Second step: introduction of Integrated Farming concepts on commercial farms (Wijnands, 1992); a four-year project was set-up in which about 40 farmers consisting of 5 pilot-group participate. These 5 groups represent contrasted agro-ecological regions (annex 1)

Such a network has the same disadvantages as the survey's method: high risks of effect's confusion, but possibility to identify innovations and constraints (Meynard and Girardin, 1991).

* Third step: quantitative evaluation of IFS, based on the results obtained in the two first steps (Spiertz, 1991); IAFS will be modelised using a production systems generator and interactive multiple goal linear programming techniques. Based on this evaluation procedure, FS with a high degree of multiple goal attainment can be selected.

I.1.2/ Development of Ecological Arable Farming Systems (EAFS)

a/ Theorical approach

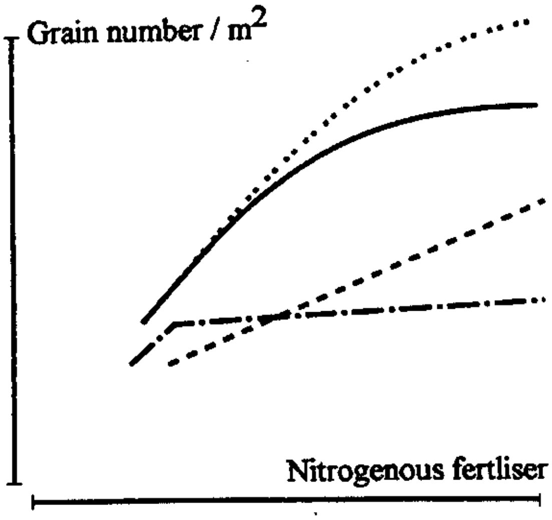
Definition: EAFS aims at the most consistent integration of all basic values and interests (table 1) involved in agriculture (Vereijken, 1992). EAFS should not use chemicals, and should be supported by a strong home-market with a label of certified quality (Vereijken, 1992).

Table 1: Priorities of the three basic farming visions with respect to the basic values and interests involved in agriculture (according to Vereijken, 1992)

Values/interests	World-market-oriented	Integrated	Ecosystem-oriented[1]
1 Food supply	+	++	+++
2 Employment and basic income	+	++	+++
3 Profit	+++	++	+
4 Abiotic environment	+	++	+++
5 Nature and landscape	+	++	+++
6 Health and well-being	+	++	+++

[1] Ecosystem-oriented agriculture starts from the responsibility of society as a whole. The rural population is responsible for a sustainable and multi-functional management of the agro-ecosystems as reflected in certified quality products. The urban population is responsible for an acceptable standard of living for the rural population by paying appropriate prices for the certified products. As a result, quality of both urban and rural life has higher priority than profit.

Figure 1: Environmental conditions and crop response to nitrogen fertilization (according to Meynard and al, 1981)



Type of curve	Long water shortage (from tillering to flowering)	Soil K shortage (from soil analysis)	Early damages of eye-spot	Soil compaction	Good soil structure, no disease, drought, or deficiency	Number of cases
δ α	0	1	0	5	12	18
γ	0	1	0	11	0	12
β	4	3	2	0	3	12

* 42 experiments in 3 years, from 1975 to 1977
* for each column, the most frequent case is pointed out

According to Vereijken, this ecosystem-oriented agriculture constitutes a further step compared to organic agriculture. It integrates more parameters (cf supra), it has to be more scientific and less dogmatic; the results should not be only theoritical (reduction of pollutions...) but effective, that is to say tested. This system has also been developed and compared with Integrated and Conventionnel ones, first in Nagele.

b/ *Practical lay-out*

Presently, Vereijken is in the second step of development of this advanced ecological FS: introduction of the acquired experiences into commercial organic farms and evaluation in practice of the real performances. The prototypes are tested and improved in cooperation with a group of 9 farmers producing according to the EC guidelines for organic agriculture (Vereijken and Kloen, 1993). The pilot group approach should allow the implementation of innovations in farmer's practice and in research.

The objectives are defined together with the farmers. They are said to be strategic: choice of the rotation's type, fertilization decision's rules, lay-out of an ecological infrastructure. On the other side, the tactical decisions (crop's management) are only defined by the farmer himself, at own risk. Furthermore, the farmers also determine the commercial strategy and the choice of the crop.

I.2/ LAY-OUT OF THE WHEAT DIAGNOSIS

We have choosen to analyse yield formation and variation of wheat, notably in EAFS because we expected here the strongest effects of low external inputs. Indeed, the first results obtained in this pilote group (1991,1992) showed a strong variation of yield in the 3 major crops (oignon, potato, wheat) (Vereijken, 1992).

The lowest yields represent 50 to 70 % of the highest: for 5.2 to 9 tons/ha for wheat. As the wheat has been a lot studied, especially in France (Meynard and Sebillotte, 1983), we have decided to choose this crop, and to analyse its yield variation in the pilot group, added with 5 integrated farms. We will try to identify through an agronomical diagnosis the major limiting factors of wheat yield.

In the following chapter, we will try to get some hypothesis on the expected limiting factors according to knowledge about soil and climate, practices of the farming system, and bibliography.

I.2.1/ Natural environment: presentation of its general lines

The present study was done in the most recent polders (40 years) of the Netherlands: Flevoland polder; they are located at 60 km north-east of Amsterdam. These polders have a latitude of 53°, and an altitude of -4 meters. 40 kms is the maximum distance between two farms of the pilot group.

a/ *Soils and land planning*

These polders were still recently under sea. Their geologic substratum is sedimentary. There are a lot of shells in the soil; and under 30 to 50 cm there is sand and peat layers.

The polders are totally flat. A performant drainage allows a good evacuation of the all water: ground water table is maintained at 1 meter depth. Soil characteristics are very homogeneous

Table 2: General matrix for definition, elaboration and evaluation of farming visions and systems (according to Vereijken, 1992)

Social values or interests involved		Parameters	Objectives of the 3 basic visions[1]		
			world-market oriented	integrated	ecosystem-oriented
1	*Food supply*				
1.1	quantity	food/person in energy equivalents	-	WHO	WHO
1.2	quality				
	- nutritional value	composition of single products in relation to a daily diet	-	WHO	WHO
	- harmful compounds and micro-organisms	content of single products in relation to a daily diet	L	≥L	>L
	- taste	appreciation by taste pannels	S	S	S
	- appearance and suitability for preservation and processing	various commercial and industrial standards of single products	S	S	S
1.3	stability	variation in yields ($kg\ ha^{-1}$) in relation to (inter)national food stocks	L	L	L and FAO
1.4	sustainability				
	- soil fertility	content of air, water, nutrients, org. matter	S	S	S
		input/output of dry and organic matter	-	≥1	≥1
	- climate	input/output of CO_2	-	max.	max. and >1
	- non-renewable resources	input (non-solar)/output of energy	-	min.	min. and <1
		input/output of phosphorus	-	1	1
1.5	accessibility	prices of single products in relation to a daily diet	L	L	S[2]
2	*Employment*				
2.1	at farm level	full-time workers/farm	min.	≥1	≥1
2.2	at regional and national level	full-timers in agriculture and related industries and services	-	S	S
3	*Basic income and profit*				
	at farm, regional and national level	income/hired worker	L	≥L	≥L
		income/entrepreneur	max.	max.	≥L hired worker
4	*Abiotic environment*	emissions/ha of:			
4.1	soil	persistent and accumulating compounds such as heavy metals and pesticides	L	≥L	>L
4.2	air	volatile compounds such as NH_3 and certain pesticides	L	≥L	>L
4.3	shallow and ground waters	mobile and persistent compounds such as nutrients and pesticides	L	≥L	>L
5	*Nature and landscape*				
5.1	flora and fauna	various indices of diversity	-[3]	max.[4]	max.[4]
5.2	landscape	nature and culture historical uniqueness	-	S	S
		functionalism (agriculture, nature recreation etc.)	L	S	S
6	*Health and well-being*				
6.1	health and well-being of animals	veterinary and ethological parameters	L	≥L	>L
6.2	health and well-being of humans	medical and sociopsychological parameters	L	≥L	>L

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[1] Objectives: WHO and FAO is norms of the United Nations, stated by World Health Organization and Food and Agriculture Organization. (>) L and S is (better than) (inter)national Legal or System-specific norms towards certain values. Max. and min. is effort for maximal or minimal quantity or effect.

[2] Prices of products from ecosystem-oriented farming have to be higher than those of market oriented farming, but a wholesome diet based on ecoproducts does not necessarily have to cost more than a conventional diet

[3] Nature and landscape conservation are separated from agriculture

[4] Nature and landscape conservation are integrated with agriculture

on a field scale (6 ha in general), and even on a farm scale. There is no more problem with salinity.

Soils have good equilibrated texture; they are relatively clayey for the Netherlands. Nutrients soil reserves are often excessive (Vereijken and Kloen, 1993), especially in phosphates and potassium.

Therefore, soil's physico-chimical characteristics are pretty favourable. The environment is in fact totally artificialised by humans, and has a high production potentiel (Spiertz, 1991).

b/ *Climate*

Despite the high latitude (53°), temperatures are moderated by the sea proximity, but soil are often froozen 10 to 15 cm deep in winter. Climate is fairly wet with a good rain repartition.

c/ *1992-1993's climate characterization and wheat growth*

In annex 2 are given the climatic data. The year 1993 is characterized by a wet autumn, from the beginning of october to the end of december. Some late crops (especially celeriac, sugar beet and cabbage) were harvested in very bad conditions.

Spring was favourable and enabled a fast growth of wheat crops, and flowering occures at 6-10 june. It was rather dry, with no lack of water. Rainfalls beginn to be nearly every day and abundant from the beginning of july. Therefore wheat maturition took a lot of time; harvest occurs at half-august.

1.2.2/ Presentation of EAFS and IAFS

Arable farming is dominant in the polders: potato and vegetables such as onion are very important (cash-crop). Animal husbandry is rare, but huge amounts of slurry are brought in from animal production regions elsewhere.

a/ *EAFS*

Wheat in the rotation depends on the multifonctional crop rotation model (Vereijken, 1992): crops should not be cultivated in the same field before 6 years, in order to avoid the risks of certains diseases, like stem base diseases (like eye spot). Cereal should not preceed wheat in the rotation. In general, the previous crop for wheat is a lifted crop, early (potato, oignon), or late harvested (cabbage, sugar beet, celeriac).

Wheat management:

Manure is applied before wheat, but the quantity is variable. It is few composteed. Risk of eye spot is low in the polders, so they don't fear a supply of inoculum.

Ploughing is usual after each crop, because soil structure is often damaged, and they want to control perennials weeds. A false **seed-bed preparation** is often made before sowing.

The choosen **varieties** have a good backing quality, because organic wheat for bread is well-paid. Disease resistance is not the first criterion. A mixture of varieties is sometimes sown to obtain a better resistance to foliair diseases.

Weeds are controled by hoeing, in 4 to 6 harrow-crossing. Red-klover is often undersown as a suppressor of weeds, and as a green manure for the next crop.

b/ *IAFS*

Compared to conventional farming, nitrogen fertilisation is moderate (40 kg N less in general), and pesticide inputs are limited.

Contrary to EAFS, IAFS does not grow wheat varieties with high baking quality, because they yield less in kg and there is hardly a price compensation.

I.2.3/ Variations factors in wheat yield

Wheat has been intensively studied, especially in France. Boiffin and al (1981) could identify in "Champagne crayeuse" (France) the important effect of nitrogen on grains'number. Nitrogen absorption appeared to be of first importance (figure 2), and especially influenced by soil structure (Meynard and al, 1981). Diseases, lodging and water defeciency have strong effects on grain weight (Meynard, 1985).

But all these studies have been done with conventional farming. What do we know about limiting factors in EAFS ? We have only certain hypothesis from the general knowledge on wheat and natural conditions.

The factors related to soil or climate in the Dutch polders are pretty favourable. Minerals elements are abundant and easily absorbable (soil pH near neutrality). Water is rarely a limiting factor. Rainfall is usually sufficient for wheat. Besides, wheat root is deep, up to 1,5 meter, where the water-table is maintained.

The abandonning of mineral fertilisation is very important: the lack of available nitrogen for the crop is a real risk. Furthermore, the mineralisation of manure or soil organic matter depends on climate and thus may no be synchronic to the wheat demand.

The abandonning of pesticides has two probable impacts. Weeds control is more dependant to farmer's skill. Disease control will only be preventive (variety choice, rotation). On the contrary, the non-use of growth regulator is probably not an important factor: risk of lodging is low because nitrogen nutrition is moderate.

I.3/ AGRONOMICAL DIAGNOSIS OF YIELD FORMATION AND VARIATION

To realise an on-farm evaluation by identifying yield limiting factors, we have some initial hypothesis, and we should ask which methodology can allow us to make a good diagnosis ?

We will answer this question by:

* presenting what is the method usually used for agronomical diagnosis,
* analysing what is the specificity of a study on a pilot group
* proposing some new elements of analyse which can enable us to make a diagnosis on a pilot group.

I.3.1/ What is an agronomical diagnosis ?

The aim of an agronomical diagnosis is to identify a posteriori (Meynard and David, 1992) the environmental conditions and the characteristics of the cropping system which have influenced the production of a crop. The factors which could explain yield variability are numerous and interact. A multi-variable analysis has to be done, for example multi-regression analysis. But there is strong risks of effect's confusion (Meynard and David, 1992). A simple correlation between 2 variables X and Y does not proove a causal relationships.

Therefore, it is necessary to unravel the causal relationship between climate and environmental characteristics and yield components. It is called by Sebillotte (1987) "the scheme of yield elaboration" (figure 3). When a relation is shown in a field's sample between a practice and the production level, this must be validated by agronomic knowledges about the species functionning.

There is a logical order of questions in doing an agronomical diagnosis. First, the environmental characteristics which are responsible of production variation have to be identified. Then, the practices which have generated these environmental characteristics have also to be identified.

There are 3 steps in the diagnosis:

* First step: determining the development stage in which production has been most limited, because we know from literature for each stage which yield component is being formed (figure 4) and which factors may limit this process.

* Second step: between the probable limiting factors (the environmental characteristics), we have to identify which are actually limiting the yield component in question. Was nitrogen a limiting factor ? Was it due to insufficient availibility or to bad absorption ? Weeds, diseases, water, mineral nutrition... are all factors that have to be considered at this step.

* Third step: the cropping measures which have caused the limiting factors have to be identified. For this step, existing knowledge on the causal relationship between limiting factors and climate and cropping measures are used.

I.3.2/ What is the specificity of a pilot group ?

Agronomical diagnosis is usually applied in France on a regional scale for a selected and representative sample of farms and fields.

In contrast, the choice is limited in a pilot group. In the present study, our aim is to sample 10/12 fields among 10 farms with 2 or 3 wheat fields each, so in total about 25 wheat fields! Therefore, it is very difficult to find enough fields with the same variety. So the major constraint is the error caused by undocumented varietes and variety mixture. Most diagnosis tools need the same variety. On the other hand, a pilot group has the advantage of having a lot of field and farm data available. This can make the diagnosis more confident.

I.3.3/ The choice of indicators, innovative indicators

Facing a range of wheat varietes in the pilot group, we looked for variety independant diagnosis instruments. This methodical reflexion and testing is the second objective of the study.

a/ Indicators of datation

Usual indicators: the range of varieties in our sample makes usual indicators such as yield component difficult to use, because each variety has its own potential, especially for numbers of ears/m^2. We can compare the differents grain weights only if the potential grain weight is

Figure 2: The scheme of yield elaboration (from Sebillotte, 1987)

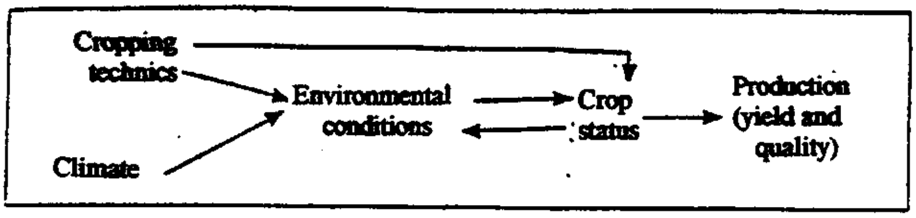


Figure 3: The periods of yield component formation

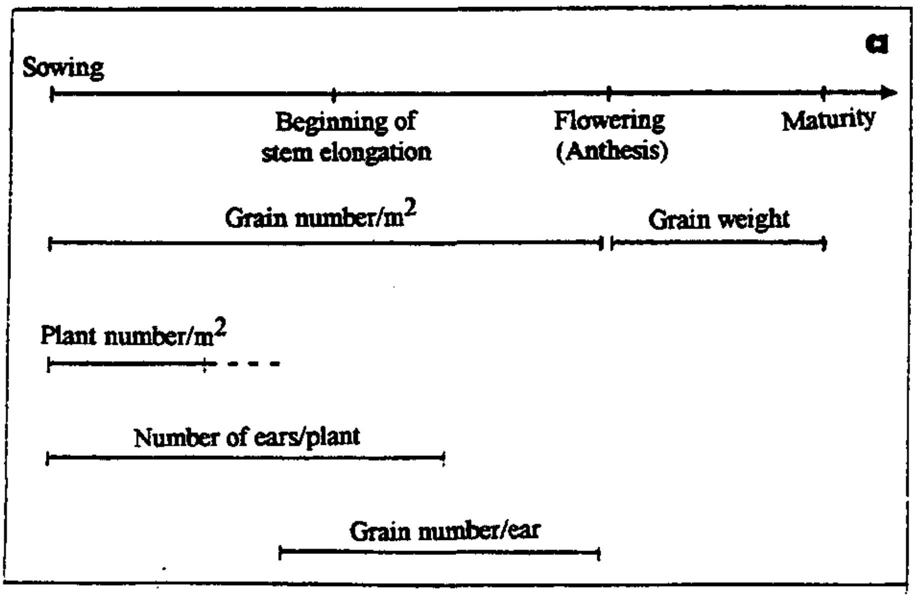
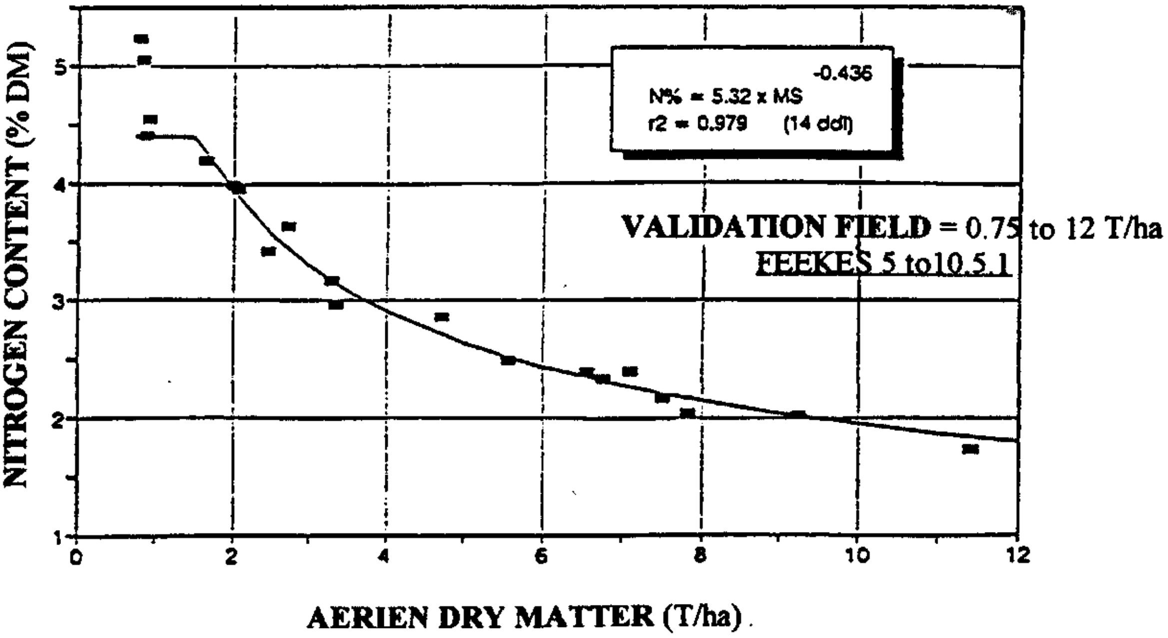


Figure 4: Nitrogen reference curve in non-nitrogen limited conditions. Adaptation to wheat by Justes, 1993.



known. Numbers of grains per m^2 can also be compared for varieties whose potential grain weight are equal.

