Chapter 32

Development of high-input systems of cereal production in Europe

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Introduction

The recent history of cereal crops in Western Europe is associated with the names of several researchers who, on the basis of increased knowledge of the soil/climate medium and a greater understanding of plant physiology, have proposed new techniques in crop production, thus opening the way for rapid intensification which, from 1950 to 1980, have resulted in a doubling of yields.

Coic (1960) presented the results of an experiment on nitrogen fertilization of cereals, especially on the role of nitrogen on plant growth and development, grain yield and quality. He indicated also his reasoning behind the 'splitting' of nitrogen fertilizer during the course of the growing season. He proposed, for example:

(a) No nitrogen top dressing before the end of winter in winter cereals;
(b) Essential top dressings to be given to wheat during the course of tillering (first application) and, especially, at stem extension (second application);
(c) In certain conditions, the advantage of a late supply of nitrogen i.e. up to the end of flowering, by application of a complementary dose of nitrogen fertilizer at ear emergence.

In 1967, Laloux proposed a method of crop management carried out in the edaphic, climatic and agricultural conditions of the Belgian loam region. This method is characterized, essentially, by the desire to avoid, in so far as it is possible, excessive vegetation density in cereal crops. These low densities reduce the risks of lodging and the development of disease epidemics, thus allowing the formation of relatively low ear numbers, all individually with high productive capacity (high fertility, high grain weight). To achieve these objectives the following rules were recommended:

(a) Sowing densities which will give rise to about 200 plants per m^2 at the beginning of tillering; this applies to crops sown at a normal date i.e. end of October to beginning of November;
(b) Supplying nitrogen fertilizer according to a scheme similar to that given by Coic (1960), i.e. using moderate doses up to the end of tillering, increasing the nitrogen application at stem extension (leaf sheath erect stage), extending nitrogen nutrition until the end of vegetation by means of a moderate

application around the 'flag leaf stage' with the intention of complementing nitrogen supplies from the soil, as a result of mineralization.

The method presented rigorous guidelines (precise objectives for plant and ear densities, precision as regards the doses of nitrogen and the stages of application) and, at the same time, a flexibility in relation to the definition of the quantity of nitrogen for different soil humus contents, previous cropping and autumn/winter climatic conditions, which demand different annual adaptations. In addition to these husbandry practices, new techniques (growth regulators, early and efficient weed control, fungicide protection, new varieties, etc.) have also been incorporated.

This method has been successful in Belgium and neighbouring regions, not only because of its capacity to constantly achieve high yields but also because its founders have ensured widespread acquaintance of farmers with the method by means of conferences, debates, literature and in following through its application with the farmers themselves. However, outside Belgium the method has sometimes been associated with certain problems, mainly due to the unsuitability of certain aspects of the method to local conditions of soil, climate and agricultural practices (varieties, crop sequences, etc.). This has been the case with low seed densities, the usefulness of the late application of nitrogen, the advantage of growth regulators and the nature of the plant protection regimes.

Since its initiation in about 1974, interest in the method has led official research organizations, as well as private companies, to propose numerous methods or systems in many western European countries. The word 'method' encompasses several other meanings in this context:

(a) Some involve a 'complete method' covering the whole crop period from sowing to harvest, i.e. a collection of directives concerning sowing, nitrogen fertilizer, weed control, fungicide protection and other techniques which will be useful eventually (Laloux method, Schleswig-Holstein method, low-input and high-input methods of ADAS, Heyland system in Bonn region, and so on).
(b) Others involve a 'limited method' dealing mainly with the determination of the quantity of nitrogen fertilizer (N-min method, ITCF method of balances recently included in a general method of multiple choices, known as '5 rendez-vous de blé').

However, the two systems which are followed most enthusiastically and which have aroused the greatest controversy are the Laloux and the Schleswig-Holstein systems and these are briefly described.

The 'Laloux System' – a semi-intensive system

Precise and complete references to this system can be found in French language publications (Laloux, 1967; Laloux, Falisse and Poelaert, 1975; Laloux *et al.*, 1980; 1982). There are also several resumés of the method in the English language (Laloux, Falisse and Poelaert, 1980). The method is briefly described as follows for winter wheat:

Type of rotations

Rotation may be varied, but very rarely is there a repetition of the same cereal (two or more successive wheats, or barleys); winter cereals are generally grown. The more frequent rotation is sugar beet (yielding 50–70 t ha^{-1} of roots with a 16% sugar content), winter wheat and six-row winter barley.

Sowing dates

The sowing of winter wheat is, on average, relatively late, due to the presence in the rotation of sugar beet which is harvested from October to December. The drilling period extends, thus, from 15 October to 15 January and sometimes up to the end of February.

