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J.P. HARDOUIN
RESEARCH DIRECTOR
ETS C.C. BENOIST
FERME DE MOYENCOURT
ORGERUS
FRANCE

**SUMMARY -** After a brief history of durum Benoist's varieties, and the definition of breeding targets for agronomic and quality characteristics which must be done as in equal part, the germplasm and the pedigree method are described from $F_1$ to the registered variety. The new breeding techniques for the study of genotype x environment interaction and for durable disease resistances are considered for integration in the breeding method. The costs of these new breeding methods will be supported only with a good development of the durum seed market in Europe.

**Key words:** Cross, environment, genotype, germplasm, pedigree, quality, variety.

***RESUME -*** *"Nouvelle technologie de sélection". Après un rapide historique des variétés de blé dur des Ets C.C. Benoist, et la définition des objectifs de sélection pour les caractères agronomiques et technologiques qui doivent être menés à part égale, le matériel végétal utilisé est décrit, la sélection pedigree est détaillée depuis la $F_1$ jusqu'à la variété inscrite. Les nouvelles techniques de sélection pour l'étude de l'interaction génotype x milieu et pour la création de variétés possédant une résistance durable aux maladies, sont envisagées pour une intégration dans le schéma de sélection. Les coûts de ces nouveaux schémas de sélection ne pourront être supportés que par un bon développement du marché des semences de blé dur en Europe.*

***Mots-clés :*** *Croisement, environnement, génotype, géniteur, généalogie, qualité, variété.*

## Introduction

The breeding durum programme started in Benoist company at the beginning of the 60's. The first works were done with INRA materials of Professor Grignac, we obtained our first commercial variety Durtal in 1971. Durtal was an INRA variety with exclusive commercialisation of Benoist company, Durtal was completely new for agronomic characteristics including very high yield, shortness (dwarf genes), good earliness, but the quality was very weak with small grains of low colour and protein content and very poor pasta cooking, so the main factories in Europe decided to exclude Durtal from the commercial market of durum grains.

The Durtal episode in the 70's was the beginning of new breeding for durum in France with the studies in equal part for:

(i) Agronomic characteristics for high yield, disease and lodging resistances and earliness.

(ii) Good quality characteristics for industrial uses, including high 1000 kernel weight, low rate of black points and yellow berry, high carotenoid pigment content, high protein content and good type of protein (gliadin 45), good pasta cooking and good gluten characteristics.

With this new target, introduction of new genetic materials from CIMMYT, Italy, North Africa, USA, etc., and the transfer of our durum nursery from spring sowing to winter sowing (1982), the main points of interests were:

(i) In 1980 registration of the variety Regal, a cobreeding with the US company Northrup King, which was a very high yielding variety with very good colour (yellow), but medium cooking, Regal was a gliadin 42 type.

(ii) The GIE Blé Dur (Group of Economic Interests for Durum Wheat) started in October 1983 with INRA, ITCF, private breeding companies, and French industrials of pasta. The target is to improve quality and yield and exports of durum wheat.

(iii) In 1983, C.C. Benoist started the selection for white glumes on ear to select gliadin 45 plants, and introduced, in the breeding process of cereals, the disease nurseries with artificial infections in different locations (2 at the beginning) for all breeding materials in yield trials.

(iv) In 1986 registration of Ambral, this variety was the first developed after GIE Blé Dur trial in fields and in laboratories, immediately recommended by the CFSI (Comité Français de la Semoulerie Industrielle). C.C. Benoist started a biochemical markers laboratory, essentially for bread wheat (glutenin and gliadin banding), with some works for durum.

(v) In 1987 C.C. Benoist started a special quality laboratory for durum with physical analyses on grains (1000 grains weight, black point and yellow berry), infrared system for protein content, extraction of carotenoid pigments for measuring colour of semolina, Zeleny SDS (protein extraction with Sodium Dodecyl Sulphate) to determine the quality of proteins.

(vi) Agrial registered in 1988 with a class A for quality by the French CTPS. It was the first class A durum variety, A is the highest class for high quality characteristics.

(vii) In 1989 registration of Endural and Goal.

(viii) In 1991 registration of Durental and Digital. To test the colour of semolina, we started with the Colorimeter Minolta, now we use the terms yellow (b*), brightness (L*) and red (a*) for colour estimation.

(ix) In 1992 registration of Escal and Prodigal.

(x) In 1993 the new Common Agricultural Policy (CAP) starts with new rules for durum in Europe, with a new system of prices in the different parts of south EEC, a northern breeder like us will change his breeding to adapt the new varieties for southern Europe, this new target will be very important in the future.