Innovative indicators: first of all, we could compare actual to potential dry matter. This needs a lot of field-work to sample and measure the dry matter. It also needs accurate models to simulate and calculate the potential production (Lemaire, 1985).

SUCROS, a Crop Simulation Model (CSP) is a deterministic model, developed at Wageningen (Van Keulen and al, 1989). It simulates the daily potential growth of a crop (dry matter accumulation) under the actual climatic conditions, in well supplied environnement (water, nutrients...). So, it is a tool to simulate the potential yield under the measured climatic data.

As a mechanistic (Van Keulen, 1992) and complex model, SUCROS yield prediction is not always accurate (Whisler and al, 1986). It needs a lot of parameters each with its error, that can lead to an overall important error. Therefore, these models are not yet ready for use in yield diagnosis (Wallach, 1990, Fisher, 1984, Meynard, 1985).

Nevertheless, SUCROS has been validated and parametered in the dutch polders conditions. Its predictive value is therefore relativily good for the polders (Van Keulen, personnal communication). To reduce simulations uncertainty, we have decided to proceed in two simulations. The first simulation begins at early stage (tillering) until flowering; the second one from flowering till maturity. For each phase, dry matter and Leaf Area Index (LAI) are measured in the field and are the model's input; dry matter (or yield for harvest) and LAI for flowering are the output.

b/ *Indicators of limiting factors*

Usual indicators: in same research (Doré, 1992, Diouf, 1990), wheat nitrogen content and soil nitrogen reserves are measured, soil structure is observed, lodging, weeds and diseases development are followed. Mineral nutrients (P and K) and water supply is controlled.

Innovative tools: to quantify nitrogen supply, it is possible to use the model of nitrogen dilution, established by Lemaire and Salette (1984), adapted to wheat by Justes (1993) (figure 4).

TABLE 3 : EXPECTED RELATIONS BETWEEN THE PREVIOUS CROP AND ITS EFFECTS ON ENVIRONMENTAL CONDITIONS. CHOOSEN PLOT'S COUPLE

	USUAL EFFECT OF THE PREVIOUS CROP ON		EXPERIMENTAL LAY- OUT	
TYPE OF PREVIOUS CROP	SOIL STRUCTURE	QUANTITY OF NITROGEN IN THE RESIDUES	PLOT'S NUMBER	COUPLE OF FIELDS
Potato, onion barley, oats	no degradated	weak to moderate	7	• • •
Luzerna, grass / klover	no degradated	high	2	• •
Sugar beet, celeriac, cabbage	degradated	high	8	• • •

TABLE 4 : EXPERIMENTAL LAY-OUT BUILT ACCORDING TO THE TYPE OF THE PREVIOUS CROP

	FARM NUMBER										
	ECOLOGICAL FARMING SYSTEM						INTEGRATED FARMING SYSTEM				
WHEAT PREVIOUS CROP	1	2	3	6	8	9	11	12	13	14	15
Potato	•										
Onion		•		•		•	•				•
Barley		•									
Luzerna		•									
Grass / klover					•						
Celeriac			•	•		•					
Sugar beet				•				•	•	•	
Cabbage					•						

TABLE 5 : OBSERVATIONS SET - UP

"PERIODES"	STAGE "EAR 1 CM"	FLOWERING	MATURITY
CROP OBSERVATIONS			
Development	Exact development stage	Exact day of flowering	
Growth	Dry matter / m2 LAI	Dry matter / m2 LAI	Dry matter / m2 (straw and grain)
Yield component	Nb of plants / m2		Nb of grains / m2 1000 grain weight
Nitrogen	N content of the plant	N content of the plant	N content of the plant (straw and grain)
ENVIRONMENTAL CONDITIONS			
Nitrogen in soil	Nitrogen content at 0-30 cm and 30-100 cm		Nitrogen content at 0-30 cm and 30-100 cm
Weeds	Nb / m2	Dry matter / m2	Dry matter / m2
Diseases	Root, stem base and foliair	Stem base and foliair	Stem base and foliair
Soil structure	Profil observation	Profil observation	
Lodging			in % of the field

II / MATERIALS AND METHODS

II.1/ THE EXPERIMENTAL LAY-OUT

The experimental lay-out should allow analysis and the synthesis of the results and the test of the hypothesis. It should be representative of the existing situations, but should also allow a maximum variability of the sample (Boiffin and al, 1981). The wheat crops to be sampled have been classified according to the previous crop. The previous crops have been classified (table 3) according to their agronomic characteristics, established by P. Vereijken for his multifonctional crop rotation model. It concerns:

* quantity of crop residues and their nitrogen effect,

* their impact on soil structure. Lifted crops which are harvested late in season, often in wet conditions, are considered as harmful to soil structure.

There are 17 sampled fields from 11 farms in the lay-out (table 4): 12 fields are from 6 ecological farms, and 5 fields from the 5 integrated farms. Some characteristics of the farming system and wheat management in 1992/93 in the selected fields are presented in annex 3. Each farm has a code number, from 11 to 15 for the integrated farms, and from 1 to 9 for the six ecological farms (1; 2; 3; 6; 8; 9). It is possible that several fields of the same farm are observed, then the different fields are identified with letters: a, b, c... as for example 8a and 8b are 2 fields of the ecological farm number 8.

The lay-out should provide for sufficient variation in yields to point out limiting factors.

Besides, we need some couples of fields with minimum difference in cropping factors to facilitate the diagnosis on a single factor, to avoid confusion, and to test an hypothesis (Boiffin and al, 1981). The 4 couple of fields in our lay-out have a different previous crop in the same field. We have to be carefull because a different previous crop can change more that only one factor.

II.2/ THE PROTOCOL OF MEASURES AND OBSERVATIONS

As fields are very homogeneous, each sampling area is a block of 1.5 ha. The plots (50 to 50 cm or 0.25cm2, or 4 wheat rows of 50 cm) are situated along a diagonale of the field. 6 plots were harvested at early shooting and at flowering, 12 at grain maturity.

The protocol is shown in table 5. 3 periods of observations have been choosen as Meynard (1985): stage ear 1 cm (see annex 4 for definitions and more details on the protocol), flowering and maturity. So it is possible to do a more precise diagnosis for the 3 different wheat growth phases:

\# from sowing to beginning of shooting
\# from shooting to flowering
\# from flowering to maturity.

FIGURE 6 - YIELD

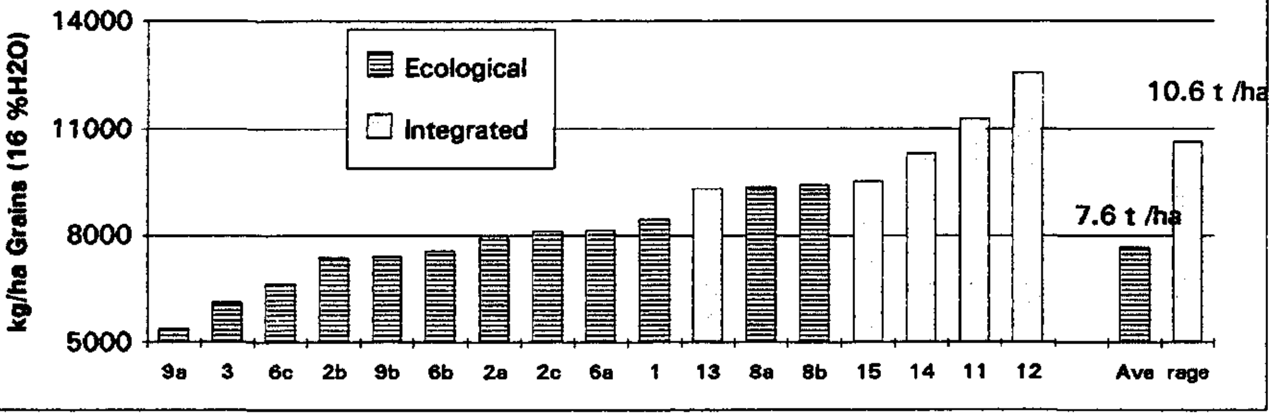


FIGURE 7 - PROTEIN CONTENT OF DRY GRAIN

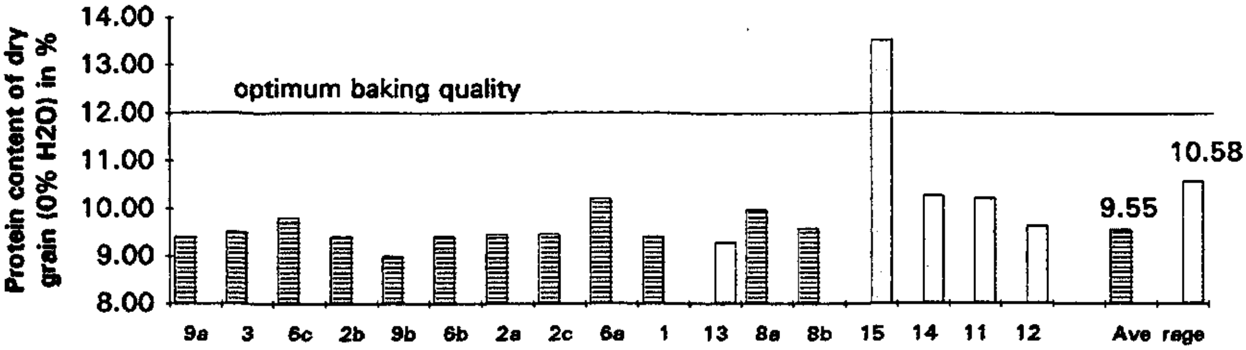
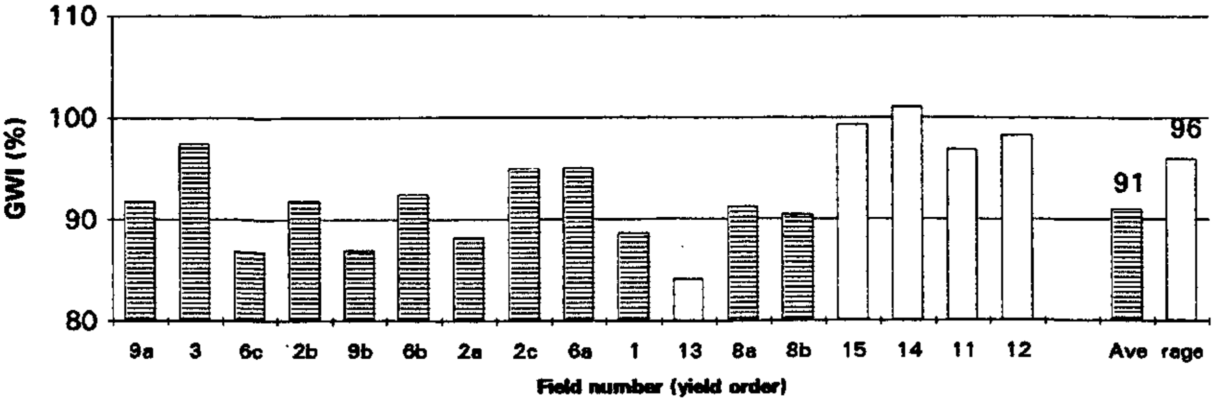


FIGURE 8 - GRAIN WEIGHT AS % OF VARIETY POTENTIAL (Grain Weight Index)



III / RESULTS

Yield variation will be analysed through :

- the analysis of nitrogen supply and yield component variation,
- and through the use of SUCROS simulations and of crop growth measures.

In a second step, we will try to identify the environmental factors, causing a nitrogen or growth or yield component shortage.
Finally, relations between these identified factors and farmers practices should be established.
This sheme of analysis has been used in the same kind of study (Meynard, 1985; Doré, 1992).

III.1 / YIELD ANALYSIS

III.1.1 / Variations in yield and its components

a/ *Variations in yield and grain protein content*

Yields vary strongly (*Fig.6*), which is of advantage for analysis. Yield potential is high, if we look at the highest yields of integrated fields, 12.5 t/ha for field 12, and of ecological fields, 9 t/ha for field 8. The variation is strong within each system. Therefore, we may expect that yields have been strongly limited. The mean difference of yield is of 3 t/ha between integrated and ecological.

Yield (16 % moisture) variation: differences between the highest and lowest yield

- within the ecological system: "4023" kg/ha (from 5398 to 9421 kg/ha)
- within the integrated system: "3249" kg/ha (9323 to 12572 kg/ha)
- overall: "7174" kg/ha (from 5398 to 12572 kg/ha).

Grain protein content on the contrary (*Fig.7*) is little different, except field 15. Most of the produced grain is meant as baking grain, which requires a high grain protein content (Martin, 1987); therefore grain for bread is now more and more payed according to its protein content. We can observe (*Fig.7*) that protein content is much to low, compared with required baking quality, in both systems. Further analysis of grain protein content is impossible because of lack of variation.

b/ *Grain Weight Index to neutralize variety effects*

As it has been said, we will not use ear/m2, because it is to variable between varieties; but 1000 grain weight (1000GW) and grain number/m2 (GN/m2) can be used if **potential 1000 grains weight (P1000GW)** is known. M. Darwinkel from PAGV (technical institut for arable crops) in Lelystad provided these values for the varieties used in our sample (*Table 6*). They have been calculated from results of multi-located varieties trials, done in 1989, 1990, 1991 in experimental conditions. Arminda and Obelisk were used as varieties references, because their potential 1000 grain wheight is well known. Except RENAN, all varieties have P1000GW in a range of 49-54 g.

For **varieties mixture**, the choosen value of P1000GW is the mean of the P1000GW of the varieties of the mixture. This is not totally correct because certain varieties can be predominant in their yield contribution.

In order to compare the field measured 1000GW, it is necessary to take into account the differences of P1000GW. Therefore, we have created a variable: GWI (Grain Weight Index):

FIGURE 9 - GRAIN YIELD (16% H2O) related to GRAIN DENSITY

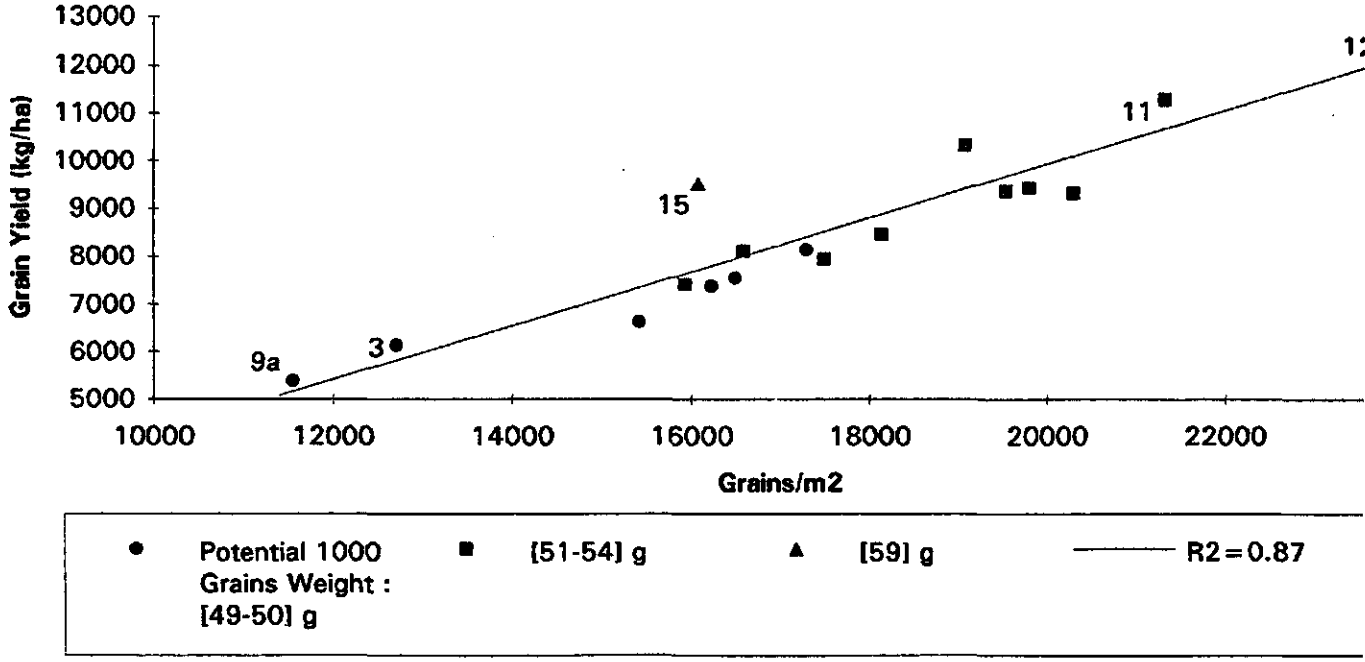


FIGURE 10 - GRAIN YIELD related to 1000 GRAINS' WEIGHT

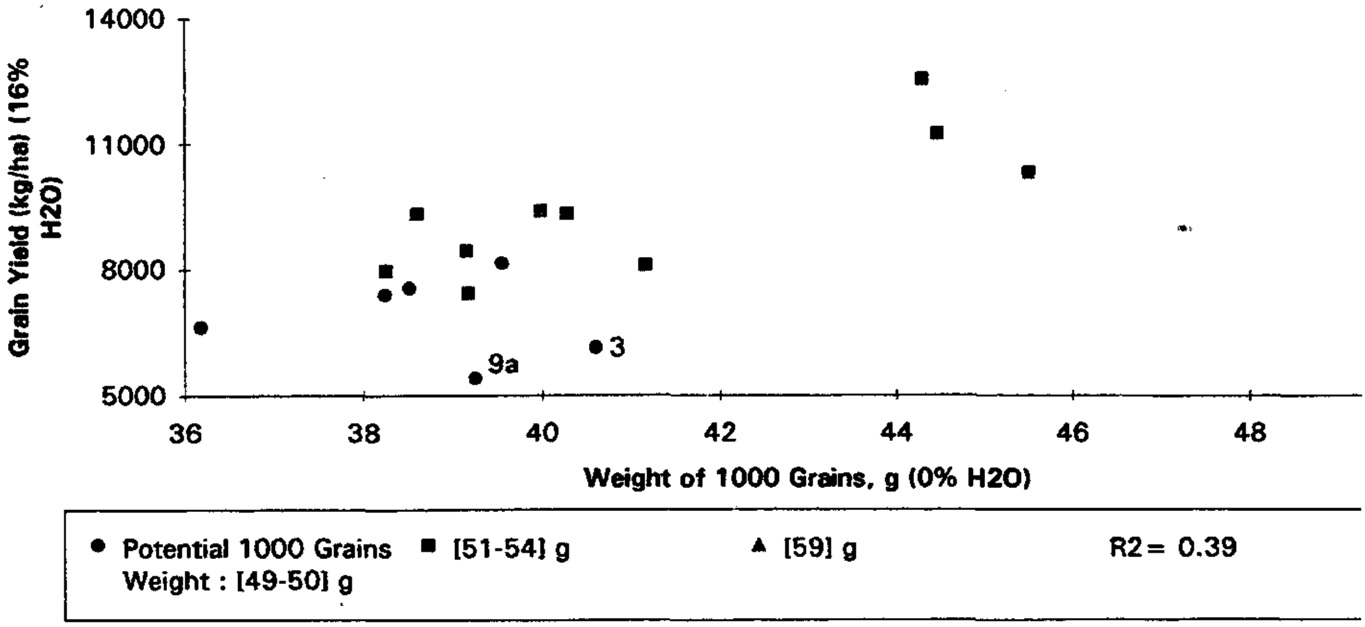


TABLE 6 : POTENTIAL 1000 GRAIN WEIGHT ACCORDING TO VARIETIES

VARIETY	ESTIMATED POTENTIAL 1000 GRAIN WEIGHT ACCORDING TO VARIETIES TRIALS (g / 1000 grains at 15 % humidity)
REFERENCE VARIETIES	
Arminda	46
Obelisk	53
USED VARIETIES IN OUR SAMPLE	
Hereward (He)	52
Bussard (Bu)	49
Promessa (Pr)	54
Rektor (Re)	49
Urban (Ur)	53
Herzog (Her)	55
Ritmo (Ri)	54
Trawler (Tr)	53
Vivant (Vi)	53
Renan (Ren)	59
VARIETY MIXTURE (Mi)	Weighed Mean's of the 1000 potential grain weight of varieties in seed-mixture

GWI (%) = (measured 1000GW / P1000GW of the variety) * 100

Theorically, GWI should be less or equal to 100%. That's what we observed (*Fig.8*) which is a first validation that P1000GW has not been underestimated. But we are not sure that there is no overestimation of the P1000GW! If limiting factors occur during the grain filling period, GWI is lower than 100%.

