WINTER WHEAT AND ITS PHYSIOLOGY ACCORDING TO THE FUKUOKA - BONFILS METHOD

1. Reminder of several requirements of wheat
2. The problem of carbon starvation
3. The problem of nitrogen starvation
4. Growing periods of winter cereals
5. Weed problems

THE BONFILS METHOD

1. Permanent cover crop of white clover
2. Surface sowing
3. Early sowing: why and when?
4. Open sowing: why and how much?
5. What varieties?
6. Several problems

1. SEVERAL REMINDERS

Wheat requires 100°C to 150°C T-sum to rise, so the later one sows the slower and more difficult it will be for it to germinate. The optimum temperature for germination lies between 20°C and 25°C, the minimum temperature being 1°C and the maximum 35°C.

Germination occurs within 4 days in August 7 days in September, and one month in November.

The optimum temperature for side-shooting is between 20°C and 25°C, temperatures more common in summer and early autumn in our climate than in December or January.

Prior to side-shooting the cereal seedling is at its stage of minimum resistance to cold. In effect, before side-shooting occurs, the vegetable tissues have not yet hardened to resist cold.

WHEAT is more resistant than rye to damp conditions, but too much damp causes losses at the rising stage, from suffocation. Excessive moisture inhibits rooting, while very sunny weather encourages it. Wheat is relatively tolerant of soils that are only moderately rich, and of fairly low pH (roughly pH 5.5 and above).

RYE is very susceptible to root asphyxia and to inundation. On the other hand it is tolerant of low pH (optimum pH about 5.5) and can be cultivated in soils of pH 5 and below. Its very great vigour enables it to utilize poor sandy soils, and its powerful roots can explore the mother rock to dissolve fertilizing elements at depth. Particularly rapid and strong side-shooting makes it very competitive with weeds.

BARLEY is fairly sensitive to low pH (minimum pH about 5.5) and is unsuited to acid soils. It is very resistant to drought and prefers limey soils, even relatively poor ones.

OATS tolerates poor, acid soils, but is susceptible to cold, though an early sowing and cover crop increase its resistance. Despite this it is reserved for mild damp climates such as Brittany, Ireland, and Scotland.

2. CARBON STARVATION: No Longer A Problem

a) If one considers the plant physiology of winter cereals (germination, photosynthesis, and side-shooting, with an optimum temperature of around 25°C) and the natural wealth in nitrogen of the soil during the months of August-September, the consequences will be appreciated of October or November sowings, at a period of short days (10 hours), poor light and solar intensity, and moderately low or low temperatures:

i) foliar elongation to compensate for lack of sunlight

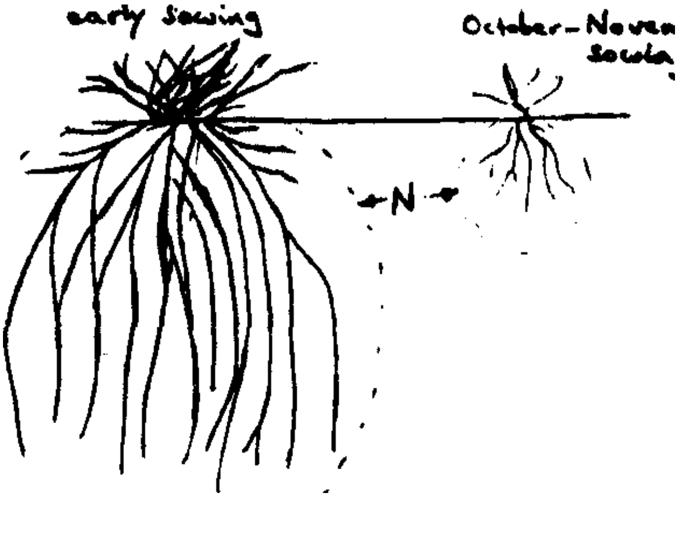
ii) expenditure of energy on the leaves at the expense of the roots

iii) which favours:

- Enfeeblement of the plant to the detriment of the solidity of the supporting tissues
- lack of resistance to disease and cold
- slowing down of the metabolism on account of lengthening of the sap canals

iv) wasting of the fertilizing elements in the soil: nitrogen is washed out by the autumn rains' or taken up by weeds

v) the accumulated amino acids cause intoxication that provides a favourable terrain for diseases and Insect pests Thus poor photosynthesis results in carbon starvation.



b. Thanks to early sowing, the cereal employs to maximum advantage the conditions offered at a period of long days (16 hours), strong solar activity, and maximum photosynthesis. This photosynthesis permits a robust development of the root system, there is no carbon starvation, and the nitrogen is recovered and stored in the roots of the cereal.

