Durum wheat

When genetic progress combines quality and agronomy

Farmers, and more generally the durum wheat trade, expect a lot from breeding : quality, yield, tolerance of diseases and bad weather, efficient nitrogen use, etc. Is the present feeling of yield stagnation attributable to genetic progress ? Here we intend to focus on the genetic progress made over the last 30 years as regards agronomic value and technology.

For 25 years, depending on the production region, the average yield increase of durum wheat varieties has been 0.7 – 0.9 %/ha/year.

The registration rules guide the profiles of the varieties offered to the users. To be registered in France, a new variety must satisfy numerous demands. The eligibility of durum wheat varieties in the different technological classes *(table 1)* is determined primarily by colour, speckling, protein content, « yellow berry », the 1000-grains weight, etc. (criteria for which the scores can also lead to rejection). A second filter, based on the yields obtained at sites with and without fungicidal protection, together with disease tolerances, expressed as percentages of reference varieties, is applied. The lower the quality class, the higher is the yield demanded. Conversely, the yield levels required are lower for varieties of high industrial quality.

In 2008, 54 durum wheat varieties appeared in the official French catalogue and 483 in the European catalogue. The appearance of new varieties is fairly regular, with one to five per year in recent years.

Table 1 : Yield thresholds (as % of controls) according to technological class of durum wheat varieties on the final listing

Technological classes	Thresholds
Quality durum wheat	90 %
Durum wheat colour	100 %
Protein durum wheat	95 %
Average durum wheat	103 %
Durum wheat	108 %

How was genetic progress calculated ? 1

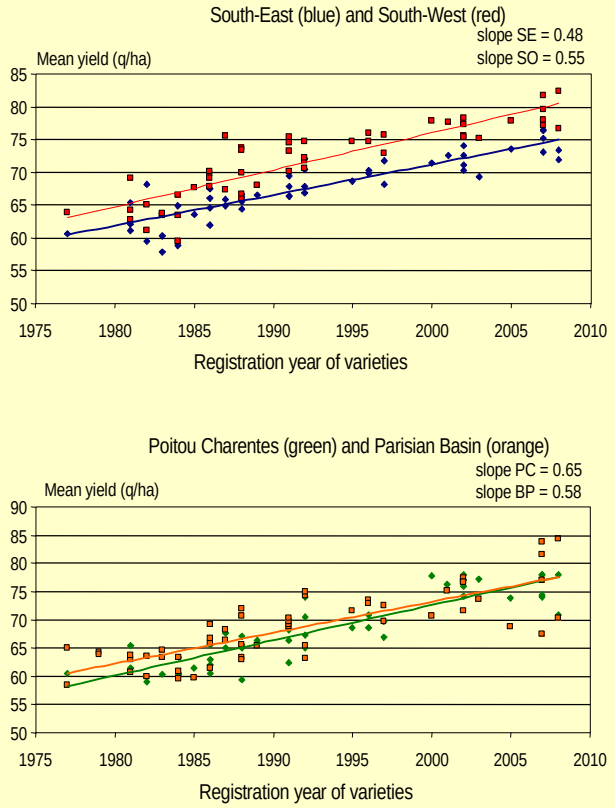
The data come from ARVALIS– Institut du végétal post-registration trials carried out over the period 1983-2008.The genetic progress is taken to be the slope of the curve describing the mean yield of the varieties plotted against their year of registration. The mean yield of a variety cannot be estimated from the arithmetic mean of the observed varieties. In fact not all the varieties were grown in the same year and the differences between varieties could be confounded with the differences between years. There are many overlaps: more than 50% of the varieties from one year were included in the preceding year and the trials include reference varieties maintained over several years. So that the varietal yields can be comparable, one must adjust the observed mean yields of the varieties for the effect of the year in which they were grown. These adjustments were calculated with a mixed linear model by treating the varietal effects as fixed effects and the year effects as random. The mixed model allows the maximum amount of data to be recovered and leads to the most precise comparisons as possible between varieties.

A species which has not lagged behind in yield improvement

The estimates of genetic progress have been calculated from the results of post-registration variety trials between the years 1983 and 2008 *(box 1).* They fall between 40 and 70 kg/ha/yr *(figure 1)* with a national mean of 50 kg/ha/yr. Although the trends are similar for the four production regions, one can see some differences. The genetic progress shows up most clearly in the north (+ 0.9 %/ha/yr) than in the south (+ 0.7 %/ha/yr), and as significantly different between the Poitou-Charentes and South-East zones.