Sowing densities

The seed rate is low compared with other systems, ranging from 225 grains m^{-2} for end of October sowings to 375 grains m^{-2} for December or later sowings. Generally it will be adapted to obtain populations of about 200 plants m^{-2} at the end of winter.

Ear densities

The amount generally achieved is between 400 and 550 ears m^{-2}, prior to harvest.

Nitrogen fertilizer

The total nitrogen quantity must be adapted to:

(a) The climatic conditions of the year, which influence mineralization and leaching;
(b) The amount of nitrogen produced by mineralization, depending on the humus content of the soils;
(c) The amount of fertilizer remaining in the soil from the previous crop; and
(d) The type of previous crop.

On average, the total nitrogen fertilizer dose is 140 kg ha^{-1} for 'normal' climatic conditions in a situation where the preceding crop was sugar beet with tops removed from the field, grown on an acid soil, with a low humus content (2%). The 'splitting' is normally programmed in three applications: at full tillering stage (growth stage 3–4), possibly mid-March, 30 kg N ha^{-1}; at leaf sheath erect stage (growth stage 5), possibly mid-April, 80 kg N ha^{-1}; at the flag leaf stage (growth stage 8), 30 kg N ha^{-1}.

Growth regulators

At the beginning of stem extension (growth stage 5) on a growing crop a rate of 1–1.5 ℓ ha^{-1} of CCC (at 46% a.i.) is applied.

Weed control

This is carried out as early as possible, in particular by pre-emergence treatment or by treatment at the beginning of spring.

Crop protection

Generally, a single broad-spectrum treatment is carried out around earing (growth stage 10.4) in order to give protection against all the diseases of the upper vegetative layers. The more damaging diseases in the climatic conditions of the region include mildew, rusts, *Septoria* and *Fusaria* of the leaves and ears. The treatment is carried out with the aid of a mixture of active ingredients at relatively low doses, e.g. 150 g ha^{-1} benomyl plus 3 kg sulphur plus 2 kg maneb or 125 g ha^{-1} triadimefon plus 1.25 kg captafol. In some particular cases only a control of lower stem diseases (eyespot) is achieved by an application of MBC at stem elongation. If there is an early attack of yellow rust or mildew an early treatment is given at the second node/flag leaf stage. If conditions are very favourable to the development of late diseases a second application (in addition to that at ear emergence) is carried out. Insect control is never automatic and is limited to the control of aphids, if present above a defined damaging threshold.

The 'Schleswig-Holstein System' – a very intensive system

This system is very intensive in the sense that it recommends the use of all the means of production at a very high level (high inputs) and ensures, in the specific region, very high yields (high outputs). A number of publications exist on the subject, e.g. Effland (1981).

Type of rotations

Generally, oilseed rape, winter wheat, winter barley (six-row) but also sugar beet, winter wheat, winter barley.

Sowing dates

On average very early, after oilseed rape; sometimes after winter oats, from 20 September to 10 October; after sugar beet, sown until mid-November.

Sowing densities

190–230 and up to 280 kg ha^{-1} or 400–550 grains m^{-2}, according to the date of sowing.

Row spacing

The row spacing is as narrow as possible, 11–14 cm.

Plant densities

At the end of winter, 400–500 plants m^{-2} are obtained, and up to 550 for late sowings.

Ear densities

At least 550–600 ears m^{-2} are achieved and, on better soils, more than 700 ears m^{-2}.

Nitrogen fertilizer

The overall level of nitrogen is very high in the order of 170–235 kg N ha^{-1}. 'Splitting' is programmed in at least three applications: end of January to beginning of February, 90–130 kg N ha^{-1}; beginning of stem extension (growth stage 3–4), 20–25 kg N ha^{-1}; before earing (growth stage 8–10), 60–80 kg N ha^{-1} (the latter application is often subdivided into two or three 'splits'). There is little influence of annual climatic conditions, preceding crops, etc. on the total nitrogen dose. Oligo-elements comprising a mixture of six minor elements (Fretilon-Combi) are automatically applied with the late application of nitrogen.

Growth regulators

CCC is used systematically; the doses vary according to the variety, from 2–3.5 ℓ ha^{-1}, applied in two or three splits (growth stage 3–4, again at growth stage 5–7 and growth stage 8).

Fungicide protection

A number of treatments (at least three) are used, directed against foliar and ear diseases (two treatments at least, with broad spectrum activity resulting from a mixture of two or three active ingredients, plus an insecticide in many cases). The fungicide protection programme is very thorough and aims to protect the crop against all risks.