3. NITROGEN STARVATION: A Well-Known Problem, Crucial To Cereal Yields

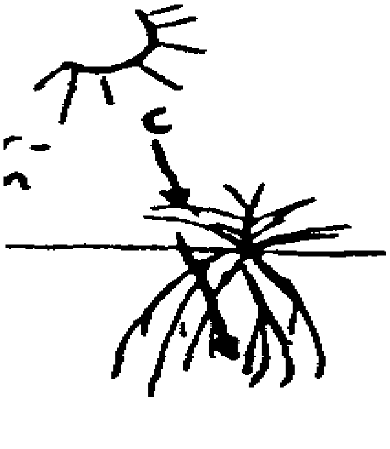
Reminders: we know that

- maximum photosynthesis occurs at 25°C
- the optimum temperature for side-shooting is 20°C to 25°C
- the side-shooting is the most critical period for the nitrogen requirement of cereals
- the level of soil nitrogen is twenty times lower in March than in August

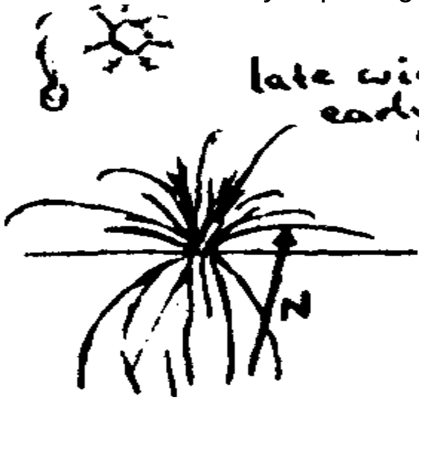
a) October and November sowings cause side-shooting to coincide with the low level of nitrogen in the cold spring soil. Thus side-shooting will last from one to one-and-a-half months at a time of low temperatures and is halted by nitrogen starvation, which results in few secondary ears. To counteract this nitrogen shortage, the spreading of soluble nitrogen fertilizer is the only solution that avoids poor or derisory yields.

b) Sowing in the latter part of June causes side-shooting to coincide with the moment the earth is warm, rich in nitrogen, where the bacterial activity is intense, activated by the autumn rains. Hence side-shooting lasts 8 months, without being limited by nitrogen starvation, and produces very numerous secondary ears.

Summer/autumn



late winter/early spring



4. GROWTH PERIODS OF WINTER CEREALS

Shortening Days: 21st June - 21st December
Vegetative Phase

- warm rich soil
- clover releases rhyzobium
- side-shooting after seven leaves no mounting
- growth not employed by reproductive system is stored in roots

Lengthening Days: 21st December - 2lst June
Reproductive Phase

- floral initiation
- mounting
- forming of ears
- all the root reserves rise into the reproductive system

Thus between the 9th April and the 11th June the reproductive system uses up 70% N, 80% CaO, and 95% K2O, employed by the cereal in the whole of its growth cycle.

The Phenomenon of Exponential Growth in Winter Cereals

The Bonfils Method gives 2500°C T-sum at 21st December; accumulation of major reserves in the roots, which permit rapid start to vegetation in the spring.

Conventional method gives 250°C T-sum at 21st December end of accumulation of reserves, or rather no accumulation of reserves: slow start to vegetation in the spring.

5. THE PROBLEM OF WEEDS

Contrary to popular belief, cereals have a great ability to resist weeds. This capacity of resistance, known as the index of competitiveness, depends upon the T-sum necessary per unfolded leaf.

Rye has the greatest index of competitiveness. Wheat requires 80°C of T-sum per leaf; Italian rye grass 120°C of T-sum and English rye grass 140°C of T-sum per leaf.

Consequently, prior to mounting and in particular during the summer and autumn following the sowing, cutting and grazing of the cereal is possible, up until two months before the first frosts.

After the mounting, no weed can compete with winter cereals.

METHOD OF MARC BONFILS

1. WHY A PERMANENT COVER CROP OF WHITE CLOVER?

Spreading white clover is complementary to upward-growing cereals.

It is a leguminous plant - it fixes nitrogen from the air in its spreading and perennial root nodes, it forms a living mulch that reduces evaporation, favours soil bacteria, allows the infiltration of rainwater without risk either of degradation of soil structure or of washing out, encourages the formation and retention of moisture as dew, and stops erosion.