By analogy, a second variable can be created instead of Grain Number/m2 to neutralize variety differences. Ideally, we need to know P1000GW and yield potential of each variety. This last information is not availiable. So have we created the variable **GNI (Grain Number Index)**, by choosing an arbitrary P1000GW of 44g/1000 grains. For the same yield, a variety with a P1000GW of 44g has a Grain Number which equals GNI. It allows us to identify all varieties to this imaginary variety.

GNI = (P1000GW / 44) * (actual GN/m2)

c/ Relations between yield and the main yield component

The general relations between yield and grain number (*Fig.9*) or yield and 1000 grain weight (*Fig.10*) shows that the linear regression is better for the first relation (r2=0.87). The ratio "minimal value/maximum value" is:

- 0.48 for grain number
- 0.79 for 1000 grain weight.

Grain number is also more variable, so it is the principal yield component to explain yield variation.

FIGURE 11 - YIELD related to GRAIN WEIGHT INDEX

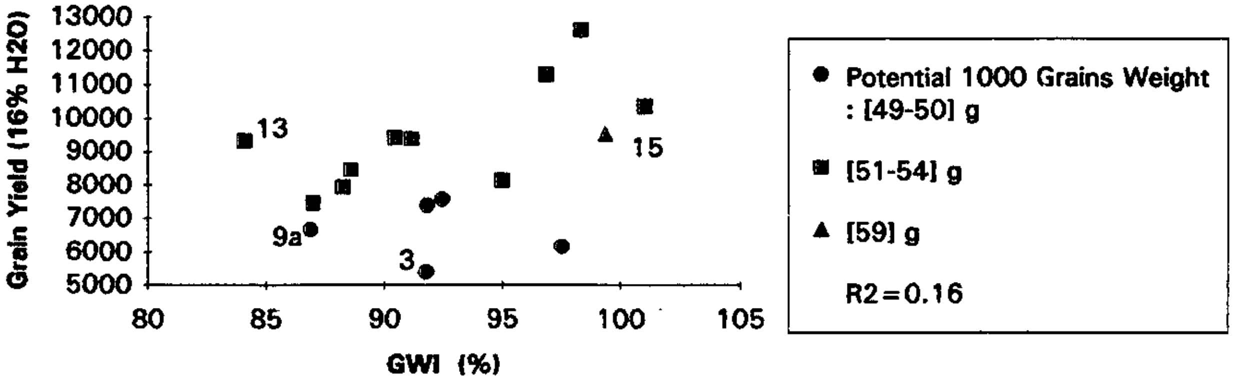


FIGURE 12 - PLANT DENSITY RELATED TO % OF EMERGENCE

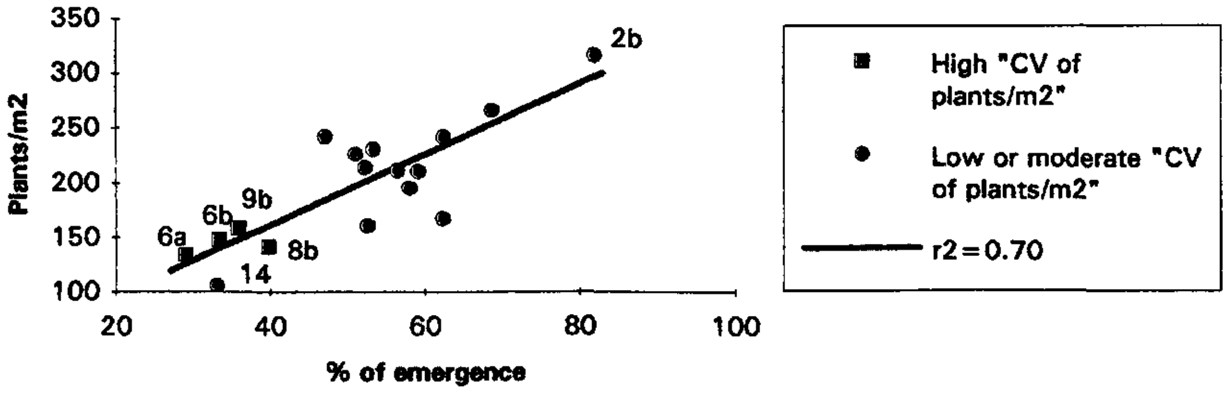
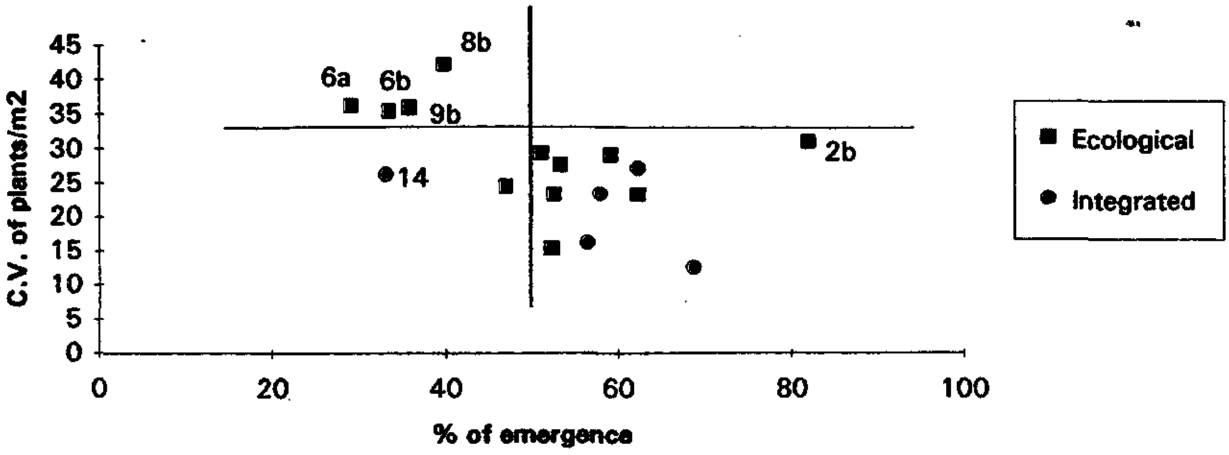


FIGURE 13 - COEFFICIENT VARIATION OF PLANT DENSITY related to % OF EMERGENCE



When index are used to neutralize variety effects, the relation between yield and GNI becomes better (r2=0.93), whereas the relation yield / GWI is worse (r2=0.16) (*Fig.11*). The ratio "minimal value/maximal value" is:

- 0.41 for GNI
- 0.83 for GWI.

Therefore, when the variation induced by varieties is taken into account, we observe that yield is in fact much more related to the first component (grain number) then seemed before corrections, in line with Meynard, 1985. Therefore, we will only use these index in the following parts.

III.1.2/ Yield analysis during early stage: from sowing to tillering

This period is seldom of importance and therefore the only observations made during this period were number of seedlings/m2. Therefore conclusions must be carefully made.

a/ *Emergence, plant density and growth until tillering*

As in 12 plots per field plant density has been established (*annexe 4*), it is possible to calculate a coefficient of variation of the plant density: CV of plants/m2 = standart error / mean. The % of emergence (100*(plant/m2)/(seed/m2)) is very variable (*Fig.12*), and is the main factor which explains the final plant density: r2=0.70. We can observe that fields with low emergence are also those with high CV of plant/m2 (*Fig.13*). It is also obvious that integrated fields have a lower CV of plants/m2.

From low plant densities can be concluded that growth from sowing to stem elongation (*Fig.14*) is very variable; only one field (9b) has a low dry matter. There is no significant difference between ecological and integrated systems.

FIGURE 14 - DRY MATTER at stage "EAR 1 CM" (fields in order of yield, cf figure 1)

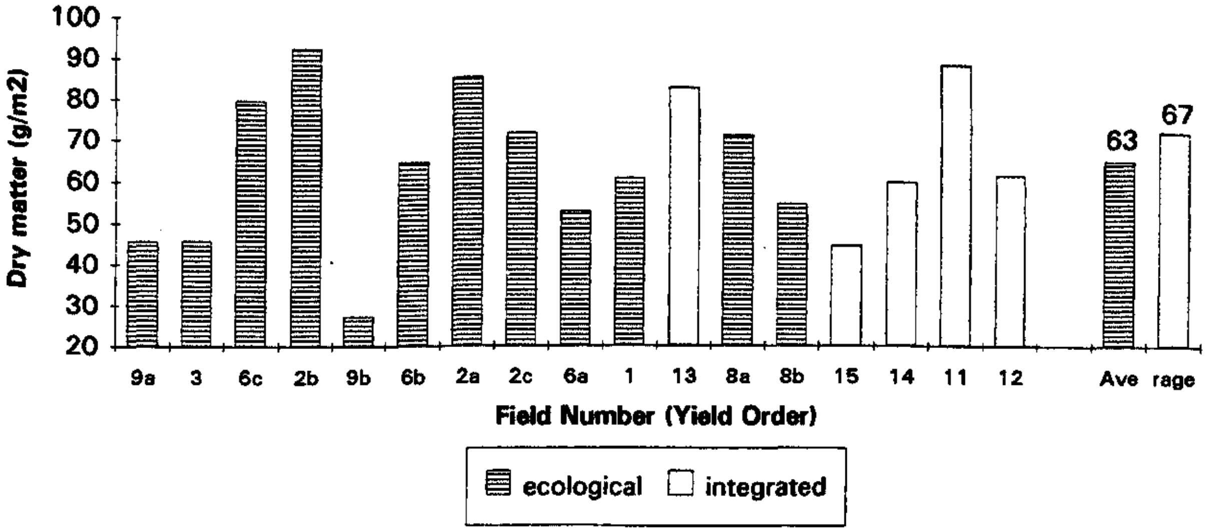


FIGURE 15 - DRY MATTER at "stage 1cm" related to PLANT DENSITY

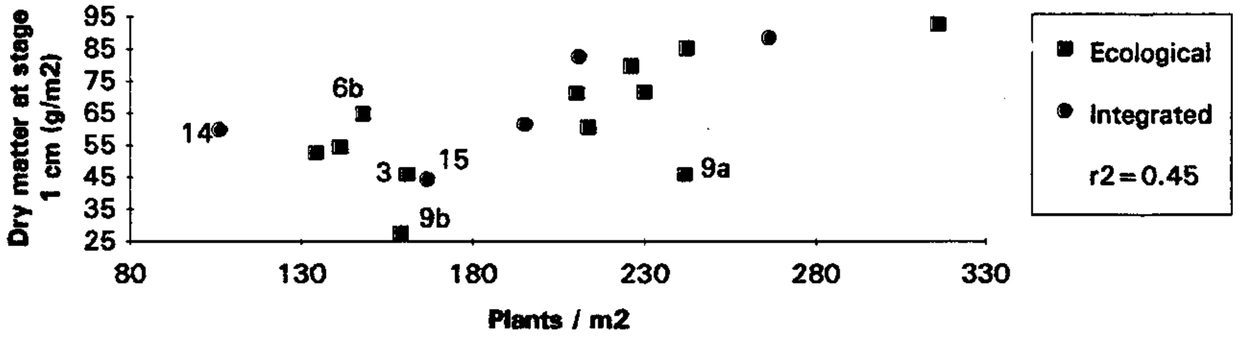


FIGURE 16 - GRAIN NUMBER INDEX related to PLANT DENSITY

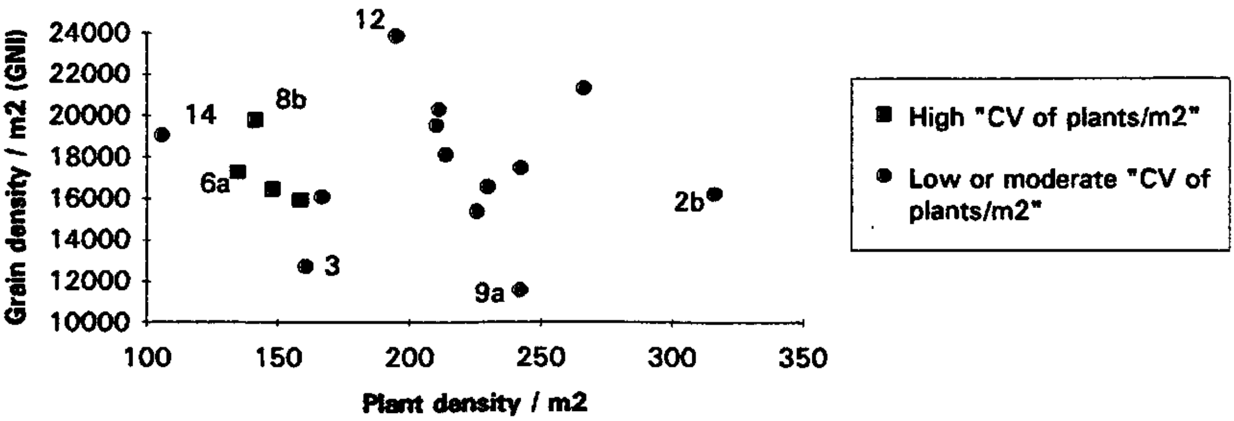
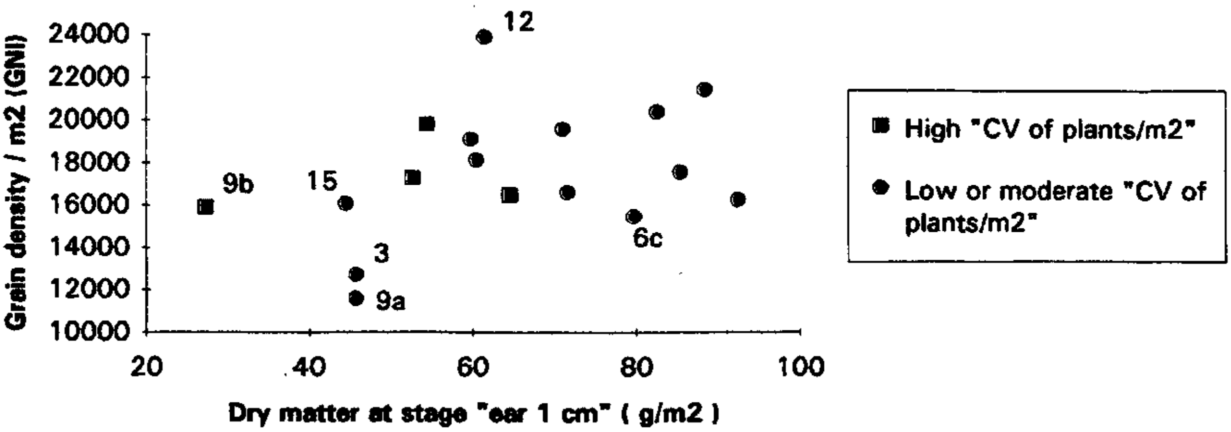


FIGURE 17 - GRAIN NUMBER INDEX related to DRY MATTER at stage "EAR 1 CM"



So, three questions are to be answered:

1- are the 5 fields with low emergence (less than 40%), and low plant density (less than 150 plants/m2) limited in achieving a sufficient grain number?

2- is the high CV of plants/m2 at tillering related to low dry matter at tillering, and also to grain number?

3- is low dry matter at tillering (field 9b especially) a limitation for grain number?

b/ *The possibility of yield limitation related to plant density*

Even if we do not know the real relation between dry matter at tillering and plant density, because it is a non-linear one, dependant on variety and date of sowing (Meynard, 1985), we can observe that the linear relation is pretty good (*Fig.15*). Plants/m2 is not a limiting factor because it is possible to reach relatively good level of dry matter with a low number of plants/m2 (field 6b and 14). High CV of plant/m2 (6a, 6b, 8b, 9b) can not explain low dry matter (9a,9b,3,15); neither can the date of sowing.

To answer to the two first questions, we have looked to the relation between Grain Nuber Index (GNI) and plant density (*Fig.16*). It is obvious that plant density is not limiting grain number. Fields 14, 6a, 8b are able to reach high grain density with low plant density. The covariable "high CV of plant/m2" does not explain fields with low grain density. The same remarks can be done for the *Figure 17*, except for field 9b: it is possible that this field was limited in its grain number formation by a to low dry matter at tillering. On the contrary, we are quite sure that in fields 9a and 3 tillering authorizes a higher grain number than obtained: their low grain number has developed between tillering and flowering.

c/ *Partial conclusion*

For all these relations, analyses are very general: the impossibility of using standart diagnosis is obviously a shortcoming, and is caused by the diversity of variety. Plant densities as for as dry matter are very variable at tillering. Apart from one field (9b), it does not seem that yield limitation occured before tillering. High CV of plant/m2 is not expected to explain growth at this stage.