Two new varieties are in registration in France, and other varieties are in different countries of Europe.

Since Ambral, all Benoist's varieties have gliadin 45 type with white glumes and generally a good resistance for black points and very high colour of semolina.

## Material

To obtain new commercial varieties, it is necessary to collect a lot of germplasm from different countries of the world, in our breeding programme. We use very different material.

The Regal cross is Flamingo/Leeds, a CIMMYT's variety by a US North Dakota variety. Ambral = D76018/Valdur, D76018 was a Benoist's advanced line ($F_6$) from the cross CI15332/D56-1, a US collection by a Benoist's advanced line from CIMMYT origin. Agrial was a very simple cross Regal/Valdur, two French varieties, one from Benoist and the second from GAE. The two latter varieties: Escal is from D79068/Mondur, the advanced line D79068 = Ward/46590, an US North Dakota variety by a F4 originally from CIMMYT, and Mondur a French variety from GAE, Prodigal = D81108/Valdur, the advanced line D81108 = D56-1/Rugby a CIMMYT origin by an US North Dakota variety and Valdur a French variety from GAE.

These different examples of pedigrees show well the complexity and the philosophy of my breeding programme, we use six different origins of germplasm:

(i) CIMMYT origin selected in Orgerus directly or after one or two crosses with French material for a better adaptation, this material is excellent for a large area of cultivation, some disease resistance, earliness, short straw, but it has low to medium quality especially for the yellow colour, it is generally gliadin 45 type with relatively high protein content, the CIMMYT material has generally a very poor frost resistance.

(ii) French commercial varieties for a good adaptation in France, they come from other breeders or from INRA, in the GIE Blé Dur, we exchange every year some germplasm for testing in different locations and using in our breeding programme, it is a very important point for our mutual cooperation.

(iii) US commercial varieties, essentially from North Dakota with generally good quality especially for the yellow colour, this material sometimes has a relatively good frost resistance, and some varieties from Washington State, California or Arizona.

(iv) Italian varieties, are important sources for adaptation to south Europe and especially in Italy, Spain or Greece. The Italian material is short and early, with some disease resistance, the grain is generally big with low yellow colour, high protein content good pasta cooking but susceptible to black point under French conditions.

(v) INRA germplasm from Montpellier, for earliness, leaf rust resistance, good quality of grain, but generally susceptible to frost.

(vi) Miscellaneous germplasm, from ICARDA, North Africa, CEI, Turkey, Israel, Chile, Argentina, etc., for special characteristics and to improve the large adaptation of the material.

## Methods

The breeding of durum is done in 7 locations in the world:

(i) Orgerus (F-78), the main station 50 kilometres west of Paris, with the complete nurseries $F_0$ to $F_9$, 4 diseases nurseries in artificial infection (stripe rust, fusarium, septoria, eyespot), the yield trials, a growth room for two generations per year, laboratories for quality tests.

(ii) Levet (F-18), in the centre of France near Bourges, with yield trials and one disease nursery in natural infection.

(iii) Artenay (F-45), in the centre of France for yield trials.

(iv) Le Blanc (F-36), in the centre of France, only one disease nursery, for Soil Born Mosaic Virus.

(v) Beaumont sur Leze (F-31), near Toulouse in the south west of France, for yield trials, nurseries ($F_2$, $F_3$, $F_4$) and one disease nursery in natural infection especially to select for the special leaf rust of south France, this location is expanding greatly for breeding.

(vi) Conselice (I-Bologna), in cooperation with the Italian seed company Venturoli Sementi for $F_2$ selection in Italy and yield trials.

(vii) Argentina (RA), for an extra generation during european winter $F_3$ to $F_4$.

A pure pedigree method is used, the objective is to conduct at the same level the different parts of breeding: (i) High yield and large adaptation of varieties; (ii) Regularity of yield that means disease, frost and lodging resistances, good earliness for the area of cultivation; (iii) Industrial quality requirements.

The scheme of crossing is very simple, and only with durum germplasm (28 chromosomes) for quality reasons, the different types of crossings are the following:

- single cross A/B
- three ways A/B//C

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| - double hybrid | A/B//C/D |
| | A/B//A/C (a kind of three ways) |
| - back cross | A/2*B (no more than 2) |

If possible, the female is the best quality of the 2 parents, all the crosses are done in the field in winter sowing in our station of Orgerus (78) in the northern part of France, with the objective to obtain 20-25 $F_1$ seeds.

The $F_1$ is in the field in Orgerus, some crosses of special interest are grown in the growth room during winter and resown, in $F_2$, in spring sowing.

