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# Wheat varieties and technological change in Europe, 19th and 20th centuries: New issues in economic history

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## 1. INTRODUCTION

Although biological innovations are consubstantial to economic development, they are not a popular subject in economic history. This is partly because specific evidence on the issue is scarce when compared with the sort of evidence which economists and historians are most used to. Paradoxically, this lack of attention to biological innovations is also related to a marked tendency among economic historians to neglect the importance of biological cycles in the agricultural and food sectors[1]. These two factors explain, for example, why specialists in the field often apply the 'induced innovation' model to the analysis of technological changes in agriculture, though this model is better suited to activities less affected, at least in the short term, by those cycles (Hayami and Ruttan, 1985; Federico, 2005).

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1. We understand as biological innovations those technological innovations targeted at improving the physical development of plants and animals and their productivity, responding to the final aims intended. In the current article only those innovations related to the creation of new wheat varieties will be considered. Innovations towards improved soil fertilisation, pest and illness control and the irrigation will, therefore, not be assessed.

Similarly, although specialists in agrarian history pay somewhat more attention to biological innovations, their interest is limited to those cases in which the consideration of these is unavoidable. Good examples of this are the numerous studies of the wine producing sector and the *Phylloxera vástarix* plague. With very few exceptions, however, specialists tend to focus their attention on innovations in working practices, products and tools related to soil fertilisation, land cultivation and harvesting operations, rather than on innovations of a biological basis. This trend becomes even more pronounced when both agrarian and economic historians try to assess the relationship between the evolution of agriculture and economic growth over time (Lains and Pinilla, 2008). Similarly, and though recent research also considers the effect of environmental conditions on the path of technical change in agriculture, the tendency is to give preference to the relationship between the environment and the diffusion of chemical and mechanical innovations (Pujol-Andreu, 1999).

These deficiencies are ever present in the European agrarian history. The historiography of the United States, on the other hand, has offered new contributions to the consideration of biological innovations and their incidence on the economic activity (Kloppenburg, 1988; Olmstead and Rhode, 2008). As a result of this research, we now have a more comprehensive perspective of the different circumstances affecting economic growth from the 19th century. This research has also shown how different paths of technical change evolved in close relation to one another, and how the consideration of innovations in animal and plant varieties enhances our understanding of these relationships over time and space. In order to better understand these relationships, this article focuses on two variables: evolution of wheat yields in Great Britain, France, Italy and Spain from the mid 19th to the late 20th century; and the coeval changes promoted by different social sectors in these four countries in the cultivated varieties of this cereal[2].

Regarding the first variable, I shall be using available official statistics on extension, production and yield in the wheat sector, with consideration of two indicators: wheat production per surface unit and, in the Spanish case, wheat production per weight unit of harvested straw. This last indicator allows, as we shall see, to appreciate new aspects of the evolution of the wheat sector hitherto unremarked upon by agrarian historians. As to the second variable, I shall be using recent research from the field of agronomic science and a number of sources and databases on the new wheat varieties sown from the late 19th century in the four countries under consideration.

2. For a first approach to this issue see Pujol-Andreu (2002, 2005).

Finally, it should be noted that these four countries have not been selected at random. Great Britain is an exceptional case, due to its very favourable environmental conditions for wheat production, but also because governmental economic policies hindered its development for a long time. Large areas of France enjoy similar environmental conditions, but in contrast to the latter case governmental policies promoted development of the wheat sector in order to ensure domestic supply of grain. Environmental conditions in Italy and Spain were not as favourable, but the increase of wheat production was even more necessary due to structural problems affecting the balance of payments.

## 2. YIELDS PER HECTARE AND BIOLOGICAL INNOVATIONS

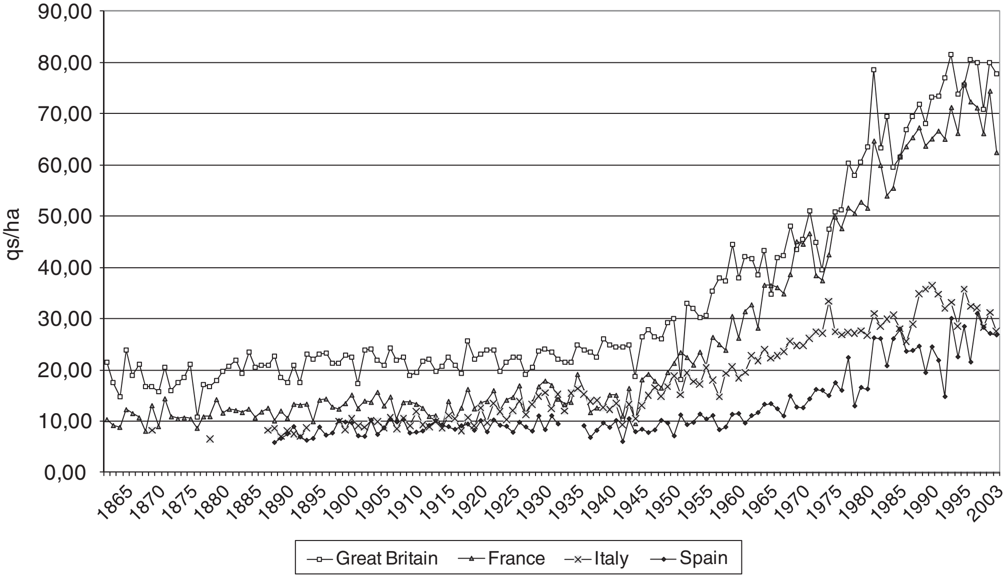
Figures 1 and 2 help to better understand the issue at stake. The first observation that can be made about the figures refers to a well known fact: innovations introduced in the wheat sector after the Second World War sharply and consistently raised grain production per surface unit. Secondly, Figure 1 shows that these technologies had very uneven effects in different geographical contexts, because yield differentials between Atlantic (Great Britain and France) and Mediterranean (Italy and Spain) Europe increased, instead of diminishing over time. Figure 2 presents this differential even more conspicuously: the extension of wheat cultivation increased in Great Britain and France in the second half of the 20th century, while diminishing in Spain and Italy. Finally, wheat yields per hectare in Spain were always very low, not reaching Italian levels until the late 20th century. The detailed trajectories are as follows.

Until the Second World War yields per hectare in Great Britain must have been among the highest in Europe, but they barely increased from 19 qs/ha in 1865-1869 to slightly over 22 qs/ha in 1901-1910. After that, yields remained stable until the 1930s. At the same time, extension of wheat cultivation decreased from 1.5 million ha to barely 700,000 ha, subsequently fluctuating around the latter figure. The key achievements of the British wheat sector until the Second World War seem therefore to have been more associated with the progressive reduction of extension of cultivation rather than the diffusion of new production techniques. In France and Italy, where wheat was cultivated much more extensively, yields were lower but increased more sharply. In France, yields increased from 10.5 to 13.5 qs/ha, between the mid 19th century and the First World War, reaching 15.5 qs/ha during the 1930s. During this period, wheat cultivated areas reached 6.5 and 7 million ha, dropping by about 1 million during the interwar period. In Italy, yields merely increased from 7.8 to 8.5 qs/ha between the late 19th century and the First World War, rising more sharply afterwards to 14 qs/ha during the 1930s. During the same period, extension of wheat cultivation increased from 4.5 to around 5 million hectares.

In short, while wheat yields in Great Britain were already high by the mid 19th century, increasing by around 16% by the 1930s, in France they soared by about 50%, while in Italy they doubled.

**GRAPH 1**

**Wheat yield per hectare in Great Britain, France, Italy and Spain, 1865-2003**




Sources: Based on data from Mitchell (1988, 1998); Faostat database from 1960; Barciela et altri (1989); *Boletín Semanal de Estadística y Mercados,* 1891-1902; *Boletín de Agricultura Técnica y Estadística de Mercados,* 1903-1930; *Anuario Estadístico de la producción Agrícola,* 1929-1971; *Anuario Estadístico de la Producción Agraria,* 1972-1997; and *Anuario de Estadística Agroalimentaria,* 1999-2006.

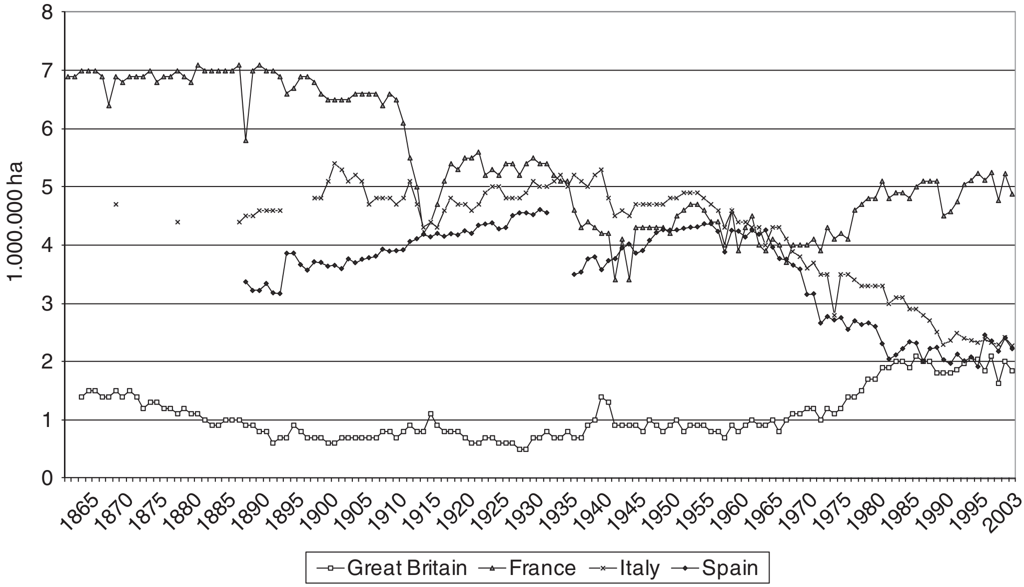
In Spain, the extension of wheat cultivation increased from over 3 million hectares from the late 19th century to around 5 million before the Civil War, but yields barely increased from 7 qs/ha in the 1890s to slightly over 9 qs/ha in the 1930s. Consequently, wheat yields in Spain were always around 65% lower than in Great Britain and 50% lower than in France. Regarding Italy, the differential widened: in the late 19th century yields in both countries were very similar but by the 1930s Italian yields were 35% higher than the Spanish.