This soil cover that conserves moisture, in association with the warmth of the hot season, encourages bacterial life in the upper layers of the soil. Hence it fosters also the development of algae associated with the nitrogen-fixing bacteria known as azotobacters.

These algae can fix 100-200 kg of nitrogen per hectare and up to 500-600 kg of nitrogen per hectare under clover.

The maximum soil cover results in a maximum production of sugars to feed the bacteria.

These bacteria can yield 5-6 tonnes of microbial corpses per hectare or as much as 140-180 tonnes per hectare under clover.

The clover is only competed with in its development between the mount and the harvest that is to say between April/May and August in the year of harvesting.

2. WHY SURFACE-SOWING OF THE CEREAL?

Surface sowing is possible thanks to the cover crop of white clover that shelters the grain.

Surface sowing permits more rapid rising (80°C T-sum to rise) and avoids useless elongation of the stems.

It requires less energy from the seed and permits in the event of natural disaster the use of small or dried-up seeds.

Each seed should preferably be pressed into contact with the soil.

3. WHY AN EARLY SOWING?

Early sowing makes for more rapid germination and above all a very important lengthening of the vegetative period.

Side-shooting, which starts at the seven-leaf stage - in early August - lasts 6 to 9 months in place of 1 to 2 months for an October-November sowing.

The floral initiation - when the secondary ears start to form -begins with the lengthening of the days (21st December, winter solstice) once the plant has gone beyond seven leaves, and will occur at the 25 leaf stage and over a period of 40 to 50 days (instead of, as with a sowing at the conventional time, 15 to 20 days with the plant having only 7 leaves, which results in abortion of the secondary ears).

Early sowing permits a very considerable deepening of the roots. which utilize to the maximum the nitrification of the hot months (August-September) and the autumn rains; this deep rooting stops all risk of washing-out by the autumn rains and of pollution of the water-table (which can occur even in the case of organic or biodynamic cultivation).

These strong roots permit the storing of all the energy made available by photosynthesis. In the month of August the rhyzobium of white clover is at its most available: a cereal sown in August, that would not yet have developed its roots, would leave the rhizobium available for weeds, rye-grass, foxtail, etc. On the other hand a cereal sown In June puts the rhizobium at the service of the roots of the cereal at the 7 to 8 leaf stage - the moment of rapid growth when the roots are in full development and capable of absorbing a great deal.

Strong roots - resulting from early sowing - which have stocked up reserves, will release their riches during the critical moments of the reproductive phase, when the soil is cold and the soil bacteria little active or totally inactive. Thus the floral initiation will be intense, with a large number of well-filled terminal buds.

The habitual nitrogen-starvation of the side-shooting phase disappears. There is very active side-shooting (100 ear-shoots per plant). The beginnings of the secondary ears are not aborted. And there is a rapid start to spring growth.

Thanks to early sowing, the competitive ability of cereals over weeds shows itself by seeing off couch-grass, brambles, and bracken.

The drying out of the grain before maturity (this phenomenon is due to the break in sap supply to the grain caused by high levels of evaporative transpiration when cereal plants have only shallow roots) is no longer encountered: the grain has a higher density.

After the harvest, the roots of the harvested cereal rot from the top downwards. The new roots of the cereal sown in June penetrate the channels left by the decaying roots and feed on the detritus of those roots, and from the bacterial corpses and the rhizosphere.

The soil becomes richer year by year, and the yields should increase.