The $F_2$ is sown in Orgerus in winter and in spring with artificial infection of stripe rust, in Beaumont sur Leze in winter, and in Italy in winter sowing, we select the plants in these three locations for aspect, disease resistance, and for white glumes at maturity.

The $F_3$ is located in two locations Orgerus and Beaumont sur Leze, one ear per plant in each location, we select the best rows (one row = one ear = one plant) for aspect, disease resistance and white glumes, we harvest 6 ears to continue the nursery and 15 ears for the laboratory. Some special crosses go to Argentina for an extra generation in winter and $F_4$ resowing in spring in Orgerus.

After the $F_3$ harvest, each year, some ears are harvested in nursery for quality analysis, on selected families. In our laboratory, we analyze all the generations for the following characteristics:

(i) 1000 kernel weight.

(ii) Score for aspect of grain, 10 is excellent, 90 very poor.

(iii) Score for black points, 10 is excellent, 90 grain completely black.

(iv) Score for yellow berry, 10 is without, 90 completely white.

(v) Colour analyses with a Colorimeter Minolta: L* the brightness, b* the yellow, a* the red; this analysis is done on whole flour obtained with a Cyclotec mill grate 0.5 mm.

(vi) Zeleny SDS on whole flour.

(vii) Protein content with infra red Inframatic 8100 on whole flour, we also read the hardness and the RMT from bread wheat on our Inframatic 8100.

(viii) We calculate the firmness Panzani with a personal regression including protein content, Zeleny SDS, hardness, and RMT (r=0.7).

The $F_4$ is in two locations Orgerus and Beaumont sur Leze, only in nursery, 6 ear rows per family harvested on one $F_3$ ear row, we choose the family to continue on aspect, disease resistance and quality analysis done on $F_3$ harvest, the selected families continue with harvesting of 12 ears for nursery, and a bulk of two rows to start in yield trial and disease nurseries and continue analysis in the laboratory.

In $F_5$ we start the multilocal trialing and disease nurseries to know the new advanced lines for adaptation, yield and quality. The nursery (12 ear rows) is located in Orgerus, 5 disease nurseries are done: two nurseries in Orgerus, one in Levet, one in Le Blanc for mosaic virus, one in Beaumont sur Leze for leaf rust. We do a non replicated trial of all $F_5$ in three locations: Orgerus, Beaumont sur Leze, and in Italy.

The selection continues in $F_6$-$F_7$ with the same scheme, one nursery for homogeneity in Orgerus with 12 ear rows per family, 5 disease nurseries, and multilocation replicated trials in France, Italy, Germany, and Spain, and we continue the analysis in our laboratory and also in one laboratory for pasta industrial (Crecerpal of Panzani).

We start the purification and the first seed multiplication on large scale in $F_8$ to prepare the material for official registration.

$F_9$ and $F_{10}$ are the two official years for French national testing, at the end the varieties are registered and protected.

$F_{11}$ is the first year of commercialisation of the new variety.

## New advances

For the future, in my opinion, the selection for stability of every characteristic will be very important especially for yield stability in space or in time, with durable disease resistance, and with stability of quality characteristics in different areas and during the different years of cultivation.

We are working to introduce in the breeding programme a test for genotype x environment interaction with a Finlay-Wilkinson regression on multilocation yield trials, for yield and some quality characteristics like yellow berry, black point or protein content which are very sensitive to the environmental conditions. This new approach will be done for yield and quality to insure a high stability in the new varieties.

For disease resistance, it will be necessary to have a very good and durable resistance to reduce the parts of fungicides, in the very intensive areas of cultivation, or to obtain a good stability of yield in traditional areas of cultivation (without fungicides), in both cases a durable resistance will be necessary.

We have started in durum and in bread wheat, this kind of programme for mildew and leaf rust, in collecting all the genes of resistance (major or minor) for these diseases, after crossing, we hope to obtain new plants with good and durable resistance. It will be necessary to select with the help of biochemical markers for this particular point, and we hope new developments of genes markers will be available to accelerate this part of the programme.

## Conclusion

The durum cultivation is done on small acreage in Europe, comparative to the bread wheat, but durum has very special characteristics, the area of cultivation is limited in the southern part of Europe, the use is limited to human consumption. To breed new commercial varieties in this special market will be essential to obtain high and stable yield and quality altogether. A multilocation breeding system is obligatory to test the new lines for adaptation, yield and stability. The new breeding, with many locations, disease nurseries, and the use of new technologies (genes markers), is very expansive. The private companies are completely dependent of the seed market to invest in breeding, we hope for a good development of this market to continue a very efficient breeding to obtain new profitable varieties, for the breeder and for the farmers.