III.1.3/ <u>Yield analysis between tillering and flowering: effects of nitrogen supply</u>

a/ *Evolution in nitrogen content of the crops*

In order to characterize nitrogen supply and to identify nitrogen shortage, we have used the model of nitrogen dilution (Lemaire et Salette, 1984), adapted to wheat by Justes in 1993, at tillering and at flowering. The use of this model is to enable comparison of nitrogen content of different fields independantly of their dry matter. The optimal nitrogen content for a certain dry matter is calculated according to the adjusted equation of Justes:

$$\boxed{N\% = 5.32 * MS^{-0.436}}$$

This equation is valid in a confident interval of 1.55 to 12 t/ha of dry matter. From 0 to 1.55 t/ha, there is a unique value of 4.4 %. So have we used an index of nitrogen nutrition satisfaction, NI (F) or NI (T):

NI (at Flowering or at Tillering) = actual [N] for the measured dry matter * 100 / optimal [N] for the same dry matter

FIGURE 18 - NITROGEN INDEX at flowering (NI flo) related to NITROGEN INDEX at tillering (NI til)

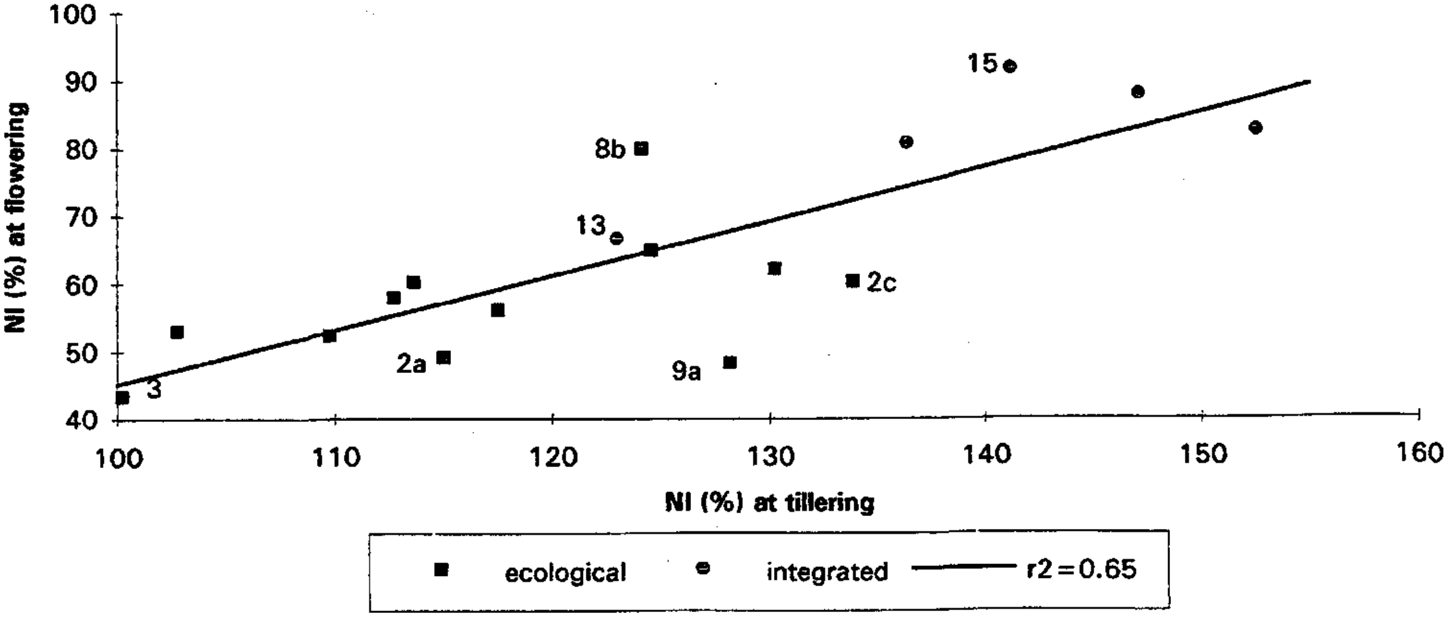
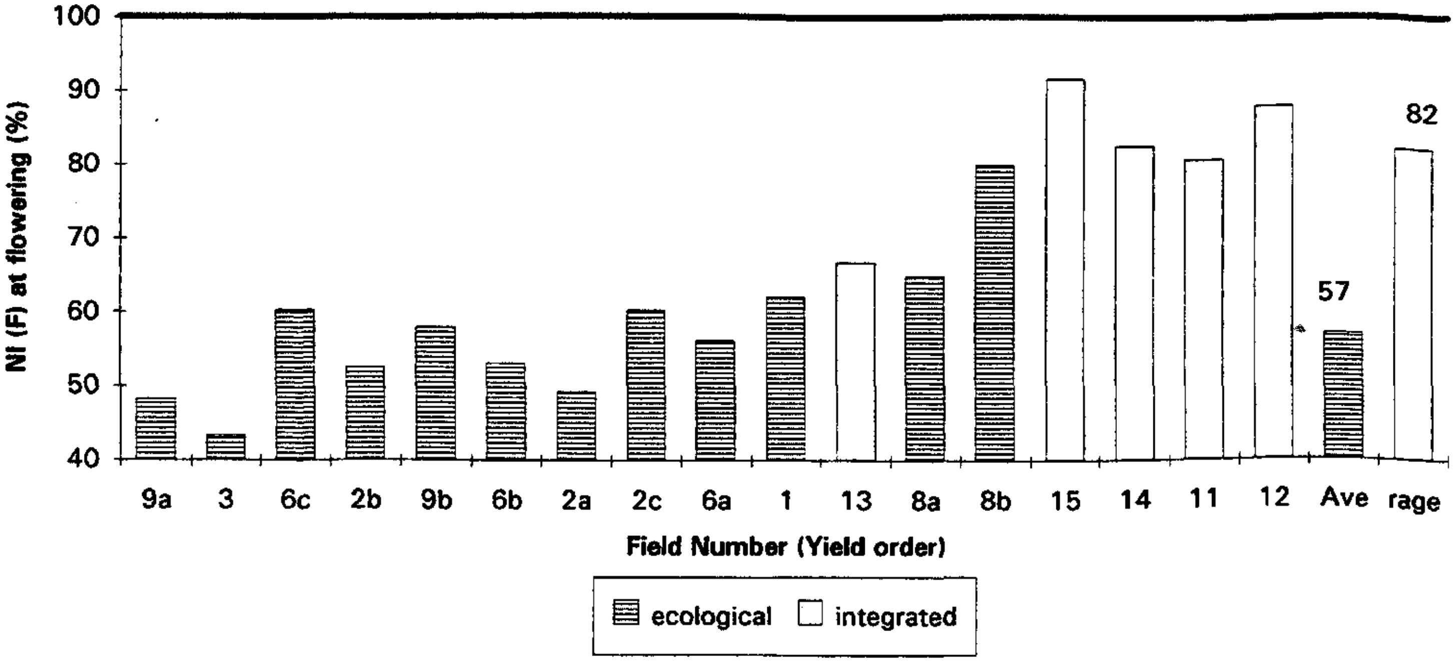


FIGURE 19 - NITROGEN INDEX AT FLOWERING: NI (F)



A value of 100% for NI means a sufficient nitrogen nutrition, a value over 100% an excess of nitrogen, but under 100%, there is a shortage of nitrogen. The lower this index is, the higher is the shortage of nitrogen.

The nitrogen nutrition at tillering was not limited (see abscisses values of *Figure 18*), because NI (T) was beyond 100%; integrated fields have higher values of NI (T). NI (F) on the contrary (*Fig.19*) is lower than 100% for all fields, it indicates nitrogen stress during the shooting period. This stress is especially strong for the ecological fields: their NI (F) values, except field 8b, are in the range 42-63%, which is quite low. On average, it is obvious that the difference between the two systems has remained and that Integrated fields do not really suffer of a nitrogen shortage.

The relation between NI (T) and NI (F) (*Fig.18*) seems good, but is created by the values of the integrated fields. These fields received mineral nitrogen fertilization after tillering, we should not consider them in this relation; r2 is of 0.25 when only ecological fields are considered. As a result, nitrogen status at tillering is not predictive for the ecological fields: it may rapidly decrease between tillering and flowering (field 9a for example).

b/ *Relations between nitrogen and yield and grain number*

Nitrogen is a very important limiting factor of grain number (Boiffin and al, 1981). In the present study we also observe the good relation between NI(F) and GNI (r2=0.63), which is even better with nitrogen uptake at flowering (*Fig.20*): r2=0.66. Also yield is better related to this variable (*Fig.21*): r2=0.75. As grain number is closely related to yield, this is logical. It confirms that yield level has already been strongly determined at flowering by its nitrogen nutrition and its grain number.

FIGURE 20 - GRAIN NUMBER INDEX related to NITROGEN UPTAKE at FLOWERING

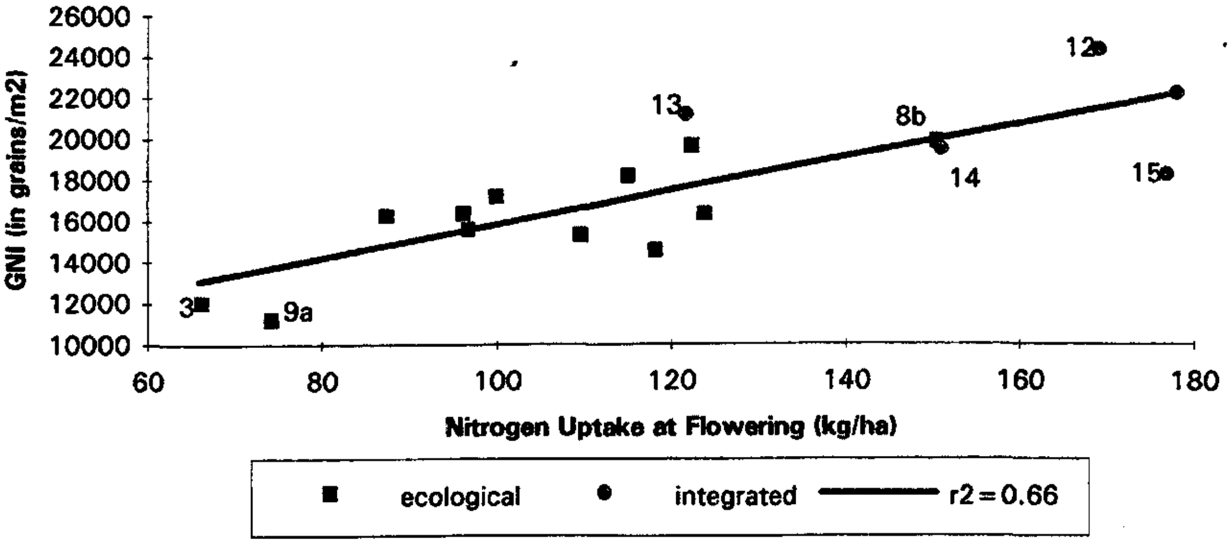


FIGURE 21 - YIELD related to NITROGEN UPTAKE at FLOWERING

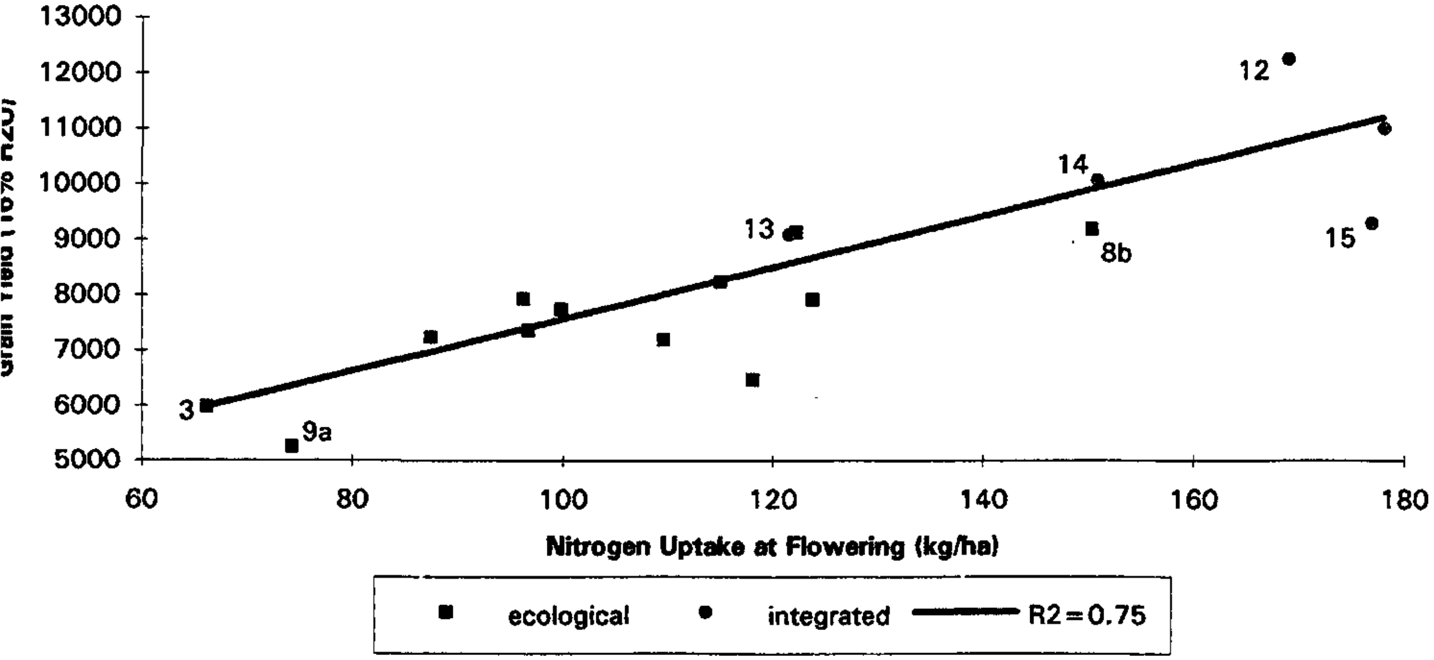
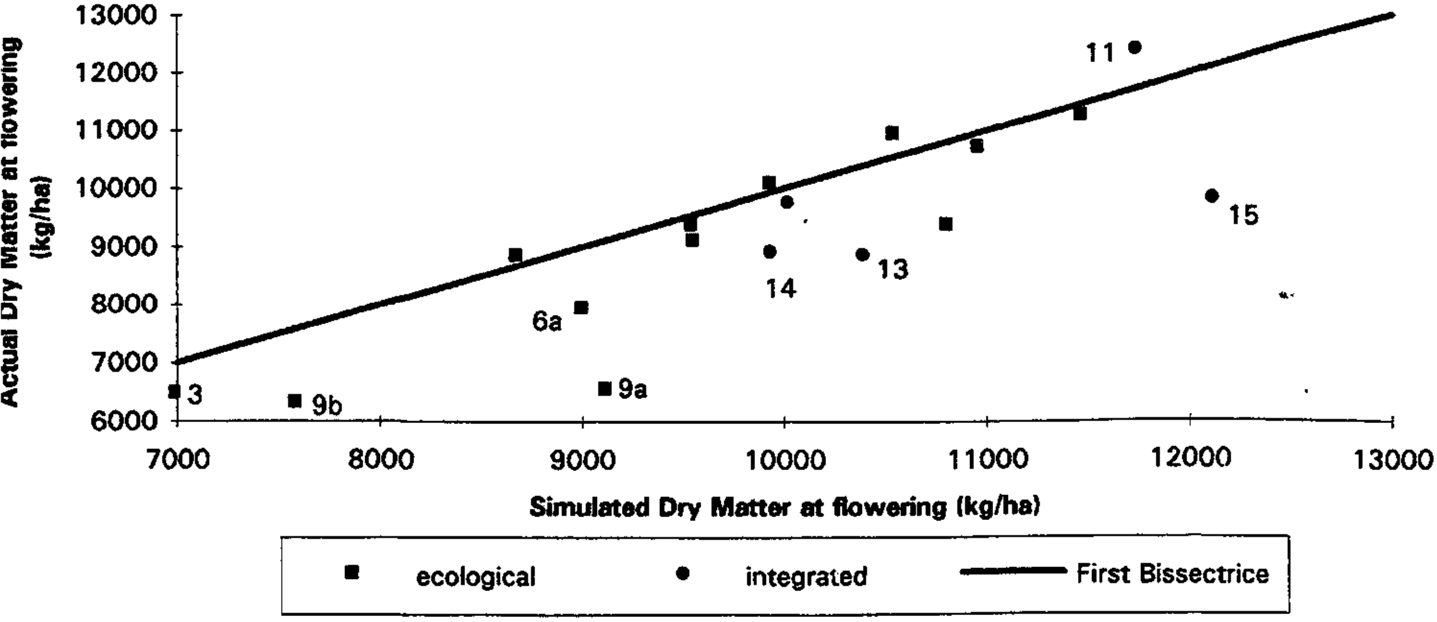


FIGURE 22 - Relation between SIMULATED AND ACTUAL DRY MATTER at flowering



III.1.4/ Yield analysis during the grain filling period

To analyse reduction of grain filling, we use GWI's values *(Fig.8)*. They are not very different, on average, from their potential: 100% means that they have reached their Potential 1000 Grain Weight (P1000GW). Only 5 fields are below 90%.

Furthermore, GWI is not correlated to yield (r2=0.16). As observed by Meynard, 1985, nitrogen is not correlated to grain weight (r2=0.20 between GWI and NI(F)).

So can we conclude that grain filling is not or scarcely limited, and that integrated fields have a better filling, except one field.

III.1.5/ Partial conclusion of yield analysis (part III.1)

This first part has shown the high interest to use index to correct variety induced errors (GWI and GNI). Two limits still remain:

- yield potential of each variety should be available to a more confident calculation of GNI
- the normal harvest index of each variety could certainly explain a part of the residual variability in the relation between grain number and nitrogen uptake at flowering (*Fig.20*). It is probable that differences with varieties exist in the ability to produce the same grain number with different nitrogen uptake.

It is thus necessary to use these index, but they need several estimations, each estimation with a certain uncertainty, so there is a final error in GNI and GWI values.

Yield seems closely related to grain number and nitrogen status at flowering. Nitrogen nutrition is not limited at tillering, but stress can occur during the shooting; almost all ecological fields have important nitrogen stress at flowering. The first stage (before tillering) and last one (filling period) are of minor importance in their contribution to yield elaboration.

III.2/ SUCROS SIMULATIONS

III.2.1/ The different simulations

Several simulations have been done with SUCROS, in order to simulate the potential yield. For SUCROS, two fields with the same dry matter and LAI (Leaf Area Index) at the same development stage have the same yield potential, independantly of the variety. This variety effect is not taken into account with simulation from sowing, but is more or less taken into account when simulations begins with a developped crop: SUCROS is very sensitive to differences of LAI, even if dry matter are equal.

Therefore, we decided to begin simulation at tillering, by measuring on-field dry matter and LAI, and calculating the development stage of each crop. The same measures are made at flowering; it is so possible to compare the simulated values to the actual values (it will be called **"Dry Matter at Flowering simulation"**). Potential yield can be simulated in two ways:

- from tillering: we use the on-field measures of tillering, and the model (SUCROS) runs from tillering until grain maturity (it will be called **"Yield Simulation from Tillering"**)
- from flowering: on-field measures at flowering are used as input of the model which runs from flowering until grain maturity (it will be called **"Yield Simulation from Flowering"**).

FIGURE 23 - DRY MATTER AT FLOWERING AS % OF THE DRY MATTER SIMULATED BY SUCROS FROM TILLERING

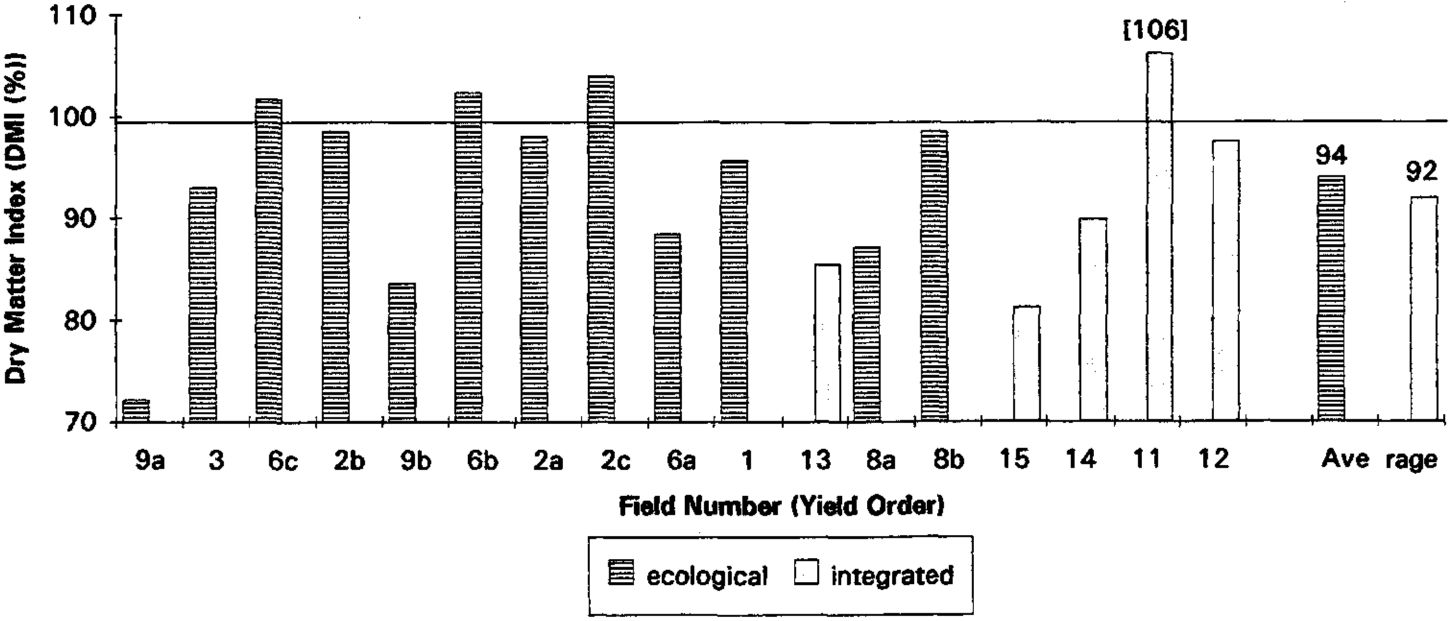
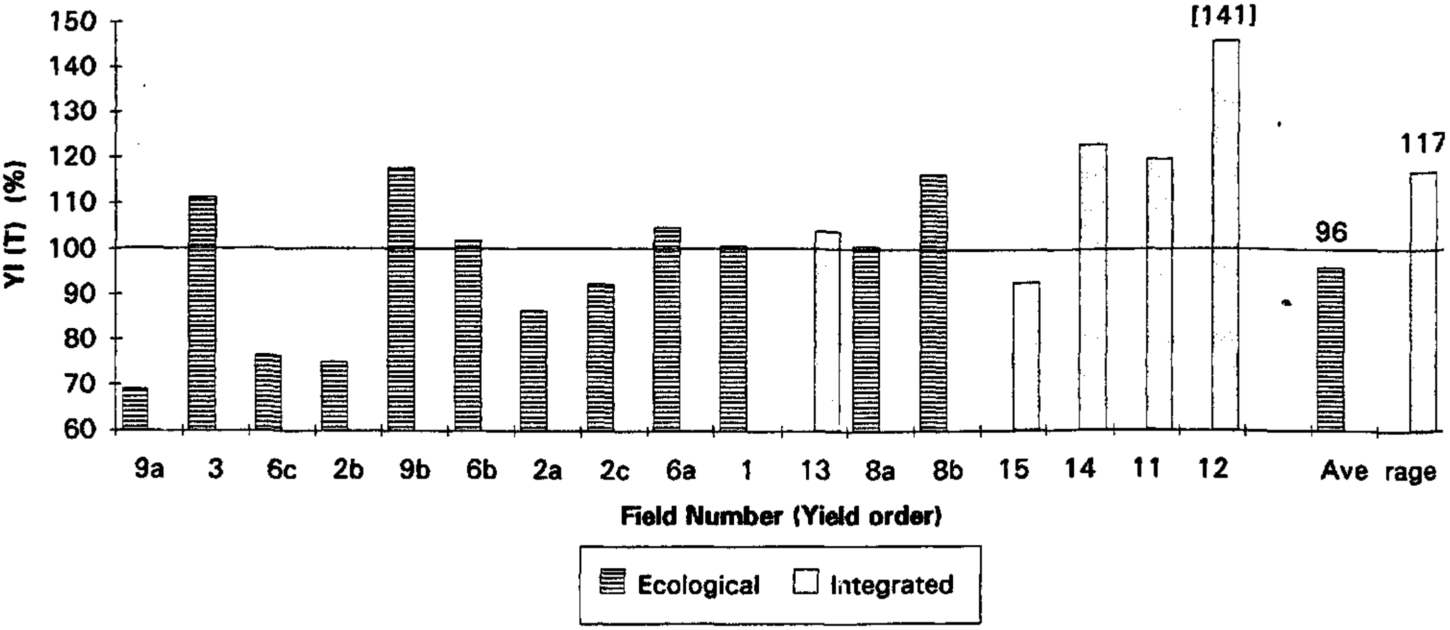


FIGURE 24 - GRAIN YIELD AS % OF POTENTIAL YIELD SIMULATED BY SUCROS FROM TILLERING



III.2.2/ Results of the simulation

Is it possible to be confident in the simulations values? The reliability of the simulated values depends on two things:

- the precisions of the on-field measures of the model inputs and outputs: dry matter and LAI
- the accuracy of the model SUCROS itself.

