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CHAPTER III

DURUM WHEAT

Triticum durum Desf. (2 $n = 28$).

I. ECONOMICS OF PRODUCTION.

1° DURUM WHEAT IN THE WORLD.

The main durum wheat producing regions in the world are the Middle East, South America (Argentina) and especially North America (nearly 2 million hectares and nearly 3,400,000 t in 1969, including 1,400,000 ha and 2,600,000 t in the USA.

In Europe the two main producers are Italy and France.

2° DURUM WHEAT IN FRANCE.

Durum wheat is grown in France mainly for *semolina* production in order to make pasta: the vitreous albumen of *Tr. durum* gives it a much higher semolina yield than soft wheat.

This culture has taken on a certain extension in France over the last ten years, first in the southern regions, then in the northern half of France in 1970 1 : from 1951 to the areas increased from 2,000 ha to 163,000 ha and production from 45,000 to 4,500,000 q; from 1966, moreover, the northern half of France produced 40% of the production compared to 0 % before 1960 (fig. III-1 and table III-1). Various factors are at the origin of this recent increase in metropolitan wheat production hard.

a) Considerable increase in French consumption of pasta.

This increased from 150,000 t in 1939 to 320,000 in 1960. It is, per inhabitant, 6.5 kg in France, against 3.4 in Germany, 2.3 in Belgium and 30 kg in Italy.

b) Common market for durum wheat.

The EEC imports 12 to 15 million quintals of dul wheat each year from North America, Argentina and the Middle East , with Italy and France being the main importers.

1. Regions located approximately above the 45th parallel.

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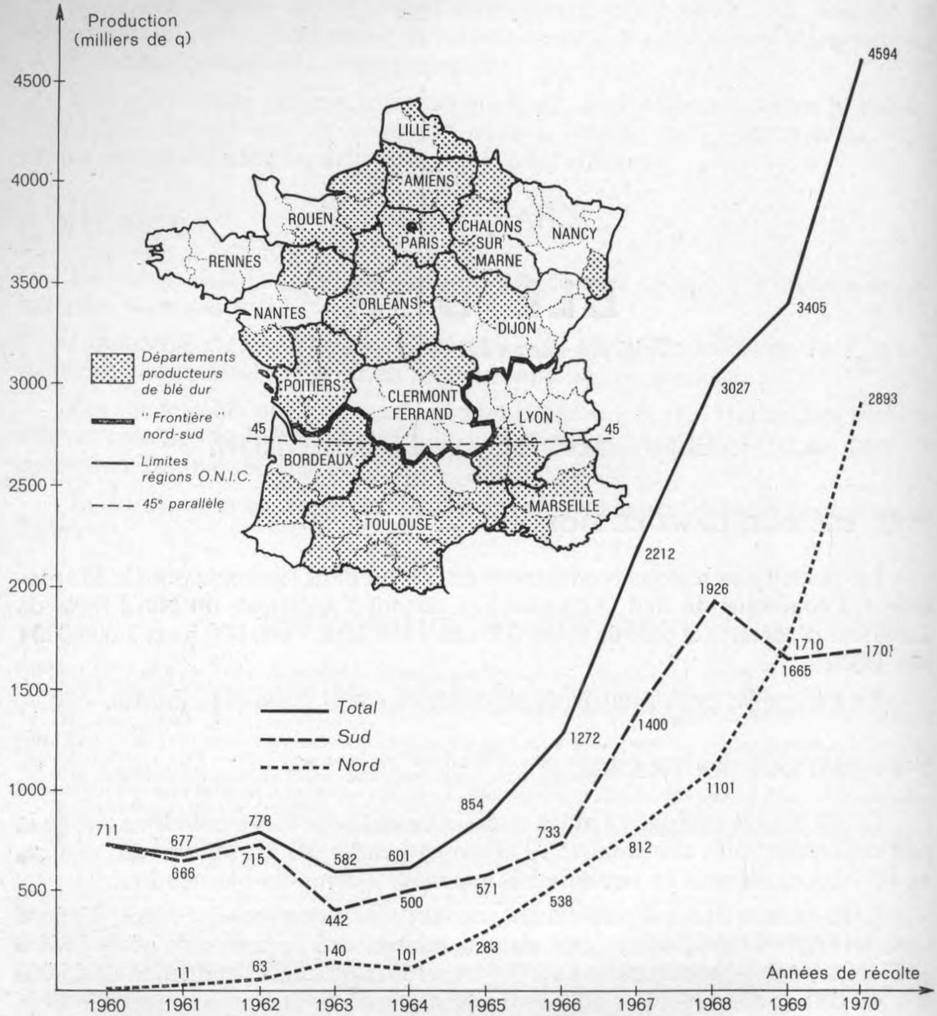

FIG. III-1.- Evolution of French durum wheat production (1960-1970).

(According to ONIC source.) 1

the main importers. These two countries should be able to find an interesting place on this market .

(c) **Price support.**

Since 1954, durum wheat has benefited from a higher base price than wheat. tender.

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TABLE **III-1. —** *Evolution of durum wheat collection in France* (Source ONIC)

YEARS HARVEST	COLLECTIONS TOTALS	SOUTH		NORTH	
		Quantities (q)	Proportions (%)	Quantities (q)	Proportions (%)
1951	40,000	40,000	100	—	
1955	162,000	162,000	100	—	
1960	639 554	635,087	99.3	4,467	0.7
1961	571 184	558	98	13,032	
1962	762 437	152,710	93	51,964	
1963	589 689	473,450	76	139 206	2 7
1964	518 820	483	86	72,446	24
1965	830 350 1	445,774	71	236 879	14
1966	229 758 2	593	54	571 077	29
1967	184 080 2	471,658,681	63	804 878	46
1968	762 810 3	1,379,202	65	982 051	37
1969	154 633 4	1,800,759	48	1,632 243	35
1970 [1]	415 863	1,522,390 1,712,587	39	2,703 276	52 61

(1) Forecasts.

(d) **Improvement of varieties and cultivation techniques.**

Improvement work undertaken in 1950 at the Montpellier Station **(INRA)** by Professor ALABOUVETTE and continued by GRIGNAC led to the production of varieties adapted to southern areas. Gradually and in parallel, the experimentation undertaken by **INRA** and professional organizations (ITCF) made it possible to specify and improve cultivation techniques (sowing, fertilization, weeding) in the southern area and then in the northern area.

II. THE PLANT.

A. BOTANICAL STUDY.

1st PLACE IN THE BOTANICAL CLASSIFICATION.

Durum wheat belongs to the genus *Triticum* and the species *durum* (Desfontaines). 11 is therefore part of the group of *tetraploid* species (2 *n* = 28).

Generally speaking, durum wheat is characterized

by : — *an ear with a* solid rachis, with glumes keeled to their base, with a lower lemma ending in a long colored beard;

— *a very large grain* (45-60 mg), subtriangular section, very rich in albumen, vitreous texture;

— *a vegetative apparatus with* low tillering (often only one ear per plant), long, supple stubble, sensitive to lodging.

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Tr. durum is, however, relatively poorly characterized within the tetraploid group: it presents characteristics in common with the other species. On the other hand, the species lacks unity, containing a set of forms sometimes very distant from each other.

Thus, according to **GRIGNAC,** *Tr. durum* would be subdivided into three subspecies : *mediterraneum, syriacum, europeum,* each corresponding to a specific diversification center (North Africa, Middle East and southern USSR) and themselves comprising a certain number of forms or *prey* (according to the type of ear, the hairiness of the foliage, the tillering habit, etc.).

2° GENETIC ORIGIN OF DURUM WHEAT.

RILEY and CHAPMAN (1957) demonstrated the hybrid origin of tetraploid *Triticum .* These species are amphidiploids between a diploid *Triticum (Tr. beoticum* or *Tr. monococcum)* providing the A genome and *speltoid Aegilops* providing the **B** genome.

Such hybridization would have given rise to *Tr. dicoccotdes* which would then have diversified *into Tr. dicoccum and Tr. durum.*

B. BIOLOGICAL STUDY .

1° DEVELOPMENTAL PHYSIOLOGY.

a) **GRIGNAC**a showed (1965) that most durum wheat varieties have a " *spring"* development rhythm characterized by a vegetative period (sowing-A) and a floral initiation phase **(AB)** that are too short, resulting in low herbaceous tillering, a reduced number of tillering and anchoring roots, very early emergence and high sensitivity to cold.

However, some varieties belonging to the subspecies *europeum* are characterized by a late bolting, and therefore, have a more abundant tillering, better resistance to lodging and cold.

b) For the same variety, the length of the *growing season* depends on the *temperature* and the *photoperiod:* in long days (over 12 hours), spring varieties have an extremely short growing season. On the other hand, the speed of leaf and tiller formation is independent of the *photoperiod :* it is a linear function of the temperature.

c) The length of *the floral initiation phase* depends on the *temperature and* the *ph* in long days, this phase is very short and the number of spikelet sketches very low.

Furthermore, the gap between the development of the apex of the main strand and the different apices of the tillers is always excessive, significantly greater than in soft wheat varieties : this results in irregular tillering and a low

population of ears. *d) The* duration of the *elongation phase*

is particularly long. *e) The* duration of the *maturation period* is normally longer than that of soft wheats of the same earliness: for the same sum of temperatures, the growth rate is slower in durum wheat than in soft wheat.

2° ECOLOGY OF GROWTH.

a) **Temperature.**

The germination zero of wheat is, like that of soft wheat, very close to 0 °C.

°C.

The sum of temperatures required for lifting is similar according to GRIGNAC

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A durum wheat crop.

SPIEA Photo

(for sowing at 4 cm) of 124 OC, therefore slightly higher than that observed in soft wheat.

Subsequently, the rate of formation of a leaf outline is relatively constant; it requires a sum of temperatures close to 50 OC, without varietal differences .
variétales.

The minimum critical temperatures are also close to those of soft wheat: a "spring" type durum wheat suffers leaf damage at around -8 OC. On the other hand, durum wheat is particularly *resistant to high temperatures* during maturation : in the absence of drought, temperatures of around 31-32 OC do not cause any disturbance (Grignac). (Gri-
gnac).

beautiful .

Until the end of tillering, water requirements are relatively low. In addition, excessive soil moisture is detrimental to the establishment of the root system in depth.

On the other hand, during the tillering phase and up to flowering, the crop's water requirements are considerable and can be estimated at 180 mm (between March and May). After flowering, wheat becomes very resistant to drought (as well as to high temperatures).

c) Nutrients.

Phosphorus and Potash. A harvest of 30 q of grain and 54 q of straw exports approximately 30 kg of P205 and 54 kg of **K20 :** durum wheat therefore has P2O5 requirements comparable to those of soft wheat, although higher in K20 because it produces more straw than soft wheat for the same weight of grain.

Nitrogen. Exports per quintal of grain can be estimated at 13 % water, at 4 *kg of nitrogen* , i.e .: *.1 kg more than for soft wheat.*

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The nitrogen absorption curve (fig. III-2) also shows that it becomes very important at the end of tillering, during the heading and until post-flowering, during the first 10-15 days of grain formation. It follows and this is confirmed by experience that : — the

nitrogen supply during tillering and at the beginning of heading has an effect on two of the yield components: the *number of ears* and their *fertility ;*

— any nitrogen deficiency in the *days following flowering* reduces protein synthesis while carbohydrate synthesis can remain normal, which leads to a floury and non-glassy texture, i.e. to *mitadinage.*

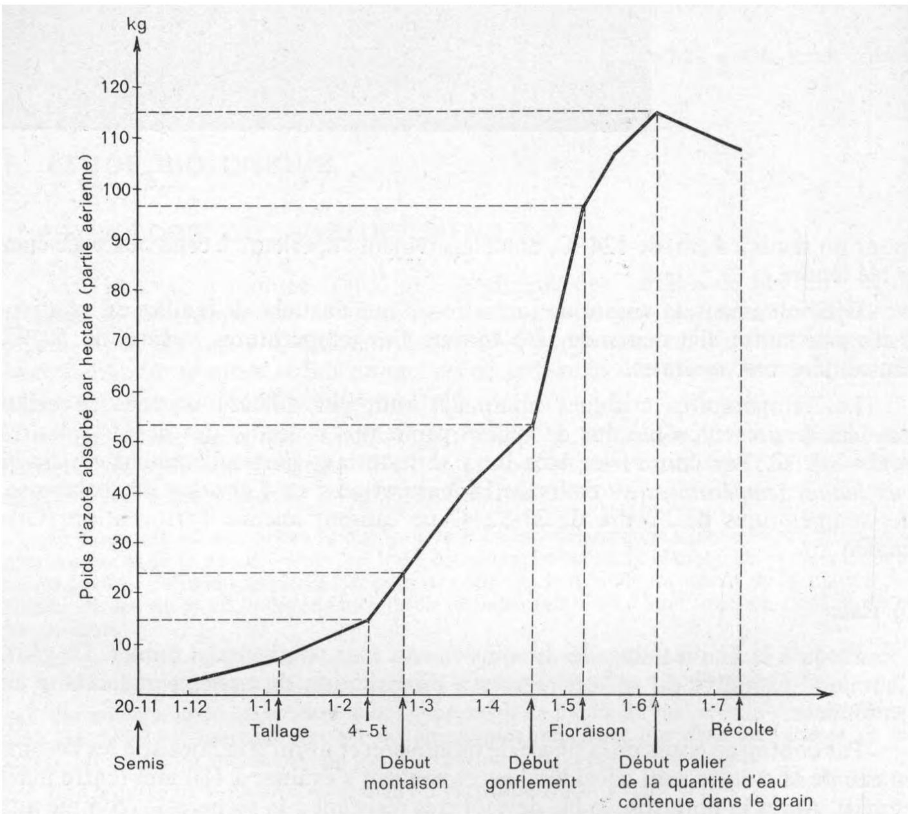

FIG. III-2. — Nitrogen absorption curve for a durum wheat crop.

(According to A. COTTE and P. GRIGNAC.)

3° ACCIDENTS AND PARASITES.

a) **Damping off of seedlings.**

Damping off of seedlings is caused by stagnant moisture and germination parasites *(Fusarium roseum, F. nivale).*

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b) Winter frost.

It can completely destroy, during autumn sowing, the crops in the northern zone.

c) The pour.

Lodging, especially root lodging, is the most frequent accident. and most severe during the “swelling, milky stage ” period.

This particular sensitivity of durum wheat is mainly due to poor anchoring of the plant: aerial part too heavy, few adventitious roots.

d) Rusts.

Black rust does not seem to be *dangerous* for durum wheat. On the other hand, they are very sensitive to *yellow rust, brown rust,* fusarium and septoria ; *they* are also sensitive to various *foot rots.*

e) The spur.

Ergot is quite common in fields infested with foxtail, the agent of propagation of this parasite. Commercial legislation imposes a rate of less than 1% of ergot at harvest.

f) Germination on the foot.

Most cultivated durum wheat varieties are white grained, without dormancy. Thus, humidity during the maturation period can cause many grains to start germinating, which reduces the semolina yield.

g) Mitadinage.

Sometimes the albumen has, instead of a glassy and homogeneous structure, areas with a floury texture: we then say that the grain is *mitadinated.* We have seen above that it is caused by poor nitrogen nutrition after flowering : at identical maturation and for the same variety, the richer the grain is *in proteins,* the lower the mitadinage (table **III-2).**

Mitadinage can significantly reduce semolina yield and pasta quality. It is measured by the percentage of grains that are more or less mitadinage (mitadinage index).

The choice of a region with a warm and dry climate during ripening, high potassium fertilization, ensuring rapid migration of proteins to the grain, continuous nitrogen feeding , the choice of a resistant variety are the best ways to combat mitadinage.

h) The speckle.

Speckle is characterized by the presence in the furrow or on the embryo of a blackish mycelium *(Cladosporium herbarum).* It is more common in humid areas at the end of vegetation; it leads to stained flours.

According to **BOURNIER** (1971), the speckles are due to the bites of Thrips *(Haplothrips tritici and Limothrips cerealium).*

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TABLE III-2. — *Relationships between the mitadinage index and the* protein content *according to the* varieties

(According to P. Grignac)

VARIETIES ACCORDING TO THEIR SENSITIVITY TO MIDDLING	PROTEIN CONTENT WHEN THE MIDDLE-TIME INDEX IS BETWEEN 10 AND 55and50	50 et 5
Resistant varieties		
`Bidi 17'	10.98	12.74
'Montferrier'	11.10	12.68
Low sensitivity variety		
`Chile 831'	11.50	13.09
Quite sensitive variety		
'D117'	12.85	14.10
Sensitive varieties		
'Lakota'	12.58	14.71
'Wells'	12.64	14.88
Mandon'	12.42	15.10
Lez'	12.68	15.15
Little significant difference	0.25	0.19

III. CULTIVATED VARIETIES.

Currently (1970) six main varieties are cultivated in France : — in the southern zone: `Bidi17', Montferrier' (INRA), `Lez' (INRA) and `Mandon' (INRA); — in the northern zone `Lakota' and `Wells', American varieties. Table III-3 summarizes the main characteristics of each of these varieties.

1° CULTURAL **CHARACTERISTICS .**

Current varieties are characterized by :

— a "spring" to " **semi-alternate" development rhythm ; — a high sensitivity to cold. (`Mandon' is however not very sensitive), prohibiting their autumn sowing in the northern zone;**

— fairly weak tillering — ears (with the exception of `Lakota' and `Wells'); — generally poor resistance to lodging;

— high susceptibility to eyespot, fusarium, and some susceptibility to yellow and brown rust.

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TABLE *III -3. Main characteristics of the most widely cultivated hardwood varieties in France*

VARIETIES	.5 RELATIVE	EARLINESS	TILLAGE RESISTANCE - SPIKE	TO THE VERSE	PRODUCTION	QUALITIES TECHNOLOGICAL: Mitadina	Color pasta
'Bidi 17' (1953)	P	half-early	weak	very sensitive	enough good		slightly gray
'Montferrier (1962)	A late		weak	little sensitive to good little	good		slightly gray white
'Lez' (1966)	P semi-early		weak	sensitive to good	Good		
' Wells'	P half early		enough strong	sensitive	good or quite good good		YELLOW
'Lakota' (1968)	P	half early	enough	sensitive			amber yellow
Mandon' (1968)	1/2 A late		strong weak	Good	Good		amber yellow

Caption. A, alternate — 1/2 A, 1/2 alternative — P, spring — R, resistant — S, sensitive.

2° TECHNOLOGICAL CHARACTERISTICS.

a) **Resistance to mitadination.**

Durum wheat varieties exhibit very different levels of mitadinage behavior.

The resistant or less susceptible varieties all come from the western Mediterranean basin, where the climate is favourable to mitadinage, and belong to the Mediterranean subspecies *T. durum ;* (e.g.: `Oued Zenati', `Bidi 17'). On the other hand, the most susceptible varieties are of Russian and American origin; generally speaking , they come from regions with a continental climate, where mitadinage is r

The high resistance to mitadinage would be due, according to GRIGNAC (1970) , to the combination of several varietal

characteristics : — ability to produce a grain rich

in proteins; — tendency to rapidly accumulate nitrogen during the first phases of grain development (particularly the water plateau phase);

— ability to produce an elastic and tenacious gluten.

b) **Ability to produce yellow and light-coloured pastes.**

In France, the development of the cultivation of American varieties, `Lakota', `Wells' is mainly due to their superiority concerning the color of the pasta.

The main factors determining the color of pasta are the content of

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carotenoid pigments of semolina, and the activity of lipoxidases destroying these pigments during dough making.

Compared to the variety effect, growing conditions have relatively little influence on these characteristics.

Unfortunately, no variety currently combines resistance to mitadinage and good ability to colour dough: there is, in fact, a very close and negative link between gluten tenacity and colouring index . yellow; only the characteristics "grain rich in low tenacity proteins" and " colour indices " can be combined in the same variety.

3° IMPROVEMENT OBJECTIVES.

Given their present characteristics, the objectives of improving varieties are of interest to :

— *resistance to lodging,* the increase in the level of which would make it possible to increase nitrogen fertilization, and therefore to better

combat mitadination; —

tillering capacity; — resistance to parasites (fusarium, yellow rust) and

humidity; — *technological quality:* resistance to mitadination, coloring of the dough

IV. CULTURE.

1° PLACE IN THE CROPPING.

From an agronomic point of view, durum wheat should normally follow a crop head, with the exception of maize (Fusarium wilt). For economic reasons , it often has the same place as spring barley behind a soft winter wheat whose straw has been destroyed.

However, you should not sow hard wheat after poorly grown soft wheat. (many impurities during harvest).

You should also never plant soft wheat after hard wheat (parasites).

Soles infested with foxtail, wild oats or bentgrass should be avoided.

20 PREPARATION OF THE SOIL.

Due to its sensitivity to excess water, heavy soils should be excluded, drying out badly in spring.

In the southern zone, summer plowing is carried out and is resumed using superficial methods.

In the northern zone, after autumn or winter plowing, the land, once dried, will be taken up so as to be neither too cloddy nor hollow in depth.

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A trial of durum wheat lines under selection.

Photo INRA

3° FUMURE.

a) Basic fertilization.

It consists of 80 kg to 120 kg/ha of phosphoric acid and 120 to 150 kg/ha of potash.

b) Nitrogen fertilization.

— *in autumn sowing,* is generally applied twice : — at the start of tillering (end of January) : 40 kg/ha; — at the start of the rise (at the 10 cm stage of elongation of the main strand) : 40 kg/ha. — *in spring sowing:*

— with a variety resistant to mitadinage and low sensitivity to lodging `Montferrier': 80 to 120 kg/ha of nitrogen applied in full at sowing can ensure a good yield and suitable quality; — with a variety sensitive to mitadinage and lodging `Lakota', split applications are preferable (60 kg/ha +60 kg for example).

4° SOWING.

a) Seed treatment.

It is essential to treat them against fusarium and septoria using products based on *organomercury* compounds or *maneb.* Products based on *mancozcbe* or *copper oxynate* can also be used.

b) Sowing date.