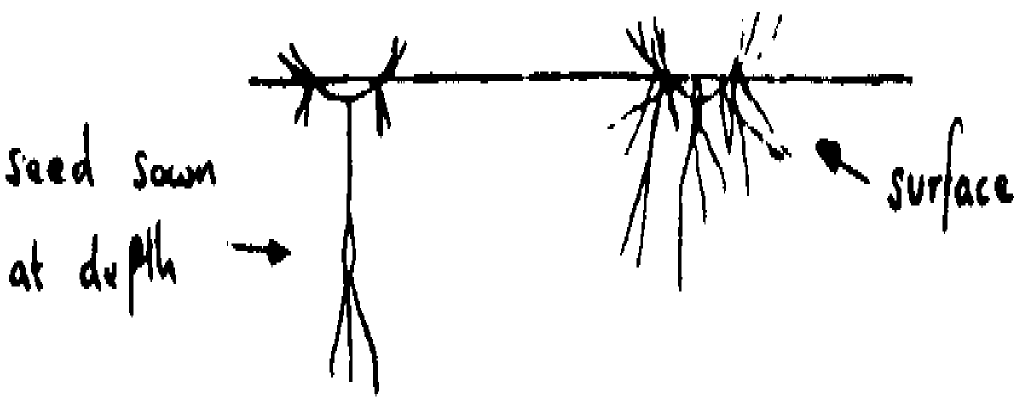
<u>When to Sow?</u>

For all modern varieties it is necessary to sow as soon as possible after the summer solstice (21/6) when the days begin to shorten. This is because modern varieties have within their heredity characteristics of alternativity (spring variety) or of semi-alternativity (semi-winter variety) which risks them going to seed in the year of sowing, if they were sown earlier.

For the true non-alternative varieties, a slightly earlier sowing would be possible (from the first fortnight in June); this should increase the yield still further. It would be necessary to diminish still more the density of sowing.

The last date for sowing is two months before the first frosts, at this stage the cereal should have 7 to 8 leaves and beginning the stage of side-shooting and of maximum resistance to cold. Although with such a late sowing it will be necessary to increase sowing density.

However, October or even November sowings are possible for warm temperate, some Mediterranean and sub tropical climates where sunshine is not a problem but rain is, Algiers or Marrakech for example where high T-sums would be achieved by the time floral initiation occurs. Seeding the cereal crop coincides with autumn rains whereas an earlier sowing would result in withering of the plants.



4. WHY OPEN SOWING?

Fairly obviously the first reason - perhaps of secondary Importance, but nonetheless in certain circumstances vital - is economy of seed. Here are extreme examples, from Africa, according to rainfall:

Annual rainfall	20mm		200mm	500mm	
With 1 plant/m2	Seed	recovered	100 ears/plant	Upto 450	ears/plant

So try recovering the quantity of seed sown at 150 kg/ha with only 20mm of rain!

Open sowing allows the development and survival of the white clover that is to be an essential foodstuff for the cereal over the years. Close sowing would cut off sunlight to the clover, causing it to disappear.

Above all, open sowing safeguards the maximum potential yields offered by early sowing: it avoids wheat-wheat competition. It allows each plant the tine and space to develop its roots to the greatest extent: roots •that cannot develop cannot accumulate reserves. The root system of wheat is matted and spreading: on this depends the production and quality of the harvest.

The number of ears is proportional to the number of spreading side-shoots.

The number of grains per ear is proportional to the length of the roots.

The earlier the sowing the more open it should be When in bygone times early sowing was practised (for example, 22nd July in the Champagne) at high density (200kg/ha) low or very low yields were obtained: the density of sowing should not have exceeded 6kg/ha.

When wheat is associated with white clover it tends to grow tall and lodge on account of its richness in nitrogen relative to carbon. It is necessary on this account to reduce the sowing density.

Open sowing results in maximum sunlight and a large leaf surface to make for better photosynthesis, thus avoiding carbon starvation. The risk of the grain drying out before maturity, increased by the greater leaf surface, is largely compensated by the very extensive root system.

Open sowing, offering as it does maximum sunlight, permits the development of considerable resistance to diseases such as rusts, helmintho-sporiosis, etc.

In conventional sowing as maturity approaches only the last leaf is alive. If it is attacked by disease, the consequences can be serious. However, open sowing allows for a large active leaf surface, even if several of the leaves are attacked, the others continue to play their role.

<u>Open Sowing: What Density?</u>

The sowing density should vary according to the vegetative vigour *of* the chosen variety:

- modern, early, short-strawed variety, of feeble vigour: 4 plants/m^2
- 50cm in both directions, which corresponds to approx 2kg of seed/hectare
- long-strawed, late variety, pre-dating 1826, of strong vigour: 1.5 plants/m^2 - 80cm in either direction, corresponds to approx 0.7kg/ha.

N.B. The vegetative vigour of rye is generally greater than that of wheat.

As a rule-of-thumb the maximum quantity of seed is halved for each month of ear1iness.