As stated previously, wheat yields in Great Britain experienced a sharp rise after the Second World War, reaching 77 qs/ha between 2000 and 2003 and thus attaining levels that were between 3 and 4 times higher than those of the 1930s. Additionally, during this period extension of wheat cultivation soared from 1 million hectares in the late 1960s to

2 million forty years later. In France, yield increases were even more intense, reaching 70 qs/ha by the end of the 20th century. In this case, yields grew to a level between 4 and 5 times higher than in the pre-war period. At the same time, the extension of cultivated areas increased after a period of contraction during the 1950s and 1960s, reaching similar levels to those achieved during the 1930s.

**GRAPH 2**

**Wheat surface in Great Britain, France, Itly and Spain, 1865-2003**




Sources: See Figure 1.

In Italy and Spain wheat yields and the extension of wheat cultivation evolved in a different way. In Italy, yields also soared after the Second World War, but less sharply than in France and Great Britain, stagnating around 30 qs/ha from the 1980s. In Spain, yields did not start increasing until the 1970s, reaching, and stabilising at, the same levels attained in Italy by the late 20th century. Until 1965 the Spanish wheat sector rarely achieved yields over 11 qs/ha, reaching 26 and 30 qs/ha between 2000 and 2003. Spanish yields, however, fluctuated more than Italian during the 1980s and 1990s, probably, though only partially, because of the irregularity of interannual rainfall. During the same period extension of wheat cultivation in both countries dropped quite significantly. In Italy it fell from 5 million hectares just before the Second World War to 2 million between 2000 and 2003. In Spain it diminished from 4.5 million to 2.3 million hectares.

Reduction of wheat cultivation in Italy and Spain is not, however, the main factor explaining increasing yields during the second half of the 20th century. Furthermore, it is more reasonable to suppose that in both cases the extension of wheat cultivation decreased because yields increased to a sufficient degree, although this is difficult to prove with currently available evidence. Regarding Italy, we have already seen that both yield and extension of wheat cultivation were increasing from the 1920s. Similarly, the evolution of wheat cultivation in Italy and Spain after the Second World War cannot be explained merely with reference to the abandonment of the least productive wheat fields. In Italy, domestic wheat production increased from 70.9 million qs between 1931 and 1935 to 84.9 million between 1986 and 1990, subsequently stabilising around 77 million. In Spain, domestic production first increased from 43.6 million qs to 53.9 million, later reaching 60 million.

The sharp increase in wheat yields throughout Western Europe during the second half of the 20th century must be linked to a series of innovations in the vegetative development of that cereal. Agrarian historiography has highlighted, though offering limited quantitative evidence, the marked incidence of two related groups of innovations: the diffusion of new fertilisation methods and phytosanitary treatments, and the diffusion of more productive wheat varieties. Extension of irrigation, on the other hand, seems to have had little effect on the evolution of yields[3]. Specifically, recent agronomic research has concluded that innovations in wheat variety account for approximately 50% of yield increase during the second half of the 20th century in Great Britain, France, Germany, Norway, Hungary, USA and Canada[4]. For the Spanish case, a recent study regarding wheat varieties cultivated in Catalonia between 1977 and 2008 attains the same results (Voltes et al., 2009: 32-34).

Research also shows that one of the key factors in these innovations was the reduction of plant height, allowing for a sharp yield increase. On the one hand, the reduction of plant height permitted a higher concentration of the effects of photosynthesis on grain production, significantly augmenting productive potential. On the other, this same morphologic feature increased the plant's resistance to bending in the latest stages of development (lodging) even with heavier ears, allowing farmers to apply larger doses of fertilisers in cultivated areas. These factors not only increased yields per surface unit, but also

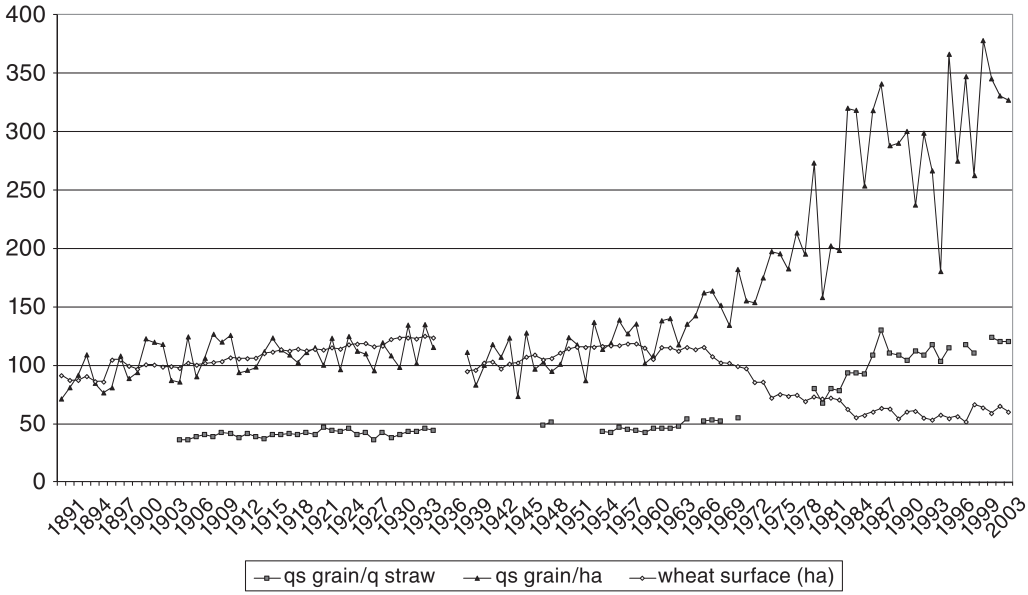
3. In Spain dryland cultivation always produced between 86 and 90% of total wheat production. While wheat yields in irrigated areas increased from about 20 qs/ha around 1960 to approximately 43 qs/ha around 2000, dryland yields increased from 10 qs/ha to nearly 25 qs/ha.

4. Brancourt-Hülmel et al. (2003: 37-38); Roll-Hansen (2000: 1109). For further details see Slafer, Satorre, Andrade (1994); Royo et al. (2007: 259-260).

the proportion of grain per harvested straw weight unit, as shown in Figure 3 for the Spanish case. Production of straw per hectare also increased, although less markedly, due to the higher number of stems per plant (tillering). Finally, this research shows that productive potential of new wheat varieties was much higher in Atlantic Europe than in Mediterranean Europe, because in the former varieties with a longer cycle can be cultivated. Pluviometric and temperature conditions in Mediterranean Europe, particularly during spring and summer, accelerate grain development and maturity, reducing productivity. In this region, wheat has to be harvested between mid June and mid July, whereas in central and northern Europe and northern Italy harvesting begins later, and can be delayed until late August.

**GRAPH 3**

**Productivity and wheat surface indexes, Spain, 1891-2003 (1905/1907=100)**




Sources: Based on data from *Boletín Semanal de Estadística y Mercados,* 1891-1902; *Boletín de Agricultura Técnica y Estadística de Mercados,* 1903- 1930, *Anuario Estadístico de la producción Agrícola,* 1929-1971, *Anuario Estadístico de la Producción Agraria,* 1972-1997, and *Anuario de Estadística Agroalimentaria,* 1999-2006.

In the following paragraphs the wheat yields trends explained above will be related to the evolution of cultivated varieties. I will begin by focusing on the period predating 1940, because it was then that the scientific and technological basis for the processes that were to unfold after the Second World War was established.

## 3. NEW VARIETIES IN TRADITIONAL WHEAT SECTORS: THE IMPORTANCE OF STRAW

Although innovation in wheat varieties in the second half of the 20th century has often been associated with the operation of CIMMYT –since its creation in Mexico in 1963– its scientific basis had already been laid in the early 20th century. This followed several decades of intensive work on wheat breeding by farmers and seed companies and the rediscovery of Mendel's laws around 1900 by E. Carl Correns, E. Von Tschermark, and Hugo de Vries[5]. As a result of these processes breeding practices gained in efficiency but also became more complex, demanding the establishment of new public and private institutions directed at the creation of new varieties suited to specific regional needs (Kloppenburg, 1988: 66-129; Busch, 1997: 243-247). During the first third of the 20th century, however, wheat breeders did not only aim at increasing the grain yield per hectare, but also that of straw. During this period, animal power was still a key source in cultivation and harvest operations and in short-distance transport, making straw a very valuable resource. Straw was necessary for the preparation of fertilisers, animal beds and animal fodder for bovine and ovine livestock. In Spain, straw amounted to 16% of the total income yielded by a wheat-cultivated hectare between 1903 and 1931. The percentage was even higher in the Mediterranean coast, where it reached between 18 and 28%, and the northernmost provinces of the Cantabrian coast and Galicia, where it amounted to between 23 and 35%[6].