Sowing should : — in the southern zone: be carried out in autumn, from the end of October to the end of December; — in the northern zone: immediately after the cold, from the end of February to mid-March, when the soil, well dried, reaches +5 0C at 5 cm.

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c) Density.

Experience shows that it is necessary :

to obtain : — in autumn sowing: 200 to 250 plants per square meter, providing approximately 300 ears per square meter (with `Bidi 17', `Montferrier' or `Lez');

— in late winter or spring sowing: 250 to 300 plants per square meter, (with `Lakota' or `Wells').

These densities correspond to seed doses ranging from 90 to 150 kg/ha, depending on the varieties.

d) Depth.

It is necessary to sow shallowly, between 2 and 4 cm : plants from seeds that are too buried will rise with difficulty and will be more fragile...

5° WEEDING.

Due to its low tillering capacity, durum wheat is not very competitive with weeds. Weeding should therefore be carried out early if possible and sustainable.

It can be carried out using :

— nitrate dyes (DNOC at 2.5-4 kg/ha of active ingredient or dinoseb at 1-1.5 kg/ha of active ingredient) for early weeding;

— using phytohormones, MCPA (0.6 to 0.8 kg/ha, preferably 2.4-D), at the start of the climb.

The sensitivity of durum wheat to phytohormones is comparable to that of soft spring wheat.

6° APPLICATION OF THE CCC.

Given the high risk of lodging in durum wheat, treatment with CCC (at a dose of 1.5 kg/ha of activated matter [1]) carried out at the end of tillering can reduce the height of the straw and improve its rigidity. Treatment with CCC can also allow the use of higher doses of nitrogen.

7° HARVEST.

a) Harvest stage.

In the southern region, overripe harvesting is possible , with minimal risk of germination on the vine or shattering.

In the northern region, the risks of germination on the ground and speckling may require harvesting before this stage: *if a dryer is available,* harvesting can be carried out using a combine harvester as soon as the grain moisture content is below 20 %.

1. Either 4 1/ha of commercial product, diluted in 300 to 500 1 of water.

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b) **Technological value of the harvest.**

This is measured by its yield of high-quality semolina.

This yield depends on:
• non-varietal or weakly varietal characteristics ,
— the homogeneity of the batch (absence of mixtures with soft wheat in particular);
— absence of disease or maturation accidents;
— cleanliness and dryness of the grain;
• mainly varietal characteristics ,
— mitadinage index (itself conditioned by the content and quality of proteins);
— ability of the grain to produce amber-yellow pasta;
— grain content of husks and miner

Currently (1970), the standards required for use in semolina are as follows: boasts :

— minimum specific weight: 78 kg/ha,
— overall percentage of mitaded grains: 20 % maximum,
— percentage of soft wheat grains : 4 % maximum,
— percentage of various impurities : 0.5 % maximum,
— percentage of impurities from cereals (germinated grains, broken grains, etc.) : 3.5 % maximum.

As an indication, from 1958 to 1968, 6 to 28 % of the batches harvested annually in France were unfit for use in semolina due to excessive mixing and 28 to 65 % were penalized by reductions.

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CHAPTER IV

BARLEY

Hordeum vulgare L. *(H. sativum* Pers.) (2 *n = 14)*

I. ECONOMICS OF PRODUCTION.

A. BARLEY IN THE WORLD.

1° Of all cereals, barley is the one with *the most extensive cultivation area :* it extends from northern Sweden to the Middle East and Egypt, from sea level to 4,000 m in the Himalayas: it is therefore a very hardy species.

2° The cultivation is *clearly progressing,* both in terms of areas and yields (table IV-1). Currently (1970) world production of barley is slightly less than half that of soft wheat.

TABLE IV-1. — *World barley production* (according to FAO)

	1934-38	1948-52	1956	1961	1968
Areas (million hectares)	36.4	46.0	55.5	50.7	74.9
Productions (millions of quintals)	418	543	754	770	307
Yields (q/ha)	11.5	11.8	13.6	15.2	17.4

3° The main producers are (FAO, 1969).

Europe. .... 15,485,000 ha and 459,000,000 q
USSR .... 19,350,000 ha and 289,000,000 q
America. .... 11,550,000 ha 7,730,000 ha and 165,000,000 q North
Asia .... and 136,000,000q

The United States and Canada are the main exporting countries.

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4° On a European scale (USSR not included) the progression is also very clear (table IV-2).

TABLE IV-2. — *European barley production* (according to FAO)

	1934-38	1948-52	1956	1966	1968
Areas (million hectares)	9.4	8.9	11.0	13.8	15.5
Production (millions of quintals)	144	151	237	368	459
Yields (q/ha)	15.4	17.0	21.5	26.6	29.7

Barley production in the six Common Market countries increased from 45 million lions of quintals in 1950-1954 98 million in 1960 and 150 in 1968.

5° The extension of this culture since 1945 is correlative to the impetus given in most countries to *animal production.*

B. BARLEY IN FRANCE.

1° As in all other European countries, *since 1950* there has been *a very strong expansion* of barley cultivation in France.

This phenomenon, associated with the development of corn cultivation , constitutes *the most significant element of French cereal production after the war.*

Table IV-3 summarizes the evolution of barley production in France since the beginning of the century.

TABLE IV-3. — *Evolution of barley production in France*

YEARS	AREAS (thousands of hectares)	YIELDS (q/ha) (q/ha)	PRODUCTIONS (millions of quintals)
	A. — Annual averages (1901 to 1965)		
1901-1910	718	12.9	9,315
1911-1920	674	12.6	8,477
1921-1930	711	14.4	10,200
1931-1940	740	14.8	10,918
1941-1950	762	12.9	10,021
1951-1960	1,506	21.9	32,978
1961-1964	2,327	27.9	64,946
	B. — 1966 to 1970		
1966	2,649	28.1	74,517
1967	2,777	35.0	**97,131**
1968	2,739	33.0	89,794
1969	2,868	33.0	94,521
1970	2,929	27.0	80,090

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Relatively stable until 1950, the areas have quadrupled since then, yields have more than doubled; *production has increased by 1 to 9.*

The collection increased from 4 million quintals in 1950 to more than 50 million in 1968-69, or 55 % of production. Correlatively, France ranks first among European barley-exporting countries (12.5 million quintals, exported to the EEC in 1967-68).

2° Two types of barley are grown in France: *winter barley* and *spring barley .*

Winter barley, the cultivation of which tends to decline in percentage, remains cultivated mainly in the West (Poitou, Charente), the South-East (Lauragais), Champagne and the South-East.

	1950	1954	1958	1962	1964	1966	1968 338 265
Areas (thousands of hectares)	267	387	368		265	230	
Percentages of total areas	27.2	31.4	20.6	15.5	12.7	10.8	9.7

Spring barley, the cultivation of which has been increasing since 1950, now represents Today, 90 % of the barley area is sown.

The main producing departments are roughly the same as for wheat, with spring barley generally succeeding it in the rotation.
The main producing regions are therefore the Paris region (Seine-et- Marne, Yvelines), the North, Picardy, the Center (Eure-et-Loir, Indre), Champagne .

3° The reasons for this development of barley cultivation in France are the same as everywhere else :

— *the expansion of animal production* (particularly poultry and pork);

— the high (and constantly increasing) *level* of productivity of this species; — *its high energy value,* much higher in particular than that of oats (1 kg of barley = 1 FU).

Furthermore, the prospects for opening the Common Grain *Market* have strongly influenced this development.

In 1966-1967, the EEC still imported 19 million quintals from third countries . At the same date, our exports amounted to 18 million quintals, including **10** million to our EEC partners.

Taking into account export prospects in the Community countries and third countries, the objectives defined by the 5th Plan provided for French production of 90 million quintals in 1970, an objective achieved. The forecasts of the 6th Plan for 1975 are 100 million quintals (2,700,000 ha and 37 q/ha).

4° The interest shown by farmers in spring barley rather than winter barley, is due to several causes :

— the most important progress made in the improvement of winter barley (resistance to lodging) is well after that obtained in spring barley: in winter barley, they date back less than 10 years (`Ager').

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— **with** the exception of one variety, all winter barleys have grains very coarse, exclusively forage;

— finally, the precocity of maturity exposes this crop, in certain regions, to attacks by birds.

However, winter barley cultivation retains certain advantages over spring barley cultivation.

— the earliness of harvest (2 to 3 weeks before that of winter wheat), spreads out the harvest work, and allows for possible catch crops to be grown

afterwards; — the yield of the best varieties of winter barley is generally 15 to 25 % higher than that of spring barley, depending on the region.

II.LAPLANTE.

A. BOTANICAL CHARACTERS.

1st PLACE IN THE BOTANICAL CLASSIFICATION.

Cultivated barley belongs to the Gramineae family, Hordeae tribe, genus *Hordeum.* This genus includes two large groups of species.

a) Coarse-grained species, at 2 n = 14.

H. spontaneum, distichous wild barley (2 rows) with fragile rachis,

H. agriocrithon, polysticheous wild barley (6 rows) with fragile rachis,

H. vulgare, cultivated barley with 6 rows or 2 rows, with solid rachis.

b) Small-grained species. at 2 n = 14 or 28.

All these species are wild; some are annual *(H. murinum, H. maritimum)* and others perennial *(H. bulbosum, H. secalinum).*

2° GEOGRAPHICAL AND GENETIC ORIGIN.

Cultivated barleys are all thought to be derived *from Hordeum spontaneum. H. agrio-crithon* is thought to be a recent, subspontaneous hybrid, derived from natural crosses between *H. spontaneum* and 6-row cultivated barleys.

According to **VAVILov,** the diversification of cultivated barleys would have taken place in two main geographical :

centers : **NEAR EAST** (Transcaucasia, *central* Anatolia, Syria) where Hordeum *spontaneum* predominates.

CENTRAL MIE (High plateaus of Tibet) where we find *Hordeum agriocrithon,* unarmed or short-bearded barleys as well as forms with naked grain.

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3° GENERAL CHARACTERS OF THE PLANT.

a) **Vegetative apparatus.**

At the herbaceous stage, cultivated barley is distinguished from other cereals by : — light green foliage; — the presence of a developed ligule, of glal^,res auricles , generally anthocyanin (however, mutants without auricles have been obtained); — a strong tillering, greater than that of wheat; — a more superficial root system than that of wheat; — a weaker stubble, lodging more easily than that of wheat.

b) Inflorescence.

The inflorescence is a white, bearded *spike .* The rachis bears on each article (**10** to 15) three single-flowered spikelets: one median and two lateral. These are attached directly to the nodes of the rachis in an alternate position, in two rows.

Each spikelet has very narrow glumes; each glume is topped with an awn or beard (except in the case of unarmed or hooded barley). Depending on the fertility of these spikelets, two subspecies are distinguished : — *H. hexastichum* *L.* or 6- row barley also called barley barley : all the spikelets are fertile, the lateral grains being however smaller than the median grains.

— *H. distichum L.* or 2-row barley: only the median spikelets are fertile, the lateral spikelets are sterile and not awned.

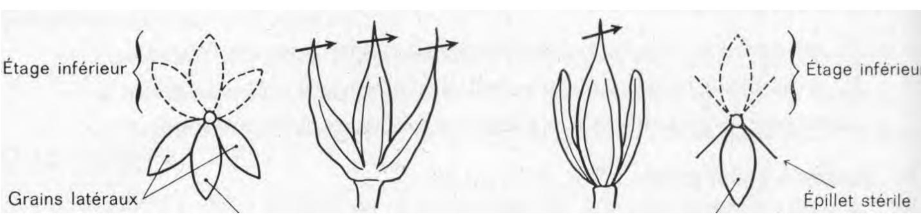

FIG. IV-1. — Comparative arrangement of spikelets in six- row (left) and two-row (right) barley .

By taking into account the compactness of the ear and the adherence of the caryopsis to the glumes (clothed or naked grain), BERGAL and FRIEDBERG distinguished within the two subspecies the following botanical varieties :

	H. hexastichum L.	*H. distichum L.*
Very compact ear — dressed grain	var. *pyramidatum*	var. *zeocrithum L.*
Semi-compact ear — dressed grain	var. *parallelum*	var. *erectum*
Loose ear — dressed grain	var. *pallidum*	var. *nutans*
Loose ear — naked grain	var. *caeleste*	var. *nudum L.*

Some Japanese 6- row varieties are hulless.

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INRA Photos

Six-row barley spike

Two-row barley ear.

c) **Grain.**

It is a caryopsis with adherent glumes in cultivated varieties. In cross section, the same layers of cells can be seen as in wheat; the aleurone layer , however, has three layers of cells instead of just one. The stick (or rachillet) remaining adherent to the grain is always more or less hairy (varietal characteristic).

B. DEVELOPMENT.

1° The development cycle of barley is identical, in its major lines, to that of wheat.

2° *The physiology of development,* although still little studied, appears also very comparable to that of wheat.

Winter barleys need vernalizing temperatures (slightly above the zero growth point, 0 °C) to grow. Correlatively, they show the phenomenon *of hardening when* the temperature gradually drops, giving them a more or less *high* degree of resistance to winter cold.

Spring barley, on the other hand, does not need vernalization to bolt.

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Barley is, moreover, a *long-day species.* It only rises in photoperiods greater than 12-13 hours and the duration of the emergence-earing phase expressed in days or sum of temperatures decreases constantly with the lengthening of the day until reaching a minimum characteristic of the variety.

Thus, for a harvest at the beginning of November, it reaches, for the *Hâtif de Grignon variety,* 170 days and 1,350°C; for a harvest in March, it is only 65 days and 900°C; for a harvest after the end of June, it increases very quickly.

Finally, between the two extreme types of development "winter" and "spring time" there is a range of more or less alternative varieties.

C. ECOLOGY OF GROWTH.

0 TEMPERATURE. 1

The germination zero of barley is very close to 0 OC, identical to that of wheat. However, barley germination is generally faster than that of wheat (greater importance and faster hydrolysis of reserves).

The thermal threshold for leaf damage after winter frost is, as for neighbouring wheat, — 8 oC (at 2 m under cover). The thermal threshold for mortality is approximately — 12 oC without hardening for the most cold-sensitive varieties but reaches — 16 oC for the most resistant types.

The temperature sums required for the entire growing cycle are lower than those for wheat :

— for spring barley, the cycle is 110-120 days or 1,600 to 1,700 OC; — for winter barley, the cycle is 250 days or 1,900 to 2,000 OC.

2° WATER.

The water requirements of a barley crop producing 40 q of grain and 3.5 t of straw can be estimated at around 450-500 mm. These requirements are generally satisfied when it comes to winter barley.

In the case of spring barley, the growing season is reduced At 4 months, the spring rainfall cannot satisfy them.

This explains the importance of soil water reserves for this crop, reserves ensured by *early,* autumn or winter plowing.

Finally, let us note that these water requirements are especially high at the beginning of its development; barley at the end of vegetation is relatively insensitive to drought ; it is the cereal of regions with dry summers such as, in France, *Champagne Berry* for example.

3° NATURE OF THE SOIL.

Barley does not adapt well to heavy, clayey soils, which nitrify slowly in the spring (limiting tillering). It takes better advantage of light, shallow soils, calcareous subsoils, and in particular, of the "rendzina" type.

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This may explain the very ancient location of this culture in Champagne , Berry, Gâtinais.

Like wheat, however, it gives very good yields on loams when it does not lodge; barley also requires non-hollow soils, therefore ploughing carried out well before sowing, followed by careful superficial cultivation.

4° FERTILIZING ELEMENTS.

a) **Nitrogen.**

The numerous tests carried out on nitrogen fertilization of barley allow us to estimate at approximately :

— 25 % the nitrogen utilization coefficient in the grain; —

45 kg/ha the quantities exported by a harvest of 30 q of grain; —

105 to 110 kg the quantities exported by the same harvest and the corresponding straw.

In practice, taking into account the level of resistance to lodging of the best spring barley varieties, the profitability threshold for nitrogen in the Paris Basin would be around 70-80 kg/ha.

Yield factor, nitrogen applied *at high* or *late doses,* also has an influence on the richness of the grain in this element :

Late contribution	*N % of dry grain*	
N kg/ha	*Test A*	*Test **B***
0	**1.48**	**1.79**
12	**1.43**	1.75
24	1.51	1.77
36	**1.52**	**1.80**

b) Phosphorus and potash.

The grain content of these two elements is relatively stable : 0.80 — 0.85 of the dry matter for phosphorus; 0.65 — 0.75 for potash. A harvest of 40 q therefore exports approximately 35 kg of P 205 and 25 to 30 kg of potash.

The composition of straws is more variable. **DEMOLON** cites figures ranging from 0.70 % to 1.07 % of dry matter for P 205 and 0.78 - 1.80 % for K20.

40 q of straw therefore export around 25-40 kg of P205 and 25 to 60 kg of K20.

In total, it can be considered that a contribution of 100 units of these two elements should, in most cases, cover the exports of a barley crop.

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D. ACCIDENTS AND PARASITES.

1° WINTER FROST.

Cold damage is very similar to that observed in winter wheat: damage to the rhizome — to the tillering plate — to the leaves. It is all the more serious as the drop in temperature is more sudden (absence of hardening) and the variety more sensitive.

2°_ THE VERSE.

Of the three cereals (wheat, barley, oats), barley is the most sensitive to this accident.

Winter barley, with very strong tillering, tall straw, late woody, is more sensitive to lodging than spring barley. This actually reflects a lower level of genetic improvement.

In both cases, the sensitivity to lodging is the limiting factor. main source of *nitrogen fertilization,* therefore increasing yields.

3° PARASITES.

The most frequently encountered and most serious are as follows.

a) **Loose smut,** *Ustilago nuda* (Jens.) Rostr.

It is a floral infection smut : the parasite is in a latent state in the embryo. The most classic means of control are : — seed treatment with hot water

(51 °C); — sanitary selection: elimination of smut-affected

plants before ear emergence during the first generations of multiplication.

However, a systemic fungicide, *carboxin,* has recently been developed which is particularly effective against smut, and can be used either alone or in combination with other fungicide products (copper oxyquinolate).

b) Dwarf rust, *Puccinia hordei* (Otth.).

Urediniospores appear in late spring, after ear emergence, under forms very small brown pustules scattered on both sides of the leaves.

c) Yellow rust, *Puccinia glumarum.* Eriks. and Henn.

Although it is a special form of barley, yellow rust of barley has the same characteristics as those of wheat. In recent years, this rust has been observed more frequently in France and Europe. This is the result of the extension of race 24 (some races are said to be common to barley and wheat)

d) Powdery mildew, *Erysiphe graminis* **DC.**

It is very common and often serious, especially on spring barley. Its characteristics are the same as on wheat.

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e) Rhynchosporiosis, *Rhynchosporium secalis* (Oud.) Davis or *Marssonia.*

This disease develops during cool, wet springs. It is characterized by oval-shaped spots 1 to 2 cm long, grayish-white in the center, surrounded by brown.

Common in the West on winter barley, it is rarer on spring barley , except in very early sowing.

f) Helminthosporium blight, *Helminthosporium gramineum* Rabh.

This parasite first develops yellowish streaks on the leaves parallel to the veins; then these streaks turn brown and soon the leaves are as if lacerated into longitudinal strips. The development of the ear is inhibited in parallel (sterility).

The parasite is transmitted by seeds in the grain envelopes.

Seed treatment with organomercury products can combat this disease quite effectively.

Another form of Helminthosporiosis due *to Helminthosporium teres* is much less serious than the previous one.

g) Animal parasites.

Wireworms, oscinia, chlorops, are found on barley, as in others cereals.

Barley is also particularly sensitive to *nematodes,* notably the species *Ditylenchus dipsaci.*

E. TECHNOLOGICAL QUALITIES.

Barley is generally grown for its *grain :* —

either for *livestock feed* (cattle, pigs, poultry); — or for *brewing.*

Secondarily, barley is cultivated for its *straw* (livestock feed or source of humus).

Barley can also be grazed at the tillering stage (winter barley), or harvested green at ear emergence, in pure culture or in association with a legume (winter or spring vetch).

1° GRAIN COMPOSITION.

Overall, the composition of the barley grain differs very little from that of a wheat or corn (see Table 1-2, p.). However, we note :

— a higher cellulose content (2.2 — 6.5 %);

correlatively a lower non-nitrogenous extractive content (63 — 70 %). This results mainly from the existence of the glumes.

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2° QUALITY CRITERIA OF BARLEY.

a) **Criteria of interest to both the** brewer and the breeder.

THE FINESSE.

The finer the grain envelopes, the higher the richness. in starch, energy value and diastatic extract content.

The fineness of the grain can be assessed either by weight (e.g. by weight of glumes) or more simply by eye; a fine grain can be recognized by its very finely wrinkled lower glumes .

This characteristic, being varietal, will constitute a fundamental element in the choice of varieties, *whatever the destination of the harvest.*

PROTEIN CONTENT.

For the farmer, a maximum protein content is desirable; the ideal feed barley should contain 15 % *protein.* But a high carbohydrate content cannot be reconciled with a very high protein content.

To achieve this, it would be necessary to significantly reduce the cellulose content, i.e. to cultivate *naked barley;* these are, for the moment, insufficiently productive.

For the brewer: any excess of proteins is harmful because more proteins = less starch; on the other hand, musts too rich in nitrogen clarify poorly (unstable foams) give less clear and less conversational beers.

However, since proteins are necessary to feed the yeast and give the beer its "softness", the optimum protein content of barley intended for brewing is between 9 and 11 % of the dry weight of the grain.

OTHER CRITERIA.

The other criteria are :

— *the diastatic power* on which good hydrolysis of starch depends within the required time,

— *the color, the odor of the grain,* — *the percentage of broken grain.*

These criteria are indicators of good maturity and good conservation; consequently good biological value of the harvest.

b) **Criteria of interest mainly to the brewer.**

The faculty and the germination energy. During the malting operation, obtaining 95 % of germinated grains in four days constitutes a minimum threshold : high speed of germination and very high germination power are essent The dormancy phenomenon can therefore cause certain batches of barley varieties that were too freshly harvested to be rejected (See below).