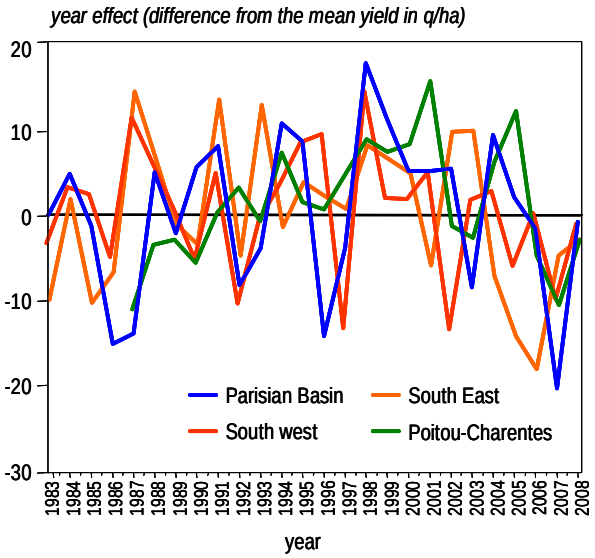
The national average genetic progress of 0.7 %/ha/yr may seem little, but it is not far behind that of soft wheat, estimated at 0.9%/ha/yr at sites protected against diseases. Models such as linear followed by a plateau, or even linear then linear (2 straight lines of different slope) do not indicate any inflexion in the slopes or a plateau, and no stagnation. Nothing suggests that genetic progress may have stagnated, and certainly not fallen.

Genetic progress between 1977 and 2008 on yields in the ARVALIS – Institut du végétal and regional technical committee trials. Analyses done on varieties protected against diseases *(Figure 1)*



The yield increase under treated conditions is linear in every region.

Revealing the effect of the year on yields when calculating genetic progress *(Figure 2)*



In the regions in the south of France, the increase in the frequency of heat waves and droughts has significantly reduced the yield potentials since the 1990s.

For durum wheat, the statistical tests confirm that genetic progress for yield has not slowed down.

The study of annual effects after removal of the effects of genetic progress *(figure 2)* confirms, on the other hand, as in soft wheat (Gate & al, 2009, n° 355 *Perspectives Agricoles*), a trend towards the lowering of regional and national yields, observed since the 1998 record. This lowering could be explained by three phenomena : a change in the relative contributions of the growing areas between regions ; the slowing down of progress on other production factors (nitrogen, fungicides etc.) ; the adverse effect of global warming. It is thus the amplification of limiting factors, associated with the economic optimisation of inputs, which has absorbed the genetic progress for yield.

Disease tolerance : progress maintained

The improvement of disease tolerance was analysed indirectly by way of the yields of varieties tested in trials unprotected against diseases. The data calculated from syntheses of the trials done in the last twenty years in the Centre-Paris Basin region show an increase of 0.8%/ha/yr. Two long-term trials in the South-East (24 years) and the South-West (17 years) show yield gains of 1.14%/ha/yr and 1.7%/ha/yr *(table 2)*. These values, which for the Paris Basin are equal to, and for the South greater than those for trials at sites well protected from diseases, indicate, as for soft wheat, a high breeding pressure for disease tolerance. These improvements are attributable to the change in the registration rules which have favoured disease tolerance since 1984, and to the fact that the plant breeders have taken this into account.

The progress made on durum wheat is very significant in view of the complexity of the improvement of this species and the numerous criteria to be taken into account.

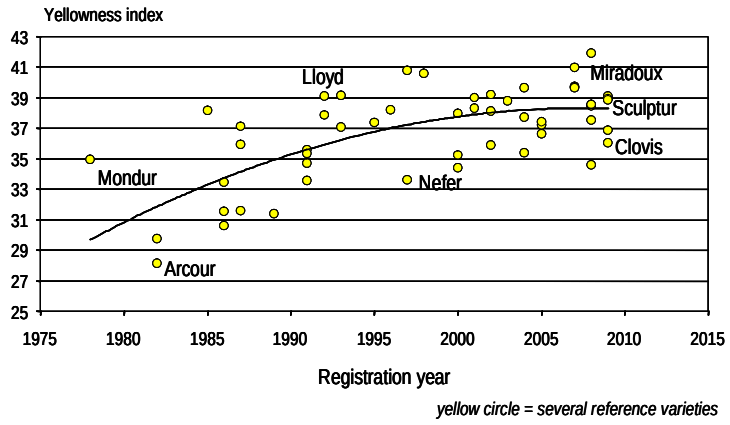
Table 2 : Genetic progress for yield					
	National treated (1983 – 2008)	Parisian Basin (1988-2008)		South-East (1 trial) (1984 – 2008)	
		treated	Non treated	traited	Non treated
Mean yield (t/ha)	6.87	7.32	6.49	6.94	5.4
Trend	Linear	Linear	Linear	Linear	Linear
Average annual increase (q/ha/yr)	+ 0.49	+ 0.52	+ 0.56	+ 0.51	+ 0.70
Variation % (slope/mean)	+ 0.71	+ 0.71	+ 0.86	+ 0.74	+ 1.14
The increase is linear at sites both protected and unprotected against diseases.					