The only way to validate the accuracy of SUCROS for potential dry matter in our study is to control that no fields have significantly more dry matter than simulated.

Result of the "**dry matter at flowering simulation**": the on-field measures of dry matter are equal or slightly superior to the "simulated dry matter" (*Fig.22*). It seems that reduction of actual dry matter compared to potential ones can occur, whatever the potential is. So, it is possible to conclude that SUCROS was accurate for this first simulation.

To compare fields, an index has been created (*Fig.23*): Dry Matter Index

DMI = (100 * actual dry matter / simulated dry matter) at flowering

This index describes crop growth during the shooting period.
In the same idea, two others index have been created for the two others simulations

Yield Index (from Tillering)

YI (T) = 100 * actual yield / yield simulated from tillering

Yield Index (from Flowering)

YI (F) = 100 * actual yield / yield simulated from flowering

YI (F) is more interesting for us because it characterizes the grain filling period according to a mechanistic integration of crop characteristics at flowering. Its significance is complementary to **GWI**, because **GWI** takes only into account the filling of the existing grains. If grains disappear (because of non-fecundation or others reasons) at or after flowering, it will not appear in **GWI**, whereas it should influence **YI (F)**.

The rule to judge the accuracy of SUCROS is that the obtained values of the index should not be significantly superior to 100%. If some fields' index are significantly over 100%, it means that SUCROS has underestimated the potential yield.

Yield simulation from tillering (*Fig.24*) shows that several fields have largelly exceeded the simulated yield potential. It is not correct to use this index, potentials being strongly underestimated. **Yield simulation from flowering** (*Fig.25*) shows an acceptable result, because the higher values of the index YI(F) equals more or less 100%. We do not know exactly the confident interval of SUCROS simulations, but we could assess that 107% belongs to it.

To understand why the global simulation (YI(T)) is so inaccurate compared with the second one (YI(F)), we have compared simulated LAI at flowering to the actual LAI (*Fig 26*). It appears that SUCROS has underestimated the LAI, for the high values only. According to Van Keulen (personal communication), who develops SUCROS, it is not surprising, seing that the "assimilates repartition function" is the weak point of SUCROS.

Conclusion on the accuracy of SUCROS simulations in our survey: the predictive value of SUCROS is not satisfactory enough when used in a long period. But used in a smaller period, SUCROS seems accurate enough, therefore DMI and YI(F) will be used in the following analyses.

FIGURE 25 - GRAIN YIELD AS % OF POTENTIAL YIELD SIMULATED BY SUCROS FROM THE FLOWERING

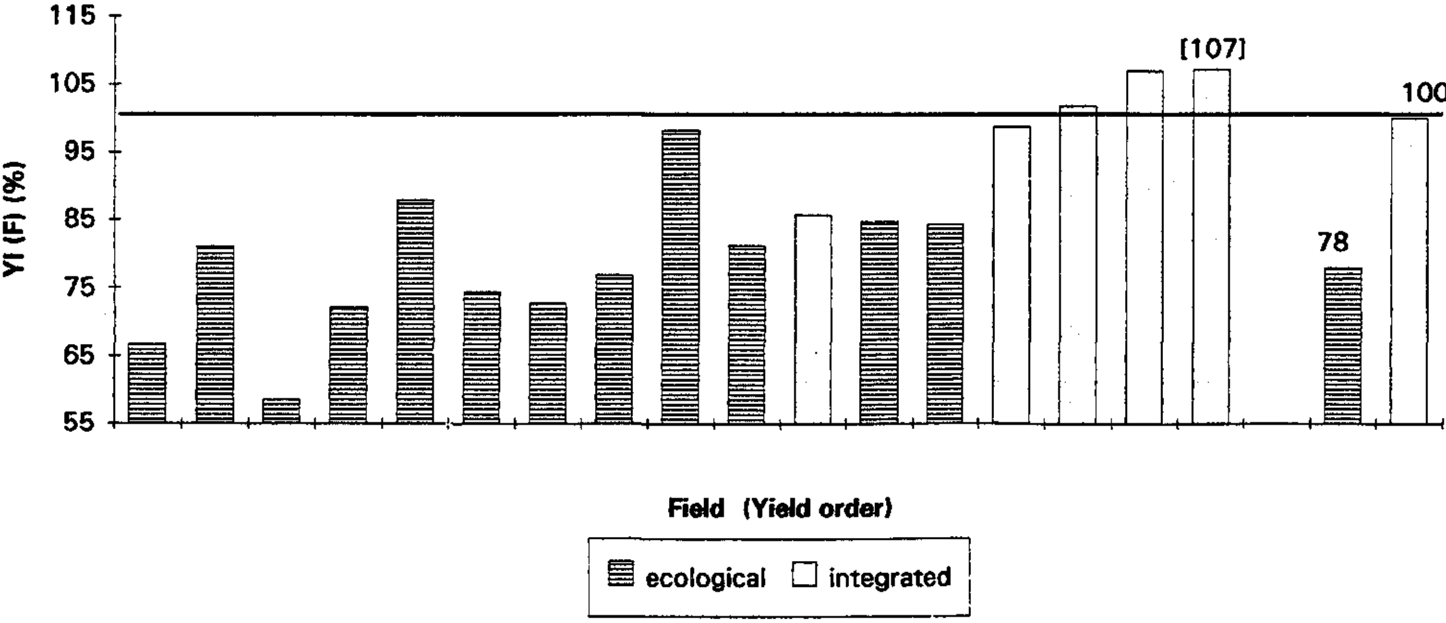
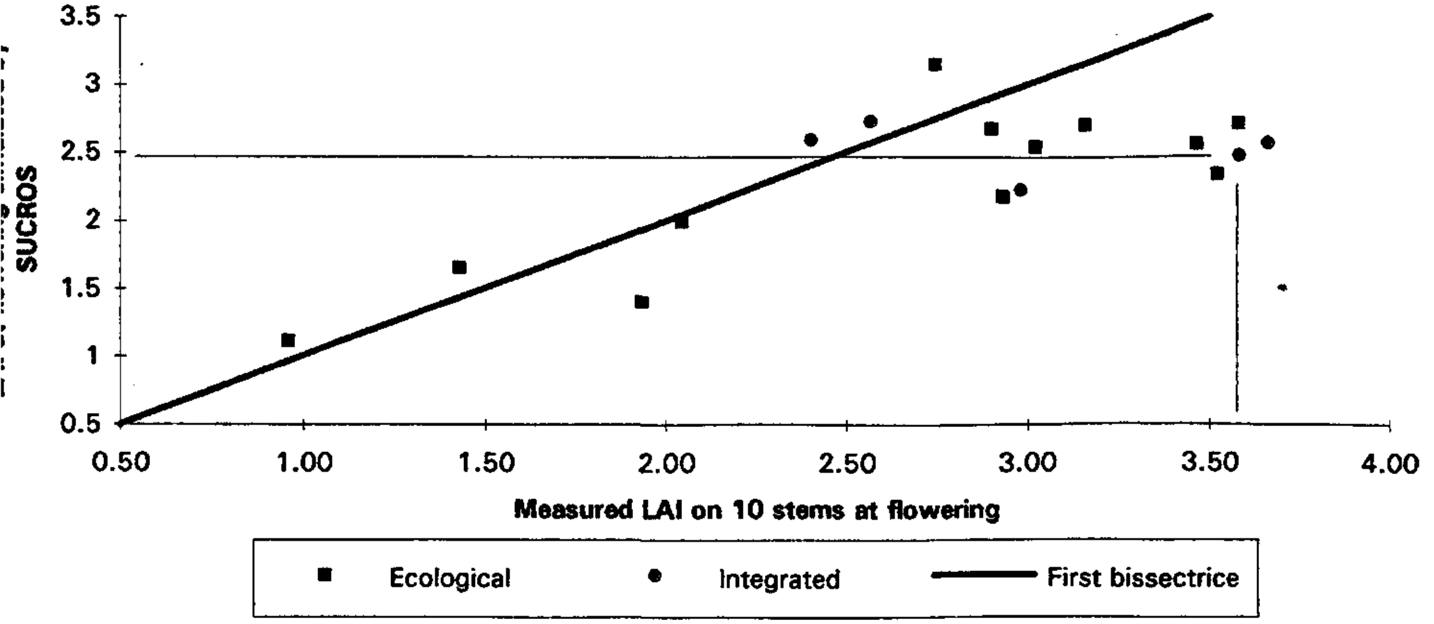


FIGURE 26 - LAI simulated by SUCROS related to measured LAI at flowering



III.2.3/ Relations between DMI and others variable at flowering

Some correlations between variables:

Several variables are describing crop growth, it is

- Dry matter at stage ear 1 cm (variable 1)
- Dry matter at flowering (2)
- DMI (3)

These three variables are well correlated together: r2 of 0.47 (relation between variable 2 and 3), 0.35 (1 and 2) and 0.65 (1 and 3).

On the contrary, none of these variables is well correlated to yield component or nitrogen:

- yield (4): r2 is of 0.24 and 0.07 with variable 2 and 3
- GNI (5): r2 is of 0.24 and 0.07 with variable 2 and 3
- Nitrogen uptake at flowering (6): r2 is of 0.42 and 0.07 with variable 2 and 3

We have seen in preceding parts that yield, GNI (Grain Number Index) and Nitrogen uptake at flowering were well correlated together.

Analysis of these correlations:

The SUCROS index (DMI) is not sensitive to grain number or nitrogen nutrition variation because the variable "dry matter at flowering" is not. Effectively, different dry matter

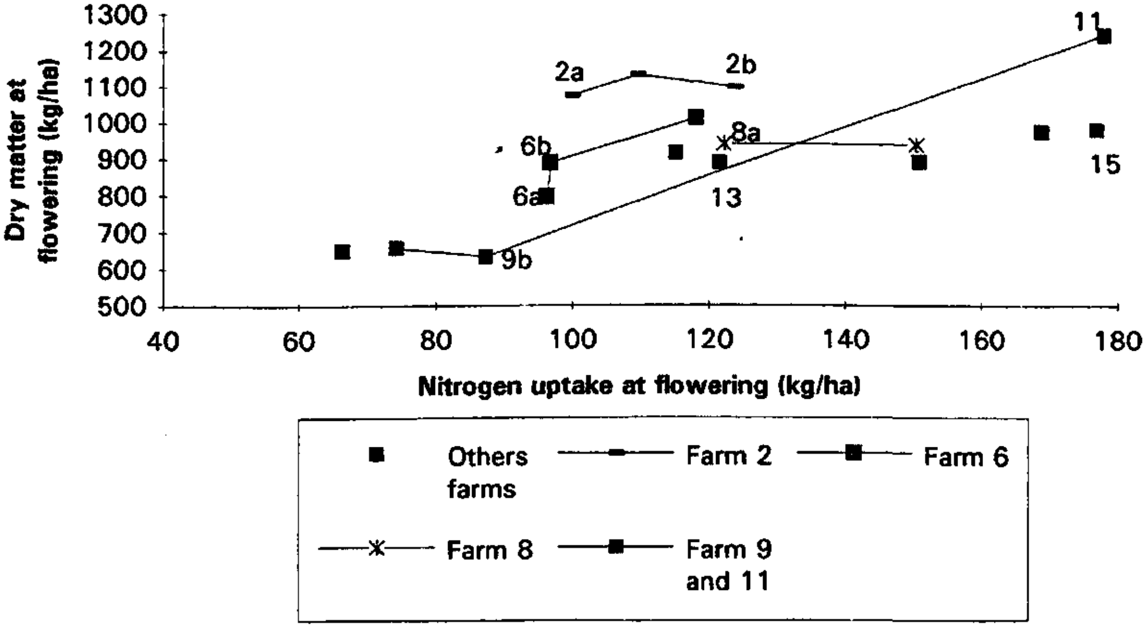


FIGURE 27 - DRY MATTER at flowering related to NITROGEN absorption at flowering

FIGURE 28 - LAI related to NITROGEN ABSORPTION, at Flowering

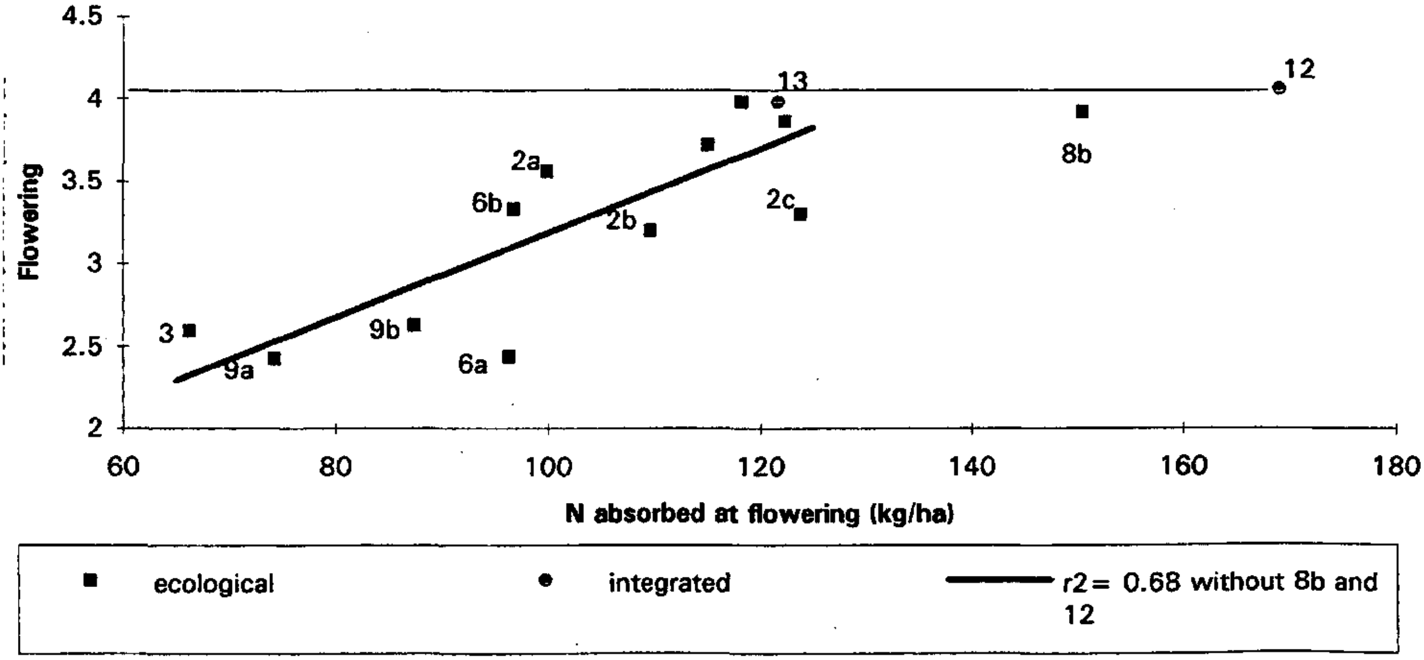
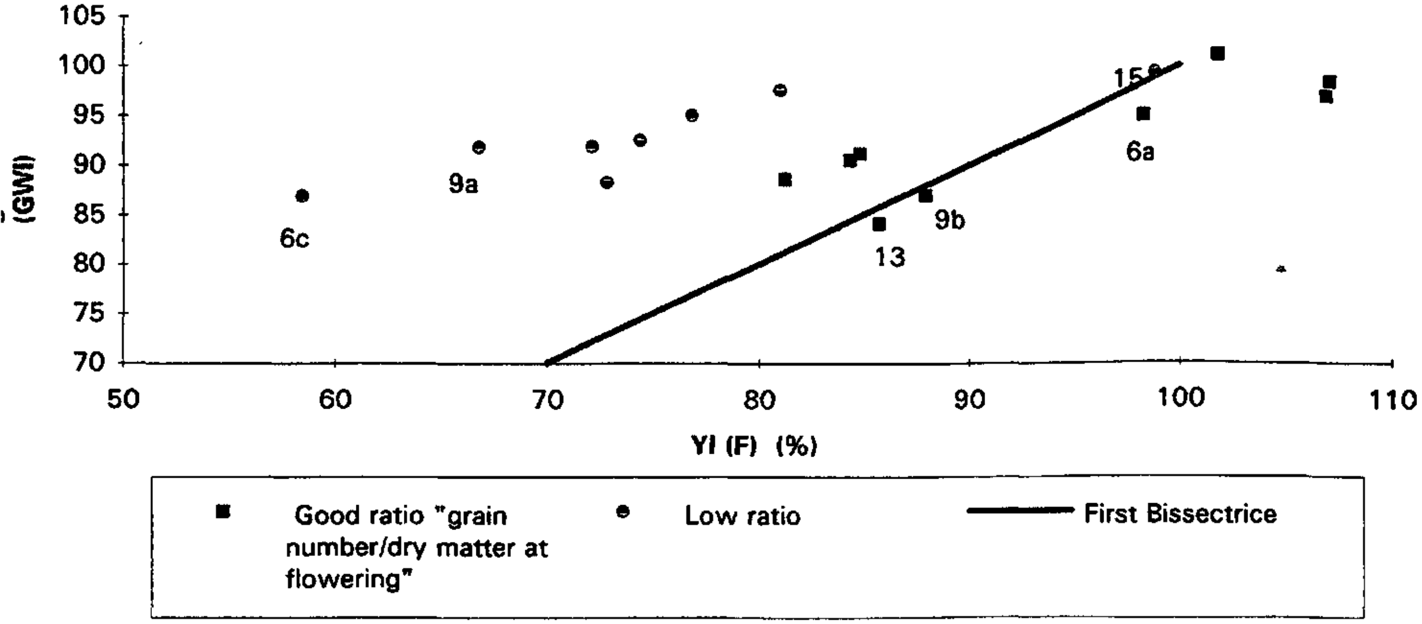


FIGURE 29 - GRAIN WEIGHT INDEX related to YIELD INDEX (at flowering) (r2 = 0.37)



production are possible with the same absorption of nitrogen (*Fig.27*). On the contrary, the actual LAI is dependant to the nitrogen absorption (*Fig.28*) level. The relation between LAI and dry matter production is linear correlated (r2=0.98) in our sample at tillering. Aase (1979) has shown that there is effectively a strong relation, but in early stage only. Therefore, it seems logical that the relation in our sample between LAI and dry matter at flowering is not good.