High **1,000 grain weight and good sizing.** Starch richness and germination energy are correlated with a high 1,000 grain weight. For this, it is necessary to try to have *a homogeneous batch,* with a maximum of large grains.

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The homogeneity of a batch is measured by a series of three sieves: 2.8; 2.5 and 2.2 mm. Commercially 90 % of the grains should remain on the 2.8 and 2.5 grids; below 2.21e "bottom" should not exceed 2-3 %.

It is because of this *homogeneity* criterion that 6-row barley is excluded from brewing .

Extract content. All the materials in malt which result from the action of amylases, from the splitting of starch into dextrins and maltose, conventionally constitute the "extract".

This extract rate determines the yield in the brewery.

It is varietal and necessarily very correlated with the *fineness of the grain.* It can vary from *76 to 82 % of the dry weight* of the grain depending on the variety and the year.

III. CULTIVATED VARIETIES.

A. SPRING BARLEY VARIETIES.

1⁰ HISTORICAL.

In the last century, only *populations* of barley were cultivated throughout Europe , such as : in England, *the Chevalier Barley;* in Sweden, *the Golden Barley; in* Bohemia and Moravia, the *Hanna Barley;* in France, the *Baillarges,* the *Puy Barley.*

These barleys, mainly grown for brewing, were all 2-row, fine-grained, but *very sensitive to lodging.*

The improvement of these varieties only really began at the beginning of the 20th century. It was carried out in two main stages :

1st step. **Genealogical selection in the populations** with the aim of obtaining pure lines, with grain of as good quality as that of the populations, but more *resistant to lodging.*

This gave rise to a number of varieties that have now disappeared: `Bavaria', `Danubia' (Germany), 'Primus' (Sweden), 'Binder' (Denmark), `Comtesse', Sarah' (France). *2nd stage.* **Genealogical selection after hybridisation** of the first pure lines, with the aim, until before the war, of increasing resistance to lodging and yield; since 1945, the improvement of resistance to parasites, particularly powdery mildew, has been addressed, using new parents from non-European populations or wild species *(Hordeum spontaneum nigrum)* for resistance to powdery mildew.

Thus were successively created : — in

Germany, `Isaria' (1929), 'Haisa **II',** `Piroline' (1955), `Wisa' (1961); — in Denmark, `Kenia' (1937); — in Sweden, 'Rika' (1951); —
in France, `Aurore' (1943),
`Ariel' (1961), `Cérès' (1962), Phi' (1966). 'Piri'

0 2 MORPHOLOGICAL CHARACTERS.

With the exception of two varieties (Iris' and `Mars'), the barley varieties of spring cultivated in France are *two-row,* loose-eared, therefore *nutans.*

Each variety, being a pure line, can be identified using small characters relating to the ear, the grain and the plant in vegetation.

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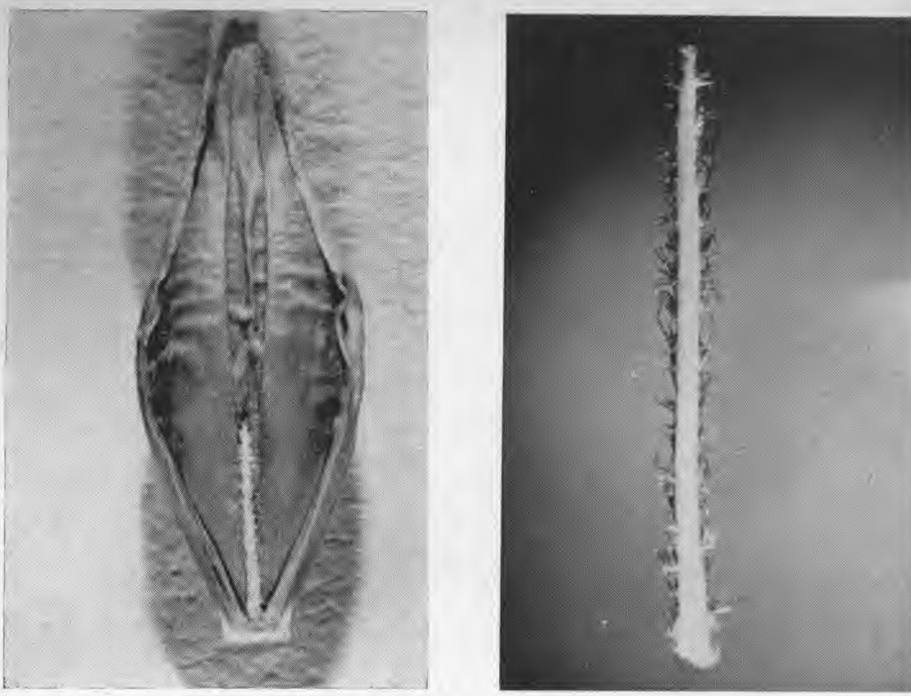
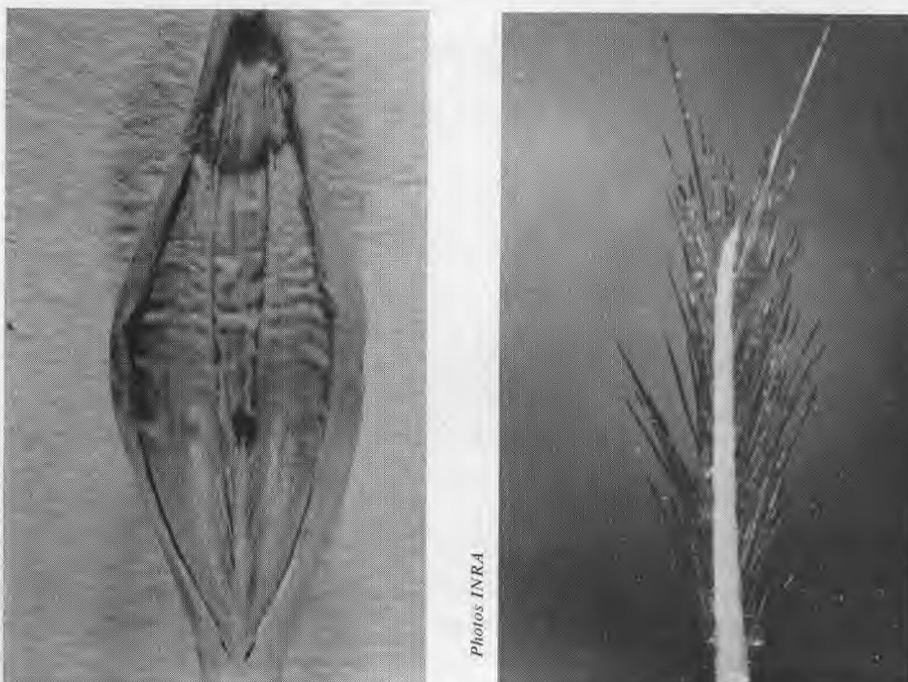


Baguette à poils courts et frisés.



Photos INRA

Baguette à poils longs et droits.

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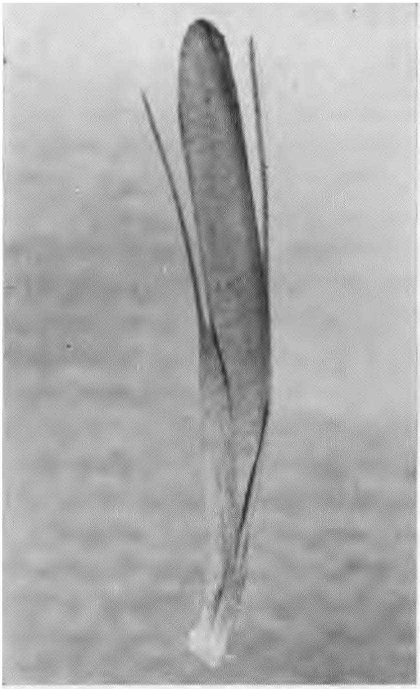
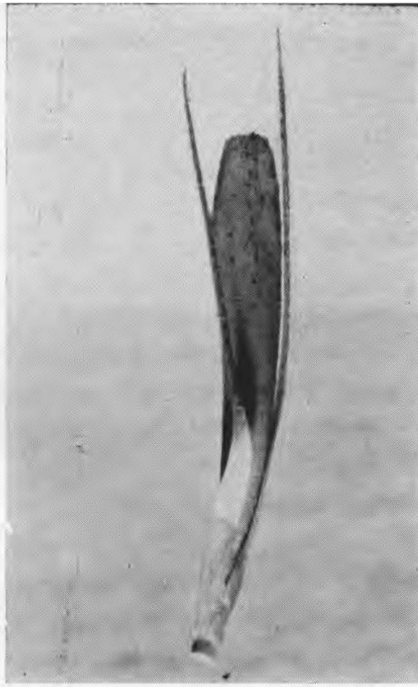
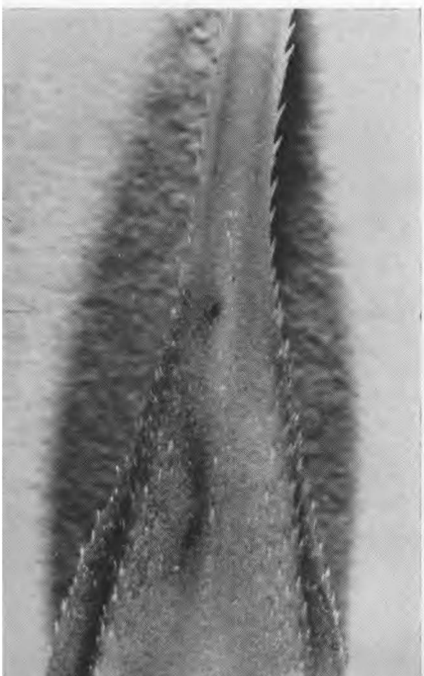


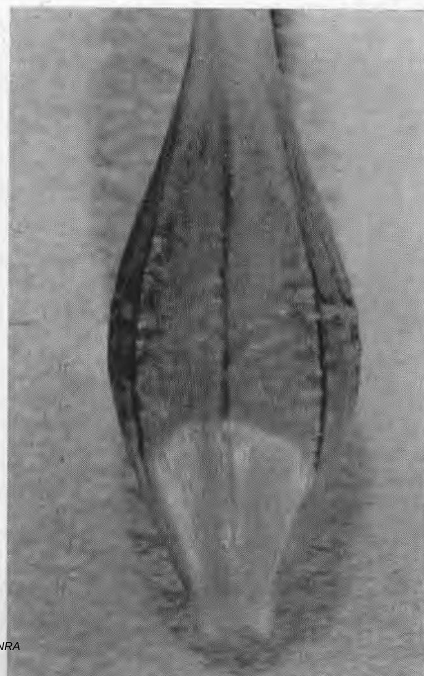
Glumes shorter
than the lower lemma of the sterile spikelet.



Glumes longer than
the lower lemma of the sterile spikelet.



With spines



Without spine

Photos INRA

Dorsal lateral veins of the lower lemma.

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a) The ear.

Shape and dimension of the first article of the rachis, profile of the rachis, shape and length of the sterile spikelet, etc.

b) The grain.

The length of the hairs on the rod and the presence (or absence) of spines on the veins of the lower lemma (Neergaard's caractera) allow the varieties to be classified into four categories **A, B, C** and D. according to the table below.

TABLE IV-4. — *Neergaard Characteristics for the Classification of Barley Varieties*

LOWER *GLUMELLA*	**BAGUETTE** Long, straight hair	Short and curly hair
Lateral ribs without spine and dorsal glume	HAS	C
ribs with spine lower glumelle	B	**D**

Other characteristics can be observed on the grain: hairiness of the edges of the furrow, size and shape of the lodicules, etc.

c) The plant in vegetation ::

Tillering habit, hairiness of leaf sheaths, sensitivity to DDT, barberry, last leaf shape, etc., allow varieties to be differentiated.

0 3 CULTURAL CHARACTERS: CRITERIA FOR CHOOSING VARIETIES.

a) **Productivity and resistance to lodging.**

The current level of productivity of the best spring barley (`Ceres', `Mamie') exceeds 50 q/ha.

The manifestation of this productivity is conditioned at least partially by the dose of nitrogen that the variety can withstand without lodging : the varieties most resistant to lodging are generally also the most productive.

The resistance scale of current varieties is roughly as follows : — *Resistant:* `Betina', `Cérès', `Mamie', `Rika'.

— *Quite resistant:* `Aurore', `Carlsberg **II'.**
— *Quite sensitive:* `Pirline'.
— *Sensitive :* `Beka'.

The varieties of the `Rika' group can, in good soil, behind winter wheat, tolerate 60 kg/ha of nitrogen without risk of lodging.

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overripe barley (the so - called "ears on the cob").

SPIEA Photo

b) Resistance to parasites.

Only a few recent varieties, the majority of which are of foreign origin, show resistance to powdery mildew. These include, in particular, resistant or very insensitive :

`Ariel', 'Betina', `Prélude', `Sultan', 'Wisa'.

c) Quality.

From a varietal point of view, the essential qualitative criterion is the proportion of almond in the grain, that is to say, *the fineness of the glumes :* — this is a characteristic that fluctuates relatively little and is noticeable to the eye; — it is a factor of both *brewing and fodder* quality.

Very fine grained barleys (`Beka') have a hull percentage of 8-9 %; medium fineness barleys (`Rika') are at 10-11 %; coarse grained barleys are at 11-12 % and above.

The extract content closely linked to the percentage of glumes is also varietal and leads to practically the same classification.

Protein content is also a varietal characteristic but seems more fluctuating than extract content: it depends on ripening conditions , linked to the climatic factors of the year; it is also a function of nitrogen fertilization (high doses and late use).

TABLE IV-5. — *Comparative variations in protein and extract content with nitrogen dose* (according to SECOBRA, 1959)

VARIETIES	PROTEIN % DRIED BARLEY			% DRIED BARLEY EXTRACT		
	25 kg/ha of nitrogen	50 kg/ha of nitrogen	difference % 25 kg	25 kg/ha of nitrogen	50 kg/ha of nitrogen	difference % 25 kg
Proctor'	10.3	11.0	+ 6.8	78.4	78.0	— 0.5
`Haïsall'	10.7	11.4	+ 6.5	78.8	78.9	+ 0.1
'Kenia'	10.9	10.7	— 1.9	78.9	79.1	+0.3

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Finally; the manifestation of dormancy *after* harvest makes it impossible to use in brewing of varieties that were too recently harvested : such as `Piroline', `Ariel'.

d) **Precocity.**

In more or less dry conditions (soils with low retention capacity, low spring rainfall), the choice of an early variety is essential, such as `Astrid', for example.

4° CURRENT IMPROVEMENT PROBLEMS.

This essentially :
involves : — further increasing productivity (more rational choice of breeders, use possible hybrid vigor);

— to improve the regularity of yields by increasing *resistance to lodging (creation* of short-strawed barley, even *semi-dwarf),* resistance to parasites (to various races of powdery mildew, and yellow rust;

— to improve the *quality,* particularly the *fineness* of the envelopes, and, especially- in fodder barley, protein content and quality (lysine richness).

B. VARIETIES OF WINTER BARLEY AND WINTER BARLEY.

1° HISTORY.

Until 1937 only *local populations* were cultivated in France : — :
populations known as Vendée and Ile de Ré, very productive, early, but quite sensitive to cold and lodging;

— *populations of the Centre and Champagne,* more resistant to cold but sensitive to lodging and late.

It was only around 1920 that selection work was undertaken abroad and in France with the aim of obtaining *pure lines* more resistant to lodging and more productive than the old populations.

Thus were successively obtained : :

— in Belgium: `Professeur Damseaux' (1937), `Bordia' (1948); —

in Germany : `Probstdorf' (1937), `Atlas' (1955); — in

France: `Hâtif de Grignon' (Bretignère 1937), `Hâtif Bonte' (Bonte 1951), `Frimas' (Blondeau 1956), `Arès'. (INRA, 1959), `Ager' (INRA, 1963), `France Déa' (1962), `Nymphe' (1963), `Maguelone' (INRA, 1966), `Monlon' (1966), `Astrix' (Desprez, 1969).

2° MORPHOLOGICAL CHARACTERS.

With the exception of the *'Noelle'* variety, all these varieties are *six-row* (squash). Furthermore, they differ by small identifying characters similar to those observed in spring barley.

3° CULTURAL CHARACTERS: CRITERIA FOR CHOOSING VARIETIES.

a) **Productivity and resistance to lodging.**

The productivity of the best varieties of winter barley is probably greater than 60 q/ha.

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According to the experimental results of the last 6 years (1964-1969) : — in the West and South zones: `Ager', `Monlon' and `Maguelone' are the most productive; — in the North and Center zones: `Astrix' and `Ager' provide the best yields.

As with other cereals, lodging is one of the main factors limiting the externalization of productivity.

The search for varieties resistant to lodging has led to the creation, as with winter wheat, of varieties with increasingly shorter straw (a characteristic provided in most hybridizations carried out by spring barley).

The following scale illustrates the progress made : high size (120 cm)
`Atlas' fairly high size (110 cm) `Hâtif de
Grignon' medium size (95-100
cm) `Astrix' fairly short size (90
cm) *figer' short size (85 cm) `Maguelone'.

b) Cold resistance.

There is a very large variability between varieties for resistance to cold. Compared to winter wheat, we have roughly the following scale :

	BARLEY	WHEAT
Highly resistant, type...	—	`Minhardi'
Very resistant, type	`Vima'	`Alsace 22'
Resistant, type	`Atlas'	`Côte-d'Or'
Quite tough, type	`Bordia'	`Extra Kolben'
Low sensitivity, type	'Probtsdorf'	`Preparer Etienne'
Quite sensitive, type	—	`Vilmorin 27'
Sensitive, type	`Haity .of Grignon'	`Vilmorin 23'
Very sensitive, type	`Rika'	`Bersée Hybrid'

Given their degree of resistance to cold, the growing area of winter barley : — of the `Hâtif de Grignon' level, is limited to the west and south of France :
ex. `Monlon', `Précoce Lepeuple';

— from the level `Probstdorf, can extend to the Paris basin, eg. `Ager', `Astrix', `Nymphe'; — from the level `Bordia' to `Atlas'; reaches the Eastern region, eg. `France Déa', `Manon'.

c) Alternativeness.

As in winter wheat, there is great variability in this trait, represented by the following scale :

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Winter (sowing deadline, January 15) . . . . `Atlas', `Manou'.
Half-winter ....`Ager', `Astrix', `Noelle'.
Half-alternate .... `Monlon', `Précoce Lepeuple'.
Alternative .... `Nymph', `Maguelone'
Very alternative .... Hâtif de Grignon'.

Most winter or semi-winter varieties should always be sown in the fall.

d) Precocity.

Generally speaking, winter barleys ear and ripen 10 to 15 days before spring barleys. However, there is a fairly wide range of earliness between varieties: ten to twelve days separate the earing of `Hâtif de Grignon' from `Manon' or `Atlas'.

It is in particular his great precocity that "Hâtif de Grignon" has retained some interest in ret in the West, where it is often followed by transplanted cabbage or other stolen summer fodder.

On the other hand, in the East and the Centre, the earliest varieties risk suffering from late frosts on the ears.

e) Quality.

With the exception of 'Noelle', a two-row barley of good brewing value, winter barley is intended solely for fodder.

The six-row varieties (barnyard) do indeed have coarse envelopes. Their extract content is, as a result, 1 to 3 % lower than that of spring barley (77 versus 79 % on average); their protein content is also lower.

There are, moreover, notable differences in thousand grain weight. `Agen' has the lowest (30-32 g), `Hâtif de Grignon', `Astrix', `Monlon' have a high thousand grain weight (40-42 g).

40 CURRENT IMPROVEMENT ISSUES.

The main aim is to obtain : —

winter *barleys that* are even more resistant to lodging, more productive and more resistant to cold than "Ager", resistant to the main *parasites* (powdery mildew, marssonia, dwarf rust), of better grain *quality ;* winter

— *two-row barleys* barleys that are as productive as winter barleys and of better quality.

IV. CULTURE.

A. CULTURE OF SPRING BARLEY.

1st PLACE IN THE ROTATION.

The normal and traditional precedent of spring barley in the rotation is **winter** wheat , The increased resistance to lodging of modern varieties

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However, it allows spring barley to be grown even after *corn* or *beetroot.* It can also follow a *winter catch crop* (forage cabbage, rape, Italian ryegrass).

Finally, it is common in farms with a high cereal production to turn the barley back on itself: under these conditions the yields obtained are always lower than those obtained in a rotation where a weeded plant is used.

2° PREPARATION OF THE SOIL.

a) After cereals, it is necessary to first carry out *early stubble cultivation,* then *autumn plowing,* fairly deep (22-25 cm), burying the basic manure

To store the maximum amount of water, improve or maintain the soil structure, this ploughing must be cloddy and well-dressed.

In the spring, harrowing and cross-cultivation will allow the soil to be reclaimed and the seedbed to be prepared. **b) After a weeded plant or winter catch crop,** plowing 15-20 cm in the fall or spring followed by superficial tillage will generally be sufficient.

3° FUMURE.

a) Base fertilization.

Behind *wheat,* 70 to 100 kg of P205 will be added either in full, during autumn plowing, in the form of slag, or two thirds in the autumn, and one third in the spring , in the form of superphosphate; in parallel 70 to 100 kg of K20 will generally be added during autumn plowing in the form of chloride.

It is also common in spring to add these elements and nitrogen in the form of complete fertilizers.

b) Nitrogen fertilization.

It will essentially depend on the previous one, the nature of the soil and the variety's resistance to lodging.

Behind wheat, in loamy soil, `Rika' and even better `Cérès' can withstand a dose of 70 kg/ha of nitrogen without lodging, whereas `Piroline' will only tolerate 50 kg and `Béka', 40 kg.

According to the experimental results of SPIEA, the national economic optimum can be considered fairly constant between years and equal to 80 nitrogen units per hectare.

In 1966 and 1967, the optimum for the `Mamie' variety was 95 and 108 kg. nitrogen respectively; for `Cérès' 85 and 87; for `Rika', 71 and 85. In calcareous or sandy soils, less well provided with organic matter, the quantities of nitrogen must be increased by 10 to 20 additional units per hectare. The same applies to barley on barley.