Protein contents: dilution effects

The analysis of genetic progress for protein content shows a fall in protein content of 0.026%/yr at the national level, i.e. a loss of 0.26% in 10 years *(table 3)*, which is not much. This trend is appreciable in the south but less marked in the north, with hardly any positive trend. But to give a verdict on this character is difficult without taking account of genetic progress for yield and changes in nitrogen fertilisation practices. However the slope for the quantity of protein produced per hectare is about 0.25%/yr

Table 3 : Genetic progress for technological quality					
	Protein %	Yellowness index	Flecking %	1000-grain weight g	Density kg/hl
Mean	14.4	36.7	5.8	46.4	79.5
Trend	Linear	Linear (1980 to 2000) + plateau	Linear	Linear (1980 to 2000) + plateau	Linear
Average annual increase (10^{-3} t/ha/yr)	- 2.6	+ 45	(-0.04)	+ 27	- 7.6
Variation % (slope/mean)	- 0.18 %	+ 1.23 %	(- 0.006 %) statistically insignifiant	+ 0.59 %	- 0.10 %

Genetic progress for the yellowness index *(Figure 3)*



These yellowness indices place the French crop on a par with that of Canada, which was the original objective.

Colour: full marks !

As regards quality, improving he colour has been the primary objective of French breeding since the sixties. The yellowness index, its most heritable component, has gained 9% in 20 years, from 1980 to 2000, i.e. 1.2%/yr *(figure 3)*. Since then it has remained virtually stable and all the varieties can be described as excellent for this criterion.

Cooking quality, colour… the breeders have been able to include the manufacturers' demands in their breeding schemes.

Speckling: fewer susceptible varieties

With 1- 8 % of speckled grains on average, and 12 % in 2007, speckling is the character which is most harmful to French durum wheat exports, especially to north Africa. Compared with less susceptible varieties like Dakter or Miradoux, the susceptibility of French varieties varies widely, by a factor of 0.5 to a factor of 4. The interaction with the weather complicates the comparisons over 30 years, but nevertheless one can say that nearly all the varieties registered since 2001 show a speckling incidence between 0.5 and 1.5 x those of the reference varieties. For 20 years only two varieties with susceptibilities close to that of Néodur, the susceptible control, have been registered.

1000-grains weight: + 6 g in 20 years

A key yield factor for semolina, the 1000-grain weight increased markedly from 1980 to 2000, after which it stabilised.
Since 2001, 80 % of the varieties registered had a 1000-grain weight between 44 and 50 g, i.e. a gain of 6 g compared with the eighties.

Density: a slight lowering

For density the trend is a slight fall, - 1.5 % in 20 years, but significant.

Genetic progress to pursue

Global warming, reduction of inputs and the need for economic competitiveness: genetic progress is a strategic lever.

In 30 years, French breeding has hoisted up durum wheat varieties remarkably in terms of quality (colour and grain size). The demand from now on is for yield and its stability, improvements in disease tolerance (of the plant, the leaves and the ears), the efficiency of use of water and nitrogen, and the maintenance of a high standard and wide range of technological qualities. Resistance to cold and heat remain important characters to improve. Tolerance of mosaic and other viruses is also being sought. Since the accumulation of all the valuable characters is a long process, the definition of ideotypes for given production contexts and families of limiting factors should help in the management of the different priorities.

Jean-Baptiste PIERRE
jb.pierre@arvalisinstitutduvegetal.fr
Philippe BRAUN
p.braun@arvalisinstitutduvegetal.fr
François PIRAUX
f.piraux@arvalisinstitutduvegetal.fr

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