In short, until the Second World War farmers only adopted new wheat varieties when, apart from increasing grain yield per surface unit, they also guaranteed the production of enough straw to satisfy regional livestock needs and demand for fertilisers, forcing the cultivation of tall varieties which were also resistant to lodging. Whenever this accident occurred, as a consequence of an excessive weight of the ear, inappropriate fertilisation, out-of season rainfall or strong winds, the plants became particularly vulnerable to cereal diseases. Additionally, the costs of harvesting operations increased substantially. Lodging could even prevent the use of reapers when these were available. Moreover, though it was known that shorter varieties were in cultivation in Japan, it was not until the 1940s that wheat breeders in Europe and the USA abandoned the idea that taller varieties offered higher yields (Dalrymple, 1988: 27-30; Walton, 1999: 34-39; Kingsbury, 2009: 277-279).

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5. On scientific advances in the improvement of wheat varieties and the new relationships established between farmers, seed companies and scientists see, for example, Harro (2001) and Bonneuil (2006).

6. Calculations based on Junta Consultiva Agronómica (1915, 1923) and *Anuario Estadístico de la Producción Agrícola*, 1930 and 1931.

In this context, differences in the institutional framework promoted different innovation strategies. Although the development of the farming model known as *high farming* has often been associated with British farmers aiming to increase the production of bread wheat, the fact is that its development was more closely related to the expansion of animal husbandry. For that reason, English and Scottish farmers and technicians involved in the improvement of wheat varieties were already favouring tall and lodging-resistant varieties by the end of the 18th century, though this strategy also tended to reduce the amount of gluten present in the grain. This process intensified during the 19th century, because the falling trend followed by wheat prices during this period further encouraged farmers to increase yield per hectare, since the prices paid for bread varieties, less productive, often offered insufficient returns. As a consequence, British wheat flours became less and less suitable for bread production unless mixed with imported flours, often being used instead in the production of biscuits, of which the Royal Navy was a massive customer. A study on the chemistry of wheat published in 1886 showed that Rivet wheat was almost totally lacking in gluten. In other varieties, the gluten content of seeds was between 14.5% (Squareheads) and 27.6% (Rough Chaff). In imported wheats, gluten content was usually between 16 and 32% (Walton, 1999).

In the following decades, custom duty policy made British wheat supply almost completely dependent on imports, accentuating this process of biological changes (Percival, 1934: 72). According to the Pelshenke index, which establishes the minimum value for bread wheat flours at 30, the British wheat flours scored values between 12 and 15 in 1934. Other western and eastern European wheat flours obtained values between 80 and 110, and Canadian wheat flours between 80 and 240 (Arana, 1934: 447). Improvement in this matter in Great Britain did not start until the creation in Cambridge of the Plant Breeding Institute in 1912, which prompted the creation of the Yeoman I (1916), Yeoman II (1924) and Holdfast (1936) varieties (Palladino, 1996: 116-123). These varieties were developed from the Browick –English– and the Red Fife and White Fife –Canadian– varieties; the latter two had been developed in Canada in the 19th century from a Ukrainian wheat variety (Angus, 2001: 111-117; Kingsbury 2009: 169-173)[7]. During the 1930s, however, Squareheads and Red Standard remained the most common wheats in Great Britain, only improved by selection within heterogeneous varieties (wheat landrace) (see Table 1 in the Appendix) (Percival, 1934: 123).

Notwithstanding, English wheats were extensively used in the continent in a wide range of cross breedings with indigenous and eastern European varieties, due to the charac-

7. The variety Little Joss, obtained between 1908 and 1911, must also be highlighted for its grain yields, though its capacity for flour production was poor.

teristics of their straw (Lupton, 1987: 53-61; Pujol-Andreu, 2005: 61-62; Angus, 2001: 111-117). Of the 46 wheat varieties flows that I have documented elsewhere for western Europe between 1823 and 1913, 35 originated in Scotland and England[8]. By contrast, of all new wheat varieties obtained by crossing and genealogical selection between the second half of the 19th century and the Second World War, only 14 were developed in Great Britain while 25 were obtained in France (see Table 1 in the Appendix). This differential in favour of continental Europe would be even more notable if we considered the new varieties obtained in Holland, Germany and Sweden and their adoption in British agriculture during the 1930s[9]. In his 1934 study, Percival affirms that 12 winter wheats from other countries, mainly France, were in cultivation in Great Britain, alongside 8 varieties of Swedish spring wheats.

In France, the innovative practices carried out by seed companies, particularly the firm founded by Ph. V. L. de Vilmorin in1815 (see Table 1 in the Appendix), were particularly relevant[10]. This company offered the first seed catalogue in France in the mid 19th century, created the first training centre for plant breeders at the end of the century, and started marketing its own wheats with the Dattel variety, in 1883. As a result, the Bordier, Trésor, Hâtif Inversable and Bon Fermier varieties, among others, amounted to around 30% of all wheat cultivated in France in 1918. These varieties mainly expanded in the northern and central regions, in which wheat yields were traditionally higher. In more southerly regions, however, the adoption of these varieties was not significant, and only the Noé or Aquitanian wheats, from Russia, gained some importance in the southwest. During the 1920s and 1930s the most common varieties, again in the central and northern regions, were Alliés and Vilmorin 23, 27 and 29, which between 1918 and 1938 yielded up to 40 kg more grain per hectare per year than previously favoured varieties[11]. In 1937, 2.2 million hectares were cultivated with Vilmorin's varieties, 1.1 million with other new varieties also developed in France and 2 million with indigenous or foreign

8. Significant British varieties were, among others, the selections by P. Shirreff, A.D. Shirreff and Hallett, or the Prince's Prolific, Prince Albert, Ambrose Standup, and Goldendrop varieties. Crossings also made use of eastern European varieties, such as Noe or Aquitania. (Percival, 1934: 91-129; Pujol-Andreu, 2002: 69-72).

9. Here we make no distinction between 'hybridation' and 'crossing' to refer to breeding processes involving the development of new commercial wheat varieties by cross-pollination, without «heterosis» (see note 40). By genealogical selection, wheat plants of a population of similar varieties are self-fertilized and selected through several productive cycles, in order to obtain new varieties with the desired features. Varieties thus obtained can be commercialised or used in subsequent hybridation and selection processes for the development of further varieties.

10. The Institut de Reserches Agronomiques was created in Paris in 1921, and the Centre de Reserches Agronomiques in Versailles in 1923.

11. Vilmorin et Menuisier (1918); Bonjean, Doussinault and Stragliati (2001: 140-149); Brancourt-Hulmel et al. (2003: 38-39); Kingsbury (2009: 107-109).

wheat varieties (Sala Roca, 1948: 135-138). By 1949, local varieties covered just 10% of total cultivated areas (Belderock et al., 2000: 236-240). Vilmorin's wheats also spread to Great Britain, Belgium, Holland and Germany, where they were often additionally used for the development of newer varieties.

In the latter three countries, and in Sweden, the role of public institutions in the development of new wheat varieties was far more important[12]. In Holland, L. Broekema developed the Wilhelmina and Juliana varieties, which between 1931 and 1935 amounted to 70% of winter wheats in the country. The first of these varieties was developed in 1890 from a Squarehead wheat and the local variety Spijk. The second was obtained in 1903 from the Wilhelmina and the Essex varieties, the latter also originating in Great Britain. These two varieties also spread to Great Britain, Belgium and Germany (Haan, 1957; Zeven, 1990). In the Swedish case, yield increase caused by the diffusion of new wheat varieties between the late 19th century and the 1940s has been estimated at 30% for winter wheats and 12% for spring wheats. In the German case, yield increase due to these innovations between 1880 and 1935, has been estimated between 20 and 25% (Sala Roca, 1948: 146-147; Lupton, 1992: 40; Porsche and Taylor, 2001: 176-183).

Innovation in wheat varieties in Italy needs to be regarded with special attention (see Table 1 in the Appendix)[13]. Italian wheat breeders, particularly F. Todaro, tried at first to adapt the new varieties developed in central and northern Europe to the Italian environmental conditions, but this strategy had to be abandoned because the northern varieties had been developed in very different enviromments. F. Todaro also tried to create new varieties through selection within indigenous wheats, but the new varieties obtained only improved productivity at a local level (Felice, 2004: 23-25). From the early 20th century, however, N. Strampelli started following a different approach, based on the crossing of the Italian variety Rieti with new varieties of different origins, thus abandoning the research strategy previously favoured in the country. For his first crossings Strampelli used French wheats, but the results remained poor. His breakthrough was in 1913, with the hybridisation of the Rieti variety with the Dutch variety Wilhelmina and the Japanese va-

12. Belgium: Research Station for Plant Breeding at Gembloux (1872) and Station du Selection du Boerenbond (1925); Holland: Plant Breeding Institute at Wageningen (1912) and Station de Recerches Agronomiques de Groningen (1889); Sweden: Plant Breeding Station at Svalöf (1886) and Landskrona (1904); Germany: Plant Breeding Institut Munich (1872), Breslau (1872), Halle (1863) and Hohenheim (1905). See Pujol-Andreu (2002: 70-72; 2005: 59).

13. The main Italian research centres were the Regia Stazione di Granicultura di Rieti (1907), the Instituto Nazionale di Genética per la Cerealicultura di Roma (1919), and the Instituto di Allevamento per la Cerealicultura di Bologna (1920), the latter promoted by the seed company Società Produttori Sementi (1911).

riety Akagomughi. The new varieties obtained were quickly adopted by farmers after the First World War, prompting a unanimous change in the innovation strategies followed by Italian wheat bredeers.