	Nov	Oct	Sept	Aug	July	June
Quantity kg/ha	180	90	45	20	10	5

Several examples of results

	Conventional Sowing late October	INRA Trial Plot Early October	Bonfils Method Late June	
no. of plants/m^2	350	80-100	3-4	1.5-2
qty. of seed/ha	160-180kg	40-50kg	1.5-2kg	0.7-1.5kg
ears/plant	0-3	5-7	100-150	200-300
earlets/ear	12-15	18-20	35	
grains/earlet	1-3	2-5	7	
quality of grain	low unit weight of grain	relatively high unit weight	high unit weight of grain	

5. WHICH VARIETIES OF CEREALS?

All the varieties currently shown in the seed catalogues are descendants of Noah variety (1826)

Noah comes from Russia, but its forebears came from North Africa. It is the result of cross-breeding with an alternative spring variety suited to the Mediterranean region.

These varieties issued from Noah have mutated according to the region, but have as a common characteristic: short straw, spring development, and sensitivity to cold, root exposure, and rust.

All of which increases the risk of drying out of the immature grain, despite the original precursors being varieties resistant to drying out.

Why such cross-breeding?

Essentially as result of the quest for earliness to compensate for late sowing after sugar beet in the cereal-producing regions.

Short straw is also an advantage for mechanization in the regions where straw is more of a handicap than an asset.

Modern objective of selection: short straw and earliness, which result in:

- lowering of side-shooting capacity
- reduction of competitiveness with weeds
- decrease in rooting vigour

All these handicaps are, certainly, compensated by chemical means: treatment of the seed, pre- and post-germination herbicides, measured doses of soluble fertilizers, growth regulating hormones, and pesticides.

How to recognize ancient and modern varieties?

What to look for:

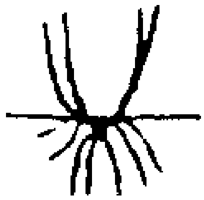
- varieties pre-dating 1826
- long straw
- strong vegetative vigour
- broad area of side-shooting
- high resistance to cold
- very late maturity
- winter or hard-winter type
- floral initiation requiring at least 600-700°C T-sum (800°C Poulard wheat)

- large leaf area for:
- better photosynthesis
- absence of carbon starvation
- highly developed root-system to offset risk of drying out of immature grain

1 part above ground

2 parts below ground

<u>What to avoid:</u>



- exotic modern varieties
- short straw
- poor vegetative vigour
- restricted area of side-shooting
- poor resistance to cold
- earliness, alternative or semi-alternative type
- floral Initiation occurring at 400°C T-sum
- small leaf area to limit evaporative transpiration and the risk of drying out of the Immature grain, with the following consequences:
- carbon starvation
- large requirement of soluble fertilizers
- good resistance to drying out, when Irrigated (whereas the forebears were resistant to drought)
- 12 parts above ground/ 1 part below ground

<u>Several Varieties to Look For</u>

1. Blé Seigle (bled seigle, Ralet, wheat-rye)
2. Autumn Victoria
3. Prince Albert

4. Autumn Chiddam
5. Dattel
6. Golden Top
7. Sheriff Square Head
8. Poulard d'Auvergne wheat
9. Giant white square-headed hybrid wheat (tritical [1907] cross of 7x9)
10. Schlanstedt rye
11.

Varieties 2 to 7 originate in Great Britain.

Wheat is a self-pollinating plant, and hybridisation must therefore be provoked. However in cases of extreme heat at the time of fertilization the glumes can open and the wind cause cross-pollination of cereals. Hence natural triticals are to be found in the Soviet Union.

Modern triticals, which are formed from rye (strong vegetative vigour) and spring wheats (poor vegetative vigour in our climate) are to be avoided.

Properties of Several Varieties

A) Winter Poulard wheats; numerous varieties

- semi-hard wheat, can be used for noodles
- good resistance to drying out
- straw very resistant to lodging
- high stem/root ratio
- very fertile ears, having tendency to branch (e.g. Osiris)
- very strong side-shooting despite relatively restricted area of side-shooting

Varieties: Nonnette do Lausanne
B1anc du Gatinais
Australian
Auvergne
Osiris (to be avoided: alternative)

B) Champlan equals Victoria x Autumn Chiddam
Bordier: very strong side-shooting, great resistance to cold and to rusts, very late.

C) Rouge de Champagne, Rouge d'Alsace, Alsace Blé-Roseau/reed-wheat (northern France): enormous stalks and ears.

D) Varieties contaminated by spring types: certain of these have retained their winter character, e.g. Vilmorin 27, and Ceres (Victoria x Prince Albert x Noah).

Leave aside all the varieties in the catalogue that are not "winter" although "semi-winter" would be tolerable if there is no other choice.

COMPARATIVE TIMING