To summarize, the method involves the establishment, growth and development of a high number of plants. The number of ears will be high and the main stems play a major role vs. that of the tillers. All inputs – nitrogen, growth regulators, fungicides, seeds – are used at high levels and generally prove themselves to be profitable, especially in early-drilled crops.

A comparison between the systems

It is interesting to compare the new systems with the old-established or conventional ones; innumerable comparisons have been made and some of the more interesting results are discussed below. In France, Pellot (1981) and Faivre-Dupaigre (1981) reported the results of a network of trials carried out over five years in the North Paris Basin area; the objective of the trials was the comparison of three systems. System 1, referred to as 'intensive'' was characterized by the establishment of wheat of very high yield potential (high-yielding varieties, drilled very early), and by the suppression of all limiting factors of production, i.e. by using those techniques which permit the maximum yield to be attained. System 2, referred to as 'moderate', envisaged the attainment of high yields by using non-systemic techniques, except when it appeared profitable to do so at the moment of their application. System 3, referred to as 'extensive', was concerned with establishing wheat of average potential (hardy variety, drilled much later) with a limit as regard costs of production.

TABLE 32.1. Comparison of three systems of cereal production in the North Paris Basin area of France from 1976 to 1981. From Ambolet and Maumene (1981)

System	*Yield ($t\,ha^{-1}$)*	*Variable costs ($FF\,ha^{-1}$)*	*Gross margin ($FF\,ha^{-1}$)*
1 (intensive)	7.42	1846	5570
2 (moderate)	6.21	1116	5092
3 (extensive)	5.37	864	4502

The results are shown in *Table 32.1* and can be summarized as follows:

(a) System 1, the 'intensive' system, gives an average of 1.2 t ha^{-1} more than System 2, the 'moderate' system; System 3 gives an average of 0.8 t ha^{-1} less than System 2;

(b) Economic results: the gross margin (produce value less variable costs) was much higher for System 1 (411 FF ha^{-1} more than System 2 and 1039 FF ha^{-1} more than System 3).

The conclusions of the authors were that, in this region, intensification is often profitable. It should always be noted that the results are strongly dependent on establishment conditions of the wheat crop (in particular the drilling dates) which will determine the level of potential yield, which is an integral part of the system.

In the UK, Hughes (1981) reported the results of trials carried out by ADAS in England and Wales. The four systems compared were as follows: Schleswig-Holstein system, Laloux system, a low cost system and the ADAS system of high nitrogen levels. *Table 32.2* gives the results for 1980, results which agree very much with those of earlier years.

TABLE 32.2. Comparison of systems of cereal production in England and Wales in 1980. From Hughes (1981)

System	*Yield ($t\,ha^{-1}$)*	*Variable costs ($FF\,ha^{-1}$)*	*Gross margin ($FF\,ha^{-1}$)*
Schleswig-Holstein	8.54	2380	6140
Laloux	8.68	1872	6811
Low cost	7.68	1260	6402
ADAS high nitrogen	8.70	1803	6871

In Belgium, Laloux *et al.* (1980; 1982) presented the results of trials carried out at Gembloux and in other regions; the actual conclusions were as follows (*Tables 32.3* and *32.4*):

TABLE 32.3. Effects of sowing densities on yield. From Laloux *et al* (1982)

Date of sowing (Gembloux)	*Densities*	
	220 grains m^{-2}	*450 grains m^{-2}*
1978: 17 November	7868	7658
1979: 31 October	5367	5483
1980: 19 October	5829	5976
1981: 14 November	6441	7084
Average	6376	6550

TABLE 32.4. Comparison of sowing densities. From Laloux *et al.* (1982)

Location	*Dates of sowing 1981*	*Low densities*		*High densities*	
		Grains m^{-2}	*Yield (kg ha^{-1})*	*Grains m^{-2}*	*Difference (kg ha^{-1})*
Fraire	11 October	275	7952	400	−314
Thisnes	29 October	300	8191	450	+ 25
Ath	21 October	300	4980	450	0
Thuin	15 October	360	5979	550	+177

(1) There was little advantage in increasing systematically the sowing densities; drillings carried out between 11 October and 15 November, with sowing densities of between 275 and 360 grains m^{-2} were, at least, equivalent to the much higher seed rates of 400–550 grains m^{-2}.
(2) The 'splitting' of CCC (with much higher total doses) had, on average, little effect on yield;
(3) A comparison between the Laloux system and the Schleswig-Holstein system during the course of three years, gave the results shown in *Table 32.5*.