Strampelli's new wheats yielded up to an additional 40 qs/ha per year in the most fertile agricultural areas in northern Italy, were highly resistant to lodging and constituted good quality bread wheat. The new varieties of bread wheat included Villa Glori, Damiano Chiesa, Mentana and Ardito, the diffusion of which was again particularly significant, as in the French case, in the central and northern regions. That is, in those regions where environmental conditions were more favourable for plant development and consequently grain yields were higher. Meanwhile, the durum variety Senatore Capelli, used for the preparation of pasta and obtained by Strampelli by selection from a northern African wheat variety, gained a significant position in southern Italy. By 1934, the Mentana variety amounted to 20.4% of the total wheat cultivated in the country; other important varieties were Senatore Capelli (10%), Damiano Chiesa (5.6%) and Villa Glori (4.9%) (De Angelis, 1935; Felice, 2004: 78-79, 118-119, 134-140; Borghi, 2001: 296-300). Notwithstanding the possibilities offered by the Akagomughi variety, the reduction of plant height was still not deemed convenient in the 1930s; only the Ardito variety, another of Strampelli's creations, around 100 cm tall, was clearly shorter than the varieties then in cultivation. In 1934, however, this variety barely covered 0.9% of all wheat cultivated areas though it was already in use for new hybridisations (see Table 2 in the Appendix) (Borojevic and Borojevic, 2005: 455-459).

Wheat breeding in Italy, however, was to have a much wider impact. In 1937 the company Società Produttori Sementi, founded by Todaro in 1911, developed new wheat varieties from the Japanese variety Saitama 27, which sported a significant difference to the Akagomughi variety (Borghi, 2001: 297-298; Felice, 2004: 135-140, 179). As determined in the late 20th century, while the latter variety allowed for the development of new, shorter varieties, due to the presence of the Rht8 and Rht9 genes, the Saitama 27 variety permited the development of semidwarf wheats, due to the action of the Rht1 and Rht3 genes. In contrast with the former genes, these genes inhibit the action of gibberellins, the hormones responsible for plant growth (Borojevic and Borojevic, 2005: 455-456; Worland and Petrovic, 1988: 55-56).

Research aimed at the creation of new wheat varieties had very little impact in Spain, despite the numerous initiatives launched for its promotion from the 1880s on[14]. As in

14. The most important among the new research centres were: the Estación de Ensayo de Semillas de La Moncloa (1908), the Instituto de Ceralicultura (1929), the Granja Regional de Castilla la Vieja

Italy, Spanish seed breeders tried to acclimatise wheat varieties created in Atlantic Europe to different wheat producing regions within the country, but these attempts were also fruitless: the new varieties did not adapt, or in the words of one of the technicians involved, 'could not compete with local varieties'. After the First World War, Spanish wheat breeders started trying Strampelli's new varieties and other varieties from similar climates, but the results also failed to answer to 'the hopes we had put in them'[15]. As a consequence of this fiasco a new approach, based on improvement of indigenous wheats by selection and later by hybridisation and genealogical selection, was adopted. The results remained poor. The new wheats obtained were mostly selections from local varieties, and had a very limited diffusion (Vitoria 8 and 9, Castilla 1, Moncloa 6, 8, 27, Catalán Blanco 6 and Rieti Navarro 25 and 27)[16].

In summary, from the late 19th century innovations in wheat varieties had a significant role in agrarian technological change, though their development remained strongly conditioned by the continued importance of straw to farmers. For this reason, seed breeders did not merely aim at improving grain yields. Since sown wheat vatieries had to be kept considerably tall, they also aimed at improving plant resistance to lodging and disease and, in the case of Western Europe, at increasing gluten content. Prior to the Second World War, however, scientific research only managed to improve those varieties cultivated in the environmental conditions prevailing in Atlantic Europe. In the south of France and Italy and most of Spain, local wheats remained predominant in the 1930s, contributing to the perpetuation of very low grain yields in the Spanish case[17].

## 4. REDUCTION OF PLANT HEIGHT AND YIELD INCREASE

The direction of wheat breeding ultimately changed after the Second World War, when breeders and seed producers included the development of potentially more productive new varieties among their targets; that is, varieties with shorter and thicker stems, and more capacity for tillering[18]. The adoption of this new approach was partially caused by the results accumulated in different research centres –initially Japanese, Italian and French– since the 1930s, which indicated that short straw wheats could offer high yields. This new

(1923), the Instituto de Mejora de Plantas de Navarra, and the Servei de Terra Campa in Catalonia (1923). See Pujol-Andreu (2002: 74-80; 2005: 63).

15. See references in Ministerio de Fomento (1912: 138) y Nagore (1934: 48-53).

16. On the diffusion of these varieties in Spain see Sala Roca (1948: 136-147) and Soler and Coll (1935: 51-67).

17. On the effect of these innovations worldwide see Olsmtead y Rhode (2007).

18. Another recent innovation has been insensitivity to photoperiod (García Olmedo, 2009: 185).

approach, however, was also made possible by the decline of the economic importance of straw caused by the growing motorisation of transport, cultivation and harvesting operations, the wider availability of affordable mineral fertilisers and agrochemical products and the emergence of new types of animal fodder.

During the second half of the 20th century, research centres and seed companies also tried to develop new marketable wheat varieties with heterosis or hybrid vigour, as had been achieved in the USA with maize in the 1930s[19]. These initiatives failed, and farmers continued using their own production for sowing. This did not discourage research into new biological innovations, because seeds had to be renovated periodically and because plant breeding innovations were endorsed with the Convention of the International Union for the Protection of New Varieties of Plants, signed in 1961 and enforced since 1968[20].

An important step forward for this new research approach was the creation in 1925 of the NORIN 10 variety in Japan; it was developed from the Daruma –Korean– and the Turkey Red and Fultz –American– varieties. The NORIN 10 variety incorporated the dwarfism genes Rht1 and Rht 2 and, after being successfully distributed among Japanese farmers in 1935, was introduced into the USA in 1946. The development of new varieties of semidwarf wheats had to wait several years, but during the 1950s and 1960s plant height nevertheless followed a diminishing trend caused by the application of new selection processes to the existing varieties. Eventually, in 1961 Orville A. Vogel obtained the Gaines (NORIN 10 x Brevor 14) variety, finally boosting diffusion of semidwarf wheats. By 1968, semidwarf varieties dominated wheat production in the north-western states, and by 1974, in the whole of the USA (Peterson et al., 2001: 416-417). On the other hand, during the 1950s the NORIN 10 variety and its derivatives, along with the Italian varieties created by Strampelli and Todaro, were incorporated into the research programme led by Bourlaug in Mexico since 1943, becoming one of the main genetic foundations of the Green Revolution (Borojevic and Borojevic, 2005: 457-458; Darymple, 1988: 28-29; Kingsbury, 2009: 277-279)[21].

The diffusion of new semidwarf varieties was slower in Europe, apart from having a different geographical dimension. New varieties remained sensitive to regional environ-

19. For maize varieties with heterosis or hybrid vigour farmers must renovate the seeds annually, because the high yields obtained in the first harvest tend to diminish sharply in subsequent productive cycles.
20. http://www.upov.int/es/about/upov_convention.htm.
21. The Brevor variety was created by Vogel in 1949. NORIN is an acronym made of the name of five Japanese research centres. The term 'Green Revolution' was coined in 1968 by USAID's Administrators.

mental conditions, and these were very diverse in Europe. Moreover, wheat varieties were in Europe hard to substitute after centuries of adaptation to the specific conditions of each region, especially since these varieties were in themselves improvements brought about by crossing and genealogical selection in preceding decades. In fact, with the sole exception of Italy, the new semidwarf varieties did not start being sown until the mid 1970s, and did not become predominant until a decade later[22]. Before then, innovation on new varieties was strongly conditioned by the research approach predominant before the Second World War.

This probably explains the importance gained after the Second World War by improvement activities developed by French seed breeders (see Table 2 in the Appendix). In this country, improvement programmes managed to reduce wheat height from 125-140 cm in the 1930s to 85-110 cm in the 1970s and 1980s (Balfourier, 2005: 26). An important step in this direction was the development of the Capelle Desprez variety in 1946, between 95 and 115 cm tall and widely distributed in the central and northern regions. Another such success was the creation of the Étoile de Choisy variety in 1950. This variety incorporated the genes Rht 8 and Rht 9 present in the Italian variety Ardito, and it became the first high yield variety adapted to southern environmental conditions. Lupton estimates that these two varieties amounted to 51% of all winter wheat cultivated areas in 1964 and to 35% in 1967. Also popular in 1967 were the Champlein and Capilote varieties, amounting to 20 and 15% of total extension of wheat cultivation respectively. These new French varieties were also widely sown in Great Britain, because they were shorter, highly productive and yielded good quality bread flour. In Great Britain, the Capelle Desprez variety covered between 73 and 84% of total area of winter wheat cultivation during the 1960s. A few years later, in 1973, this variety along with the Maris Huntsman variety, developed in Great Britain from French varieties, jointly amounted to 67% of total cultivation (see Table 2 in the Appendix)[23].

After this, plant height was to reduce even further with the arrival of semidwarf wheats, finally reaching an interval between 80 and 85 cm. Several varieties from CIMMYT and, in the French case, new Italian varieties incorporating the Rht8 gene (see Table 2 in the Appendix) played an important role in the new crossing and genealogical selection procedures developed for this purpose. Additionally, in this new stage of research a wider se-

22. For Great Britain see Angus (2001: 114-115).
23. Genech de la Louviere (1975: 118-121); Lupton (1987: 64-65, 55-56); Lupton (1992: 25-27, 57-63); Angus (2001: 113-117, 142-149); Brancourt-Hulmel et al. (2003: 39); Doré and Verognaux (2006: 137-162); Gale (1974). The latter estimates the height of British wheats at the beginning of the century at about 130 cm.

lection of varieties became available to farmers, probably due to the novel research opportunities offered by new genetic resources. Around 1978, 5 varieties of wheat covered 62% of the total extension of winter wheat cultivation in France, and 77% in Great Britain. Around 1990, these proportions could only be reached if 8 varieties in France and 10 in Great Britain were considered. In France, the Courtot variety –created in 1974 in the Institut National de la Reserche Agronomique– played an important role in the development of new varieties of semidwarf wheats. The same applies for the Hobbit variety –obtained a year later in the Plant Breeding Institute of Cambridge– in Great Britain. Finally, with the diffusion of new semidwarf varieties the presence of French wheats in Great Britain tended to diminish in favour of new British varieties[24].