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On the other hand, behind weeded plants, these doses must be reduced by 15 to 20 kg/ha.

Nitrogen will also be supplied in *full at sowing,* in the form of ammc-niaconitric preferably.

Splitting the manure (2/3 at sowing, 1/3 at tillering for example) rarely increases the yield but can improve the protein content of the grain, which is interesting for fodder barley.

4° SOWING .

a) Date.

It is necessary to sow as *early as possible,* as soon as the superficial spring work has been carried out : the all too famous saying "On Saint George's Day, sow your barley" is responsible for many failures.

In practice, in the West and the Paris region, you should sow from the end of February, if possible, to the beginning of March. In the North and in Champagne, you will often be led to sow at the end of March.

If sowing has been delayed, choose an early variety.

b) Sowing density.

The doses that we see used are often too high: *300 plants per square meter* constitute a maximum population; in no case should we exceed *150 kg* of seeds. In early sowing, on loamy soil, 100 kg/ha are to advise.

c) Disinfection of seeds.

This will be mandatory (organo-mercuric, copper oxyquinolate; carboxin.

5° MAINTENANCE CARE.

If the weather is dry after sowing, *rolling* may be necessary. On the other hand, any harrowing is to be prohibited.

Weeding of *dicotyledons* must take into account the sensitivity from various varieties of barley to weed-killing phytohormones.

— Do not treat, therefore, with more than 500-700 g/ha of active ingredient of MCPA and preferably use *the amine salts.*

— Take into account varietal sensitivities : `Rika', `Proline', `Reka', are quite sensitive.

Against *wild oats,* the only grass that can be controlled in spring barley, three products can be used: *diallate, triallate* and *barbane.*

a) In pre-sowing.

Effective are diallate and triallate, which, at a dose of 1.2 to 1.5 kg of active ingredient per hectare, diluted in at least 400 l of water, destroy wild oat seedlings when the seeds germinate. Barley can be sown on the same day or in the following days.

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b) Post-emergence.

Barbane is effective at a dose of 400-500 g of active ingredient per hectare. It produces a stop in the growth of wild oats when they are at the 1-2 leaf stage. It is necessary to treat in good weather, as the product normally absorbed by the leaves can be washed away by rain .

6° HARVEST.

Never harvest before over-ripeness; the "hook-ear" stage cons- is a very good benchmark for starting the harvest.

B. CULTURE OF CURRANT AND WINTER BARLEY.

1st PLACE IN THE ROTATION.

Winter barley often occupies the same place as spring barley: it traditionally comes as second straw, behind wheat: This results from the precocity of their sowing which places them with difficulty behind root crops (beetroot or corn) or fodder; also this results from the sensitivity to lodging of the majority of varieties.

However, the potential for producing a variety resistant to lodging (`Ager') is significantly increased when it is implanted in the first straw.

2° PREPARATION OF THE SOIL.

It is often neglected, under the pretext of the great hardiness of the plant and the planned date of sowing.

However, the soil must be prepared as for winter wheat: early stubble cultivation, medium plowing from the end of September to the beginning of October, and superficial tillage before sowing will give a soil that is well settled in depth and cloddy on the surface.

3° FUMURE.

a) The basic fertilization will be comparable to that of wheat: 70 to 100 kg/ha of P205 and as much K20 will be added during plowing, in the form of slag and K chloride, or superphosphate and chloride (super-potassium) in basic soils. **b) Nitrogen fertilization.** After wheat, the old varieties (`Hâtifde Grignon '), do not tolerate more than 35 to 40 kg/ha of nitrogen while the more recent varieties, resistant to lodging, tolerate fertilizations also higher t 80 kg/ha.

Tests carried out by SPIEA have shown that certain varieties (`Ager', `Maguelone', `Nymphe') can make fertilization greater than 100 kg/ha profitable.

As a general rule, this fertilisation should be applied at the end of winter, once or twice (February), in the ammonia-nitric form.

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In cold soil, or at risk of drought, nitrate fertilization may be preferable .

4° SOWING.

Winter squash should be sown early so that the plant has time to tiller before the cold. The optimal date seems to be : — in the East (Champagne), end of September; — in the Paris Basin and North, from end of September to October 15; — in the West and South, from October **1** to 25.

The optimum density is around *200-250 plants* per square meter. (90-120 kg/ha). Sowing should be superficial (2-3 cm maximum).

The seeds will be *disinfected* in the same way as those of spring barley.

5° MAINTENANCE CARE: WEEDING.

Apart from crosskilling if the plants are uprooted after winter, maintenance care is limited to weeding.

This must be undertaken early, if possible as soon as sowing, because the earliness of the latter exposes winter barley to invasion by grasses and weeds .

a) Against grasses, from seeds (wild oats, foxtail, ray Grass, Paturins), we can use :

— at sowing: *Triallate , at* a rate of 1.4 kg/ha of active ingredient. This herbicide must be incorporated carefully using a vibrocultor or a heavy harrow; — pre-emergence: *Neburon, at* a rate of 3 kg/ha of active ingredient; — pre- or post-emergence, *Chlortoluron, at* a dose similar to Neburon. Post-emergence, treatment should preferably be carried out at the start of tillering of the barley; — post-emergence: *metoxuron,* usable at a dose of 5 kg/ha of ma active.

b) **Against dicotyledons;** the herbicides used on soft wheat are applicable to winter barley: nitrate dyes, sodium salts of MCPA, various associations.

Note, however, that neburon, chlortoluron, metoxuron, used against grasses, are active against a very wide range of annual dicotyledons.

6° HARVEST.

This must be done when ripe, because although shelling is not generally a concern, the necks of the ears are likely to break.

Harvesting should be done in dry weather, in order to obtain a humidity level of around 15 %.

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CHAPTER V

OATS

Avena sativa L. (2 *n* = 42).

I. ECONOMICS OF PRODUCTION.

A. OATS IN THE WORLD.

1. A declining **crop ,** this is the primary characteristic of this cereal on a global scale :

1925-1929 1935-1939 1948-1953 1965-1968

Areas . 59,500,000 ha 58,000,000 ha 53,600,000 ha 31,400,000 ha Production. 674,000,000 q 633,000,000 q 621,000,000 q 500,000,000 q Returns. 11.3 q/ha 10.9 q/ha 11.6 q/ha *15.7* q/ha q/ha q/ha

Third cereal 30 years ago, after wheat and rice, oats now rank fifth.

This general decline in areas sown and production can be attributed to four main causes :

(a) The significant reduction in the horse population; following the development of mechanical traction;

(b) The increasing popularity of *other secondary cereals* for animal production : *barley and maize:* — these

are more productive; — their

energy value is much higher than that of oats :
0.80 UF/kg for oats versus 1.0 for barley and 1.15 for corn;

c) The development of wheat cultivation, on soils where previously it was not possible to would only make oats or rye.

d) The general increase in yields: the areas have in fact decreased much more than the needs: less cultivated, oats are better cultivated.

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2.' **The main producing countries** are located in the cool temperate zone of the northern hemisphere. These are (according to FAO, :

1969) : North America	10,228,000 ha	192,910,000 q
Europe . 7,567,000 ha including France		179,390,000 q
	949,000 ha	25,280,000 q
West Germany	821,000 ha	28,930,000 q
Great Britain	380,000 ha	12,240,000 q
USSR	8,998,000 ha	116,390,000 q
Asia	491,000 ha	6,060,000 q

It is in Europe, and more particularly in countries with a *maritime climate and* deep silts, that the best yields are obtained (Belgium, 36.1 q/ha in 1968; Netherlands, 42.0 q/ha). q/ha).

B. OATS IN FRANCE.

1° EVOLUTION OF CULTURE.

TABLE V-1. — *Evolution of oat cultivation in France and of horse numbers over the last sixty years*

YEARS	AREAS (thousands of hectares)	PRODUCTIONS (thousands of quintals)	YIELDS (q/ha)	HORSES (thousands of heads)
1899-1901	3,922	41,030	10.44	2,915
1934-1936	3,297	43,510	13.20	2,807
1945-1947	2,506	30,600	12.10	2,339
1951-1953	2,272	35,720	15.66	2,333
1958-1960	1,475	27,360	18.50	1,960
1964-1966	1,090	24,530	22.50	1,170
1967-1969	953	25,660	27.00	789
1970	799	20,704	26.00	672

Table V-1 shows that over the past sixty years : — the :

surface area has decreased by 3 million hectares, or three quarters of the initial surface

area; — however, production has only decreased % by 40 %, because at the same time *yields have doubled,* due to constant improvement in cultivation techniques and varieties (notably resistance to lodging).

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2° MAIN PRODUCING REGIONS.

In France, *winter oats (135,000* ha) and *spring oats (665,000* ha in *1970)* are grown . Winter oats are mainly found in the west and south of France. Spring oats are mainly grown in the Centre, Champagne and Nord regions.

3° FRENCH PRODUCTION AND MARKETS.

The French harvest is consumed, for the most part, on the farm : out of *25* million quintals produced in *1968,* only 3 million were collected , i.e. *12* % of the total (compared to 40 % for barley). % %

The EEC, which imports *7 to 8* million quintals each year, can offer outlets *for* French production, especially if it is oriented towards the qualities in demand (white or yellow grain varieties) . French exports to the EEC have also increased from *500,000* quintals in *1968* to *1,500,000* in *1969.*

4° FUTURE **OF** CULTURE.

The continued decline in oat production in France and around the world Will it continue for *50* years? Various factors suggest this : — higher prices for other cereals; — UF/ha yields of oats lower *than* those of barley; — limitation of the use of oats in compound feeds due to its very insufficient energy value (too high in cellulose); — correlatively, low marketing and low incentive for technical progress.

The future of oats will therefore depend, as a matter of priority, on its ability *to* become competitive on the cereal market. This requires : a significant increase in yields, through improved varieties and intensification of cultivation techniques; — a considerable improvement in the fodder value of a kilo of harvest : obtaining naked grain *varieties with high energy and protein value* is a possible path.

Other, more secondary elements may also be favourable *to* the survival of the crop : — maintenance, in certain regions at least, of a certain number of horses (butcher horses, breeding stock, development of racing horses); — the interest of a sole of oats, a species not very sensitive to eyespot and footrot , in cereal rotations *with* a high percentage of wheat and barley, species very sensitive *to* these same parasites.

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II. LAPLANTE

A. BOTANICAL CHARACTERS.

1st PLACE IN THE BOTANICAL CLASSIFICATION.

The oats grown in France belong to the genus *Avena,* tribe of Avenées, family of Gramineae.

Most botanists agree to divide this genus into two subgroups of species : —
Euavena or annual oats, cultivated *or* wild, with multi-veined glumes.
— *Avenastrum* or perennial oats , exclusively wild, with glumes with 1-3 veins.

All cultivated oats therefore belong to the *Euavena* group which includes many species.

The work of modern cytogeneticists **(MALZEW, KJxsxA and NISHYAMA)** demonstrates that these species form an allopolyploid series quite comparable to that of *Triticum,* comprising three groups: diploids (2 n = 14, genomes A or Ao), tetraploids (2 n = 28, genomes A and C) and hexaploids (2 n = 42, genomes A, C and **D).**

a) **Diploid group, 2 n = 14 (genome A or A 9).**

Avena strigosa, Strigose oat , with lower glue ending in two fine points, an awn on each grain; *A. pilosa, A. clauda.*

1 Strigueuse, from the Latin *strigosus,* skinny, thin.

Photos IN)

first and second grain of strigosa oats *(Aven strigosa)*

First and second grain of wild oats *(Aven fafua)*

First and second grain of Byzantine avena *(Avena byza*

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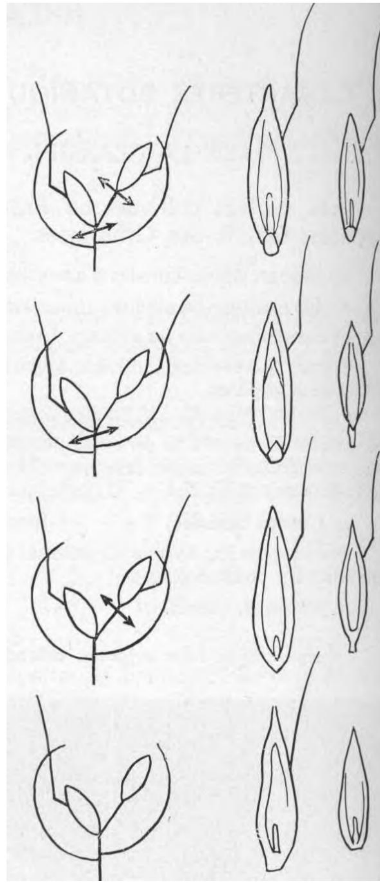
TABLE V-2. — *Classification of the main hexaploid species of the genus Avena*

Mediterranean oats with coated grains.
Lower flowers articulated.
(detaching when ripe)
Upper flowers articulated.
(horseshoe scar)
Strong, angled edge on
each flower .... *A. fatua*
(Northern wild oats)

Upper flowers not articulated. (the entire
spikelet falls off at maturity)
Sharp edge on each
grain .... *A. sterilis*
(Wild oats of the South)

Lower flowers not articulated; the
spikelet only separates from the panicle when
threshing.
Articulated upper flowers. (the
2 grains separate by breaking the rod in
its middle)
An edge on each
grain .... *A. byzantina*
(Byzantine oat)

Upper flowers not articulated.
(the 2 grains only separate during
beating and the breakage of the rod
occurs at the base of the 2nd grain)
Unerarête_seulement:... *A. sativa*
(Cultivated oats)



Asian Oats with naked grains. 5 to 6 fertile
flowers .... *A. nuda*
(Naked Oats)

b) Tetraploid group, 2 n = 28 (genomes A and C).

Avena barbata, Bearded oat.

A. abyssinica, Abyssinian oat, lower lemma ending in four teeth, short spikelets, — cultivated.

c) Hexaploid group

,2 *n* = 42 (genomes A, C and **D).**

This group contains most of the oats currently cultivated. *(A. sativa, A. byzantina)* and the *wild* oats found there *(A. sterilis, A. fatua).*

Their classification is based essentially on the articulation of the first and second flowers, the dressed or naked character of the grain, the area of extension.

Table V-2 presents the essential elements of this classification.

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2° GEOGRAPHICAL AND GENETIC ORIGIN OF THE DIFFERENT SPECIES.

According to MALZEW (1930) annual oats would have a diphyletic origin :

— *the di and tetraploid species* (phylum *Aristulatae)* would have had their center of origin in the western Mediterranean region;

— *the hexaploid species* (phylum *Denticulatae)* would have had their center of origin in Central Asia (Mongolia) cultivated oats having been introduced into Europe as a weed in the starch plant. However, there is no certainty as to the exact lineage of the three chromosomal groups and the species that compose them.

According to TRABUT and MALZEWon would have the lineage :

*A. fatua -*A. sativa --rA. nuda.*
A. sterilis —»ÿ A. byzantine.

According to COFFMAN (1946), on the other hand, we would have the :
lineage : *A. sterilis--> A. byzantins —+A. sativa —>A. fatua.*

In any case, the oats grown in France almost entirely belong to the species *Avena sativa.*

A few rare populations *of Avena byzantina* are cultivated in the Mediterranean area . In addition, a variety belonging to the species *Avena nuda* came into cultivation in 1966.

The wild oats or "wild oats" found in France are : — in the northern half of France. *A. fatua,* mainly — in the southern half, *A. sterilis* (subspecies *ludoviciana, macrocarpa, etc.).*

Photo INRA

Two spikelets of naked oats *(Avena nuda).*

Photo INRA

A batch of naked oat grains *(Avena nuda).*

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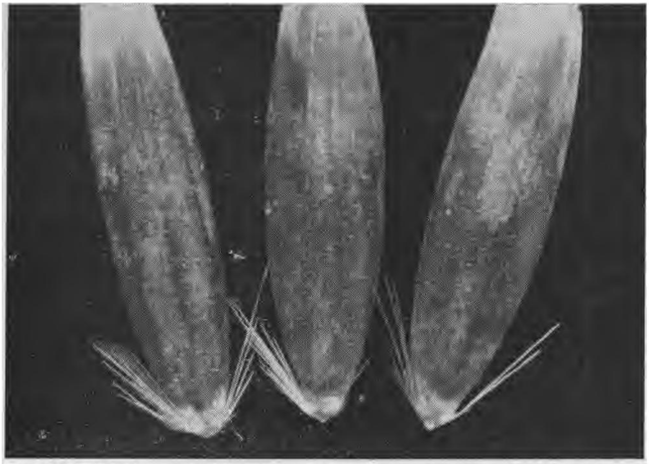
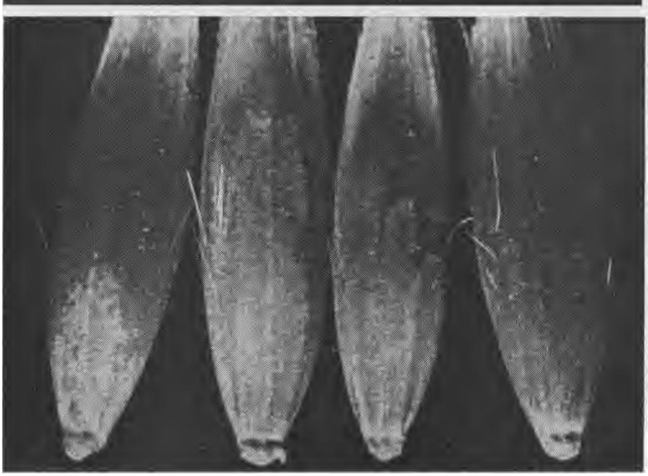


Grain hairiness : long bristles.

Grain hairiness: short bristles.



Hairiness on the back of the glume.

INRA Photos

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0 GENERAL CHARACTERS OF THE PLANT. 3

a) Vegetative apparatus.

At the herbaceous stage, cultivated oats are distinguished from other cereals by : — fairly dark bluish-green foliage, very different from the light green of barley; — the presence, at the base of the blades, of a ligule *without an auricle;* — lower tillering than that of barley (at an equivalent type and stage of development); — a pseudofasciculate root system, deeper than that of barley and wheat.

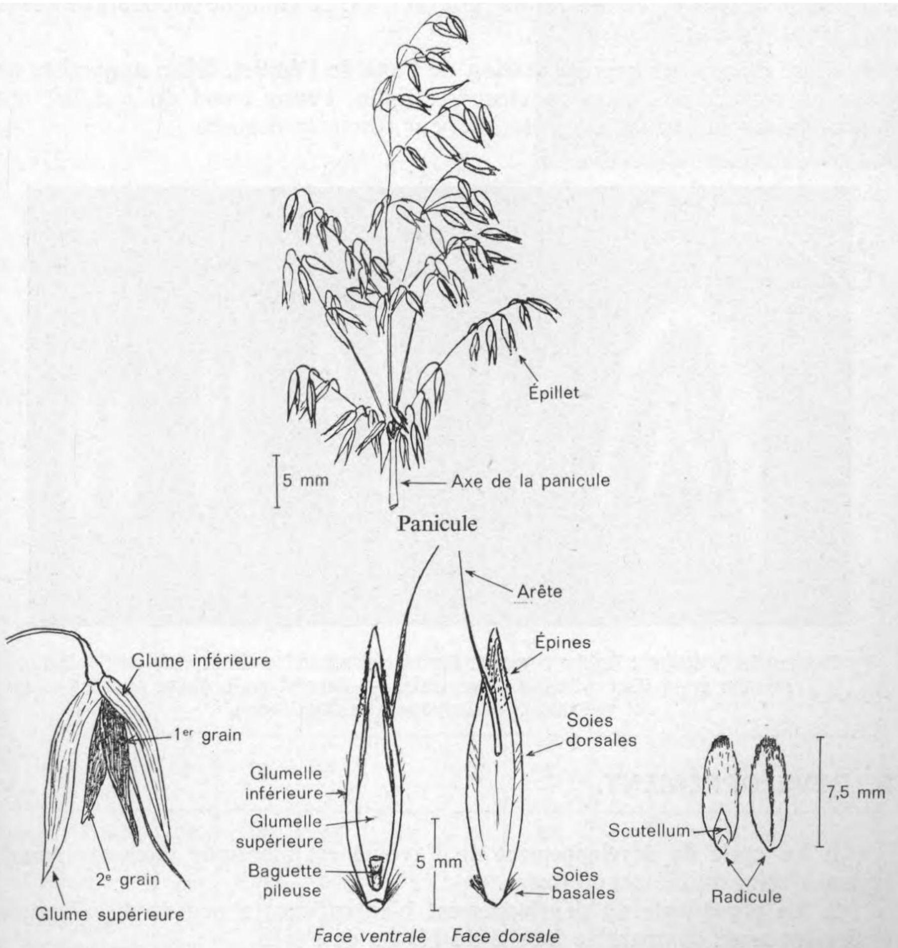

FIG. V-1. — Caractères morphologiques de l'avoine cultivée *(Avena sativa L.)*

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b) Inflorescence (fig. V-1).

The inflorescence is a *panicle,* that is to say a cluster of spikelets carried by long peduncles or racemes arranged in half-whorls.

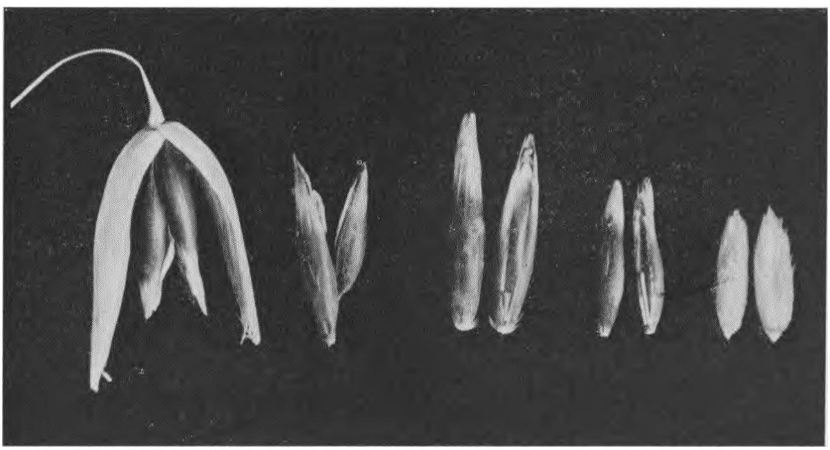
Each spikelet is composed, following the structure specific to grasses, of two multi-veined glumes (lower glume and upper glume), an axis or rachilla bearing two to three flowers surrounded by their glumes.