It may be concluded therefore that there was:

(i) a higher yield of nearly 0.4 t for the Schleswig-Holstein system;
(ii) however, a supplementary cost per hectare, equivalent to 480 kg of grain for this same method;
(iii) therefore, a higher gross margin for the Laloux system on average, except in the course of the third year of trials with better results being recorded for the Schleswig-Holstein system.

TABLE 32.5. Comparison between Laloux system and Schleswig-Holstein system – Gembloux – 1979–81. From Laloux *et al.* (1982)

Year	*Laloux system (kg ha^{-1})*	*Schleswig-Holstein system (kg ha^{-1})*	*Differences (kg ha^{-1})*
1979	5366	5483	117
1980	5568	5955	387
1981	6441	7084	643
Average	5792	6174	382

Aspects of intensive systems

Crop planting and sowing

Intensification with regard to sowing concerns the date of sowing, the quality of the seed, the density of sowing and the type of distribution, in particular, inter-row spacings.

Date of sowing

It is generally agreed that, all other factors being equal, on average early sowing results in higher yields. *Table 32.6* illustrates this phenomenon between the two regions under consideration. A number of other examples could also be given. Nevertheless, limits do exist, e.g. in 1974 and 1975 it was noted in France that the earliest sown winter wheats had a much greater sensitivity to yellow rust attacks; the earliest sown winter barleys had a much greater sensitivity to autumnal attacks by aphids and, therefore, to viruses.

TABLE 32.6. Yield as a function of sowing dates

Schleswig-Holstein Futterkamp (1978)		*Belgium Gembloux (1981)*	
Sowing date	*Yield ($t\ ha^{-1}$)*	*Sowing date*	*Yield ($t\ ha^{-1}$)*
End September	10.64	16 September	7.80
10 October	9.88	29 October	7.20
End November	8.34	17 December	5.00

In other words, early sowing dates generally lead to an increase in yields but, equally, demand an intensification of husbandry practices (e.g. crop protection); this intensification is all the more justified when the level of reasonably attainable yields is high and, in many cases, may be profitable.

Sowing and ear densities

The determination of sowing density engenders considerable debate and there is no universal solution as to optimum ear populations. It is generally acknowledged that varieties of low tillering capacity should be sown at higher densities and that late drillings should be carried out with higher seed rates than earlier drillings. The systems differ in their target ear population and this leads to differences between sowing rates. As previously stated, the optimum ear populations for the Laloux system are between 450 and 550 ears m^{-2}, obtained from sowing rates of between 220 and 375 seeds m^{-2}.

The objective of ITCF in France (ITCF, 1978) is a population of 500–550 ears m^{-2} for large grain varieties in shallow soils with limited reserves; for smaller grain varieties in very fertile soils the objective is 600–700 ears m^{-2}. End of winter populations vary between 200 and 350 plants m^{-2} obtained by drilling 225–400 seeds m^{-2}.

In the Schleswig-Holstein system very high ear numbers (at least 500 and, if possible, over 600 ears m^{-2}) are desirable. The proponents of this system believe that high ear numbers can only be attained by high seed rates (about 400 grains m^{-2}) so that the crop is formed by a large proportion of ears belonging to main stems and first-order tillers. Effland (1981) believes that ear density is the yield component playing the predominant role determining yield. It seems that, when the yield potential is very high (above 9 t ha^{-1}), relatively high sowing rates are effective, especially when drilling small-grain varieties or varieties with low tillering capacity.

Method of sowing (row spacing)

Narrow row spacings are a popular subject for study. Within reasonable limits it is possible to examine the effect of a narrow row width, e.g. 8–10 cm compared with 16–20 cm. The results are not unanimous. In trials carried out in Germany, an increase in yield of around 60 kg ha^{-1} cm^{-1} of reduction in row spacing was observed (variation of row spacing between 20 and 10 cm) (Heyland, 1981). In Belgian trials, Bodson *et al.* (1982) had no evidence to indicate that a yield difference is attributal to a reduction in row spacing.

Nitrogen dressing

The subject of nitrogen fertilization is one of the most widely studied in Europe, as it is in other countries. In the intensive production systems not only is there an increase in the total quantity of nitrogen used, but also in the number of applications required. Situations where a single application would be sufficient are rare; all the systems recommend at least two applications (system of balances, ITCF, France) and four, and even up to six, applications are sometimes used (Schleswig-Holstein).

There are two main methods of determining nitrogen dressings, whether or not they belong to a completely integrated system of cereal production. One technique is based on soil analysis results, carried out on a field-to-field basis, generally at the end of winter or beginning of spring. One such method is that referred to as the 'N-min method' developed by Wehrmann and coworkers (Scharpf and Wehrmann, 1975; Wehrmann *et al.*, 1979) for the Hanover region and used also in other regions (e.g. Netherlands, Belgium) by other soil analysis laboratories. Other systems are based on 'keys of determination' which have the capacity to define, split-by-split, the dressing for each field as a function of factors characteristic of the fields being considered. These are the systems of Laloux, ITCF (system of balances), and of Schleswig-Holstein.