On the other hand, CIMMYT's varieties were seldom used in the Italian wheat-bread sector. In part this was because the genetic advantages of semidwarf wheats, regarding grain yields per surface unit, were less significant in Mediterranean Europe (Acreche et al., 2008: 32; Worland and Petrovic, 1988: 57, 61-62). In addition, wheat breeding based on the Saitama 27 variety produced good results in Italy at an early stage, further limiting the use of CIMMYT's wheats. As in the aforementioned cases, however, there was a first stage of short stemmed wheats down to the late 1970s, in which wheats derived from the Akagomughi variety played a predominant role, followed by a second stage of semidwarf wheats. The varieties of the latter that eventually gained predominance were normally derived from the Akagomughi and Saitama 27 varieties[25].

Around 1972 over 60% of the area under bread wheat cultivation was covered by varieties derived from Akagomughi wheat, 110 to 120 cm tall, but some other varieties, such as Orlandi, Produttore e Irnerio, which were to become strategic in the subsequent development of commercial semidwarf wheats, had already appeared. Innovation gained pace in the 1970s and 1980s, and by 1988 the Mec, Centauro, Gemini and Pandas varieties, at about 80 cm tall, already amounted to 55% of total extension of bread wheat cultivation. In 1999 the Centauro and Pandas retained a 33% share and a group of 10 varieties, also of the semidwarf type, a further 42.3% (see Table 2 in the Appendix) (Lupton, 1992: 37-39; Borghi, 2001: 298-303; Felice, 2004: 180-185, 209-212, 235-239).

Reduction of durum wheat height was also significant. In this case, however, seed breeders had to turn to new hydridation strategies and progress proceeded at a slower

24. Balfourier (2005: 26); Brancourt-Hulmel et al. (2003: 39); Lupton (1992: 25-27, 57-63); Angus (2001: 113-117, 142-149).

25. On the influence of environmental contidions in semidwarf wheat yields, see Acreche et al. (2008: 32).

pace. On the one hand, Senatore Capelli and other varieties derived from it were too tall, sometimes in excess of 150 cm. On the other, the development of semidwarf durum wheat varieties proved more difficult than with bread wheat, and the earliest successes, achieved in CYMMYT, had to wait until the 1970s[26]. For this reason, and in contrast to what was happening with bread wheat, Italian durum wheat production in the 1960s was still dominated by wheats between 120 and 140 cm tall and varieties such as Senatore Capelli, Russello Comune, Russello, Garigliano and Frifoni jointly amounted to 60% of the total extension of durum wheat cultivation. This situation did not change until, first, the incorporation of Middle Eastern wheats by Italian wheat breeders and, second and more decisively, the adoption of the new semidwarf varieties developed at CIMMYT. As a consequence, the aforementioned tall stemmed varieties had dropped to a share of 28% by 1974, and by 1986 only the Senatore Capelli variety remained in cultivation. In contrast, varieties such as Capeiti 8, Patricio 6 and Trinakria, derived from Syro-Palestinian wheats, at around 100 cm tall, covered 24% of all areas cultivated with durum wheat, and new semidwarf varieties, less than 90 cm tall, 60%. Among the latter, the Creso, Produra and Valnova varieties played an important role, amounting to up to 40% of all extension of durum wheat cultivation (see Table 2 in the Appendix)[27].

Innovation processes in Spain followed a very different path. As noted previously, during the 1930s research aimed at improving autochthonous varieties had not achieved significant productivity increases, and the first steps forward had to wait until the arrival of the new varieties developed at the CIMMYT. Moreover, these new varieties played a highly relevant role in the renovation of the biological basis of the sector in Spain since they remained in cultivation, untouched by new hybridisations, until nearly the end of the 20th century. Finally, when newer derivatives were eventually put into use these varieties were developed in other countries (see Table 2 in the Appendix).

The limited impact of biological innovation in Spain until the adoption of CIMMYT's wheats can be expressed in figures. Between 1951 and 1957, the Servicio Nacional del Trigo (Wheat National Service), which at the time included selling wheat seeds for sown among its activities, distributed 8.4 million qs of bread wheat seeds, 50% of which was of traditional varieties, 26.9% of the Aragón 03 variety, obtained by selection from the local Catalán del Monte variety, 6.5% of the Pané 247 variety, obtained in Lerida by hy-

26. In order to obtain comercial varieties of semidwarf durum wheat, breeders had to cross durum wheat varieties with semidwarf bread wheat varieties, subsequently selecting the varieties thus developed in successive productive cycles.

27. De Vita et al. (2007: 39-42); Alvaro et al. (2008: 87); Royo et al. (2008: 354-355); Royo et al. (2007: 261-262). About the impact of Italian varieties in China, South America, the former Yugoslavia or Russia, see Borghi (2001: 300); and Borojevic and Borojevic (2005: 455-456).

bridisation, and 5.6% of the Florence Aurora variety, of Tunisian origins. This institution also distributed, though in very limited quantities, seeds of the varieties Híbrido J-1 (1.8%), of French origins, Mentana (2.8%), Mara (2.1%), Impeto (1.3%), Quaderna (0.7%) and Roma (0.7%), all of the latter of Italian origins (Servicio Nacional del Trigo, 1958: 82-97). Some years later, in 1962, this organisation also indicated that the Aragón 03, Pané 247, Híbrido J-1 and Estrella, or Etoile de Choisy, had been distributed almost exclusively in the northern half of the country, and that only the first of these varieties was used to a significant degree. The other three had been distributed in just a few areas and always for use on very fertile soils. Italian wheats were distributed in the south, although again only in fertile or irrigated areas[28].

This evidence agrees with Lupton's estimations for the period between 1960 and 1973. According to his calculations indigenous varieties still covered 50% of the total wheat cultivated area during this period, and among the new varieties Aragón 03 covered 18%, Pané 247 and Estrella 19%, Impeto, of Italian origins, 7% and Florence Aurora, 6% (Lupton, 1992: 52-54). Newly created varieties –developed either in Spain or in other countries– were also marketed but their distribution areas were very limited. Of the 50 varieties of bread wheat available on the Spanish market in 1965, 19 were autochthonous wheats, 17 were of foreign origins and 15 had been developed in Spanish research centres[29].

Additionally, most of the aforementioned varieties were long stemmed. Tests carried out in Catalonia between 1949 and 1952 indicated a height between 120 and 140 cm for the local varieties Candeal, Jeja, Blanco de la Segarra and Montjuic; 116 and 140 cm for Aragón 03; and 105 and 117 cm for Pané 247. The latter, however, was of low quality for bread production. Among the most common foreign varieties only the Mara wheat, which carried a dwarfism gene, attained shorter heights, between 95 and 100 cm. In contrast, varieties such as Quaderna, Florence Aurora, Roma and Impeto, were between 110 and 135 cm tall (Solé Caralt, 1953: 15-19; Pané i Mercé, 1964).

Up to the late 1960s, therefore, long stemmed wheats were still predominant, which in my opinion explains to a large extent the persistence of low wheat yields in Spain during this period. In this sense, the description of the Aragón 03 variety given in 1950 by

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28. Servicio Nacional del Trigo (1962); Instituto Nacional para la Producción de Semillas Selectas (1957); Instituto Nacional de Investigaciones Agronómicas (1961); Servicio Nacional del Trigo (1965).

29. A highly relevant role in these achievements was played by the Granja Agrícola de Jérez and Badajoz, the Servicio(s) Agronómico(s) de la(s) Diputación(es) de Barcelona, Navarra and Lerida, the Jefatura Agronómica de Cuenca, and, most remarkably, the Granja de Egea de los Caballeros and the Centro de Ceralicultura de Madrid. On the new wheat varieties developed see Statistic Appendix.

the engineer Jordana de Pozas (1950: 127-128) is very illustrative. According to this technician the main advantages offered by the variety was its ability to develop multiple ears, its resistance to drought and its good adaptation to poor soils and climatic fluctuations. He also affirmed, however, that 'if treated to plentiful fertilisation and water, this wheat bends, or lodges, so other varieties capable of higher yields are to be preferred'.

This situation started to change around 1974 with the spread of the the Siete Cerros variety, a semidwarft variety from the CIMMYT. From that point on, the diffusion of these new varieties was quick, and by 1978 the Anza, Cajeme and Yecora varieties, between 65 and 80 cm tall, covered 40% of the total extension of bread wheat cultivation. Some years later, between 1988 and 1990, these and the Rinconada variety, obtained by selection from a CIMMYT variety, amounted to 54%, and the Marius, Astral and Talento varieties, new semidwarf varieties from France, to 17%. The only relevant transformation observed since 1990 is the progressive substitution of Mexican varieties for newer French varieties (see Table 2 in the Appendix) (Lupton, 1992: 52-54).

Regarding durum wheat, the cultivation of which did not reach Spain in significant proportions until the 1990s, the main biological innovation before the Civil War was undoubtedly the adoption of the Italian Senatore Capelli variety[30]. Another important innovation, albeit with a more limited impact, was the diffusion of the Híbrido D variety, developed in Spain from the latter variety and an earlier variety of the local wheat Rubio de Belalcázar. Between 1951 and 1957 the Servicio Nacional del Trigo sold 51,900 t of Senatore Capelli seeds, 14,800 t of Híbrido D, and 10,000 t of Jerez 36 and Andalucía 344, two new selections of local tall stemmed wheats[31]. Up to the mid 1970s, however, local varieties remained predominant. In 1974 the autochthonous variety Furto amounted to 44% of the total durum wheat cultivated areas, and the Senatore Capelli and Andalucía 344 varieties, to 19%. Another new variety sown at that time was Bidi 17, introduced from Tunisia around 1960 and approximately 100 cm tall, which amounted to 20% (Lupton, 1992: 52-54; Solé Caralt, 1953: 15-19; Alvaro et al., 2008: 87). From that moment, and as was happening with bread wheats, diffusion of CIMMYT's varieties was very swift. By 1986 the Mexicali and Safari varieties, between 85 and 100 cm tall, and the Vitron variety, between 65 and 80 cm, amounted to over 80% of total extension of durum wheat cul-

30. For most of the 20th century durum wheat never exceded 10% of the total extension of wheat cultivation. From 1990 this proportion has been growing as a consequence of the agrarian policies prompted by the EU, and by 2003 they amounted to over 900,000 hectares, 41% of wheat area in cultivation.