These flowers produce two to three grains through almost absolute *self-fertilization .*

c) Grain.

It is formed of a hairy caryopsis or *almond* and the two *non-adherent glumes* of the flower that gave birth to it. At maturity, these glumes are either white or colored black, yellow, gray or red. The lower glumes of each grain may have an

awn. The base of the grain, after separation from the axis of the spikelet, reveals a more or less wide area or *scar.* Finally, the internode of the rachillet remaining attached to the grain just below it forms the *rod.*



From left to right : Complete spikelet. First and second grain separated from the spikelet. First grain (dorsal and ventral faces). — Second grain (dorsal and ventral faces). — Caryopsis (both faces).

B. DEVELOPMENT.

1. The development cycle of oats is identical in its major lines, to that of wheat or barley.

2. The physiology of development, although still little studied, also appears to be quite comparable to that of wheat or

barley. a) **Winter oats** have moderate and varietal temperature requiremer vernalizing.

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Aristation. An unaristated grain between two aristated grains.
aristés.

Photo INRA

In spring sowing (April 16) a winter oat (`Winter Grey') not vernalized for 30 days, it can ear on July 3 while vernalized prior to sowing at 2 ears on June 25; another variety (`Rouge d'Algérie') will ear, under the same conditions, respectively on (July 3 and June 14).

These moderate vernalization requirements are correlated with a fairly poor ability to harden off and, consequently, a lower resistance to cold than in wheat or barley. *b)* **Spring oats,** for their part, have no need for

vernalization to bolt.

TABLE V-3. — *Variation in the "emergence-earing "* duration
with the sowing date in Rennes (1965)

VARIETIES	SOWING DATES									
	• March 11		March 25		April 16		May 10		June 21	
	J	T	J	T	I	T	J	T	J	T
Algerian Red	78	900	75	908	64	885	92	1,393	00	∞
Winter Grey (Desprez)	86	1 042	81	995	63	885	85	1,289	00	∞
Winter Avenue of the Priory	87	1,064	77	951	58	818	73		C	C
N. Moyencourt	77	891	71	837	51	700	45	1,079,625,45		'09

J : number of days. — T: sum of temperatures — oc : apex in the vegetative state on September 25. — C: apex at stage C on September 25.

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c) **Oats** are, on the other hand, a **long-day species:** the duration of the emergence-earing phase decreases constantly with *the lengthening of the* day until reaching a minimum characteristic of the variety, all the lower and later the less "winter" the variety. (Table V-3.)

Beyond a certain sowing date, corresponding to a development in *decreasing daylight,* the most "winter" varieties remain *in the vegetative state.*

C. ECOLOGY OF GROWTH.

1° TEMPERATURE.

The germination zero of oats is very close to 0 °C. The sowing-emergence period is however generally longer than that of wheat or barley, due to the presence of the glumes and their greater thickness.

The thermal threshold for leaf damage after winter frost is, as in wheat and barley, around — 8 °C. The thermal threshold for mortality is around — 10 °C without hardening for spring varieties and — **14** °C for the most cold-resistant varieties (grey or black winter).

2° WATER.

a) The water requirements of cultivated oats of the *Avena sativa* type are very high, higher than those of wheat or barley (approximately 1.5 times those of wheat): these are the oats par excellence of regions with *a humid temperate climate,* therefore No and maritime.

Correlatively, cultivated oats require maturity without excessive heat : there is *physiological scalding* as soon as the temperature exceeds a certain threshold close to 28°C (lower threshold than for wheat).

b) Conversely, *Avena byzantina* varieties are much better adapted to dry and hot climates (North Africa, Middle East, southern USA etc.), their water requirements are much lower.

3° NATURE OF THE SOIL.

Traditionally, oats are considered the least demanding cereal in terms of soil (physical nature, acidity, fertility).

It can probably tolerate "raised" land better than wheat or barley.

However, the optimum conditions for germination and then growth of oats *are the same as those for barley or wheat:* it is in deep, well-watered, slightly acidic loamy soils that oats, like wheat, give their best yields. We must therefore not *abuse the hardiness* of this cereal and prepare the soil all the better since, either because of its shallow depth or texture or because of the conditions of the year, its *water reserves* will be limited.

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0 4 FERTILIZING ELEMENTS.

Oats owe their reputation as a "low fertilizer requirement" cereal to their deeper and more developed root system than wheat or barley, which allows them to make better use of leftover manure.

In reality its requirements in fertilizing elements are not much lower than those of wheat, only limited, from a nitrogen point of view, by the level of resistance to lodging of the variety.

In practice: 70-80 kg of P2 05 and K20, 35 to 70 kg of nitrogen per hectare (depending on before the variety and the previous one) will constitute normal contributions.

D. ACCIDENTS AND PARASITES.

1° WINTER FROST .

The destruction is always very serious on winter oats, when the drop in temperature is sudden (no hardening) or early (December).
It is this risk which practically limits the area of winter oat cultivation in the west and south of France, and is also the cause of its decline.

2° THE VERSE.

3° PHYSIOLOGICAL SCALDING.

It is very common on spring oats, due to its *water requirements,* and the existence of a particularly long phase of sensitivity to "heat waves" (it largely exceeds the "water weight threshold").

4° PARASITES.

a) Crown rust, *Puccinia coronata avenae* (Pers.).

It generally appears at ear emergence (early June) in the form of small orange-red pustules (sori), oval in shape, on the blades of the basal leaves; then practically all the leaves can be parasitized. It is a heteroecious rust (secondary hosts: *Rhamnus frangula and Rh. cathartica).*

A severe attack of crown rust (1960) can cause very serious pathological scalding (drop in yields of 30 to 40 %). This rust, common in the West (Finistère) is much rarer elsewhere.

The only current means of control remains *varietal resistance,* despite the very numerous physiological races of this parasite.

b) Loose coal, *Ustilago avenae* (Pers.) Rostr.

Of the two smuts that parasitize oats *(U. avenae and U. levis* = covered smut), **loose smut is the most common in France.**

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Like wheat bunt, it is a *germinative* smut : having penetrated the seedling, at its germination, it only manifests itself at ear emergence : the panicles of infected plants bear blackish masses formed of chlamydospores in place of the spikelets.

In a very serious attack, up to 10 % of charred panicles can be counted. good. The means of control are :

— chemical: organomercuric products; —

genetic: varietal resistance.

c) Powdery mildew, *Erysiphe graminis* DC.

It is common and serious in the West.

d) Black rust, *Puccinia graminis avenae* Ericks. et Henn., is very rare in the West; rarely and always late in the Paris Basin. On the other hand, it is quite common in the east and centre of France.

e) Septoria blight, *Leptosphaeriaavenaria* or *Septoriaavenae* (Frank).

First characterized by the development of brownish, oval spots on the leaf blades, this disease affects the internodes at maturity. These then present a blackish zone a few centimeters above the lower node . The delignification of the tissues then leads to over-ripe *lodging* by *break.*

f) Oscinia, *Oscinella frit L.* is a small dipteran which often causes serious damage to spring oats in the east and south of France. In the Paris Basin and the West, in normal early sowing, its action is negligible.

There are at least three generations per year; the first, or " tillering" generation is the most dangerous on oats.

The symptoms of the attack are very characteristic: the youngest leaf, the third or fourth in early attacks, turns yellow and dries up, the others remaining green; the first generation larvae have destroyed the growing point of the plant. The plant then tends to tiller excessively and will only grow very partially. The best means of control remain cultural : early sowing, stubble cultivation to eliminate the egg-laying sites of the summ

g) Nematodes.

— **The stem** nematode *(Ditylenchus dipsaci)* causes what is called “leek oat” disease: the stems thicken at the base in the shape of a leek, then rot.

The only current means of control is to avoid bringing oats back to the same plot.

— **The root worm (Pratylenchus** *pratensis, Heterodera avenae) :* invaded by the larvae, the young roots quickly cease all absorption activity and decompose.

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h) Deficiency diseases.

— *In manganese* (gray spot disease) : It is common in Brittany on acidic soils where the pH has been raised too quickly (conditioned deficiency). The plant is initially chlorotic, then grey spots appear on the leaf, which breaks at mid-length. Spraying 25-30 kg/ha of a 0.5 % manganese sulphate solution can be a good control measure if applied early.

— *Copper* (land clearing disease) : It is recognized by chlorosis and a wilted appearance of the leaves, the ends of which then dry out.

Spraying young seedlings with a 0.5% copper sulfate solution is a good control method.

III. CULTIVATED VARIETIES.

A. SPRING OAT VARIETIES.

1° HISTORY.

a) Before 1900, the varieties cultivated in France were exclusively *populations* from countries or lines resulting from selection from these populations.

Ex.: `Noire de Brie', `Grise de Houdan', `Joanette'.

These are oats with *colored grains* (black or gray) with very *fine* envelopes, but very *sensitive to lodging* (tall, *fine straw).*

b) From 1900 to 1920, abroad, in Sweden in particular (SVALOF), a genealogical selection was undertaken in certain populations (MILTON), resulting in pure lines with good *resistance to lodging:* `Victoire', `Pluie d'or', `Couronne'.

Then hybridizations are carried out between these varieties leading to new lines, still cultivated today : `Star' (Victory X Crown) `Golden Rain II' (Victory X Golden Rain).

Unlike the French varieties, these varieties all had *white* or *yellow grains,* fairly to very *coarse,* but with good *resistance to* lodging.

c) From 1920 to the present day, hybridizations have been undertaken in France between the two groups of oats :

— from French populations x from Nordic populations, i.e. the crossing of varieties with black and fine grain (sensitive to lodging) with varieties with white and coarse grain (less sensitive to lodging).

One of these crosses `Ligowo'x `Noire de Brie' carried out by Professor **SCHRIBAUX** (1920) was particularly fruitful, with several pure lines combining the desired characteristics .

These `Ligowo' X `Brie' lines have been taken up as parents in multiple crosses with pure French or foreign lines (`M.Binder', `Carsten's') and are at the origin, directly or indirectly, of a certain number of French varieties. Ex.:

(`Ligowo'x `Brie') 176 X `Grise de Houdan, —s `Avoine de Versailles'.

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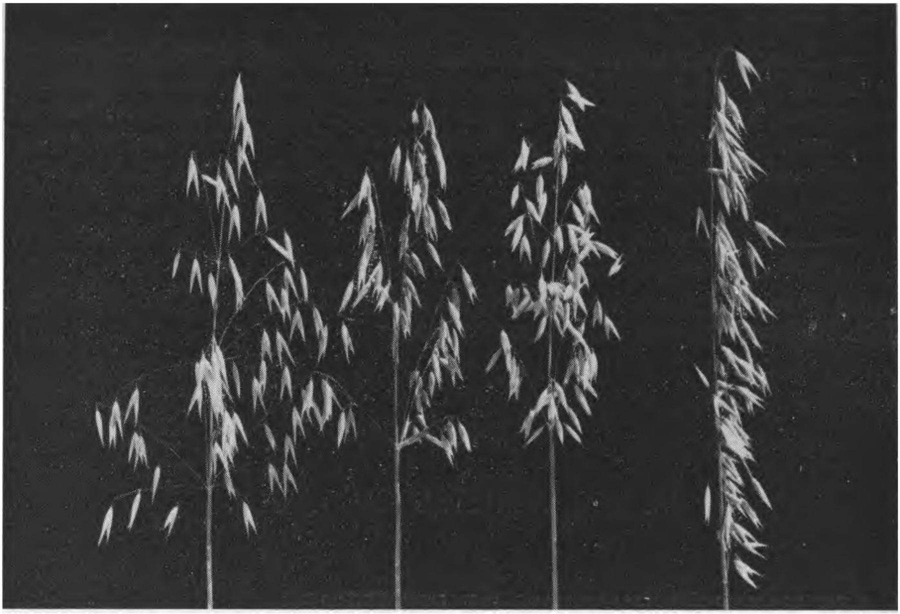

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Four types of panicle habit.

2° MORPHOLOGICAL CHARACTERS.

The main characteristics used to identify current varieties are :

— *the grain,* color, shape, hairiness of the back, of the rod, awn, etc.; — *the plant in vegetation,* hairiness of the sheath of the first leaf, of the edge of the blade; —

the panicle, shape, glaucescence, etc.

3° CULTURAL CHARACTERS: CRITERIA FOR CHOOSING VARIETIES.

a) Grain color.

Traditionally, the colour of the grain remains the primary element on which too many farmers choose their variety of oats: a majority of them in France give preference to a black grain, which explains why the most cultivated French variety is `Noire de Moyencourt'.

The reason is that for these farmers: black grain = fine grain and white grain = coarse grain.

This was right in the past. Because of the way they were obtained (hybridization), fine or coarse varieties exist today in the different coloring groups : the coloring of the grain *should therefore not be taken* into consideration *today* in the choice of variety.

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b) Productivity.

This is certainly a more serious element of choice. But given the great fluctuation of yields, this characteristic is difficult to judge. On the other hand, since oats are most often self-consumed, and less often sold, the farmer does not always attach the desirable importance to this character.

However, the currently (1970) most productive varieties (`Astor', `Borrus', `Condor', `Phoenix') represent a gain of more than 15 % compared to the old varieties (`Pluied'or **II',** `Soleil II') .

c) Resistance to lodging.

Generally speaking, the most productive varieties are also the most resistant to lodging (`Astor', `Condor', `Phoenix', `Borrus'), which allows them to tolerate higher nitrogen fertilizations.

This increase in resistance was achieved by a reduction in size of the plant (90-100 cm) and an increase in the diameter of the culm.

d) Precocity.

Between varieties, there is a variation range of 18 days to more than three weeks (depending on the year) at earing; the earliest ones ear in the first days of June.

Early varieties are especially to be sought where water reserves are limited (shallow soil, or late sowing) and scalding is to be feared. Examples of early to semi-early varieties include: `Caravelle', `•uprime', `Pendek

e) Resistance to parasites.

Crown rust. With the exception of two varieties ('Starblonde' and 'Caravelle'), all varieties cultivated in France, are sensitive to this rust.

However, resistance genes exist in *A. sativa, A. byzantine and A. strigosa* which have been widely used in the USA, Canada and Argentina and have given rise to numerous varieties resistant to various races ('Bond', `Victoria', `Landhafer').

A poured oat.

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Loose smut. The most widely cultivated varieties (such as `Noire de Moyencourt') are very sensitive to it.

However, various French varieties are not very sensitive or resistant to this parasite (`Arabelle', `Gelinotte', `Starblonde').

The possibility of chemical control obviously reduces the interest in this genetic resistance.

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Loose smut of oats *(Ustilago avenae).*

Powdery mildew. Resistances also exist which are still poorly exploited by current varieties: with the exception of `Caravelle' all varieties are sensitive.

f) **Grain quality.**

Various qualitative criteria (brightness of the coloring, shape of the grain) can testify to its *finesse.*

The fundamental element, however, is the *percentage of almond.* This varies from less than 70 % for coarse varieties ('Noire de Moyencourt') to more than 75 % for very fine grain varieties ('Véga').

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From this point of view, naked grain varieties ('Nuprime', the only current variety), represent an ideal solution: the energy value of the grain then increases from 0.80 UF/kg to 1.15 UF, equivalent to that of corn; and the protein content increases from 10-11 % to 14-16 %.

40 CURRENT IMPROVEMENT ISSUES.

These are mainly : —

obtaining varieties with naked grain, with high energy and protein value; — increasing resistance to lodging by a greater reduction in size ; — increasing productivity; — improving resistance to parasites, mainly septoria, powdery mildew and rust.

B. VARIETIES OF WINTER OATS.

1° HISTORY.

As with barley, improvement in winter oats was later than that of spring oats.

Until 1938, only *populations* were cultivated in France, and lines drawn directly from the latter *(Winter Greys, Winter Blacks).*

Their main characteristics were : — a colored grain (gray or black), very fine (76-78 % almond); — a certain resistance to cold; — a fine and tall straw, hence a great *sensitivity to lodging.*

The general principle of the work carried out in France was to combine the qualities of the winter Grey or Black lines (finesse, resistance to cold) with those of the most improved spring oats (resistance to lodging in particular).

Thus were *successively* obtained : — in 1938, `Priory Winter Oats' (`Grised'hiver' X `Grignonnaise'); — in 1959 (`Blancheneige') (`Priory Oats ' X 'Richland').

2° CULTURAL CHARACTERS: CRITERIA **FOR CHOOSING** VARIETIES.

a) Cold resistance.

The `Grise d'hiver' and `Noire d'hiver' lines are still the most resistant to cold of our winter oats. This explains why they are still present in certain regions. `B1ancheneige', which is quite sensitive, can only be grown in the south of France; `Avoine du Prieuré' is of intermediate resistance.

b) Resistance to lodging.

`Priory Oats' and `Snow White' are far ahead, because of their straw medium to short, more resistant than `Winter Grey' or `Winter Black'.

c) Precocity.

`Blancheneige' is very early, an interesting quality in the Mediterranean region .

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d) Resistance to parasites.

All winter oats are susceptible to very susceptible to rust; `Blanche- neige' is slightly susceptible to loose smut. `Peniarth' is slightly susceptible to powdery mildew.

e) Productivity.

`Peniarth' and `Pendrum' are the most productive.

3° IMPROVEMENT OBJECTIVES.

The combination of greater resistance to cold, lodging and parasites with greater productivity remains the main objective. The problem of obtaining naked grain varieties is also posed.

IV. CULTURE.

A. CULTURE OF SPRING OATS.

a) Place in rotation.

Due to its ability to exploit manure residues, the normal place- male and traditional spring oats, is behind a wheat.

However, a very productive variety, resistant to lodging (`Condor') can come directly behind *fodder,* or even *a weeded plant,* or at the head of a crop rotation, on meadow turning for example.

b) Soil preparation.

Stubble cultivation, autumn plowing, spring superficial cultivation, must be the same and carried out as carefully as for spring barley.

c) Manure.

The base dressing will be 70 to 80 units of P_2O_5 and the same amount of K_2O added under the same conditions and in the same forms as for barley.

Nitrogen should be applied just *before sowing,* at the time of superficial cultivation ; 35 to 70 kg of nitrogen per hectare depending on the previous crop and the variety's resistance to lodging are normal inputs. The ammoniaconitric form, the least expensive, is perfectly suitable.

According to the SPIEA results, in 1967, the economic optimum for spring oats corresponded to a nitrogen fertilization of 73 kg/ha. The productivity was 12.7 kg of grain per unit of nitrogen.

d) Sowing.

As with barley, the earliest sowing is always the best ("February oats fill the granary"). So sow as soon as you can get in

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in the land and prepare the soil, that is to say from the end of February and *at the latest the end March.*

According to SPIEA, in 1967, the optimum for oats sown before April *1* (30 trials) was at 78 kg/ha of nitrogen, compared to only 55 kg after this date (8 trials).

350 plants per square meter or 120-130 kg/ha constitutes a *maximum density,* not *to be* exceeded (for early sowing, 300 plants per square meter constitutes an optimum).

The seeds will be treated against smut (organomercurics).

e) Maintenance care.

They limit themselves to chemical weed control.

Some oats are sensitive to synthetic phytohormones (`Blanche de Wattines', `Véga', `Noire de Moyencourt').

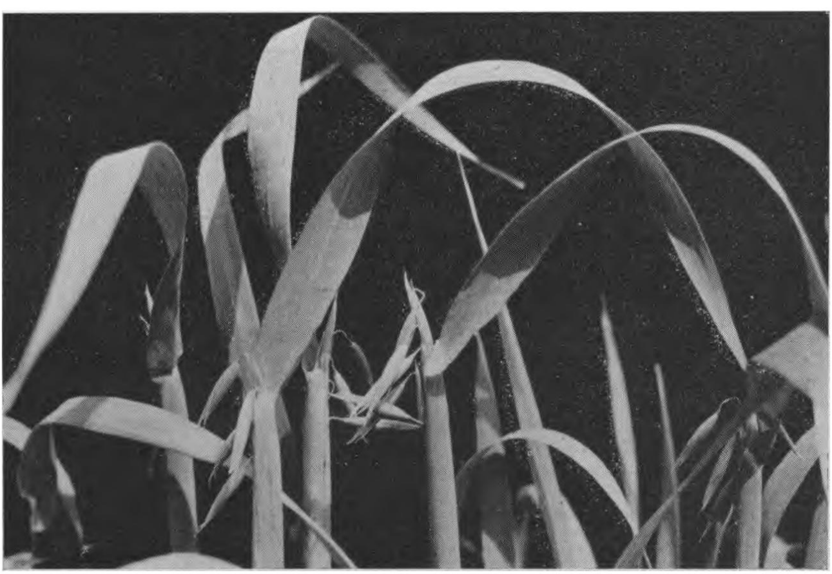
If you are unaware of the resistance of a variety, do not treat with more than 0.5 - 0.7 kg/ha of MCPA active ingredient and preferably use amine or sodium salts and a fairly high quantity of water.

Or treat at the "three leaf" stage with nitrate dyes.

f) Harvest.

A good harvest can reach and exceed 50/qha.

The percentage of waste (broken grains, scalded grains, grain coloring), the *specific weight* (50-60 kg) allows us to assess its quality.



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An oat at the "earing " stage.

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B. CULTURE OF WINTER OATS.

a) Place in rotation.

-Winter oats generally occupy the same place in the rotation as spring oats, that is to say in second straw, behind wheat, or after fodder or a meadow turning.

b) Soil preparation.