To determine nitrogen dressings the *Laloux method* takes into consideration the following factors:

(a) The soil richness in humus, or more precisely, an estimation of the nitrogen fertility of soils;
(b) The previous crop, its nature, its restitutions of fresh organic matter and its eventual residues of non-utilized nitrogen fertilizer; and
(c) The climate, essentially the climatic elements which concern mineralization and leaching during the course of the autumn/winter period.

For the past few years the determination of nitrogen fertilizer doses has been supported by analytical results of mineral nitrogen profiles in the soil, for several 'specific' situations.

For the *ITCF system of balances* successive splits, two or three in number, are determined in the following manner:

(a) For the first split at the end of winter the quantity of nitrogen to be applied is a function of the population and the stage of development of the crop, according to pre-determined dates, varying from 15 January (south-west zone) to 10 March (northern zone); the quantities will be from 90 kg N ha^{-1} (wheat at three-leaf stage, low population less than 180 plants m^{-2}) to 30 kg N ha^{-1} (wheat at three tillers plus stage, more than 300 plants m^{-2}).
(b) The second split, at stem extension, is determined by the difference between the total quantity of nitrogen fertilizers, less the first split; if the result is greater than 120 kg nitrogen an application of a maximum of 80 kg nitrogen is recommended at the indicated growth stage and the remaining 40 kg nitrogen (or more) will be applied later, towards the flag leaf stage.

The total nitrogen quantity is determined by a balance in which the conditions of application are well defined and whose suitability has been established for northern and north-eastern regions of France. The elements of these balances are given in *Table 32.7*.

TABLE 32.7. Elements to take into account for calculating the total quantity of nitrogen fertilizer according to the system of balances, ITCF, France

Requirements	*Supplies*
(1) Nitrogen absorbed by wheat (yield objective to be estimated), requirements estimated at 3 kg N 100 kg^{-1} grain.	(3) Residual nitrogen at end of winter (according to predetermined tables).
(2) Nitrogen which will remain in the soil after the harvesting of the wheat.	(4) Residual nitrogen from previous harvest (refer to tables).
	(5) Humus nitrogen.
	(6) Old ley nitrogen.
	(7) Farmyard manure or slurry nitrogen.

(1) + (2) = total requirements; (3) + (4) + (5) + (6) + (7) = supplies.
Requirements less supplies = Total quantity of nitrogen fertilizer

In the Schleswig-Holstein system nitrogen fertilization is aimed at supporting the very high ear populations. This means that there must be a constant supply of nitrogen available to the plants and this, in turn determines (a) the high level of nitrogen fertilization used, and (b) the division of this nitrogen fertilizer supply into a relatively large number of doses.

A further step in the area of nitrogen dressing would be the prediction, by model, of soil nitrogen behaviour, allowing a more accurate determination of fertilizer applications and lead to a more complete utilization of nitrogen by the plant.

Conclusion

The determination of yield potential in a given region requires preliminary study. To subsequently achieve this potential there must be a well-defined and balanced approach on the part of the cereal grower leading, ultimately, to an improved financial situation. However, this will not be achieved by the direct application of a system originating in a foreign region. These external systems must be modified to suit the condition of the region. In this way intensification, and a high level of performance, can be achieved.

Summary

Since 1960 a number of cereal production systems have been developed in western Europe. Laloux (1967) was amongst the first to propose a complete system which was considered at that time as being intensive. Since then, new 'high-input' systems have been proposed, most notably that system originating in the region of Schleswig-Holstein.

This chapter gives a brief description of the 'Laloux' and 'Schleswig-Holstein' systems and also comparative results from 'low-input', 'moderate' and 'high-input' systems. From these comparisons it seems that the more intensive systems always permit a higher yield to be attained but are not always the more profitable.

Several aspects of intensification are also described, in particular those factors concerning drilling and the determination of nitrogen dressing for which actual research results and trends are given.

As a conclusion, it seems that profitable, intensive cereal growing can only be obtained by constant adaptation of 'systems' to environmental conditions, technical progress and economic climate.

Acknowledgements

The authors graciously acknowledge the assistance of their colleagues in the Dept. of Crop Husbandry, in particular J. Poelaert, J. Dohet and P. Nyst for their help in the preparation of this article. They are very grateful also to D. Duffy for the translation and other relevant remarks.

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