31. Servicio Nacional del Trigo (1958: 82-97); Solé Caralt (1953: 15-19); Alvaro et al. (2008: 87); Royo et al. (2007: 261-262); Royo et al. (2008: 354-355); Isidro Sánchez (2008: 54). The height of these varieties was between 110 and 140 cm.

tivation. Over the following decade average plant height was reduced even further with the substitution of taller wheats by others similar in height to the latter variety. Between 2000 and 2008, 40% of certified seed sales involved the Vitron, Antón, Nuño, Don Pedro, Don Sebastián, Gallareta, Sula and Jabato varieties, developed at CIMMYT or derived by selection from other varieties originating in this research centre. Meanwhile, Italian varieties Simeto, Claudio, Colosseo, Iride, Italo and Avispa captured 28% of market share, and Carioca and Nefer, of French origin, 9% (Solís Martel, 2010a; Asociación Española de Técnicos Cerealistas, 1994-2009). In 2010, almost 40% of durum wheat varieties cultivated in Andalusia originated in CIMMYT, and the remaining 60% had at least one parent with the same origin (Solís Martel, 2010b).

## 5. CONCLUSIONS

Returning to the issues enumerated at the beginning of the present article, I have tried to show that a closer association between agrarian history and agronomic sciences can offer agrarian and economic historians new analytic factors to better understand the evolution of the agricultural sector in the 19th century and, by extension, of contemporary economic growth. An example of this is the new indicator of grain productivity in relation to weight unit of harvested straw, as proposed here. In the Spanish case, the evolution of this variable agrees well with forecasted changes introduced by the diffusion of new short-stemmed and semidwarf wheat varieties. It can be therefore expected that, when the new indicator is calculated for other countries or regions, this will offer further references for the evolution of these innovations in other geographical contexts. A more direct contribution of agronomic sciences to agrarian history has been, in the case of wheat, the quantification of the impact of genetic improvements in wheat yields in the second half of the 20th century.

Secondly, the present article has also shown that wheat breeding took a qualitative leap forward in the late 19th century, as a result of two factors: the experience accumulated by farmers, seed companies and public research centres, and the scientific advances in genetics and biology realised from 1900. We have also shown that the national improvement programmes nurtured from this date differed broadly, and that their path of development was to heavily determine research in wheat varieties well into the 20th century. For that reason, and because its scientific foundations had already been laid in the 1930s, the impact of the Green Revolution on the European wheat sector needs to be qualified. In this sense, we have also seen that dwarfism genes had already been introduced in Italy by that decade, and that when these genes spread throughout the continent in the 1980s, new crossing and selection processes were needed, involving CIMMYT's varieties and other varieties previously sown. The latter, for their part, were the result of breeding strategies initiated in the early 20th century, and were most particularly based on wheat varieties developed after the First World War.

A factor that heavily determined, and still does determine, all these processes is the incidence of environmental conditions in plant development. This factor explains, in my view, why innovations proved easier in Atlantic Europe until the arrival of semidwarf wheats. As shown above, Italy and Spain hardly participated in the circulation of germplasm taking place at a continental level throughout the 19th and the first third of the 20th centuries. Similarly, the innovations sprouting from this exchange and the local varieties were only adequate for Atlantic environmental conditions or for irrigated areas. In Italy, and even France, there was a clear bias in favour of northern and central regions.

The close relationship between environmental conditions and biological innovation is also revealed by the more ready adaptation of semidwarf wheats to Atlantic Europe. For this reason I think that the hypothesis put forward by Acreche et al (2007), suggesting that the stagnation of wheat yields in Spain in the last decades of the 20th century was due to the use of wheat varieties developed in other environmental conditions, must be dismissed. As shown, wheat yields in Spain during that period were similar to those in Italy, also stable from the 1980s. The limitation brought about in Spain by the cultivation of foreign varieties may be related instead to the irregularities observed in wheat yields in the 1980s and 1990s.

The path followed by biological innovations in the European wheat sector in the 19th and 20th centuries, however, cannot be explained merely by differences in regional environmental conditions. The present article has also shown that these innovations were heavily conditioned by institutional and technological factors. Regarding institutions, these pages have shown that the economic policies implemented in Great Britain and in the continent from the mid 19th century until just before the Second World War favoured different approaches in the development of new wheat varieties. For this reasons, comparisons of wheat yields lose meaning, since they refer to altogether different kinds of production. In Great Britain, wheat breeders tried to increase grain yields as much as possible with the development of new wheat varieties resistant to lodging. On the continent, on the other hand, their aims also included improving the grain's quality for bread production. As a consequence, British wheat breeders preferentially opted for British wheats in their research strategies, whereas on the continent more complex hybridisation processes were carried out from a much earlier date, involving local, British and other foreign wheats.

The effect of the technological framework on the development of new wheat varieties has also been clearly illustrated. While the economic and technological importance of straw was high, it remained necessary to develop wheat varieties that were both tall and resistant to lodging, at the cost of limiting the amount of fertilisers which farmers could apply. That made British wheats a very attractive option for continental technicians. On the other hand, when the introduction of a series of new techniques in the second half of the 20th century reduced the economic relevance of straw, wheat breeders focused on reducing plant height. The substantially increased resistance of plants to lodging logically encouraged a considerable boost in the use of fertilisers in this period. These years also saw a change in the productive approach of the British wheat sector, and the circulation of wheat seeds between Great Britain and the continent changed direction. Whereas in the past British wheats had had a very good reputation in France, Holland, Belgium, Germany and Sweden because of the length of their straw, between 1950 and 1970 appreciation for French wheats soared in Great Britain, because of their productivity, their baker's quality, and their short stems.

Regarding the technological framework, the present article also offers both a solid result and a firm working hypothesis. First, it makes clear that wheat yields in Great Britain and elsewehere in Europe in the second half of the 19th and the first third of the 20th century are not strictly comparable because, as we have just seen, the wheat varieties developed in each region were very different. Second, the article also suggests that wheat breeding had to face more difficulties in the dry Mediterranean regions than in northern and central Europe, and that to a large degree this explains the low wheat yields in Spain prior to the mid 20th century.

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## APPENDIX

**TABLE 1**

**Main bread wheat varieties obtained by crossing and selection before the Second World War**

| a | b | c | d |
|---|---|---|---|
| | | **GREAT BRITAIN** | |
| Little Joss | 1908 | Squarehead x Ghirka (RUS) | R. Biffen |
| Victor | 1910 | Squarehead x Red King x Talavera | Gartons Ltd. |
| Benefactor | 1914 | 55-4-A x Garnet | Gartons Ltd. |
| Yeoman I | 1916 | Browick x Red Fife (CAN) | R. Biffen (Plant Breeding Institut Cambridge) |
| Yeoman II | 1924 | Browick x Red Fife (CAN) | R. Biffen (Plant Breeding Institut Cambridge) |
| Cambridge Browick | ? | Browick x Yeoman | R. Biffen (Plant Breeding Institut Cambridge) |
| Premier | 1924 | Benefactor x Little Joss | Messrs. C.W. Marsters |
| Ideal | 1927 | Little Joss x Victor x Yeoman | Messrs. C.W. Marsters |
| Holdfast | 1920-1935 | Yeoman x White Fife (CAN) | F. Engledow (Plant Breeding Institut Cambridge) |
| Benefactress | 1925 | Squarehead x Red King x Rough Chaff White | Gartons Ltd. |
| Garton's Sixty | 1932 | Victor x Squarehead Master | Gartons Ltd. |
| Redman | 1934 | Yeoman x Squarehead Master | Gartons Ltd. |
| Warden | 1938 | Benefactress x Yeoman | Gartons Ltd. |
| Steadfast | 1928-1941 | Little Joss x Victor | F. Engledow (Plant Breeding Institut Cambridge) |
| | | **FRANCE** | |
| Dattel | 1874-1883 | Prince Albert (GB) x Chiddam Epi Rouge | Henry de Vilmorin (Vilmorin -Andrieux & Co) |
| Lamed | 1874-1885 | Prince Albert (GB) x Noé (RUS) | Henry de Vilmorin (Vilmorin -Andrieux & Co) |
| Bordier | 1874-188? | Prince Albert (GB) x Noé (RUS) | Henry de Vilmorin (Vilmorin -Andrieux & Co) |
| Champlan | 1894 | Victoria (GB) x Chidham (GB) | Henry de Vilmorin (Vilmorin -Andrieux & Co) |
| Gross Bleu | 1897 | Noé (RUS) x Shirreff (GB) | Henry de Vilmorin (Vilmorin -Andrieux & Co) |
| Grosse Tête | 1898 | Browick (GB) x Chidham (GB) | Henry de Vilmorin (Vilmorin -Andrieux & Co) |
| Briquet Jaune | 1896 | Browick (GB) x Chidham (GB) | Henry de Vilmorin (Vilmorin -Andrieux & Co) |
| Montilleul | 1899 | Blé Blanc à Paille Raide x ? | Graineterie Denaiffe |
| Trésor | 1890-1899 | Gross Bleu x Shirreff (GB) | Henry de Vilmorin (Vilmorin -Andrieux & Co) |
| Massy | 1901 | Èpi Carré x Bordeaux | Henry de Vilmorin (Vilmorin -Andrieux & Co) |
| Bon Fermier | 1894-1904 | Gross Bleu x Blé Siegle | Henry de Vilmorin (Vilmorin -Andrieux & Co) |