Van Keulen and al (1991) has also shown a complex relation between three variable at flowering: the LAI, the nitrogen uptake and the dry matter. There is thus an explanation to this variation of dry matter in relation with nitrogen nutrition: it is possible to produce a lot of dry matter with moderate quantity of nitrogen (case of fields 2a, 2b, 2c), in these cases there is more production of stems rather than leaves, and nitrogen content of leaves are lower, so the photosynthetical capacity is also lower. Therefore, dry matter is not well related to grain number and yield. These cases seem important among ecological fields. For illustration, GNI is more related to LAI at flowering (r2=0.41) than dry matter at flowering is with this value: r2=0.28.

Conclusion on use of DMI for diagnosis on wheat:

Dry matter variation is one of the yield component, not the principal for wheat in the sample; therefore DMI do not explain yield variation. It confirms that LAI at tillering, which explains dry matter at flowering, is not a yield limiting factor.

It also seems that the crop structure of ecological fields is different of integrated: more production of stems compared to the total produced dry matter. This can be due to different variety choice and to a lower nitrogen absorption.

The interest of SUCROS simulation of dry matter could be much higher for diagnosis on others crops like potato, sugar beet...and all crops with more or less completely harvested dry matter and especially if no yield component is available.

III.2.4/ Relations between YI (F) and others variable at harvesting

YI (F) is well correlated with yield: r2=0.67 and also with nitrogen status at flowering: r2=0.52, what is completely different of GWI (Grain Weight Index). Both variables are effectively very different (*Fig.29*): r2=0.37.

To explain so important differences, we have as hypothesis that YI(F) is sensitive to factors that GWI is not, what makes YI(F) more variable. We have supposed that fields with lower grain number for the same dry matter at flowering (covariable in *Fig.29*), what characterizes 7 of the 12 ecological fields of the survey, could have a much more lower value of YI(F) than GWI. This is confirmed in *Figure 29*. GWI takes only into account the existing grains at harvesting and is therefore less variable.

III.3/ EFFECTS OF ENVIRONMENTAL FACTORS

The major environmental factors, which could potentially limit yield (*observation 's protocol in annex 4*) have been observed. We can immediatly classify **water** availibility as a non limited factor, due to abundant rain, especially during the filling period. Weeds seem also not an effective problem; mechanical weeding is good controlled by ecological farmers. **Lodging** occurred only in two integrated fields (13 and 15), but was of minor importance in the area, and very late in ripening.

FIGURE 30 - % of COMPACTION in the arable layer

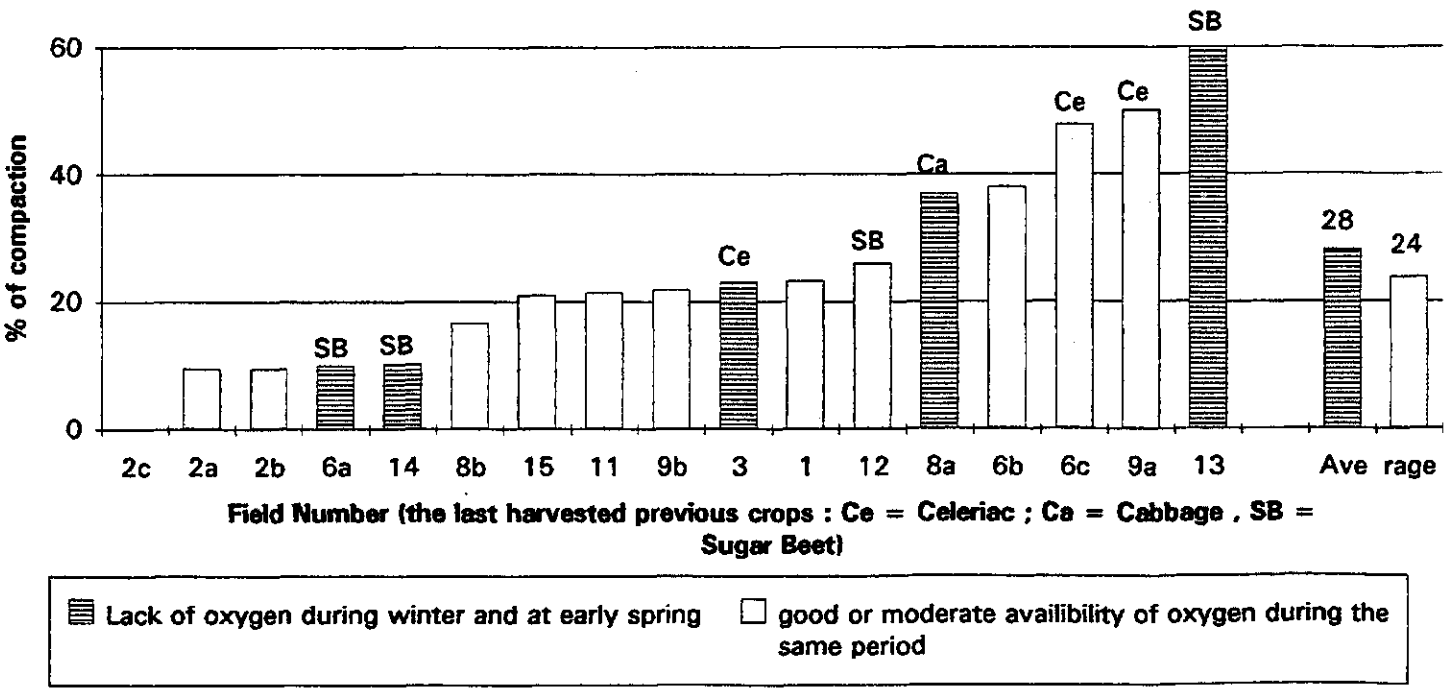
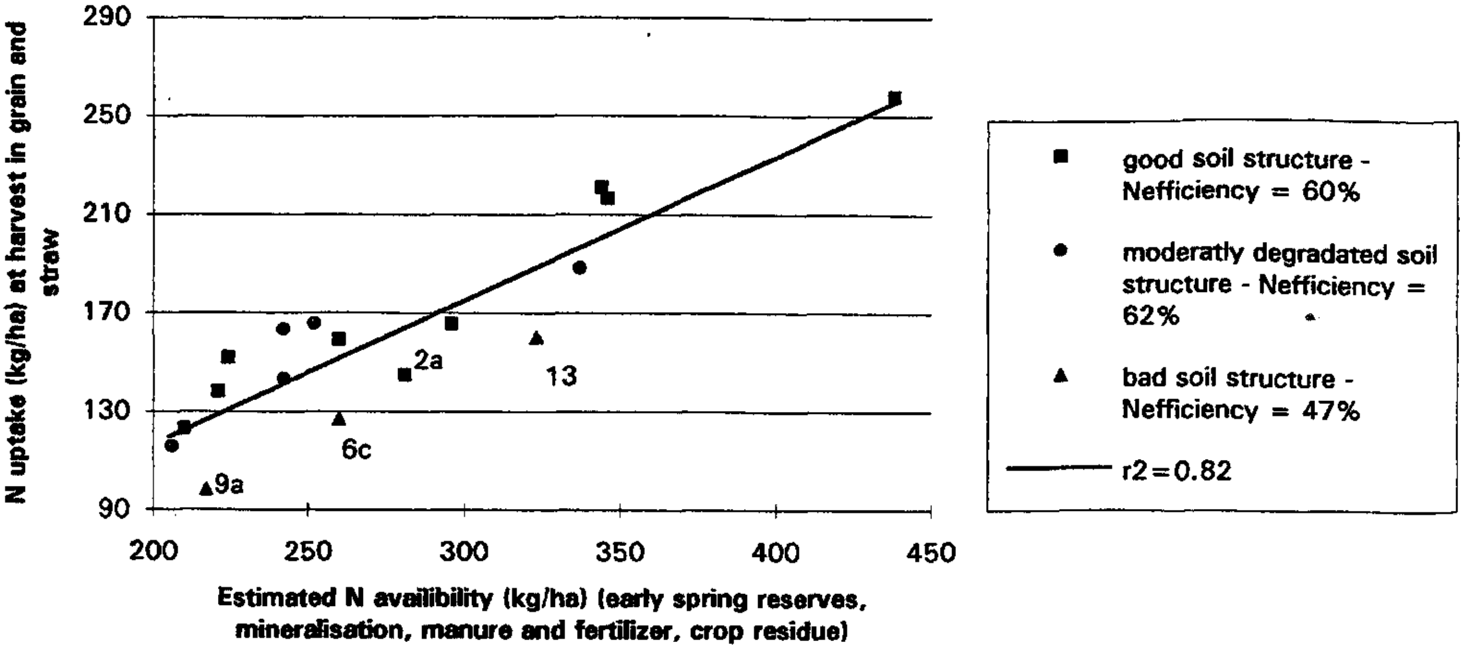


FIGURE 31 - N UPTAKE related to Estimated N AVAILIBILITY



III.3.1/ Effects of environmental factors during germination and early growth

As it has been said, the protocol has not been built to make observations in early stage, and especially during the period around sowing and winter. Therefore it is difficult to be confident in observations done at tillering concerning depth of sowing, lack of oxygen during winter, seed-bed preparation... These three characteristics have been analysed to explain low emergence or low crop growth during winter as well as mechanical weeding technics, soil structure observation, date of sowing, or even variety influence. None of these factors could help us to explain differences in emergence or growth.

III.3.2/ Effects of environmental factors on nitrogen supply

a/ *Soil structure characterization*

We have supposed that soil structure could be an important factor to understand nitrogen absorption variation (see *figure 2*, Meynard et al, 1981). We have also supposed that soil structure could be influenced by the type of previous crop. The *Figure 30* presents the observations on soil structure, with references to the late harvested previous crops, and also to observations on lack of oxygen during winter (importance of blue color in soil).

There is no significant difference in compaction between ecological and integrated systems; soils with high compaction are represented in both systems (6c, 9a in ecological and 13 in integrated), whereas a basis of organic agriculture should be a good soil structure, with a good level of microbiological activity! Except for field 12, late harvested previous crop have caused soil compaction and/or lack of oxygen, as expected. Lack of oxygen is not completely related to soil compaction.

In order to classify the different fields in relative homogeneinous group of soil structure, 3 groups have been formed:

- *first group* = "bad"soil structure = fields with more than 40% of compaction (field 13, 9a, 6c). This threshold has been choosen because it seems to be an important limit (Meynard, 1985)
- *second group* = moderate degradated soil structure = fields with relatively high compaction, between 25 and 40% (field 8a and 6c), or those with good soil structure but with lack of oxygen (field 3, 14, 6a)
- *third group* = "good" soil structure = all the others fields.

Relation between this typology and nitrogen absorption will be analysed in the next chapter.

b/ *Nitrogen availibility predicion - Effect of soil compaction on nitrogen absorption*

We have tried to predict, for ecological fields only, the nitrogen status at flowering by soil reserves at early spring measures, but this variable is not predictive enough. Therefore, we have built a model of nitrogen availibility estimation, taking into account soil reserves at early spring, organic matter mineralization, as well as manure, fertilizer and crop residues mineralization. J. Schröder provided us regional references, which is presented with the model in *annex 5*. The model's estimation of available nitrogen for wheat until maturity is well correlated to nitrogen absorption at harvest (*Fig.31*), in a linear relation. The **"N efficiency coefficient"** is calculated as a pourcentage of the estimated nitrogen available which has been absorpted.

Types of soil structure are represented as covariable. Fields with bad soil structure have a much more lower N efficiency than the two others groups: about 14% less. By extrapolation, we could suppose that 14% of the nitrogen availibility has been lost for these wheat crop, so about 31 kg/ha for field 9a, 37 kg for 6c, 46 kg for 13. With an other extrapolation, we could

TABLE 7 : SOIL NITROGEN CONTENT AT EARLY SPRING. HYPOTHESIS CONCERNING LOSSES BY DENITRIFICATION

Field number	6b	6c	8b	8a	9a	9b
Actual soil reserves at early spring (kg N/ha on 0-100 cm) (a)	140	129	140	122	87	120
Actual differences (b)		N(6c) = N(6b) - 11		N(8a) = N(8b) - 18	N(9a) = N(9b) - 33	
N crop residues (kg N/ha) (c)	0	25	35	25	15	0
Organic fertilisation (kg N/ha) (d)	12	16	6	15	0	0
Theoritical added N (kg N/ha) present in soil reserves at early spring (e=c+d)	12	41	41	40	15	0
Expected differences between the 2 neighboured fields		N(6c) = N(6b) + 29		N(8a) = N(8b) - 1	N(9a) = N(9b) + 15	
Quantity of N assumpted as "N losses" (e-b)		40 kg		17 kg	48 kg	
Note of Anoxie	1	2	0	3	1	0
% of compaction	35	46	17	36	47	21

TABLE 8 : Rust infestation during grain filling

Field number	% of leaves with rust at		Evolution (in %)	Final variable (c) c=(a+3*b)/4	Nitrogen content at flowering
	flowering (a)	milky stage (b)			
1	2	15	691	12	1.26
2a (Mix)	73	100	37	93	0.93
2b	81	100	23	95	0.97
2c (Mix)	86	100	16	97	1.13
3	1	1	48	1	1.02
6a	31	100	220	83	1.21
6b	75	100	33	94	1.09
6c	56	100	78	89	1.17
8a	1	7	624	6	1.3
8b	1	11	1020	8	1.6
9a (Mix)	24	96	297	78	1.13
9b (Mix)	43	97	126	84	1.38
11	30	12	-59	17	1.43
12	1	0	-100	0	1.73
13	21	97	364	78	1.37
14	6	0	-100	2	1.69
15	1	0	-100	0	1.8
MEAN					
Ecological	40	69	268	62	1.18
Integrated	12	22	1	19	1.6

say that each 10 kg/ha of nitrogen equals about 500 kg of wet grain (mean value of the sample in 1993).

On the contrary, soils with moderate soil structure have no reduced N efficiency. It seems that only high compacted soil have an important reducing of their nitrogen absorption. Three hypothesis are generally used to explain this fact:

- wheat root activity can be reduced because of a lack of oxygen
- wheat root development can also be reduced, especially in clods, so there is less or no absorption in these clods
- microbiological activity can be reduced in clods, so a reduction of all mineralization activity.

c/ Hypothesis concerning nitrogen losses by denitrification

If nitrogen absorption has been limited because of compaction and lack of oxygen, losses may have occured by denitrification during winter under the durable action of frost and water.

This hypothesis can be tested by the preceding predictive model of estimation of nitrogen availibility. This model allows simulation of the influence of crop residues or fertilization on the level of the nitrogen soil reserves at early spring. But it is not possible to compare different soils: their characteristics can induce important variation in soil reserves because of different nitrogen leaching during winter, which is related to soil texture and drainage.

As there are 3 couple of fields in the sample with different soil structure, we have only compare neighboured fields in the same farm (*Table 7*). It appears that each time, soil with relative compaction (9a, 8a) or lack of oxygen (8a, 6c) seems to have lost between 17 and 48 kg of nitrogen during winter compared with it neighboured field. Consequently, the hypothesis of losses by denitrification is confirmed.

As there is no protocol to test this hypothesis, we should remain careful with this result. Obviously, it could be interesting to examine this topic in the next years.

III.3.3/ Effects of environmental factors on grain filling

Only disease effect will be analysed; lodging, weeds and water stress have already been discussed.

a/ Diseases development

Foliair fungi were the principal problems. Aphids were limited and in equal quantity in all fields: a maximum of 20 to 30% of ears with aphids. Except field 1, stem base disease was also limited: 8 to 25% of infested stem.

In 1993, rust has been the most spread foliair fungus in the polder. Therefore, we have limited the analysis of disease influence to rust.

A strong rust infestation has been observed between flowering and milky stage (*Table 8*). For ecological field it seems logical, since no fungicides could be used.

On the contrary, rust pressure has reduced in the 4 integrated fields which have been sprayed (11, 12, 14, 15) against foliair fungi.

According to preceding remarks, we advice to be careful before comparing diseases measures between ecological and traited fields.

FIGURE 32 - GRAIN WEIGHT INDEX related to RUST

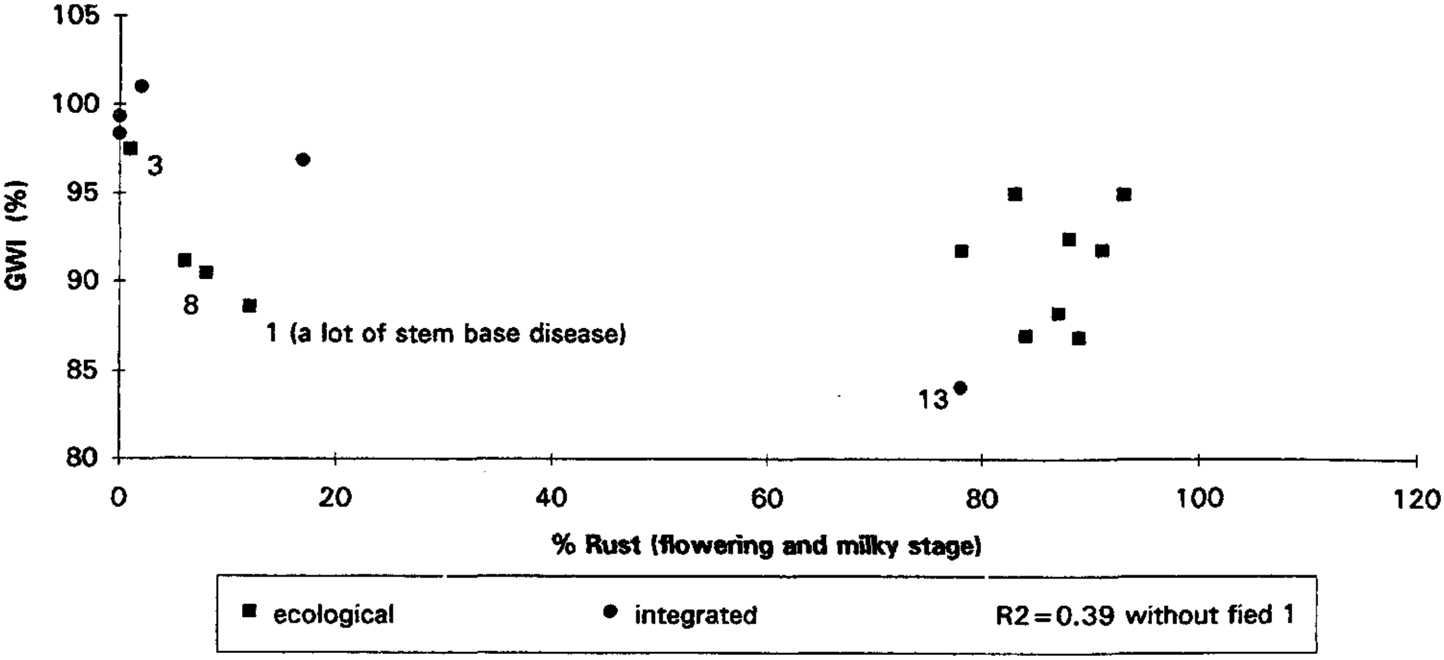
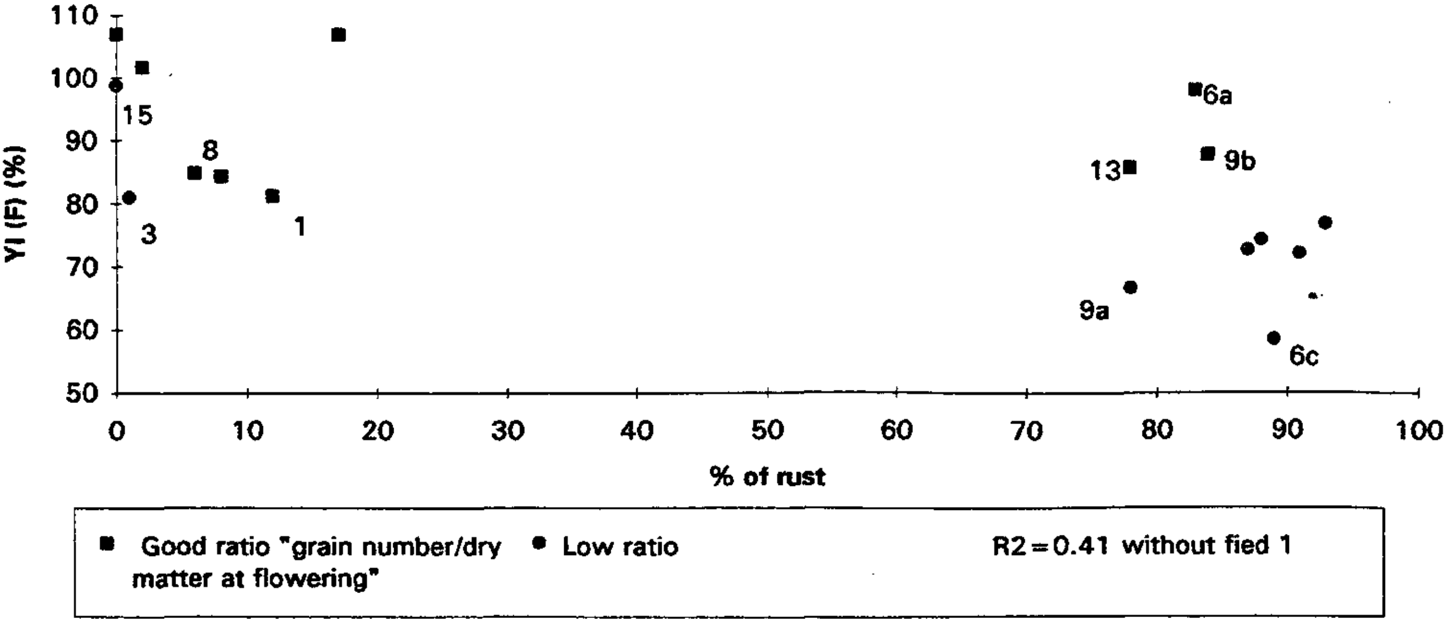


FIGURE 33 - Yield Index (at Flowering) related to RUST during flowering and milky ripe stage



b/ *Influence of rust on yield*

It is first necessary to choose between % of rust at flowering and milky stage which variable is more representative of the damage caused by rust to wheat. We have choosen to take a ponderated variable of the both, with more importance according to the last observation (*Table 8*).