Pl It is very similar to that carried out for wheat or winter barley. However, it must be carried out early, as winter oats must be sown before wheat and even winter barley.

c) Manure.

For a variety resistant to lodging and productive, such as `Avoine du Prieuré' or `Blancheneige', the basic and nitrogenous fertilization must be identical to that of spring oats.

As for nitrogen fertilization, this will not be applied at sowing but, as for winter barley, *at the end of winter* (February 15), in ammonium -nitric form.

d) Sowing.

The best sowing dates are very close to those of winter barley. However, due to the greater sensitivity of the varieties to cold and their slower vegetative development, winter oat sowing should be carried out a little before winter barley sowing: from the end of September to October 15 (West) on average.

The optimum density is 250 plants per square meter, or 100 kg/ha maximum.

The seed will be treated against anthrax (organomercurics).

e) Maintenance care.

Weeding will be carried out following the same principles as for spring oats.

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CHAPTER VI

RYE *Secale cereale L. (2 n = 14).*

I. ECONOMICS OF PRODUCTION.

A. RYE IN THE WORLD.

Like oats, rye is a cereal in *full decline:* from 1948 to 1968 the cultivated areas in the world fell from 37 million hectares to *22* million and production fell from 450 million quintals to 330 million (world yield 15 q/ha).

Currently (1970) the main producing countries are : Europe:

(especially Poland and Germany) with 8,000,000 ha and 170,000,000 q;

the USSR with *122,000,000*

q; North and Central America, 685,000 ha and 9,000,000 q.

This regression is linked to two groups of :

factors : a) Rye bread used to be the staple food of large populations, particularly in mountainous areas. The depopulation of mountainous regions, the disappearance of family bread-making and the preference of the wealthy social classes for wheat bread were *the* primary elements of this regression.

b) Rye is, par excellence, and due to the lack of a sufficient level of genetic improvement, the cereal of acidic and poor soils : the improvement in soil fertility has caused the gradual decline of "rye

lands". c) The advent of binding with twine and the adoption of hard materials roofs have taken away some of the outlets for rye straw.

B. ENIFRANCE RYE. FRANCE.

a) **Evolution of culture.**

In 1815 the areas devoted to rye exceeded 2,500,000 ha with a yield of less than 6 q/ha. Today (1970) the areas have fallen to 140,000 ha and the production is 3,000,000 q.

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This regressive evolution is as follows :

1815 .... 2,600,000 ha 15,000,000 q average yield 5.8 q/
1930 ha ....747,000 ha7,212,000 q — — 9.6 q/ q/ha
1950 ha ....503,000 ha6,062,000 q — — 12.0 q/ q/ha
1960 ha ....299,000 ha4,174,000 q — — 14.0 q / ha ....
1965 220,000 ha3,850,000 q — — 17.5 q/ha — 142,000
1970 ha3,015,000 q — — 21.2 q/ha Production is now

confined almost exclusively to the acidic and light soils of the Massif Central and Limousin.

b) **French production and market.**

20 % of French production is marketed (800,000 q in 1969-70) and goes into bread-making. The remaining 80% goes mainly into livestock feed prepared on the farm. Exports are almost non-existent.

The 6th Cereal Plan provides for a reduction in rye areas to 100,000 ha by 1975 and the harvest to 2,500,000 q, with yields increasing from 21 to 25 q/ha.

C. USE.

a) Grain.

The composition of the grain is similar to that of wheat : 9-11

.... % ....%........Lipids .... 1.7-2 Proteins
Carbohydrates. ....67-69 % %.................Cellulose .... 2 -3

The greenish coloring of the abumen gives a certain tint to the flour.

This can be used :

— *in bread making.* We obtain a brown bread, which goes stale less quickly than

wheat bread ; — *in livestock feed in the* form of flour or cooked grain.

b) Straw.

This is very popular, due to its fineness, length and regular caliber, for making roofs (thatches), mats (frames, ties, etc.

c) Green fodder.

In pure culture or in association with a legume (vetch), rye can be grown as autumn fodder for silage in spring.

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H. THE PLANT.

A. BOTANICAL CHARACTERS.

a) **Place in botanical classification.**

Cultivated rye belongs to the *Hordeae tribe,* to the Secale genus , *cereale* species (2 n = **14).**

Classified in the *Cerealia* Schiem group, rye has many affinities with certain wild affinités or subspontaneous species with 14 chromosomes also, classified in the *Agrestes* Schiem group :

Secale montanum: perennial species found in Anatolia and Turkestan.

Secale fragile : annual species whose spike disarticulates at maturity like *Aegilops,* found in central Asia. l'Ægilops,

Secale africanum : annual species found in South Africa.

The rye genome (E) is totally different from the **A, B** or **D** genomes of *Triticum* and *Ægilops* (no homology).

b) Geographical and genetic origin.

Cultivated rye would have as its wild ancestor *S. montanum.* Its center of origin would therefore be close to, if not identical to, that of soft wheat.

Rye was originally thought to have been a weed in wheat and barley. Its spread to northern and western Europe was late, apparently between the Bronze Age and the Iron Age. Its cultivation was first established in difficult areas: mountain ranges of southern Europe , sandy moors of the North. In the Middle Ages, it was found in France in the acidic lands of Bresse, Limagne, and Rouergue; around 1600, rye was the main cereal in France after wheat.

c) General characteristics of the plant.

Rye is a plant with strong tillering and a very spreading habit, with leaf sheaths hairy, leaf blades quite narrow, without auricles, short ligule.

The thatch is very high (1.50-2 m), hollow, rich in cellulose.

The inflorescence is a very awned spike. The spikelets, with narrow and short glumes, have no peduncles and closely overlap each other.

The spikelet bears three flowers, the middle of which is sterile : there are therefore only *two grains per spikelet* and sometimes only one (fig. **VI-1).**

Flowering is very early and fertilization is *cross-fertilization* due to strong self-sterility (self-incompatibility). By forced self-fertilization, however, viable offspring can be obtained within variable limits.

The grain is naked (caryopsis), its albumen is more or less greenish in color , verdâtre,

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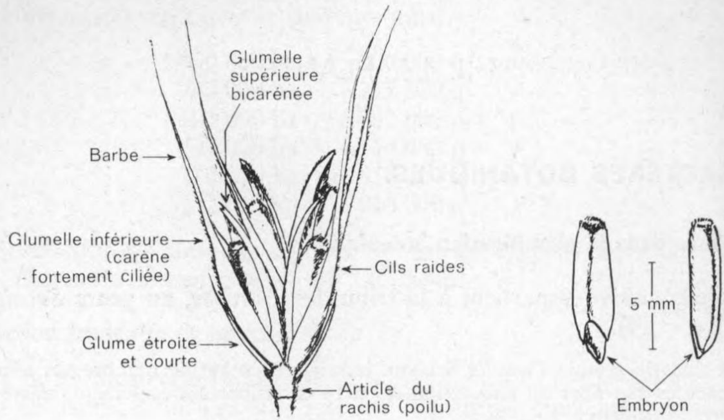

Deux épillets biflores
Caryopse

FIG. VI-1. — Épillets et caryopse du seigle.

B. DEVELOPMENT AND GROWTH.

1. **The development cycle** of rye is comparable to that of wheat.

2. Due to **lower thermal requirements,** its cycle is shorter than that of wheat :

— its germination is faster;
— its earing is much earlier (end of April-beginning of May);
— it can flower at 12 °C (15 °C at least for wheat);
— it ripens at the same time as the earliest wheats.

3. Like winter wheat, winter rye goes through **a vernalizing thermophase** during its cycle : 40 days at +6 °C for 'Petkus' rye. However, GREGORY and PURVIS have shown that the *short photoperiod* can replace the vernalizing effect of the cold (spring rye, on the other hand, has no need for vernalization).

4. In long days, spring rye forms a draft of ears at the 7-leaf stage; in short days, it must wait until the 25-leaf stage : rye is therefore typically a **long-day plant.**

5. **The cold resistance** of winter rye is high, higher than that of most cultivated wheats, which allows it to withstand very well the harsh winters of mountainous or continental regions, provided that it is well established and has tillered before the cold.

On the other hand, its very early earliness and flowering expose it to spring frosts.

6. Rye fears stagnant moisture and requires well-drained soil.

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A mature rye crop.

7. Rye's tolerance to **soil acidity** is well known (optimum pH around 5.5). However, its *requirements for fertilizing elements* are less well defined.

According to GAROLA, 25 q of rye would export approximately :

	Grain	Straw	Total
Nitrogen.	53 kg	45 kg	98 kg
Phosphorus	16	**21**	37
Potash	15 Lime	111	126
11		39	50

Exports of potash (straw) and nitrogen (4 kg/q) would therefore be the most important.

In addition, nitrogen requirements would be high between tillering and flowering. which would give the contribution to tillering a particular importance.

Rye is finally the least sensitive of cereals to copper deficiency .

C. ACCIDENTS AND PARASITES.

a) Accidents.

These are mainly **winter frost,** lodging , **which** is quite rare, and **coulure, which** is more frequent and follows spring frosts.

b) Parasites.

Fusarium wilt, *Fusarium nivale,* can develop following prolonged snow cover of the crop.

Septoria, *Septoria tritici and S. nodorum* can attack both rye and wheat.

Powdery mildew, *Erysiphe graminis,* can be observed occasionally.

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Rusts. Black rust *(P. graminis secalis),* yellow rust *(P. glumarum)* and especially brown rust *(P. dispersa)* can attack rye.

Marssonia , *Rhynchosporium secalis* can, as in winter barley, develop during cool, wet springs.

Ergot, *Claviceps purpurea* is common in some years: consumption of ergot flours can be dangerous due to the vasoconstrictor action of ergot. Sorting seeds and burying sclerotia are the best means of control.

Chlorops can cause some damage in some years .

III. VARIETIES.

A. ORIGIN AND METHODS OF OBTAINING.

Until now, the few varieties cultivated in France and in Europe are populations resulting *from hybridizations* between "country" varieties having complementary characteristics and from *mass selection* in the offspring.

This is how the variety `Petkus' was obtained around 1880 by Von Lochow (Germany), from of two local ryes `Pirnaer' and `Probsteir'.

This method is, however, quite empirical; in particular, it does not allow *the very strong heterosis effect* in rye to be fully exploited.

Studies have also been developed in France (Clermont-Ferrand) and abroad (Weihenstephan, Germany) to create other, better defined types of varieties.

— Synthetic varieties resulting from the crossing of a certain number of pure lines, themselves obtained by inbreeding and selected for their good suitability for combining.

— Synthetic tetraploid varieties resulting from artificial chromosome doubling (colchicine) from lines obtained and combined according to the previous scheme.

B. CULTURAL CHARACTERS OF CURRENT VARIETIES.

The range of varieties cultivated in France is very limited.

Alongside some poorly defined "country" varieties, the following are listed in the catalogue (1970) :

1° WINTER RYE.

a) Diploid varieties.

`Dominant' (Cebeco, Netherlands), very productive; `Petkus normal' (Germany) suitable for very light soils; `Petkus à paille courte', preferable in rich soils; `Zelder' (CIV, Netherlands), also very productive.

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b) Tetraploid varieties.

'Everest' (Lepeuple), late with short straw;

'Tetraseigle-Petkus' (Von Lochow), late with tall straw.

2° SPRING RYE.

a) Diploid variety.

'Spring Petkus', with a development rate comparable to that of spring barley.

b) Tetraploid variety.

'Pipo' (Lafite).

IV. CULTURE.

1st PLACE IN THE ROTATION.

In poor soil, rye can take the place of winter wheat and come directly ment behind a potato or fodder.

It is also common to find it in the mountains (Massif Central), as a second straw after barley or oats. In Germany, in sandy soils, rye often comes after a green manure (lupin).

2° SOIL PREPARATION AND FERTILIZATION.

Soil preparation should be similar to that of any other cereal: plowing medium, repeated croskillage and harrowing.

The recommended, but too rarely applied, base fertilization is 60 to 70 kg/ha of P205 and 70 to 80 kg of **K20** incorporated into the ploughing.

Nitrogen fertilization, according to tests carried out in Weihenstephan (Germany), should be applied in this region, two thirds at the end of February and one third at the end of tillering.

It is likely that these results could be transposed to our regions, joining in this respect the technique already recommended for winter wheat.

The doses of nitrogen will essentially depend on the previous one: they can vary from 20 kg/ha after fodder to 40-60 kg/ha after secondary cereals and in poor soils.

3° SOWING.

It is necessary to sow *as early as possible,* in the mountains as well as on the plains, particularly in light soils, where the effects of frost can be most noticeable.

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In the mountains, sowing is done from *the beginning of September to the end of October,* depending on the altitude and latitude; in the plains, from the end of September to the beginning of November, depending on the harshness of the winters.

It is necessary to sow in rows spaced 18-20 cm apart, at a density close to that of winter wheat (100-120 kg/ha).

The seeds will be treated, in particular, with organo-mercurics or maneb *(Fusarium nivale).*

4° MAINTENANCE CARE.

After a harsh winter, having lifted the earth and uprooted the rye, croskillage or rolling may be necessary.

Weeding must be carried out under the same conditions as wheat.

5° HARVEST.

A good harvest can reach and even exceed 40 q/ha, the weight per hectolitre varying from 70 to 77 kg, the straw yield from 5 to 6 t.

The productivity potential of rye *is higher than* generally believed and yields of *50 and 60 q/ ha* could be obtained in very good cultivation.

V. MIXED OIL.

In some regions, the wheat-plus-mixture was once widely cultivated. rye, or *meslin.* Today, hardly more than 11,000 ha are cultivated.

The main aim of this practice was to obtain, at the time of harvest, and without subsequent operations on the farm, a mixture that was better balanced from a nutritional point of view .

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CHAPTER VII

BUCKWHEAT

Fagopyrum esculentum Moench (2 n =16).

I. ECONOMICS OF PRODUCTION.

a) Buckwheat in the world.

A crop in constant decline, 3,400,000 ha in 1950, 2,000,000 ha in 1965, 1,850,000 ha in 1968, buckwheat is hardly cultivated today except in the USSR (1,700,000 ha in 1968), Poland, Canada and the USA.

b) Buckwheat in France.

Introduced into France probably in the 15th century, the cultivation of buckwheat, also called "black wheat", reached its peak in the 19th century around 1860 with 740,000 ha and 7,500,000 q.

Since then, it has continued to decline :

1913 : 451,000 ha - 4,600,000 1963: 44,300 ha - 443,000
q 1938 : 261,000 ha -2,400,000 q q 1970: 15,800 ha - 185,000 q

The causes of this regression are :

— soil improvement: buckwheat, like rye, is a plant of acidic and poor soils; — its yields fluctuate greatly from one year to the next; — the nutritional value of its grain is lower than that of other cereals (12 % cellulose), that of its flour also (6 % protein).

Currently, the main growing regions are the Massif Central, Limousin and Brittany.

(c) **Uses.**

Buckwheat finds its outlets in human food (cakes, crepes, porridge), secondarily in the breeding of pigs, poultry, pheasants (defective batches in addition to corn). It can also be used as green fodder: in summer catch crops, due to its great speed of growth.

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II. THE PLANT.

1° BOTANICAL STUDY.

Buckwheat belongs to the Polygonaceae family and the *Fagopyrum* genus (2 *n*= 16).

This genus includes several species. 1°

Fagopyrum esculentum (Polygonum Fagopyrum) is the common buckwheat, it is the most cultivated.

It is an annual plant *with* branched, reddish stems, pointed heart-shaped leaves , and an inflorescence in a cluster of cymes.

The flowers are very numerous (several hundred per plant), pinkish white, with *very staggered* flowering and maturation. They are hermaphroditic, but heterostylous . As a result, *cross-fertilization is the rule,* although self-fertilization is possible.

The fruit is a floury *achene ,* gray or blackish

trigone. 2° *Fagopyrum tataricum* (**Tartarian** Buckwheat), very early, still cultivated locally, is a frequent impurity in ordinary buckwheat. Its stem is greener, its leaves wider than long, *its flowers greenish.*

Its grain is of poor quality (exclusive animal consumption). 3°

Fagopyrum stenocarpa (Rye buckwheat), *F. emarginatum* (Ciliated buckwhe

Buckwheat grows wild in Manchuria, near Lake Baikal, China and in Nepal. It was *introduced* to Eastern Europe around 1400.

2° ECOLOGICAL STUDY.

(a) Climatic requirements.

The buckwheat cultivation area extends up to 70 ° north latitude and up to 800 m in altitude .

Its germination is rapid : 8 days at 4.3°C, 4 days at 10.2°C.

The sum of the temperatures of its vegetative cycle varies from 1,000 to 1,500 °C, depending on the variety; in our climate, it therefore completes its cycle in three months.

It is particularly *sensitive to cold:* spring and autumn frosts are the limiting factors for its cultivation in our regions.

It is also *very demanding in terms of water* until flowering (period of great growth). Then, dry and warm weather is necessary for good fertilization : rain and wind cause coulure.

(b) Agricultural requirements.

Buckwheat tolerates *poor and acidic* soils : it grows well on cleared land of moors, on old natural meadows.

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A buckwheat culture in full bloom.

Photo INRA

Buckwheat is not, however, an undemanding plant.

According to BOISCHOT and HURLEZ, to form a quintal of grain, it requires :

N 3.3 kg; P205 = 3.2 kg; K20 = 4.0 kg; Ca0= 3.9 kg.

Buckwheat is also very sensitive to the Cl ion: potassium chloride must therefore be added well in advance.

H. VARIETIES.

The varieties cultivated in France are all populations resulting from selection massale. Let us quote :

— **`Silver Buckwheat',** the most productive variety, introduced into France around 1877 by VILMORIN ANDRIEUX and propagated in the West by RIEFFEL.

A `LaHarpe' selection **(INRA)** *was* taken from it : it is more homogeneous and has larger grains than the initial population.

— `*Black buckwheat'* (or ordinary) cultivated in the past.

— `*Petit Prussien'* or `*Petit Breton',* small grain, grown in Brittany.

The main objectives of improving these varieties are : —
productivity: this could be increased by creating synthetic varieties from self-fertilized lines (use of hybrid vigor);
— *regularity of yields:* greater homogeneity of flowering; — *grain quality.*

IV. CULTURE.

a) Place in rotation.

Buckwheat is often grown at the head of a crop rotation, on cleared land or in place of fallow land; it is also often found in place of a second cereal, oats or rye.

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In catch crops, it comes after an annual spring fodder (vetch, rye, for example).

b) **Soil preparation and manuring.**

Medium to light plowing is carried out, ensuring well-loosened soil on the surface.

The base dressing should be :

— *in main crop :* 400-500 kg of slag and 150-200 kg of potassium chloride; — *in catch crop:* 250 kg of

superphosphate when sowing; 100 kg of chloride when plowing.

Nitrogen fertilization of the order of 40 to 60 kg/ha in the form of ammonium nitrate (150-200 kg) would be justified.

Unfortunately, buckwheat too often receives no fertilization.

c) Sowing.

As a main crop, buckwheat is sown from the end of April to the end of June in our regions.

As a catch crop, it is sown from the end of June to the end of July.

The optimum doses are around 40 to 60 kg/ha in lines spaced 10-15 cm apart.

d) Harvest.

It is done in the second half of September. It is delicate because the maturity is staggered.

The sheaves are generally placed in small staves, upright, tight at the top, loose at the base.

The grain, after threshing, must be spread out and stirred to ensure complete drying.

Yields of 20 q/ha are possible, but too frequently they reach barely 10 q/ha (French average: 12 q/ha).

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CHAPTER VIII

MAÏS *Zea mays* L. (2 *n* = 20).

I. HISTORY OF CULTURE.

Corn is thought to have originated in South or Central America.

When Europeans arrived in the New World around 1492, corn was a staple of indigenous agriculture from the latitude of La Plata to the present-day United States, while it was completely unknown in Europe and Asia.

Known to the oldest civilized peoples of America (Aztecs, Mayans, Incas, etc.), corn is probably the oldest crop on this continent: ears or grains of corn have been found in the tombs of the Incas in Peru (3,000 years BC).

Corn seems to have *been* introduced into Spain around 1519 by Fernand CORTEZ. Its cultivation was already reported in Béarn at the end of the 16th century. It thrived there at the expense of millet, hence the local names of mil or millette.

Corn then spread to Languedoc, the Rhone Valley, Isère, Bresse, Alsace and Baden; in these different regions, the fallow-wheat rotation often gave way to that of corn-wheat.

II. ECONOMICS OF PRODUCTION.

A. CORN IN THE WORLD.

a) Areas.

In 1968, the area cultivated with corn in the world was of the order of 106 million hectares, placing corn in third place among cereals, after wheat and rice. Areas have also been increasing quite significantly over the past 30 years: 89 million hectares in 1934-1938, 100 million in 1955, 106 in 1960.

b) Production.

The world corn harvest in 1968 (according to FAO) was 2,250,000,000 q. It placed corn in third place among cereals, after wheat (3,300,000,000 q) and rice (2,840,000,000 q).

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This production was distributed geographically as follows : North and Central

America .... 1,251,000,000 q of which United States 1,116,000,000 q 327,000,000 q 71,000,000 q 68,000,000 q 54,000,000 q 40,000,000 q South

Europe ....
including Romania ....

Yugoslavia ....
France ....
Italy. ....

America .... 226,000,000 q 128,000,000 q 66,000,000
including Brazil. .... q 183,000,000

Argentina. .... q 000 q 53,000

Africa. .... 173,000,000 q
including South Africa ....

Asia .... 57,000,000 q
including India. .... 88,000,000 q

USSR ....

North America (United States) is therefore clearly at the top of the producing regions with 52 % of the world tonnage. In Europe, the countries of Central Europe (Romania, Yugoslavia), and in the EEC France and Italy are the main producing countries.

Remarkably, world corn production has more than doubled in 30 years (Table VIII-1).

TABLE VIII-1. — Evolution of *corn-grain cultivation* in the world *over the past thirty years*

PERIODS	AREAS (million hectares)	PRODUCTIONS (millions of quintals)	YIELDS (q/ha)
1934-38	85	112	12.9
1948-52	88	140	15.9
1952-56	91	155	17.0
1958-62	101	208	20.5
1964-68	103	232	23.2

This increase is mainly the result of a considerable improvement yields: these have doubled.