| | | | |
|---|---|---|---|
| Hâtif Inversable | 1898-1907 | Gross Bleu x Chidham (GB) | Henry de Vilmorin (Vilmorin -Andrieux & Co) |
| Carré Géant Blanc | 1907 | Épi Carré x Siegle de Schaustedl (?) x Hybrid King (GB) | Graineterie Denaiffe |
| Carré Géant Rouge | 1907 | Épi Carré x Siegle de Schaustedl (?) x Hybrid King (GB) | Graineterie Denaiffe |
| Cérès | ? | Briquet Jaune x Victoria (GB) | Graineterie Denaiffe |
| Traveland | 1909 | Gross Tête x Teverson (GB) | Graineterie Denaiffe |
| Alliés | 1916 | Japhet (selección Noé (RUS) de 1892) x Massy x Gross Tête | Vilmorin -Andrieux & Co |
| Chanteclair | 1921 | Hâtif Inversable x Alliés | Tourneur Frèrers |
| Picardie | 1923 | Alliés x Institut Agronomique | Desprez Breeding Co |
| Vilmorin 23 | 1923 | Melbor x Gross Tête x Japhet (selection Noé (RUS)) x Parsel | Vilmorin -Andrieux & Co |
| Vilmorin 27 | 1927 | Dattel x Japhet x Parsel x Bon Fermier x Hâtif Inversable | Vilmorin -Andrieux & Co |
| Vilmorin 29 | 1929 | Vilmorin 23 x Alliés | Vilmorin -Andrieux & Co |
| Joncquois | 1933 | Vilmorin 23 x Institut Agronomique | Desprez Breeding Co |
| Bersée | 1924-1936 | Vilmorin 23 x Alliés | A. Blondeau |
| Yga Blondeau | 1938 | Vilmorin 27 x Red Fife (CAN) | A. Blondeau |
| **ITALY** | | | |
| Carlota Strampelli | 1905 | Massy (FRA) x Rieti | N. Strampelli |
| Ardito | 1916 | Akagomughi (JAP) x Wilhelmina (HOL) x Rieti | N. Strampelli (Regia Stazione di Granicoltura) |
| Mentana | 1913 | Akagomughi (JAP) x Wilhelmina (HOL) x Rieti | N. Strampelli (Regia Stazione di Granicoltura) |
| Villor Glori | 1918 | Akagomughi (JAP) x Wilhelmina (HOL) x Rieti | N. Strampelli (Regia Stazione di Granicoltura) |
| Damiano Chiesa | 1921 | Akagomughi (JAP) x Wilhelmina (HOL) x Rieti | N. Strampelli (Ins. di Genètica per la Cerealicoltura) |
| Fanfulla | 1926 | Ardito x Perfezione | N. Strampelli (Ins. di Genètica per la Cerealicoltura) |
| Libero | 1927 | Apulia x Ardito | N. Strampelli (Ins. di Genètica per la Cerealicoltura) |
| San Giorgio | 1926-1936 | Ardito x Inalletabile | C. Orlandi (Ins. di Allevamento per la Cerealicoltura) |
| Quaderna | 1926-1937 | Ardito x Inalletabile | C. Orlandi (Ins. di Allevamento per la Cerealicoltura) |
| Pieve | 1926-193? | Ardito x Gentil Rosso | C. Orlandi (Ins. di Allevamento per la Cerealicoltura) |
| Riale | 1926-193? | Ardito x Gentil Rosso | C. Orlandi (Ins. di Allevamento per la Cerealicoltura) |
| San Pastore | 1931-1947 | Balilla x Villa Glori | N. Strampelli (Ins. di Genètica per la Cerealicoltura) |
| Velino | 1933-1947 | Balilla x Ardito | N. Strampelli (Ins. di Genètica per la Cerealicoltura) |

Notes: a: Variety; b: Year it became commercially available (when two dates are given, the first refers to the year of creation); c. Parents; d: Breeder, seed companie and/or Research Institut.

Source: Based on data from http://genbank.vurv.cz/wheat/pedigree; http://www.jic.ac.uk/germplas; http://moulin.chauffour.free.fr/autour_des_moissons/varietes_de_ble.htm; Vilmorin-Andrieux (1880, 1909); Denaiffe & Coll (1920c); Percival (1934); Lupton (1987, 1992); Zeven (1990); Bonjean and Angus (2000); Pujol-Andreu (2002, 2005); and Felice (2004).

**TABLE 2**

**Most common new varieties after the Second World War**

| a | b | c | d | e | f | g |
|---|---|---|---|---|---|---|
| | | | | **GREAT BRITAIN** | | |
| Cappelle Desprez | 1946 | FRA | 1960 | Vilmorin 27 x Hibride du Joncquois | No | Florimon Desprez |
| Champlein | 1959 | FRA | 1960 | Yga Blondeau x Tadepi | No | C.C. Benoist |
| Joss Cambier | 1966 | FRA | 1960 | Cambier 194 x Tadépi x Cappelle Desprez | No | Cambier Semences |
| Maris Huntsman | 1971 | GB | 1970 | CI 12633 x Cappelle x Hybride 46 x Prof. Marchal | No | Plant Breeding Institut Cambridge (PBIC) |
| Bouquet | | FRA | 1970 | 2/7 x Cappelle x Cappelle | No | |
| Flinor | 1967 | FRA | 1970 | Elite le Peuple x Poncheau | No | Legland |
| Atou | 1971 | FRA | 1970 | Cappelle x Garnet | No | Guilleman |
| Flanders | | FRA | 1970 | Champlein x FD 281/348 | No | Florimon Desprez |
| Hobbit | 1975 | GB | 1970 | Prf. Marchal x Marne Desprez x VG 9144 x TJB16 | Yes | PBIC |
| Armada | 1978 | GB | 1970 | TP118 x R. Perdix x Hybride 46 x Cappelle x Champlein x Viking x Tetrix x Jubilegen | No | Nickerson, Rothwell Plant Breeders Ltd. |
| Avalon | 1980 | GB | 1980 | TJB 30/148 x TL 365a/34 | Yes | PBIC |
| Norman | 1981 | GB | 1980 | TJB 268/175 x Hobbit | Yes | PBIC |
| Longbow | 1980 | GB | 1980 | TJB 268/175 x Hobbit | Yes | PBIC |
| Galahad | 1983 | GB | 1980 | Joss Cambier x Durin x Hobbit | Yes | PBIC |
| Hornet | 1986 | GB | 1980 | Norman x Hedgehog | Yes | PBIC |
| Mercia | 1984 | GB | 1980 | Talent x Virtue x Flanders | Yes | PBIC |
| Riband | 1987 | GB | 1980 | Norman x Maris Hautsman x TW161 | Yes | PBIC |
| Pastiche | 1988 | GB | 1980 | Jena x Norman | Yes | PBIC |
| Haven | 1988 | GB | 1990 | Hedgehog x Norman x Moulin | Yes | PBIC |
| Hereward | 1989 | GB | 1990 | Norman x Disponent | Yes | PBIC |
| Hunter | 1991 | GB | 1990 | Apostje x Haven | Yes | PBIC |
| Torfrida | 1992 | GB | 1990 | Rendezvouz x Moulin x Mercia | Yes | PBIC |
| Brigadier | 1992 | GB | 1990 | Rendezvous x Squadron | Yes | ICI Seeds Ltd. |
| Admiral | 1992 | GB | 1990 | Mithras x Hobbit x Hedgehod | Yes | Zeneca Seeds |
| | | | | **FRANCE** | | |
| Cappelle Desprez | 1946 | FRA | 1960 | Vilmorin 27 x Hibride du Joncquois | No | Florimon Desprez |
| Étoile de Choisy | 1950 | FRA | 1960 | Ardito x Mon Desir x Mouton à Epi Rouge | No | Institut National de la Reserche Agronomique (INRA) |