GWI is very little correlated to rust (*Fig.32*), if we look at the r2 of this relation: 0.30. The r2 becomes better whithout field 1, which is the only one field with relatively high stem base disease: 0.39. Theorically, the relation should be better, since we are sure that water was not limiting, neither was lodging; so, how can we explain this low r2, even if a trend seems to exist ? First, a non-linear relation seems more adjusted to field's data.

Secondly, unprecision in estimating the variable GWI could induce uncertainty in the relation. Effectively, the two fields of farm 8 are the only one sowed with the variety "Hereward". It is perhaps not possible to be confident for all varieties in the estimation of the P1000GW: this estimation is dependant of the number and the valility of varieties trials where this variety is present. This is a limit to use GWI.

It can be concluded that the observed rust pressure did not strongly reduce grain filling.

YI and rust (*Fig.33*): r2=0.37 and 0.41 without field 1.
YI(F) has about the same correlation with rust as GWI, which is not satisfactory. But this can be understood because rust did not strongly reduce grain filling according to GWI values, and YI(F) seems to be sensitive to more factors than only diseases.

So it is impossible to assess if GWI or YI(F) is more sensitive or specific to disease: years or regions with more diseases pression are necessary for such conclusions.

III.3.4/ Conclusion on effects of environmental factors on yield

Firstly, the quantity of nitrogen available explains the nitrogen absorption. Apart from organic matter mineralization and winter drainage, this availibility depends on crop residues and fertilizer, of mineral or organic origin.

But compacted soil structure seems to induce important losses of nitrogen by denitrification in winter, and high reduction of nitrogen absorption. Of course, we have only roughly quantified theses losses, but these estimations call for further study: about 60 kg/ha more of nitrogen would have been absorpted (field 9a, 6c, 13) if there would have been a moderate compaction and no lack of oxygen. To have an idea, it would be necessary to add the quantity of 210 kg/ha of nitrogen in manure, or 130 kg/ha in mineral form, in these fields to obtain the same results as it would be with a good soil structure.

III.4/ FIELD MANAGEMENT AND ENVIRONMENTAL FACTORS

After identifying in which stage yield has been limited and which environmental factors has caused this reduction, the logic following question is to identify which farmer's practice is responsible of these limiting environmental conditions. In the preceding part, some answers have already been given.

TABLE 9 : CROP MANAGEMENT IN AUTUMN 1992
AND ITS RELATIONS WITH SOME ENVIRONMENTAL FACTORS

		TIMING OF THE PREVIOUS CROP HARVESTING			TIMING OF PLOUGHING					
Previous crop	**Field number**	*before rains*	*first rain period*	*second rain period*	*first rain period*	*second rain period*	*after the second rain period*	**% of EMERGENCE**	**SOIL STRUCTURE QUALITY**	**IN SOIL OXYGEN AVAILIBILITY**
Potato **Barley**	**1** **2b**	+ +			+	0		0 +	+ +	+ +
onion	**2a** **11** **15** **9b** **6b**	+ + + + +			+ + +	0	-	+ + + - -	+ + + 0 +	+ + + + +
Grass and legume	**2c** **8b**	+ +				0	-	0 -	+ +	+ +
Cabbage	**8a**		0				-	0	0	-
Sugar beet	**6a** **14** **12** **13**		0 0 0 0		+	0 0	-	- - 0 0	+ + 0 -	- - 0 -
Celeriac	**9a** **6c** **3**			- - -		0 0	-	- 0 0	- - +	0 - -

(Signification of + : field intervention in a favorable climatic period; favorable soil or crop characteristic

of 0 : field intervention in a less favorable climatic period; less favorable soil or crop characteristic

of - : field intervention in a bad climatic period; bad soil or crop characteristic)

III.4.1/ Practices influencing foliair fungi pressure

Sowing of **mixed varieties** did not allow a better resistance to rust development (*table 8*) in the sample. Apparently, rust as well as others foliair fungi were not correlated to **nitrogen** content at flowering. On the contrary, we observe little rust in field with good nitrogen nutrition (8a and 8b). In integrated field, chemical **treatments** could strongly reduce rust: only one integrated field (13) has not been treated and had an an increase of rust after flowering.

III.4.2/ Practices influencing or limiting soil compaction

We have assumpted that late harvest of preceding crops could lead to degradation of soil structure, in relation to bad climatic conditions (rains and cold). This seems to be confirmed (see *figure 30*). To have a better validation, it is interesting to analyse crop and soil management in autumn 1992, in correlation with the real raining periods (*annex 2* for climatic characterization). Four periods have been identified:

- before the 10 th of october; very favorable conditions, because of low rain
- from the 10 th of october to the 10 november (90 mm of rain); relatively bad conditions
- from the 10 th of november to the 10 th of december (114 mm of rain); very bad conditions: this wet period was succeeding to a another wet period, the soil was already saturated
- after the 10 th of december; rain has resided, but soils were saturated of water.

The main interventions in autumn are harvest of the preceding crop, and the ploughing. All this information is in *table 9*, in relation with wheat emergence, and soil structure.

A quite good correlation has been established between dates of harvesting and ploughing, and soil structure. All crops, harvested before rain period have good soil structure (except 6b, with a moderatly compacted soil structure), and no lack of oxygen. On the contrary, all crops, harvested in rain period, have lead to compacted soil structure and/or lack of oxygen.

Conditions of harvesting of the previous crop seem more important than plouhing: late ploughing associated with early harvesting for example (field 1, 9b, 6b, 8b) has lead to no (1, 9b, 8b) or moderate (6b) soil structure degradation.

III.4.3/ Practices influencing or limiting emergence

A good correlation appeared between date of ploughing and plant emergence. Early ploughing (5 cases) has always lead to good emergence. Ploughing in the second rain period (7 cases) has lead to bad (4 cases) and very bad emergence (3 cases). Late plouhing (5 cases) has lead to bad emergence in two cases, but especially to very bad emergence (3 cases). It seems so that the later the ploughing, the worse is emergence. It is probably due to quality of the seed-bed, but no precise observations can confirm this supposition.

III.4.4/ Conclusions on the effects of farmers practices on environmental factors

Some relations have been clairly identified, it concerns the effect of late harvesting and ploughing on soil structure quality and emergence. Farmers with late harvest of previous crop have not avoided in all cases soil structure degradation.

IV / DISCUSSION AND RECOMMENDATIONS

IV.1/ IMPROVEMENT OF WHEAT PRODUCTION IN THE EAFS PROTOTYPES

All the further conclusions and recommendations have only the value of a one year survey; it should be validated by one or two new year of survey.

IV.1.1/ How can we improve protein content?

This was not a major question in this study; and lack of variation in protein content in our sample make conclusions difficult. Only one field had a good N content for baking quality (farm 15). But this can be due to several factors like the choice of an appropriate variety (Renan), and a high nitrogen input including a late dressing around flowering.
We can only propose some ideas of experiments or trials to answer this question:

* first, the choice of variety. Renan, developed by INRA, seems very well adapted to organic agriculture conditions. It has a moderate yield potential, a very good baking quality, and a good diseases resistance.

* an increase of the nitrogen input, especially by a late dressing. It has been shown that a better repartitionning of the N input (in conventionnal agriculture with N mineral) increases the grain nitrogen content (Briffaut G., 1993). But the only way for ecological farms would be to bring slurry. Is it possible, until which date? Would the wheat be more sensitive to diseases with a late input of nitrogen ?

* it could be perhaps interesting in some cases to cultivate spring wheat.

These hypothesis should be studied and tested, if quality becomes more and more important, as it seems to be in 1993 (see QPI, Quality Production Index: Vereijken and Kloen, 1993). The same diagnosis can be done, in the next few years, focussing first on quality, and not on yield. But a relative variability of protein content in the sample should be present.

IV.1.2/ How can we improve the yield?

Some of the following recommendations are fairly sure, some others are more hypothesis that have to be tested in the next experimental years.

a/ *Increase of nitrogen availibility*

The major limiting factor for the EAFS is obviously the lack of nitrogen. The possibility to bring slurry in spring has been discussed above. The model used in this report to calculate nitrogen availibility seems accurate, it could perhaps be used as a predictive model. But organic fertilization is dosaged for overall the rotation. Therefore a predictive model can be a tool to optimize nitrogen input according to the yield response of the different crops of the rotation.

b/ *Strategy to control soil compaction before wheat sowing*

This seems very important, especially when the previous crop is harvested late and in wet conditions. I think not useful to increase nitrogen inputs if this problem of compacted structure is not solved before (see figure 2). Celeriac for example has been the last harvested, in the wettest conditions. Therefore, in the 3 fields with celeriac as a previous crop, we observed the worst soil structure, the lowest nitrogen absorption efficacy, and finally the worse yield of all the sample!

A first option to test would be to replace ploughing by deep non-inversion soil cultivation a few days before sowing, in order to simulate aerobic decomposition of crop residues whilst avoiding to make clods.

c/ Calling into question of farming system

A second option to solve the problem of compaction is to plough and let the winter frost restore soil structure. Then, it is possible to sow a spring wheat. Therefore we propose the following decision rule:

Concerning the first lifted group (late harvested crops, often in bad conditions: sugar beet, celeriac, cabbage...): "when harvesting of the previous crop occurs in bad conditions for soil structure, plough before winter and cultivate a spring cereal".

Concerning the second lifted group (early harvested, generally in good conditions: onion or potato in 1993): you can sow a winter cereal.

A third option is to change the previous crop, by adapting the crop rotation model. Cereals and mowing crops (luzerna...) are always grown in this model after lifted crops. Therefore, it would be interesting to evaluate another crop rotation model like:

first year : one crop of the first lifted group
second year: one crop of the second lifted group
third and fourth year: two mowed crops

This rotation could probably improve soil structure management, although such a choice may interfere with weed management.

d/ Variety choice

The baking quality of varieties is doubtful: apart from Renan, no differences appeared in protein content between baking wheat and feed wheat.

Foliair diseases are the second cause of yield reduction after nitrogen: 5 to 12 % reduction. Variety mixture does not seem to be a very successful strategy against foliair diseases.

Therefore, we propose to change these two strategies (table x). The baking quality should be improved by a better nitrogen availibility (points b/ and c/) and an improvement of soil structure. Control of foliair diseases should be based on the choice of highly resistant varieties, against rust and mildew especially. Of course, varieties which have both advantages would be the more interesting, even if they have a lower yield potential, like Renan.

IV.2/ RECOMMENDATIONS FOR AGRONOMICAL DIAGNOSIS IN A PILOT GROUP

IV.2.1/ The experimental lay-out

To make a real on-farm evaluation of the wheat production, it is necessary to carry out detailed analysis to test some hypothesis, which are difficult to answer only with field's observations, and essential to improve the cropping systems.

These experiments can be realised either in the experimental farm (like Nagele), or by the farmers themselves! In fact, a farmer can do in one part of his field a different practice: we create a couple of fields.

IV.2.2/ Evaluation of the innovative diagnosis tools

a/ *Diagnosis by yield components*

Diversity in sowed varieties in the field's sample is obviously a constraint. However, it is possible to analyse the main yield variation thanks to corrections with indexes. Make sow the same variety on all fields to be studied would facilitate the diagnosis. It does not mean that farmers in a Pilot Group should always sow the same variety for all crops each year, but only for a few fields per farm.

b/ *Diagnosis by yield simulation*

SUCROS is not precise enough, especially if used in only one period. But it is possible to simulate with some restrictions: only on short periods and adjusted by on-field measured LAI. But simulations before flowering was not very successful to analyse growth differences. Dry matter was not the main characteristic of the wheat population at flowering. As Van Keulen has showed (1993), LAI and nitrogen content are the two other very important crop indicators of wheat growth at flowering. Obviously, these two factors were more sensitive to differences in the studied cropping system.

On the other hand, simulation after flowering is more promising. It is well related to yield, it seems to give interesting information to what happened near flowering.

c/ *Perspectives of yield simulation for diagnosis*

It was not possible in our study to use Crop Simulation Model. Limitations in its use is the high demanded field work to obtain data (dry matter, LAI), and the lack of precision. More research is necessary in this specific topic. But some hope is provided by research on crop reflectance (Bouman and al, 1992, 1993). First it could enable more measures with more precision. Then, it can be sufficient to make LAI estimation and nitrogen content measure to make direct comparisons between fields.

d/ *Choice of observations*

Nitrogen measures seems essential. A model to evaluate or predict nitrogen availibility was very usefull and accurate, thanks to a lot of available references (annex 5) concerning the Netherlands conditions.

Precises observations of diseases have of course been strongly necesseary. Precise soil stucture observations was something new in the Pilot Group of P. Vereijken. This is a very interesting parameter, and we should encourage its use. But its use requires skill and experience.

CONCLUSION

The major goal of this study was reached: doing a diagnosis with two Farming Systems, on a Pilot Group with a wide range of varieties. The latter complication could be overcome because the potential 1000 grain weight of varieties were known and were little different. Data on nitrogen supply, soil structure and diseases were very useful to understand yield variation. The simulations with SUCROS has slightly improved the diagnosis; but it has brought a parameter which seems to be discriminant in Ecological cropping conditions: the LAI. This one-year study has brought some results and hypothesis : one or two new years would be necesseary to test these results in different climates.

According to the first results of the Pilot Group (1992, 1993), quality seems more important than yield. We think that "on-farm evaluation" focussing on quality is possible but requires also a good "on-field diagnosis". Of course, some change in the choice of observations, measures, experimental lay-out, or detail experiments is needed.

An interesting result of this study is the possibility to critisize farming systems and to propose improvement to the prototype, for example in the multifonctional crop rotation model, based on the diagnosis.

This study has also shown that tactical decisions (date of ploughing...) have about the same importance on technical results (yield or quality) than strategic decisions (rotation...). Or, the work done in a Pilot Group is mainly based on a strategic level. Shall we conclude that it is a strong shortcoming of Pilot Group research ? Or that technical results improvement should not be the major objective of a Pilot Group ? or finally that Pilot Group research should include a minimum work on the tactical level?

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ANNEXES

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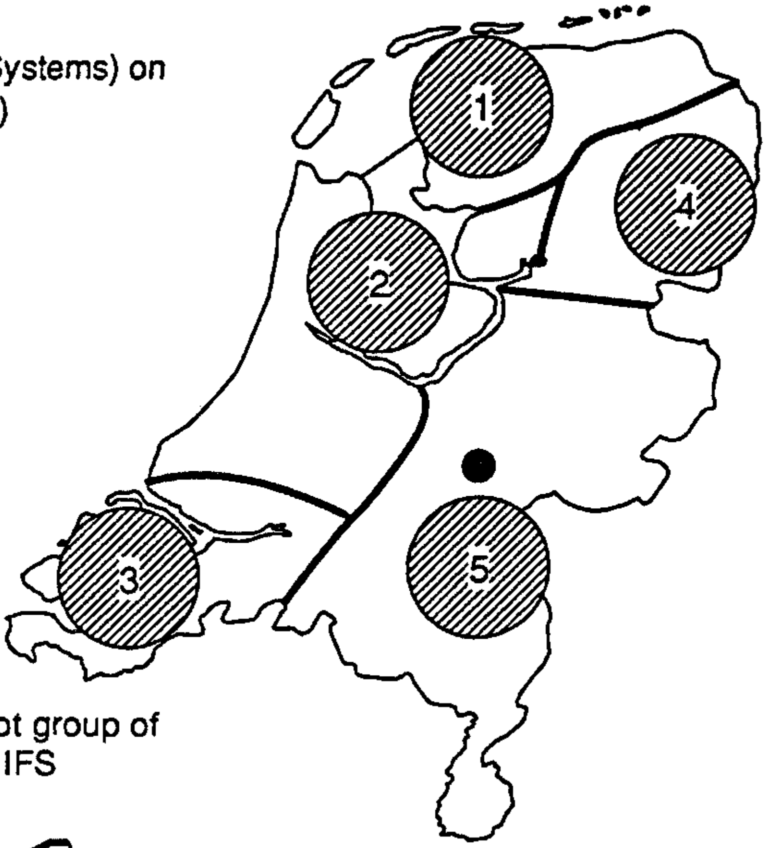
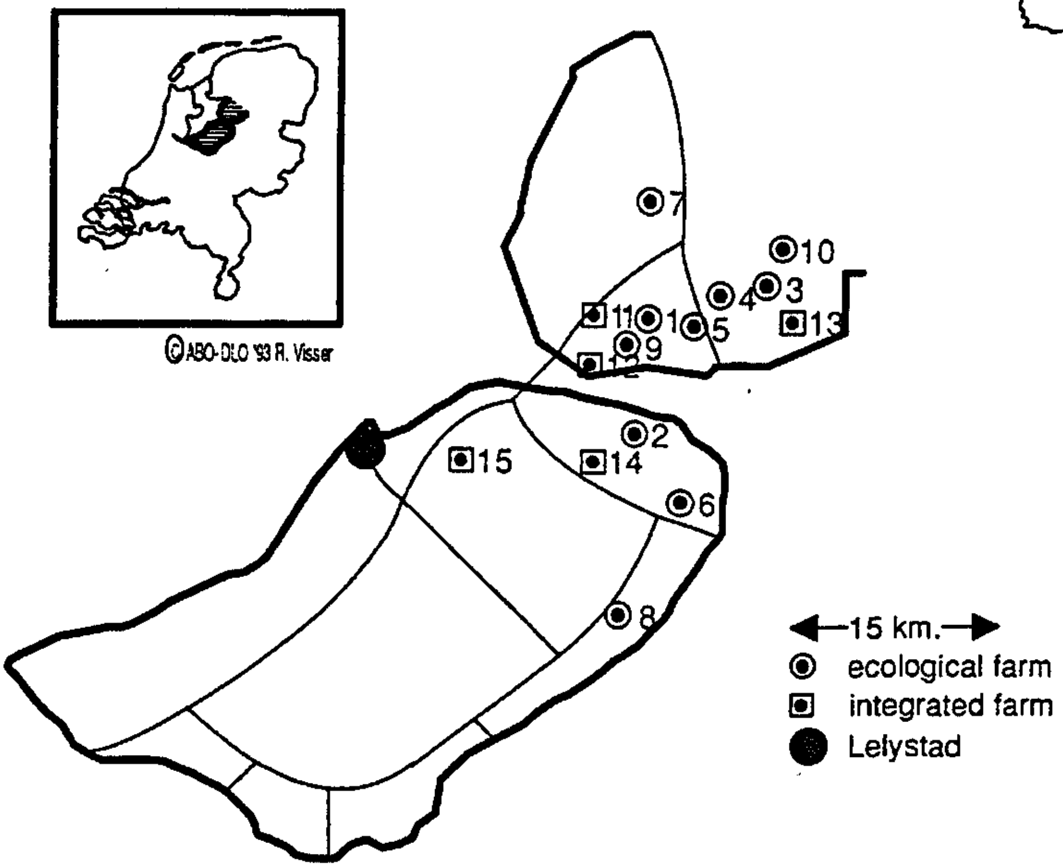
Research and introduction of Integrated and Ecological Agriculture in the Netherlan

Introduction of IFS (Integrated Farming Systems) on commercial farms (1990-1994)

▨	pilot farms + study groups
1	Northern Clay
2	Central Clay
3	Southwestern Clay
4	Northeastern Sand
5	Southeastern Sand
●	Wageningen
	Scale 1:1950000



Wheat crop diagnosis on a research pilot group of Ecological Farming Systems + 5 IFS



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ANNEXE 1: INTEGRATED AND ECOLOGICAL FARMING SYSTEM DEVELOPMENT IN THE NETHERLANDS: MAPS AND DESCRIPTION OF THE PROJECTS

On the Netherlands maps is represented the project of development of IFS in 1993. 5 agricultural regions representes the 5 natural regions of the Netherlands. Each region is characterized by a type of soil and a special farming system. The easten sandy regions have intensive cattle farming with almost a monoculture of maize.
The success of the IFS introduction on a large scale will thus be evaluated in fonction of each regions specificities (Wijnands et Vereijken, 1992).