The entry into cultivation first in the United States, then in Europe, of *hybrid varieties* is the main cause.

B. **CORN IN FRANCE.**

1° Before 1948, corn was a very localized crop in France (Basque Country, Béarn, Gers, Landes, Bresse, Alsace) and, economically, very seconda

After remaining at around 600,000 ha until the end of the 19th century,

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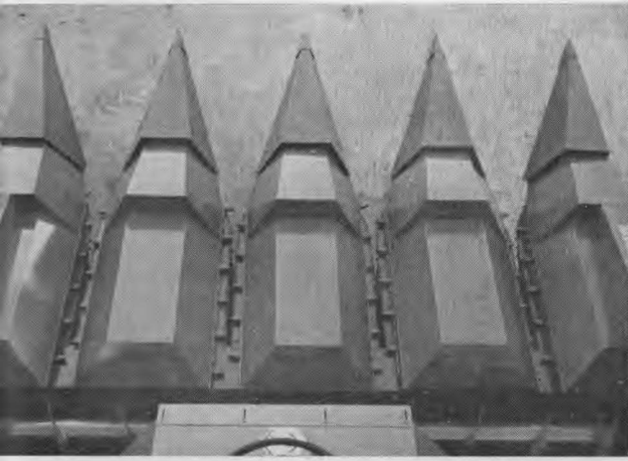

Four-row harvester headers.

Self-propelled corn sheller.

Photos RIVIERRE-CAS

The ears can also be stored on *ventilated platforms* similar to those used for drying fodder.

II. GRAIN HARVEST.

Two types of machines are used.

The " *corn sheller"* machine that picks and shells corn directly, even wet. There are 2 and even 3 row machines, towed or self-propelled.

The *combine harvester* can also thresh corn provided that the conventional cutter bar is replaced by headers and the necessary modifications are made to both the threshing drum and the counter-concave.

Grain harvesting allows acceptable work to be done up to a moisture content of 35 %.

As soon as the harvest is over, *it must be dried in hot air (unless* the wet grain is ensiled).

Dryers are of two types : *static and continuous.* Both are expensive.

— To amortize a *static dryer,* it is necessary to dry at least 2,500 q per year (40 ha).

— For a *continuous dryer,* at least *5,000 q* (80 ha) must be dried .

Practically the two harvest chains in ears and grains are not mutually exclusive,

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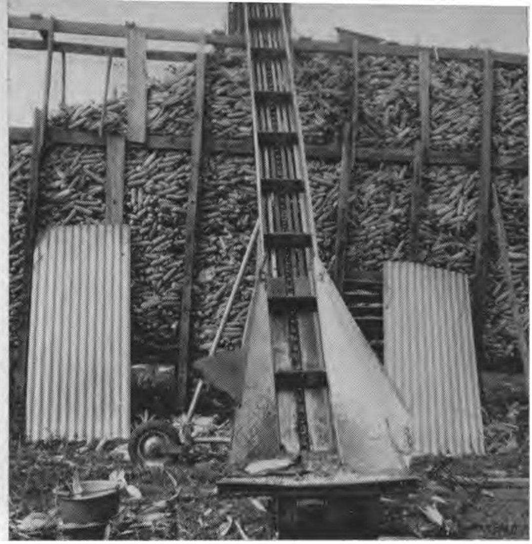

s SPJEA

A corn crib. Note the simplicity of the construction (wood, wire mesh, corrugated asbestos cement).

Loading corn cobs into a crib.

The rational development of grain corn cultivation on a farm requires means of conservation and drying : — at the :

farm level, crib; — at the regional

level , cooperative dryer and silo, for example.

B. FODDER CORN .

Refer to volume I “Foam”, p. 134.

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CHAPTER IX

SORGHUM-GRAIN

Sorghum durra Stapf, *S. subglabrescens, S. caffrorum* Beauv. (2 n = 20).

I. GENERAL CHARACTERS OF SORGHUS.

A. BOTANICAL CLASSIFICATION.

Cultivated sorghums belong to the genus *Sorghum L.,* of the tribe *Andropogoneae.*

This is characterized by spikelets which are deciduous at maturity, usually arranged in pairs, one of which is sessile, fertile and often awned, the other pedicellate, sterile.

The genus *Sorghum* includes perennial and other annual species, with panicles of very variable size, compact to more or less loose in cultivated species , especially those intended for grain production.

The systematics of sorghums has not yet been definitively established.

SNOWDEN (1961) proposed the following classification for these various species :

SUBSECTION HALEPENSIA.

— *S. halepense* (L.) Pers. 2 *n* = 40, Aleppo sorghum, herbaceous type, wild, perennial, domestic in certain regions (Mediterranean South, frequent weed).

— *S. almum* Parodi 2 n = 40 = Herbaceous type, wild perennial, also domesticated (fodder).

SUBSECTION ARUNDINACEA.

Sorghums generally annual at 2 *n* = 20.

Spontaneous series.

Wild grasses with fragile inflorescence.

Sativa series.

— *Sorghum sativum* or *S. vulgare* Pers., a species with a relatively compact inflorescence, not breaking at maturity; the sessile spikelets remain on the panicle, with or without pedicellate spikelets, thus allowing the harvesting of the entire panicles bearing the ripe grains.

— *S. vulgare var. sudanense* Piper (Hitschc).

The species *S. vulgare* includes a number of botanical subseries and varieties. Example :

— *S. durra, S. subglabrescens* (subseries Durra).

— *S. bicolor, S. dochna* (subseries Bicolor).

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B. AGRONOMIC CLASSIFICATION.

In order of decreasing economic importance, we can (according to P. HUGUES) divide cultivated sorghums into five categories.

1° **Grain sorghums (S.** *durra, S. subglabrescens, S. callrorum)*

These are the varieties and hybrids cultivated for grain production.

2° Forage sorghums *(S. bicolor).*

These are large varieties and hybrids with a juicy, more or less sweet or dry stem, as well as hybrids obtained recently, with a smaller size and for two purposes: fodder and (or grain).

3° **Syrup sorghums and sugar sorghums** *(S. dochna* var. *saccharatum).*

Generally, these are very tall sorghums, with large stems containing juicy marrow and a high sugar content.

4° Broom sorghum *(S. dochna* **var.** *technicum).*

These sorghums are cultivated for the use of their elongated panicles at the end of numerous long pedicels, by the broom and dustpan industry.

5° Herbaceous sorghums *(S. vulgare var. sudanense).*

This group is of relatively recent constitution, following the introduction (already old) into cultivation of *Sudan grass* or *Sudan-Grass* and its hybrids with sorghums (recently obtained).

To this group we can add *Aleppo Sorghum* (Johnson grass) and *Sorghum aleppo* (Perennial. Sour grass).

Until flowering, all these sorghums contain a glucoside that generates hydrocyanic acid, *durrhin*, which can cause fatal accidents in livestock . After flowering, however, the glucoside is found in much lower quantities, below the toxicity threshold.

C. GEOGRAPHICAL DISTRIBUTION OF SORGHUS CULTIVATED IN THE WORLD.

1° SORGHUS OUTSIDE EUROPE.

From the warm regions of the old continent, sorghums have spread, under the influence of human migrations and relations, throughout the intertropical zone, and even into the temperate zones of the two hemispheres; in a very general way between the 40 ° parallels North and South.

Currently, we see that a push of the culture tends to take place towards the north, in a way similar, although much more reduced, to that of corn.

In addition to its interest in feeding livestock, grain constitutes, for human consumption, in the form of flour, drinks, etc., the most important plant food in the dry and hot countries of Africa and a large part of India (it is the counterpart of rice in tropical countries with high rainfall).

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Widely cultivated in Africa and Asia, sorghums are less and less cultivated in Oceania, in the Sunda Islands and in general, as one moves away from India towards the east.

In the New Continent, sorghums were introduced following the slaves from Africa, first to the Antilles, then to the USA and South America. The first crops grown in the USA date back to 1853.

2° SORGHUS IN EUROPE.

The time of the introduction of sorghum into Europe is uncertain. PLINY (70 AD) reports a plant introduced from India and which he calls "surgo".

In the Middle Ages, the cultivation of broom sorghum imported from Anatolia was very flourishing.

3° SORGHUS IN FRANCE.

Various introductions of sorghum seeds were made from 1850 onwards.
China, 1851 Natal, 1854 India, Africa.

Later, they arrived in France and gave rise to small-scale cultivation of improved forage sorghum seeds in the USA (`Amber', 'Honey', etc.)

III. ECONOMIC STUDY.

A. GRAIN SORGHUM IN THE WORLD.

This culture is *clearly expanding* in a certain number of countries (USA, Australia) or is clearly increasing in consumption among those who cannot produce it.

In the USA: from 1955 to 1960, the areas doubled, yields increased by 30 %, production almost tripled (52 to 143 million quintals).

In Europe, for 3 countries of the Common Market and Denmark, consumption has increased from 1954 to 1960 from 4 to 14 million quintals.

	Holland	*Belgium*	*Denmark*	*France*	*Total*
				150,000	
1954	2,200,000	1,500,000	200,000	300,000	4,050,000 q
1960	2,700,000	6,600,000	4,600,000		14,200,000 q

The main reasons for the development of this production are the following:
boasts :

(a) The increasingly wide outlets on the *world market for livestock feed.* This industry tends to use *the cheapest cereals,* but sorghum remains cheaper on the world market than corn and even barley;

Sorghum grain has a composition similar to that of barley for its protein content (10.5 %) and corn for its low cellulose content (1.6-1.8 %). (b) The productivity

of varieties has increased very significantly since the entry in cultivation of the *first American hybrid varieties.*

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B. GRAIN SORGHUM IN FRANCE.

This crop is also expanding significantly in France. The areas covered increased from 3,000 hectares in 1965 to 51,500 hectares in 1970 (1,660,000 hectares, yield 37.0 hectares/ha).

The reasons for the recent interest in this crop in France are : —

economic : the importance of domestic and foreign outlets for livestock feed (particularly in the countries of the " Common Market" which cannot cultivate it);

— *technical :* in all non-irrigable areas , grain sorghum significantly more resistant to drought than corn, can replace it;

— current *F1 hybrid varieties* achieve very high yield levels , of the same order as those of corn (70-80 q/ha).

However, due to the thermal requirements of the species and the varieties selected so far, it seems that the area of cultivation of grain sorghum must be limited to France, to the South-West and South-East and more particularly to the dry *zones of these regions,* where corn does not appear profitable.

III. THE PLANT.

A. BOTANICAL CHARACTERS.

Grain sorghum is an annual species with $2n = 20$, like corn.

The plant is relatively small (1.10 to 1.20 m), with long leaves, reminiscent of those of corn, but less *wide and glabrous.* As with forage sorghums, its leaves and stems are toxic (durrhine) until flowering.

The inflorescence is a more or less compact panicle bearing *biflorous spikelets* grouped in twos or threes at the ends of the ramifications; in each group, the basal spikelet is fertile and sessile, the lateral ones are sterile (male flowers) and pedicellate (fig. IX-1).

Each fertile spikelet has *only one fertile flower, with* three stamens. and two styles with feathery stigmas.

The seed is light brown to reddish, quite small (25-35 g per 1,000 grains). It consists of a fragment of inflorescence since it includes the fertile spikelet and one or two unequal pedicels of the sterile spikelets.

The almond is a caryopsis about **4** mm long, partly visible between its envelopes; in grain sorghums grown in the USA and France, the seed is the caryopsis.

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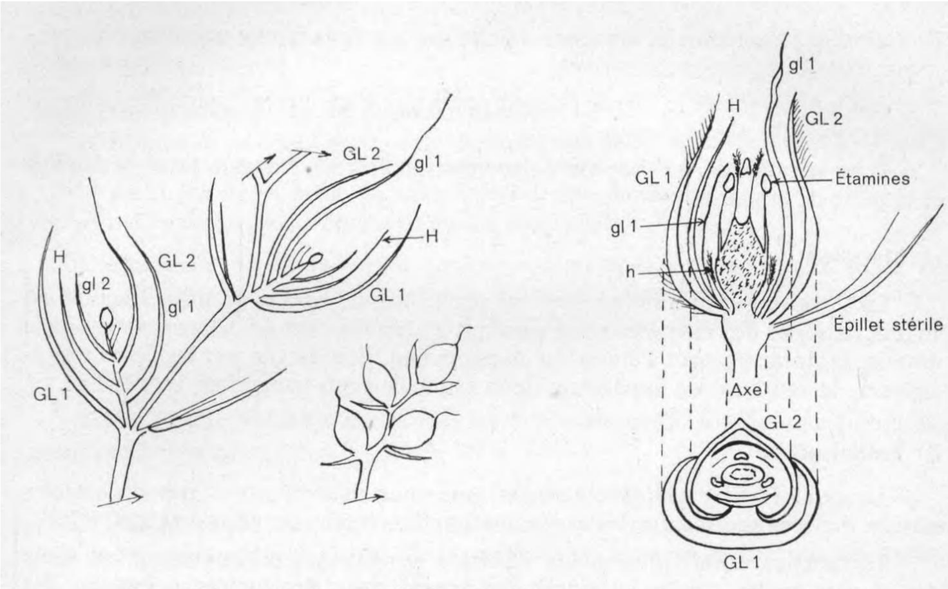

rai. **1R-1. -** acnema ue lepaieset oiagrammeae ianeur ue sorgho.

(According to **PIÉDALLU,** 1923.)

GL 1 : streamlined rule
GL 2 : 2nd glume
gl 1 : I 1 7 membranous eglumella H: hyaline membrane h:
gl2 : 2nd lemmella, hyaline lumpella

B. GROWTH AND DEVELOPMENT.

1° DEVELOPMENT CYCLE.

a) Development of the root system.

During the relatively slow early stages of aerial plant growth , sorghum develops a deep root system with fibrous, branched adventitious roots; with the same leaf surface area, the root volume is *twice that of a maize plant.*

This is one reason why sorghum *is more drought tolerant* than corn.

b) Development of the air system.

At first, the height growth of sorghum is very slow, although the number of leaves emitted increases rapidly.

According to A. COTTE, 12 days after emergence, the plants can already have 5 leaves.

Tillering generally begins at the 4-6 leaf stage : branches appear in the axils of these first leaves, with a more or less oblique orientation relative to the main axis.

Then, when the plant has reached 10 to 12 leaves, growth accelerates,

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the stem rises rapidly, the internodes at the bottom of the plant being the first to reach their final dimensions.

Stem elongation gradually slows as flowering approaches and ceases at full flowering.

There does not appear to be any correlation between total leaf number and plant size.

c) Flowering.

Flowering occurs mainly at night or in the early morning hours; the emergence of the stamens ceases during the hot hours. For an entire panicle, flowering can last for a week. It begins with the terminal flowers of the upper branch of the panicle and progresses downwards.

d) Pollination.

Pollination is generally *self-pollinating but* there are no serious obstacles to cross-fertilization, which can reach 60 *to* 70 % in grain sorghums .

The existence of male sterile individuals allowed breeders to create male sterile lines and after crossing with normal lines, F1 hybrid varieties .

2° DEVELOPMENTAL **PHYSIOLOGY .**

Sorghum is a *short-day* plant : the shorter the days, the more flowering is accelerated.

However, some authors have shown that the plant only reacts to the photoperiod when certain thermal requirements have been satisfied (influence of the thermoperiod).

3° **ECOLOGY OF GROWTH.**

a) Temperature.

A plant of tropical origin, sorghum has high thermal requirements, *higher than those of corn.*

The germination zero of sorghum is around 10 OC. andpractice- only below 15 oC, seedling growth is very poor.

The optimum growth temperature would be around 30°C.

Later sowing date and more southerly cultivation area are direct results of these requirements.

beautiful .

The water requirements of sorghum are significantly *lower than those of corn:* the evaporation coefficient of sorghum is around three-quarters of that of corn (274 compared to **361** according to SCHANTZ and PIEMEISEL).

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This lower water requirement would result from a certain number of morphological and physiological characteristics : — covering of the leaf blades by a *cutinized cuticle,* itself covered with a significant quantity of white *wax ; — stomata of smaller size,* but 50% more numerous than in corn, hence more efficient and more advantageous control of gas exchange for the plant; — *total functional leaf area* half that of corn;

— extremely branched and deep *root system .*

The water requirements of sorghum vary, as with corn, with the stage of development: they are greater from the " *swelling" stage to* the end of the "*milky" stage of the grain* (maximum at "end of swelling-start of earing").

c) **Fertilizing elements.**

According to DuLAC (Montpellier, 1964) sorghum exports, per quintal of grain produced, would be for the variety `NK 120' :

Nitrogen: 2.63 kg P205 : 1.31 kg K2 0: 3.13 kg.

Since the burial of stems and leaves after harvest returns three-quarters of the potash to the soil, the actual export of this element would therefore be of the order of 0.8 to 1 kg.

From these data, it can be deduced that a *fertilization similar to that* of corn is likely to satisfy the sorghum's needs for fertilizing elements.

C. ACCIDENTS AND PARASITES.

1. Damping off of seedlings due to *Fusarium sp., Colletotrichum graminicola,* etc. Control methods : seed treatment with TMTD, organo-mercurics, captan.

2. Payment due *to Gibberella Fujikuroi.*

3. Stem rot due *to Macrophoma phaseoli, Fusarium moniliforme, Colletotrichum graminicola ,* etc.

4. *Sphacelotheca sorghi, Sp. cruenta,* etc. **Smut** control by seed treatment to captan, TMTD, organo-mercurics.

5. Bacterial diseases.

6. Animal parasites. Wireworms, white worms, moths and sesamia.

Birds (sparrows and other passerines) are the most formidable enemies of the grain sorghum, from the milky stage.

IV. VARIETIES.

10 ORIGIN.

The few varieties (S 40, Early Hegari) very locally cultivated in France from 1950 have now disappeared.

Currently, only F1 *hybrid varieties* are cultivated , the vast majority of which are of American origin (an INRA variety).

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These F1s necessarily result from the crossing of a *sterile male line* with a *fertile male line:* manual castration is, in fact, unrealizable industrially (hermaphrodite flower).

Given this genetic nature, it is necessary, as for the corn, to *renew the seeds* each year (drop in yield in F 2).

The National Federation of Corn and Sorghum Production is responsible for the production of grain sorghum seeds. This is controlled and certified by the Official Control Service of the GNIS. This production covers around fifty hectares annually.

2° CULTURAL CHARACTERISTICS: ELEMENTS OF THE CHOICE OF VARIETIES.

Earliness , as with corn, constitutes *the fundamental element* in varietal choice : a variety that is too late will not be able to mature, or will even present significant flower drop (temperatures too low during flowering).

Other elements of choice will be *productivity, resistance to lodging,* attractiveness to birds, suitability for mechanical harvesting.

According to their earing date, sorghums have been classified in the USA according to a scale of precocity which *ranges from 400 to 800.* For Europe and for France, this scale has no correspondence with the index scale used in the but.

The table below summarizes the classification by precocity group of some grain sorghum hybrids and their cultivation zone (according to A. Corre et S. Raurou).

TABLE IX-1. — *Hybrid sorghum varieties, earliness and growing regions.*

The number in parentheses, after the variety name, is the precocity index.

Early group (indices 400 to 500). Garonne basin and middle Rhone valley.		
NK 110 A (440)	NK 123 (440)	INRA 450 (450)
NK 120(440)	SD 441 (440)	NR 125 (470)
Late group (indices 500 to 700). Mediterranean region.		
AKS 614 (600)	NK 222 (610)	Hazera 726 700)
Dekalb D50 (600)	RS 610 (610)	

Legend. NK: Northrup King. SD: South Dakota. AKS: AES Arkansas. RS: Regional Sorghum.

It turns out that *the index 500 corresponds to the limit* of lateness of hybrids which can be grown in the southwest of France.

However, hybrids with an index lower than 500 are few in number.

The best known is `Northrup King 120 (`NK120'). `INRA 450', the first French variety of hybrid sorghum (Montpellier), has proven to be equally productive.

The very numerous later hybrids (500 to 700) can only be cultivated in the Mediterranean region or in particular soil and water supply conditions .

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A field for producing hybrid grain sorghum seeds (2 lines of the male parent, 4 lines of the female parent).

V. CU LTURE.

A. PLACE IN ROTATION.

Grain sorghum can occupy the same place in the rotation as corn. It is therefore a “crop head” generally followed by a winter cereal.

The most favourable crop precedents are those which enrich the soil with humus: forage legumes-meadows.

When sorghum is followed by a fall cereal, a nitrogen supply (30 kg/ha) when sowing the latter is useful to promote decomposition of the stubble and root residues.

B. SOIL PREPARATION.

Although sorghum is more drought resistant than corn, productivity is, in the same way, conditioned by the *availability of water* in the soil.

To store the maximum amount of water in the soil, deep *plowing* will be carried out *in the fall,* or *in winter,* or even in summer in dry conditions.

In spring, surface preparation will have to be even *more careful than for corn,* due to the *small size of the grains* and their lower germination energy. During this work, treatment will be carried out against wireworms, white worms, etc

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C. FUMURE.

It will be very close to that recommended for corn.

1. Basic fertilization. 80 kg-120 kg of P 205 and K20 buried during plowing with possibly organic fertilization of 20 to 30 t/ha of manure.

2. Nitrogen fertilization. In dry regions, there is a chance of using 60-80 kg/ha.

In irrigation, 100 to 150 kg/ha can be very profitable.

D. SEEDING.

1° DATE.

As a general rule, in a given location, given the higher germination zero of sorghum, the latter should be sown *15 to 20 days after corn,* that is to say *during May.*

In the Mediterranean region and in irrigated conditions, sowing can be continued *until the end of June with the earliest hybrids.*

2° DISINFECTION OF SEEDS.

These will be treated with **TMTD,** organo-mercuric, or captan against cast iron parasites.

3° POPULATION.