| | | | | | | |
|---|---|---|---|---|---|---|
| Champlein | 1959 | FRA | 1960 | Yga Blondeau x Tadepi | No | C.C. Benoist |
| Moisson | 1961 | FRA | 1960 | Cappelle x Étoiule de Choisy x Hibride 80-3 | No | Vilmorin-Andrieux & Co |
| Capilote | 1964 | FRA | 1970 | Professeur Marchal x S6 | No | Vilmorin-Andrieux & Co |
| Hardi | 1969 | FRA | 1970 | Cappelle Desprez x Tatcher | No | Momont |
| Top | 1970 | FRA | 1970 | TF-354 x Cappelle Despréz | No | Tourneur |
| Maris Huntsman | 1971 | GB | 1970 | CI 12633 x Cappelle x Hybride 46 x Prof. Marchal | No | Plant Breeding Institut Cambridge (PBIC) |
| Talent | 1973 | FRA | 1980 | Champlein x Thatcher x Vilmorin x Fortunato | Rht8 | C.C. Benoist |
| Courtot | 1974 | FRA | 1980 | Mexico- 50/ B-21 x Versailles | Yes | INRA |
| Fidel | 1978 | FRA | 1980 | Horizon x Frontana x Capitole x Major | Rht8 | Pichot, Ringot |
| Beauchamp | 1978 | FRA | 1980 | Capitole x Palmaress | Rht8 | Lafite |
| Camp Rémy | 1980 | FRA | 1980 | GU 362 x Atou x Hardi | | UNISIGMA |
| Festival | 1981 | FRA | 1980 | 348 x 2361 x Capilote x 10491 | Rht8 | C.C. Benoist |
| Thésée | 1983 | FRA | 1980 | B1731 x Maris Huntsman x Prof. Marchal | | Verneuil Semences |
| Pernel | 1983 | FRA | 1980 | V 81/12 x US6043 x Prieur x VPM x Moisson | Yes | INRA |
| Moulin | 1985 | FRA | 1980 | Yecora x Ciano 67 x Maris Widgeon x Hobbit | Yes | PBIC-Florimon Desprez |
| Soissons | 1988 | FRA | 1990 | Hibride Naturel 35 x Jena | Yes | Florimon Desprez |
| Renan | 1989 | FRA | 1990 | Mitronovskaya x Courtot x Maris Hutsman x Moisson x VPM | Yes | INRA |
| Shango | 1994 | GB | 1990 | Moulin x Monopol x Tiresius | Yes | PBIC-Monsanto |
| Hyno-rista | 1995 | FRA | 1990 | Soissons x Renan | Yes | Hybrinova |
| | | | | **ITALY** | | |
| **Bread wheats** | | | | | | |
| Autonomia | 1938 | ITA | 1950 | Frassineto x Mentana | Rht8 | M. Michahelles |
| San Pastore | 1947 | ITA | 1960 | Balilla x Villa Glori | Rht8 | N. Strampelli (Ins. di Genètica per la Cerea-licoltura) |
| Orlandi | 1947 | ITA | | Saitama 27 x Inallettabile 95 x Ardito | Yes | Società Produttori Sementi |
| Produttore | 1954 | ITA | | Salto x Saitama 27 x Quaderna | Yes | Società Produttori Sementi |
| Argelato | 1964 | ITA | 1970 | Mara x Orlandi | Yes | Società Produttori Sementi |
| Libellula | 1965 | ITA | 1970 | Tevere x Giuliano x San Pastore | Rht8 | N. Strampelli (Instituto Sperimentale di Ge-netica) |
| Conte Marzotto | | ITA | 1970 | Mara x Impeto | Rht8 | M. Michahelles |
| Irnerio | 1970 | ITA | 1970 | Produttore S6 x Manitoba | Rht8 | Società Produttori Sementi |
| Mec | 1974 | ITA | 1980 | Marzotto x Combine | Rht8 | M. Michahelles |

| | | | | | | |
|---|---|---|---|---|---|---|
| Centauro | 1983 | ITA | 1980 | Irnerio x Strampelli | Yes | Società Produttori Sementi |
| Gemini | 1981 | ITA | 1980 | Angelato x von Rumker's Erli x Impeto x Damiano | Yes | Società Produttori Sementi |
| Pandas | 1983 | ITA | 1980 | Besostaya x S1 x Generoso 7 x Marzotto | Yes | M. Michahelles |
| Nobel | 1985 | ITA | 1990 | Stirpe 25-611 x Stirpe 427 | | M. Michahelles |
| Bolero | 1987 | FRA | 1990 | 2625 x 267 x Talent | Yes | C.C. Benoist |
| Mieti | 1992 | ITA | 1990 | Mec x Vinci | | M. Michahelles |
| Eureka | 1995 | FRA | 1990 | Mironovskaya 808 x Maris Huntsman x R!.5.2 x Courtat | Yes | INRA |
| **Durum** | | | | | | |
| Garigliano | 1955 | ITA | 1960 | Tripollino x Capelli | No | |
| Capeiti 8 | 1955 | ITA | 1970 | Eitib 6 x Capelli | No | Stazione Consorziale Sperimentale di Granicoltura |
| Patrizio 6 | 1962 | ITA | 1970 | Eitib 6 x Capelli | No | Stazione Consorziale Sperimentale di Granicoltura |
| Trinakria | 1970 | ITA | 1970 | B14 x Capeiti 8 | No | Instituto di Agronomia delle Uni. di Palermo |
| Creso | 1974 | ITA | 1980 | Yt 54 x N108B x Cp63 x Tc x CpB144 | Yes | Centro Ricerche Casaccia dell'Enea |
| Valnova | 1975 | ITA | 1980 | Giorgio x Senatore Capelli x Yuma | Yes | Instituto Sperimentale per la Cerealicoltura |
| Produra | 1976 | USA | 1980 | Complex crossing CIMMYT | Yes | Northrup King Co. |
| Simeto | 1988 | ITA | 1990 | Capeiti 8 x Valnova | Yes | Stazione Consorziale Sperimentale di Granicoltura |
| Colosseo | 1990 | ITA | 1990 | Creso x Mexa | Yes | |
| Zenit | 1992 | ITA | 1990 | Valriccardo x Vie | Yes | Società Produttori Sementi |
| | | | | **SPAIN** | | |
| **Bread wheats** | | | | | | |
| Mentana | 1913 | ITA | 1950 | Akgomughi x Wilhelmina x Rietti | Rht8 | N. Strampelli (Regia Stazione di Granicoltura) |
| Fl. Aurora | 1933 | TUN | 1950 | Florence x Aurora | No | |
| Roma | 1935 | ITA | 1950 | Akagomughi x Triticum Villosum | Rht8 | N. Strampelli (Ins. di Genètica per la Cerealicoltura) |
| Quaderna | 1937 | ITA | 1950 | Ardito x Inalletabile | Rht8 | C. Orlandi (Ins. di Allevamento per la Cerealicoltura) |
| Mara | 1947 | ITA | 1960 | Autonomia x Aquila | Rht8 | M. Michahelles |
| Impeto | 1950 | ITA | 1960 | Frassinetto 405 x Villa Glori | Rht8 | |
| Étoile de Choisy | 1950 | FRA | 1960 | Ardito x Mon Desir x Mouton à Epi Rouge | No | Institut National de la Reserche Agronomique (INRA) |
| Pané 247 | 1950 | ESP | 1970 | Mentana x Hybride L-4 | No | Sindicato Agrícola de Guisona |
| Siete Cerros | 1966 | MEX | 1970 | Penjamo 62 x Gabo 55 | Yes | CIMMYT |

| | | | | | | |
|---|---|---|---|---|---|---|
| Cajeme | 1969 | MEX | 1980 | Ciano x Sonora 64 x Klein Rendidor X Siete Cerros | Yes | CIMMYT |
| Yecora | 1970 | CHL | 1980 | Ciano x Sonora 64 x Klein Rendidor X Siete Cerros | Yes | INIA-CIMMYT |
| Anza | 1971 | USA | 1980 | Lerma Rojo x Norin 10 x Brevor x Andes Enano | Yes | California Agricultural Experiment Station |
| Rinconada | | ESP | 1980 | Selection from a CIMMYT variety | Yes | |
| Astral | 1972 | FRA | 1990 | Forunato x Yga x Florence Aurora x G4 | | Tezier |
| Marius | 1976 | FRA | 1990 | Cadet x Thatcher x Vilmorin 27 x Ariana x L:FU | | C.C. Benoist |
| Soissons | 1988 | FRA | 1990 | Hibride Naturel 35 x Jena | Yes | Florimon Desprez |
| Cezanne | 1997 | FRA | 2000 | Théses x 87B29 | | Verneuil Semences |
| **Durum** | | | | | | |
| Cocorit | 1974 | MEX | 1970 | Rojo de Alicante x Tehuacan 60 x Stewart 63 x Ahinga S | Yes | CIMMYT |
| D 104 | | MEX | 1970 | Complex crossing CIMMYT | Yes | CIMMYT |
| Mexicali | 1974 | MEX | 1980 | Gerardo VZ 469 x Jori S x 61.130 x Leeds | Yes | CIMMYT |
| Safari | | MEX | 1980 | Hazera-65174 x Mandon x Lakota x Leeds | Yes | CIMMYT |
| Abadía | 1979 | SPN | 1980 | Selection of Giorgio x Mexican variery | Yes | Estación Experimental de Aula Dei |
| Esquilache | 1976 | SPN | 1980 | Selection of Jori 69 x 21563 | Yes | |
| Gallareta | 1982 | MEX | 1990 | Ruff x Flamingo x Mexicali 75 x Shearwater | Yes | CIMMYT |
| Sula | 1983 | MEX | 1990 | Shearwater x Redneck x Yavaros | Yes | CIMMYT |
| Vitron | 1987 | MEX | 1990 | Turchia 77 x Jori 69 x Anhinga x Flamingo | Yes | CIMMYT, Semillas Batlle |
| Simeto | 1988 | ITA | 1990 | Capeiti 8 x Valnova | Yes | PRO.SE.ME |
| Regallo | 1988 | SPN | 1990 | Selection from a CIMMYT variety | Yes | Diputación General de Aragón, Agromonegros S.A. |
| Jabato | 1989 | SPN | 1990 | Selection from a CIMMYT variety | Yes | |
| Don Pedro | 1990 | MEX | 1990 | | Yes | CIMMYT |
| Anton | 1991 | SPN | 1990 | Selection from a CIMMYT variety | Yes | |

Notes: a: Variety; b: Year of inscription in the Variety Registration; c: Country of origin; d: Decade in which it enjoyed wider difussion; e. Parents; f: Dwarfism factors: presence of genes that inhibit the action of gibberellins or the gen Rht8 (see text); g: Breeder, seed companie and/or Research Institut.

Source: Based on data from http://genbank.vurv.cz/wheat/pedigree; http://www.jic.ac.uk/germplas; http://moulin.chauffour.free.fr/autour_des_moissons/varietes_de_ble.htm; Lupton (1987, 1992); Zeven (1990); Bonjean and Angus (2000); Belderok et al. (2000); Pujol-Andreu (2002, 2005); Felice (2004), Doré et Verognaux (2006), Asociación Española de Técnicos Cerealistas (1990-1992, 1994-2009), Alvaro et al. (2008), Royo et al. (2007, 2008), Acreche (2008) and Isidro Sanchéz (2008).