Design, development and evaluation of advanced ecological FS, led by P. Vereijken, is done in the fertile polders region (zone 2 of the preceding project), the central clay region. The map below represents the geographic situation of the 9 Pilot Group farms (with a cercle) in the polder area.
We have also decided to add in the present study 5 fields belonging to 5 Integrated farms in zone 2 of the preceding project (see above): they are also represented in the map below.

Climatic data, spring / summer 1993, used for SUCROS simulations

t= minimal temperatures (degree celcius) ; T = maximal temperatures (degree celcius) ; R = irradiation (kTm-2d-1) ; P = precipitation (mm d-1)

	AVRIL				MAI				JUIN				JUILLET				AOUT			
Jour	t	T	R	P	t	T	R	P	t	T	R	P	t	T	R	P	t	T	R	P
1	0	15.4	582	0	12.7	24.8	1834	0	9.6	18.9	1756	0	10.5	23.9	2496		12.3	19.8	1544	
2	0.2	8.6	507	0	9.9	14.1	263	0	13.6	23	1373	0	10.9	20.5	2689		13.7	23.7	1808	
3	-0.4	10.4	1262	0.1	6.4	12.6	1613	0	10.9	15.2	783	6.3	9.8	23.1	2287		11.7	20.8	1574	
4	2.5	9.9	654	0	1.6	14.9	2444	0	9.3	20.2	2560	0	14.2	25.2	2748		12.4	20.2	1449	
5	1	10.8	7002	0	3	13.8	1921	0	12.3	22.4	1927	0	12.5	17.6	789		14.1	20.9	1170	
6	6.1	10.2	618	0	2.8	15.6	2157	0	10.8	21.2	2533	0	11.8	18.1	1572					
7	2.9	8.3	551	0	7.4	15.3	800	0	9.1	23.6	2404	0	12.2	17.3	1608					
8	3.3	9.5	1091	0	9.5	18.2	2072	0	9.2	24.2	2604	0	8.6	21.9	1815					
9	2.4	12.9	1460	0	9.9	25.3	2202	0	12.4	27.7	2734	0	12.4	21.3	1210					
10	5.4	14.3	1439	12.9	12.7	25.2	2018	0	16.5	29.6	2001	0.4	8.8	17.7	2414					
11	2.4	11.9	846	10.1	12.9	-99	2366	0	14.6	22.9	1942	0	8.4	17.2	1591					
12	3.9	9.4	894	0	12.7	25.2	2377	0	12.3	16.5	886	0	6.1	17.6	1758					
13	0.2	12.4	653	0	9.9	15.7	504	0.1	9.1	18.4	1217	0.2	8.2	18.8	2215					
14	2.7	13.7	1598	0	9.6	13.8	778	0	10.8	13.7	648	1.9	12.1	18.3	575					
15	3.8	13.7	4724	0	5.9	15	1435	0.1	8.7	16	2595	0.3	13.9	18.2	1002					
16	0.3	15.9	3048	0	5.1	18.3	2150	0	8.9	15.4	340	17.9	15.3	21.8	1372					
17	9.4	12.5		0	7.6	23.9	2476	0	12.5	18.7	2594	3.9	14.5	20.5	1621					
18	5.2	12.1		0	13.7	21.6	1317	12.5	13.2	17.7	785	0.7	10.9	19.9	2289					
19	7	10.2		0	12.9	21.4	1497	2.5	11.3	17.5	1259	0	13.6	18.6	844					
20	7.1	11.5		1.4	11.6	23.1	1465	0.1	10.6	18.7	2665	0	13.2	19.2	1391					
21				0	10.3	15.6	995	4.6	9.1	17.7	1717	0	12.6	18.8	1775					
22				0	7.9	18	2651	0	8.4	18.4	2394	0	11.6	19.4	1806					
23	6.8			3.6	9.2	20.4	2601	0	9.2	16.7	1153	0.8	11.9	20.4	1168					
24	14.5	22.3	725	0	10.5	22.9	2374	0	10.9	16.9	2192	0.1	16	22.1	1458					
25	10	21.1	1836	0	11.4	22.9	1798	0	10.6	15.1	1283	0	12.4	19.1	2089					
26	9.7	21.6	1849	0	11.8	21.6	2001	1.9	9.3	17.3	1030	0	11.7	18.3	2086					
27	9.8	23.3	2279	0	12.6	15.5	219	8.3	13	18.5	1978	0	11.4	17.7	445					
28	9.5	25.2	916	0	10.3	14.7	873	2.9	11.4	18.6	2332	0	12.6	20.9	1422					
29	16.9	27	1360	0	10.3	18.8	2709	1.4	9.4	23.5	2821	0	12.6	21.4	706					
30	13.3	27.2	2081	0	12.4	20.5	2182	0	11.2	25.1	2834	0	16.2	18.6	364					
31					11.8	17.3	1931	1.7					12.1	19.3	1694					

Source : station meteorologique de Lelystad (Longitude: 5 27 E ; Latitude: 52 31 N ; Altitude: -4 m)

ANNEXE 2: CLIMATIC DATA OF AUTUMN 1992 AND SPRING/SUMMER 1993

(All the data between the first of April and the 5 of August are the climatic inputs of the CSM SUCROS)

The above table gives very important indications concerning the field work conditions at autumn 1992: previous crop harvest, soil preparation and ploughing, seed-bed preparation and wheat sowing. Rainfalls and cumulative rainfall in a period are the principles factors.
The other table gives the climatic data from April to August 1993. Temperatures and global radiations are indispensables data to simulate the potentiel yield with SUCROS.

Climatic data autumn 1992		**Minimal temperature** (degre celsius) Mean of the decade	**Maximal temperature** (degre celcius) Mean of the decade	**Rain** (mm j-1) Sum of the decade
AUGUST	decade 1	14.16	23.65	36.30
	decade 2	13.04	19.28	36.90
	decade 3	13.02	19.62	36.80
SEPTEMBER	decade 1	9.63	16.05	53.90
	decade 2	9.80	17.96	19.30
	decade 3	11.69	20.14	0.20
OCTOBER	decade 1	6.50	13.79	11.10
	decade 2	1.10	11.11	29.70
	decade 3	3.63	9.40	49.70
NOVEMBER	decade 1	5.36	11.40	10.30
	decade 2	3.76	8.68	48.80
	decade 3	6.01	11.47	42.90
DECEMBER	decade 1	3.27	7.30	22.10
	decade 2	3.90	8.68	29.50
	decade 3	-2.35	3.13	0.90

SOME DATA CONCERNING THE CROP MANAGEMENT IN THE FOLLOWED WHEAT FIELDS

Field	Field Number in the report	Farm	SOIL % Organic Matter (OM)	% clay	For- previous crop 1991	Previous crop 1992	Date of harvest of the previous crop	Manuring date	qty t/ha
1	1	1			spring wheat	potato	Jul-92	17/12/92	12.6
2	2a	2	3.8	29	oats	onion	11/9/92	16/9/92	35
3	2b	2	3.8	29	oats	spring barley	17/7/92	Nov-92	12
4	2c	2	3.8	29	luzerne	luzerne	Sep-92	Jan-93	0
5	3	3	2.3	17	oats	celeriac	24/11/92	Jan-93	0
6	6a	6	4.4	25	potato	sugar beet	end Oct -92	Nov-92	15
7	6b	6	4.4	25	ray-grass/ klover	onion	13/9/92	Sep-92	15
8	6c	6	3.7	23	ray-grass/ klover	celeriac	Nov-92	dec 92	15
9	8a	8	3	25	potato	white cabbage	Oct-92	15/12/92	15
10	8b	8	3	25	potato	ray-grass/ klover	Oct-92	15/12/92	8
11	9a	9	2.7	21	ray-grass/ klover	celeriac	Nov-92	Jan-93	0
12	9b	9	2.5	21	winter wheat	onion	12/9/92	Jan-93	0
13	11	11	2.3	21		onion	end Sep-92		
14	12	12	2	17		sugar beet	Oct-92		
15	13	13	3.2	31		sugar beet	Oct-92		
16	14	14	3.2	27		sugar beet	Oct-92		
17	15	15	4.1	27		sugar beet	end Sep-92		

Field Number in the report	Mineral fertilization *first input* date	qty (t/ha)	*second input* date	qty (t/ha)	*third input* date	qty (t/ha)	Green manure cultivation	Date of ploughing	Date of sowing	Sowed variety	Sowing density g/m2
1								18/12/92	18/12/92	Hereward	409
2a							moutard (4 t/ha)	9/11/92	10/11/92	Re/He/Bu/Ri	389
2b							vescia (4 t/ha)	10/11/92	10/11/92	Rektor	386
2c								30/11/92	30/11/92	Re/He/Bu/Ri	432
3								3/12/92	3/12/92	Promessa	306
6a								24/11/92	24/11/92	Rektor	463
6b								2/12/92	2/12/92	Bu	443
6c								2/12/92	2/12/92	Bu	443
8a								21/12/92	21/12/92	Here	356
8b								21/12/92	21/12/92	Here	356
9a								29/12/92	29/12/92	Rek/Bu/Ur	515
9b								5/12/92	17/12/92	Here/Rit	444
11	15/3/93	81	28/4/93	54	26/5/93	40		29/10/92	30/10/92	Ritmo	388
12	15/3/93	81	6/5/93	60				Oct-92	15/12/92	Vivant	337
13	12/3/93	92	6/5/93	27				15/1/93	18/1/92	Ritmo	374
14	15/3/93	76	5/4/93	30	2/5/93	30		15/11/92	25/11/92	Vivant	320
15	11/3/93	65	4/5/93	60	5/6/93	65		30/10/92	1/11/92	Renan	268

ANNEXE 3: INDICATIONS ON FARMING SYSTEM IN THE PILOT GROUP, AND WHEAT MANAGEMENT IN 1992/1993 IN THE STUDIED SAMPLE

It is possible with these tables to make correspondances between the used farm code in the report and some precisions about these farms or their wheat management.

SOME INFORMATIONS ABOUT THE ECOLOGICAL FARMING SYSTEM

Farm	ha	Number of fields	ha / field	Breeding	% of cereals *(% of winter wheat)*
1	23.7	6	3.9	no	44 (10)
2	43.3	6	7.2	yes	21 (15)
3	45.3	6	7.6	no	34 (6)
6	35.5	6	5.9	yes	32 (24)
8	37.5	6	6.3	yes	25 (16)
9	21.2	6	3.5	no	31 (31)

Farm	SOIL			
	% of OM mean	% OM Var. Coef.	% clay mean	% clay Var. Coef.
1	1.3	0.42	5.3	0.96
2	4.2	0.17	24.7	0.19
3	2.2	0.03	16	0.08
6	3.4	0.17	22	0.16
8	3.1	0.06	30.8	0.10
9	2.6	0.10	21.3	0

(OM = Organic Matter)

ANNEXE 4: THE PROTOCOL OF MEASURES AND OBSERVATIONS

(established according to Meynard, 1985).

I/ Yield components

We have sampled at maturity on each surveyed fields 12 plots of 4 rows on 50 cm (so 0.25 to 0.33 cm2). No plot has been sampled on rows following tractors traks at sowing. A precise grain threshing has permitted to get the all grains, even those with fusariose At stage "ear 1 cm", plant density was estimated on 12 plots.

II/ Dry matter at stage "ear 1 cm" and at flowering

Dry matter (DM) at the end of winter is strongly dependent on the stem size, noticed L. To compare dry matter of differents plants populations, it is necessary to measure them at the same developping stage.
Or, the relation between DM and L is precisely adjusted by: DM = a L , when L is between 8 and 18 mm. When L is 10 mm, development stage is called "ear 1 cm", and its dry matter is noticed DM(1).
If we notice "DM(L)", the dry matter of the plant the day it has been harvested:

$$DM(1) = 10\ DM(L)/L \qquad L \text{ in mm}$$

All the data concerning dry matter at stage "ear 1 cm" (DM (1)), have been calculated by sampling 6 plots per field (measure of the DM), and measuring L on 25 plants per field. Leaf area index (LAI) was measured on this sample. At flowering, 6 plots per field have also been sampled to measure dry matter and LAI.

III/ Soil observations

Soil structure is estimated through the observations of clods in a trench of 3 meters width and 35 cm depth, according to the methodology of Gautronneau and Manichon, 1987.
On each field, 2 observations have been done, one in april, and one in july. In the first observation, an estimation of the lack of oxygen during winter has been done: blue color of clods was the indicator of this lack of oxygen. According to the pourcentage of such blue clods, 4 classes have been created, from 0 (no sign of anoxie) to 3 (most of the clods are blue).

IV/ Weeds

Stage ear 1 cm: on 6 plots has been counted the number of weeds.
Flowering and maturity: weed's dry matter sampling on 6 plots at flowering and 12 at maturity. When this DM seems important, it has been decided to measure their N content (except for legume weeds) to estimate the N lost quantity for the wheat.

V/ Diseases

Observations have been realised in 4 periods:

- "early shooting"; from 24 to 25 April
- half shooting; from 22 to 24 May
- flowering; from 10 to 12 june
- milky stage; from 13 to 14 july

The all observations have been realised with Lambert Bastian, a phytopathologist, who realizes a pluri-annual wheat epidemiologic survey for the all Netherlands.

Beginning of the shooting period. With a sample of 25 plants, we observed the 2 mains stems of each plant (so 50 shoots). Counting leaf after leaf of the foliair diseases (mildew, rusts, septoriose), of the total leaves number, and for each shoots, the stem base diseases (eye spot, rhizoctonia, fusariose).

Are considered as green leaves all leaves with at least the half of the surface which is green. After flowering, it is not possible to distinguish if "necroses" are due to senescence or diseases.

Half shooting and flowering. 50 stems are sampled on the field diagonale. The same observations on stems and leaves are done, plus the counting of the "ravageurs" (aphids and lealminer).

Milky stage. The same observations are done, plus ear diseases observations: ear with "fusariose", number of aphids per ear, presence of white ear.

ANNEXE 5: USED REFERENCES FOR THE MODEL OF NITROGEN AVAILIBILITY FOR WHEAT

(references according to J.Schröder and the dutch bibliographic data)

The general model is written:

A = M + RP + F + RS

A = soil mineral nitrogen available for wheat for the all croppping period
M = mineralisation of the soil organic matter
RP = available nitrogen from the previous crop residues
F = available nitrogen from organic manuring or mineral fertilization
RS = nitrogen soil reserves (0,100 cm) at early spring

A part of the nitrogen of the previous crop residues or of fertilization is already present in soil reserves at early spring. Therefore it should not be counted twice. Nitrogen leaching is taken into account in this model by the N soil reserves at early spring measure.

Soil organic matter mineralisation

According to J. Schröder, it is relatively constant for soil with 2 to 4 % of organic matter content. The amount of mineralised nitrogen is estimated at 0.75 kg/ha/day, thus during 120 days (15 march / 15 june), so about 90 kg.

Mineralisation of nitrogen from the previous crop, after the early spring measure.

100% of the nitrogen from the previous crop is quickly mineralised for onion, cereals or potato; half of this quantity is leached in normal year, the other half is contained in the soil reserves at early spring. For green manure or a previous crop rich in nitrogen (sugar beet, celeriac, cabbage..), 66% is mineralized during winter, 20 % will be mineralized during the wheat growing period, and the last 13% will join the soil organic matter. The used values are in the table C.

Nitrogen availability from organic fertilization

In the total amount of nitrogen contained in an organic fertilization, 3 "compartiment" are to be considered:
Nm = mineral part
Ne = organic part, which will be mineralized within 12 months
Nr = organic part which is said "resistant"

Nm + Ne + Nr = 100 % of the nitrogen contained in the manure
Cattle manure: Nm=20, Ne=40, Nr=40.
Cattle slurry: Nm=50, Ne=25, Nr=25.
The part "Nr" is not available because it will join the soil organic matter.

Qn is the total amount of nitrogen brought by the manure. The model to calcul the quantity of nitrogen mineralized after the N soil reserves mesure (Navail.) is:

Navail. = [Nm/100 * Qn * (1-losses by volatilization) * (coefficient of date of application)] + [Ne/100 * Qn * ((coefficient of date of application)]

For application before the end of winter, the coefficient of date of application is 0 for Nm (all the nitrogen is present in early spring soil reserves) and is variable for Ne according to the month of application of the manure:

jully: 0.13 august: 0.23 sept: 0.29 oct: 0.35 nov: 0.39 dec: 0.42 jan: 0.44 feb: 0.48.

Losses by volatilization, which only concerns the mineral part, is calculated for late application and is dependant of the time of incorporation.

We have consider that 100% of the nitrogen brought at spring in a mineral fertization (IAFS) is available.

PREVIOUS CROP	NITROGEN AMOUNT IN RESIDUE (kg/ha)	NITROGEN QUANTITY OF THE RESIDUE (kg/ha or in % of the residue) WHICH			
		IS PRESENT IN SOIL RESERVES AT EARLY SPRING	HAS BEEN LEACHED DURING THE WINTER	WILL BE MINERALISED AFTER EARLY SPRING (kg/ha)	WILL BE AVAILIABLE THE YEAR AFTER
Sugar beet	120	40 kg/ha	40 kg/ha	25	
Celeriac	75	25 kg/ha	25 kg/ha	15	
cabbage	115	37 kg/ha	37 kg/ha	25	
Cereals (staw removed)		50%	50%	0	
onion		50%	60%	0	
Potato		50%	50%	0	
Cereals straw	40 kg immobilized	6 kg/ha	5	30	
Grass-clover (1 year)				50 to 75	25
Grass-clover (2 year)				100 to 150	50
Grass-clover (3 year)				100 to 225	75
Luzerna (1 year)				65 to 75	25
Luzerna (2 years)				65 to 75	55
Yellow mustard (4 % N)	80	26	26	17	
Vescia (3% N)	60	20	20	10	