The population density, taking into account tillering, does not have the same importance. tance in sorghum than in corn.

In dry cultivation, a density of around 20 to 25 plants per square metre (200,000 to 250,000 plants/ha) seems very satisfactory; in irrigated cultivation it can be significantly increased. If the crop is chemically weeded, it can be sown at a spacing of *20-40 cm ;* if the crop is hoed, 50 to 70 cm spacing. ment are necessary.

Practically with a weight of 1000 grains of 25-30 g, *10-15 kg/ha* of seeds constitute a normal dose.

E. MAINTENANCE CARE.

Due to its very slow initial development, sorghum is threatened by weeds from the moment it emerges. However, its rapid growth subsequently allows it to compete successfully with them.

When the spacing between rows is sufficient, we can hoe.

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Increasingly, treatment at the 4-5 *leaf stage* is recommended :

— either with atrazine at 1-1.5 kg/ha of MA; — or with an atrazine mixture (0.6-0.8 kg/ha) — amine salt of 2,4-D (0.5-0.8 kg/ha of MA).

F. IRRIGATION.

This should essentially aim to satisfy the needs of the *critical period : swelling - end of the milky stage.* According to A. COTTE, the recovery of the cubic meter of water would be, under these conditions, of the order of 1.5-1.6 kg of commercial grain.

G. HARVESTING AND DRYING.

Harvesting can only be done with a *combine harvester.*

On the other hand, the grain must be stored *at less than 13 % humidity.* However, like corn, it doses 25-35% at harvest , especially if the harvest must be early (lodge limitation, grain mold, crop rotation requirements, grain moisture recovery).

A close link between the producer and the storage organization is therefore essential at the time of harvest so that *drying begins within a timely man minimum.*

Yields of *70 q/ ha and more* are an objective that can be achieved under French conditions in irrigated cultivation.

H. FODDER SORGHUM.

Refer to volume I “Foam”, p. 137.

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CHAPTER X

MILLET

Panicum miliaceum L. and *Setaria italica* Beauv.

Millet cultivation is currently very small in France : in 1970, only 900 hectares were cultivated with yields of 15 q/ha. However, according to FAO, 34 million hectares were cultivated worldwide in 1968, with a yield of 4.8 q/ha.

Cultivated millets belong to the *Panicaceae* tribe, *which* differs from *Andropogoneae* by an :

inflorescence formed of *similar pedicellate* spikelets , with *unequal* membranous glumes , bearing two flowers : one hermaphrodite, the other only male, limited to one or two membranous glumes;

— more or less hard hair.

Two species are cultivated in :

France : — *Panicum miliaceum,* common millet; —

Setaria italica, which includes two varieties : bird's eye millet and Moha.

The two genera and species differ essentially in the shape of their panicle , *which* is very loose in Panicum and spike-shaped in *Setaria.*

The inflorescence of Moha differs from that of Foxtail Millet by a shorter, more compact, erect spike with generally long bristles.

1° CLUSTER MILLET OR COMMON MILLET.

Cluster millet is mainly cultivated in Germany and Hungary either for grain or for fodder (summer crop).

It is a very fast growing plant (3 months), preferring light soils; millet sup- tolerates drought particularly well.

Previous cultural. Very demanding with regard to the richness of the soil and its cleanliness, it is preferably grown behind old meadow or legume or root or tuber crop.

Sowing. It is sown, from the beginning of May, with a seeder, in rows spaced 35-50 cm apart.

Maintenance care . Repeated hoeing.

Grain harvest. Delicate due to the risk of shelling; traditionally manual.

2° **BIRD MILLET .**

It is a species that requires more heat and therefore matures later than cluster millet (5 months of vegetation).

Its growing conditions are similar to those of common millet.

3° MOHA.

It is a fast-growing, drought-resistant plant, used as *summer fodder* to be eaten young (hardens quickly), green, wilted or ensiled (see volume **I** "Fodder" p. 141).

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CHAPTER XI

RICE

Oryza sativa L. (2 *n* = 24).

I. ECONOMICS OF PRODUCTION .

A. RICE IN THE WORLD.

Along with wheat, rice is the most important cereal in the world.

In 1968, according to FAO, 132 million hectares were cultivated and production was around 2,840 million quintals, i.e. a global yield of around *21.5 q/ ha.*

q/ha.

This crop is *growing.* For the period 1948-52 the world surface area was of the order of 100 million hectares and production of 1 billion 660 million quintals (16.6 q/ha); the increase in yields was particularly noticeable in countries of traditional cultivation (India and China) thanks to the improvement of cultivation techniques (fertilizers).

The main producing countries are the *Asian countries ,* whose rice is the basis of their diet. In 1968, they produced 60 % of world production. %

India.	37,000,000 ha	....	596,000,000 q
Indonesia	7,970,000 ha	....	152,000,000
Pakistan	11,300,000 ha	....	q 201,000,000
Japan	3,280,000 ha	....	q 188,000,000
Asia.	88,770,000 ha	....	q 1,682,000,000 q

Other producing countries are South America (Brazil), the United States and Central America (Mexico), Europe (15 million quintals).

In Europe, among the countries of the Common Market, Italy (6,000,000 q) and France (950,000 q) are the only producing countries. However, Spain, Portugal and Greece are, outside the EEC, important rice producers.

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B. RICE IN FRANCE.

Rice cultivation was introduced in France around 1845. However, it was only a century later, from 1942, that the crop took on spectacular development in the departments of Bouches-du-Rhône (Camargue), Gard, Hérault, Aude and Vaucluse, where it allowed the development of salty land, previously uncultivated.

In 1970, 22,000 ha were cultivated; production amounted to 1 million quintals, or an average yield of 42 q/ha.

This production currently covers our needs.

Its rapid expansion was encouraged by the remunerative prices granted to producers from 1946 (3 1/2 times the price of wheat at the time). Today (1970), with production prices having fallen significantly, the areas seem to indicate a slight decline.

C. USE OF RICE.

1° Human food is the main outlet for rice production, particularly in Asia.

We call : — :

paddy rice, the dressed grain coming from

threshing; — *cargo rice,* the grain freed from the glumes and glumes (almond =79 80 %);

— *milled rice,* the grain freed from the germ and most of the integuments (including the aleurone layer, hence the risk of vitamin B deficiency). It is delivered either glazed with glucose and talc, or unglazed (flowered rice).

Rice grain is very digestible. **It** contains, hulled : Fat. ....

0.8 % Cellulose .... 0.5 Non-nitrogenous extractive .... 78.4 %
Ash .... 0.8 Proteins .... 7 %

It can be used to make fermented drinks, such as sake or saki (Japan).

0 2 **Animal feed** is an outlet for the by-products of decortication (brans, broken pieces).

Straw can be used as bedding and for making artificial manure. It is usually chopped and left on the field at harvest.

0 3 Finally, **industry** offers a certain outlet: starch manufacturing, brewing, powder making, brushes and brooms, etc.

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II. THE PLANT.

A. BOTANICAL CHARACTERS.

1st PLACE IN THE BOTANICAL CLASSIFICATION.

Cultivated rice belongs to the *Oryzae* tribe and the *Oryza genus,* *Oryza,* characterized by *unulorous* spikelets *uniflorus*, flattened *laterally* and gathered in a panicle.

This genus includes various species.

I. TWO CULTIVATED SPECIES.

Oryza sativa **L.,** the best known and most widespread species, including varieties originating from Asia.

O. glaberrina Stend. including varieties cultivated in West Africa.

II. VARIOUS WILD SPECIES .

Oryza fatua, a species native to India, Malaysia, Indochina, Java, to which many varieties of O. *sativa are closely related.*

Oryza minuta, subspecies *O. punctata:* widespread in tropical Asia, Java, Madagascar .

Oryza latifolia, O. breviligulata, etc.

2° GENETIC ORIGIN.

According to PORTÈRES, all varieties *of Oryza sativa* derive from O. *fatua.* But according to other authors, *O. minuta* and *O. punctata* would also have contributed to the formation of certain varieties of O. *sativa.*

As *for Oryza glaberrina,* it probably derives from O. *breviligulata.*

3° GENERAL CHARACTERS OF THE PLANT.

Rice is an *annual grass, with very abundant* tillering , rough and narrow leaf blades , a lacerated membranous ligule, and more or less hairy auricles. The panicle, branched, bears pedunculated spikelets articulated on their pedicles, arranged in loose clusters on each branch.

Each *single-flowered* spikelet has two very small, membranous glumes and two much more developed glumes, articulating at their edges to completely envelop the fruit or caryopsis.

Each flower, hermaphrodite, contains *6 stamens.* Fertilization is *self- pollinating.* *auto-game.*

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B. DEVELOPMENTAL **PHYSIOLOGY .**

The development cycle of rice is that of an annual grass. It is carried out kills in 50 to 300 days depending on the variety.

It is, like corn, a *short-day* plant : varieties well adapted to temperate regions accelerate their development considerably when they are introduced into tropical regions and yield little. Tropical and equatorial rices tiller a lot in France and do not always manage to reach flowering or to mature.

There are varieties, however, which are not very sensitive to changes in photo-period, which can be successfully grown in countries of different latitudes.

C. ECOLOGY OF GROWTH.

1° AIR TEMPERATURE.

Depending on the variety, the germination zero is between *10 and 13* °C, the optimum temperature being around 30-35°C.

The minimum temperature required for ear emergence would be 22°C, with the optimum being 30-32 °C. oC.

Maturation can take place at 19 OC but the optimum is at 30-32 OC.

The sum of temperatures required from germination to harvest varies from 2,100 OC for extremely early varieties to **4,500** OC for late varieties .

2° WATER TEMPERATURE.

According to VAN HAMME, the optimum water temperature - since in aquatic culture, it is in soil saturated with this liquid that the roots will develop and the tillers will appear - would be 30 to 34 OC and the maximum 40 OC, roughly the same as for the air.

Due to its high heat capacity, water reduces both daytime heating and nighttime cooling; it thus protects rice against frost in spring and nighttime cooling in autumn at the time of fertilization.
tions.

3° LIGHT INTENSITY.

According to TAKAHASHI, low light intensities delay the earing and ripening of early varieties but slightly advance the ripening date of late varieties.

The proportion of sterile spikelets is also increased, as is the sensitivity to cryptogamic diseases.

Rice should therefore be considered *a full light plant.*

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4° WATER.

Rice cannot be considered an exclusively aquatic plant : — :

many varieties can be grown in soil not saturated with water; —

varieties adapted to aquatic cultivation *do not require more water for their germination than* other *cereals;* — these

same varieties complete their maturation much better when the soil has been previously dried.

According to SHANTZ and PIEMEISEL, the transpiration coefficient of rice would be around 680 (compared to 350 for corn, 635 for rye, 845 for alfalfa) : rice therefore transpires comparatively less water than certain species which are not, however, cultivated on submerged soils.

However, these water requirements vary with the stage of development; they increase from germination to ear emergence and then decrease thereafter.

In practice, for a quintal of grain, the plant produced 2.2 q of dry matter, therefore evaporated 220 x 680 = 150,000 kg = 150 m3

This water will be supplied to aquatic culture, both by artificial irrigation and by rain.

While aquatic cultivation will be possible wherever the temperature is sufficient, "dry" rice cultivation will therefore only be possible in very rainy regions (intertropical zone) ensuring *1,500 mm during the active vegetation period .*

Excessive rainfall, always accompanied by overcast skies and therefore low light, results in low yields.

5° AGROLOGICAL REQUIREMENTS.

In “ dry” cultivation, rice has no special requirements.

In aquatic culture rice is also considered very accommodating. based on the physical qualities of the soil.

However, it is on light, permeable soils that it produces the best quality grains. But such soils require very large quantities of water for their submersion (up to 50-60 1/s/ha, while compact soils only require 1 or 2). For this reason, sandy soils should be avoided.

Soils that are too clayey are no more suitable: they are difficult to work before becoming saturated with water, thus preventing early ploughing, and dry out too slowly as they approach maturity.

Ultimately, you need clayey-silty soils, containing a sufficient proportion of humus. suffisante

The optimum pH for rice is between 5.5 and 6.5.

6° FERTILIZING ELEMENTS.

Yields of 80 q/ha are sometimes obtained in Camargue, Italy, Spain. In such cases, it can be assumed that exports in elements

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fertilizers are at least equal to those of good wheat. On the other hand, we should not count on the contribution of organic matter to cover the needs, because the evolution of the latter is very slow. However, these exports would be located for 1 q of grain at :

approximately : 2 kg of nitrogen, 1 kg of phosphoric acid, 1.25 kg of potash, 0.83 kg when the straw itself is harvested.

Phosphoric acid promotes rooting and tillering, advances earing and ultimately has a positive effect on productivity.

Potash regulates fertilization and, above all, promotes the migration of reserves towards the grain (greater precocity of maturity).

Potash, lime and magnesia are generally found in sufficient quantities to ensure the best yields, especially in aquatic culture.

It is practically accepted that the productivity of a kilogram of nitrogen would be 20 to 25 kg of paddy.

A. ACCIDENTS AND PARASITES.

1° THE COLD.

Given its thermal requirements : low :

temperatures *at germination* will result in defective emergence; *at flowering,* there will be coulure.

2° THE VERSE.

A lodged crop will be more difficult to harvest, there will sometimes be grains germinated on the vine, or too damp (“yellow” grains).

The best way to control it is to use resistant varieties.

3° SHELLING.

Wind can cause shelling. It is necessary to compartmentalize the rice field, plant shelters, use resistant varieties.

4° SALT .

Salt water upwellings are frequent in the Camargue. Ensuring a sufficient flow of fresh water is the only way to combat this.

5° DISEASES.

None of them are very serious in the Camargue climate. However, we :

should point out : — *pyricularia (Piricularia oryzae* Car.), the most widespread disease which can sometimes cause great damage. It manifests itself by spots

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gray surrounded by a brown area often located at the junction of the blade and the sheath. Subsequently the stem and the panicle themselves take on *a dark brown tint;* when the nodes are attacked they become less resistant and cause the stem to break and the panicle to become sterile.

To combat the disease, it is necessary to avoid excessive nitrogen fertilization and to cultivate resistant varieties.

6° ANIMAL PARASITES.

Nematodes *(Ditylenchus)* and various insects.

HI. CULTIVATED VARIETIES.

A. ORIGIN OF CURRENT VARIETIES.

More than 2,000 varieties are cultivated worldwide.

The varieties cultivated in France have a dual origin.

— *Foreign origin* (especially Italian): `Balilla', `Rinaldo-Bersani' (or `RB'), `Euribe'.
'R.B.'), 'Euribe'.

— *French origin.* Since 1960, five pure varieties have been obtained whose characteristics correspond to the Camargue cultural environment : four by INRA, `Arlésienne', `Césariot', `Cigalon' and `Fanny'; one private `Carola'.

A line of rice under selection.

Photo INRA

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B. ELEMENTS OF VARIETY CHOICE.

1° CULTURAL CHARACTERISTICS.

Precocity, resistance to lodging and productivity are, in terms of cultivation, determining elements of varietal choice.

While `Balilla' and `RB' are relatively late, French varieties such as `Césariot' and `Cigalon' are early; they also have good resistance to lodging, whereas `RB' is quite sensitive to it.

2° QUALITY OF THE PRODUCT.

From this point of view, we currently distinguish two main categories of rice :

— round or ordinary *grains* (Balilla', `Cigalon'); — *long grains*

or 'fine varieties' (`RB', 'Euribe', `Césariot', 'Arlésienne '). This group of varieties is the most sought after in the trade.

A *higher* price compensates for a lower crop yield.

IV. CULTURE (in France).

A. PLACE IN ROTATION.

Very frequently rice *succeeds itself* because it constitutes the only profitable crop in soils which must receive the large quantities of water necessary to carry the salt deep down.

However, where salt is less to be feared, the following crop rotation would be recommended : 1st year :

sown rice. 2nd year:

transplanted rice. 3rd year:

autumn wheat (1/2 durum wheat, 1/2 Florence-Aurore). 4th year: spring

crop (1/2 durum wheat, 1/2 hoed plants).

B. SOIL PREPARATION.

The creation of the rice field requires major earthworks to obtain surfaces as flat as possible, the channels for supplying and evacuating water. We will not dwell on them.

After plowing to 25 cm, repeated passes of cover crop or Canadian are carried out.

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Photos Synd. Rice. of Fra

Ground preparation with a scraper and a terracer .
(terracer).

Preparing the soil with cage wheels before transplanting.

In the case of transplanting , the last superficial methods are carried out *in water.* When considering *sowing in place ,* it is necessary to obtain as flat a surface as possible; for this, leveling boards are passed over the ground .

C. FUMURE.

1° BOTTOM **FERTILISATION .**

Phosphoric acid will be provided, taking into account the alkalinity of the soil, in the form of superphosphate or ammonium phosphate, at a rate of 80 to 150 units/ ha depending on the richness of the environment.

In potash, the quantities to be provided are of the order of **60 to 100 kg/ha** in the form of chloride or sulfate in normally provided soils (120 to **140 in** poor soils).

If the straw is returned (general case, due to the scarcity of manure in this region) these quantities should be reduced significantly.

2° NITROGEN FERTILIZER.

Nitrogen must be supplied in the form of ammonium sulfate or urea, forms retained by the absorbent complex and therefore less leached than nitric or ammonia-nitric forms .

It will be added 8 to 10 days before watering, and mixed into the soil using surface methods.

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The manure applied is 80 to 100 kg/ha in clay soils, 100 to 130 kg in silt soils, 120 to 150 kg in sandy soils.

An additional contribution of 30 to 60 kg/ha can be made (if spring is very hot) about 3 weeks after transplanting.

Late intakes, as with other cereals, increase the protein content of grains.

Photo Synd. Rizic.de France

Transplanting rice.

D. SEEDING.

For the establishment of the culture, two different techniques are used : **— sowing in a nursery,** then transplanting the plants; expensive technique in terms of labor but giving high yields (mechanization very difficult); **— direct sowing** with chemical weeding which can give up t lower yield than transplanting, but sometimes almost as productive.

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1° TRANSPLANTED CULTURE.

Sowing in the nursery is carried out in the first half of April in high density (1,000 kg/ha) at a rate of 10-12 ares for 1 hectare of rice field. The arra - change takes place 45 to 50 days later.

Transplanting is carried out from the end of May to mid-June at a rate of 15 pockets of a few plants per square meter.

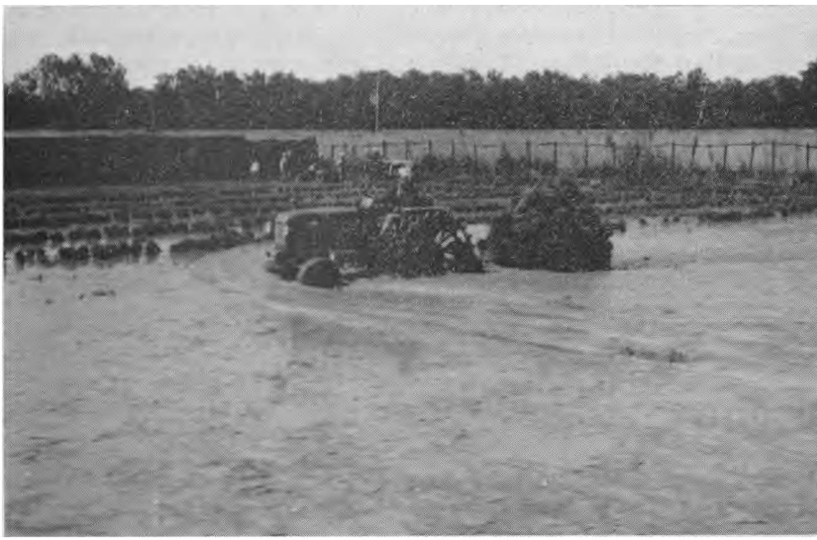

Photo Synd. Rizic. de France

Uprooting and transporting rice plants .

2° DIRECT SOWING.

Sowing takes place from the last week of April to the beginning of May.

150 to 200 kg/ha of seeds are commonly used, a very high quantity because 50 to 70 kg/ha could theoretically be enough to obtain 120 to 150 plants per square meter. But significant waste is often recorded at emergence (water too cold, seeds with too low germination energy, aquatic larvae, etc.).

It is most often sown broadcast , under 10 to 20 cm of water, the grain being previously weighed down by soaking for 24 hours and dried.

More rarely, sowing takes place *in lines,* on dry soil.

E. MAINTENANCE CARE.

1° SUBMERSION.

The water level must rise with the growth of the rice. However, it is sometimes dried after emergence to strengthen the plant and combat parasites (possible treatment against algae and characeae with copper sulphate).

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2° WEEDING.

In transplanted culture, the maintenance of the culture will be ensured by *manual weeding.*

In direct seeding, we can only weed chemically and even then quite imperfectly or, if sowing in rows, hoe between the rows.

Among chemical herbicides, MCPA is most commonly used in the fight against dicotyledons.

DCPA is effective against monocotyledons (Panics). It is necessary to treat when the Panics have one to three leaves, at a rate of 4-5 kg/ha of active ingredient in 80 to 100 l of water. Rice, whatever its development, resists very well, even at much higher doses. The rice field must be dried out 24 to 48 hours before treatment.

Unfortunately, this product is expensive. It is difficult to apply it on large areas, due to the impossibility of emptying and re-watering the rice field in a short period of time.

Another product, ethyl hexamethyleneiminecarbothiolate (ordram), is very active against Panics and is used dry, with light covering with discs, one week before watering, at a rate of 6 kg/ha of liquid at 12 AM.

F. HARVEST.

This generally takes place from *the end of September to mid-November,* by combine harvesting. Bulk harvesting, which is more economical and faster, is predominant. rant.

The grain is delivered immediately to the storage organization equipped for the drying: grain moisture is generally quite high : 16 to 26 %.

Normal yields are between *35 and 40 q/ha* of paddy (at 14.5 % of water).

The weight of a hectolitre is between 64 and 68 kg.

Milling yields are of the order of : — cargo rice : 74-76 % clean paddy; — milled rice : 55-65 %; — husks: 20 %.

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