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Not all wheats are the same: selection and improvement of wheat in Portugal since early modern times (16th to 20th centuries)

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ABSTRACT: *This article examines the dissemination processes and geography of wheat species and varieties in Portugal between the 16th and the 20th centuries. Based on a wide range of sources, from monastic records to official agricultural reports and oral interviews, it is concluded that the conditions that shaped the traditional division between soft varieties in the north and hard varieties in the south had changed by the late 19th century. At that point, soft landraces thrived in the south, but were soon replaced by improved/hybridized varieties, many of which were imported. Thus, wheat landraces persisted only in the mountainous peripheral areas, due to the agroecological and socioeconomic context. It is also emphasized that Portugal did not lag the most central countries in terms of agricultural biotechnology development.* (**CODIGOS JEL**: N53, N54, Q10, Q57)

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1. Introduction

For centuries, wheat was the most valuable crop and basis of the food consumption in Western societies. Scarcity and/or price increases of this commodity were feared by kings, emperors and other heads of state, as these problems led to enormous social tensions. Thus, wheat is one of the most studied agricultural products in economic history and other disciplines that analyses the agricultural past. Some of the topics that have been studied extensively include its productivity, the right way to sow it, what fertilizers to use, trade routes, and political protectionism. However, there is one issue that is still clearly underexplored: the impact of the selection and improvement of wheat species and varieties on the performance of wheat in a wide range of aspects: productivity, resistance to pests, adaptation to harvesting technology, meeting consumer preferences, among others[1].

This article's main objective is to trace the cultivation changes of different wheat species and varieties in Portugal, between the 16th and the mid-20th centuries, aiming to understand why some have thrived and others did not. This study also contributes to place the Portuguese wheat biotechnological development within a wider international framework. Subsequently, by expanding its analytical scope to include more cereals and other crops, this article also lays the groundwork to improve future research to explain the historical models and practices of agricultural development in the European periphery and particularly in the Iberian Peninsula[2].

Almost ignored for decades as economic historiography emphasized the mechanization of agriculture as the main factor in its development (Atack, Coclanis and Grantham, 2009), biotechnological changes slowly entered the disciplinary debates after the seminal works of several economic historians (Kloppenburg, 2004 [1988]; Olmstead and Rhode, 2002) from United States of America (USA). These and other authors (Brunt, 2004; Martín-Retortillo and Pinilla, 2015; Beddow and Pardey, 2015), including natural scientists (Borojevic, Borojevic, 2005; Morgounov et al, 2010) and historical sources (Castro, 1893), suggest that biotechnology is one of the main, if not the major cause of the changes and productivity gains that have occurred in the wheat and other crops cultivation throughout history[3]. Nevertheless, the subject is still little explored. In fact, if for the USA wheat biotechnology has been the subject of several studies, notably by the authors already mentioned, for Europe it remains scarce, despite the challenge launched more than a decade ago to economic and agrarian historians to research the role of biotechnological changes in agriculture (Atack, Coclanis and Grantham, 2009). In this context, it is not surprising that a historical approach to the Iberian Peninsula has deserved a scarce bibliography (Pujol-Andreu, 1998; Saraiva, 2010; Pujol-Andreu, 2011). By exploring the Portuguese case, this article revisits the wheat biotechnology issues in the Iberian Peninsula.

Several authors have been underlying that biotechnology has contributed between 15 and 50% to increase wheat productivity over the last two centuries (Castro 1893; Olmstead and Rhode, 2002; Kloppenburg, 2004). Thus, to understand the role of biotechnology in the changing features of wheat production is to perceive a large part of the evolution of one of

the main crops cultivated for human consumption. In Portugal, at least since the XVIII century and until very recently, wheat not only competed with maize for the status of the most produced cereal by national agriculture (Branco and Silva, 2017; Amaral and Freire, 2017; Faísca, 2019; Viana et al, 2021), but it also accounted for just over 40% of Portuguese bread consumption by the early 20th century (Fialho, 1907, pp. 26-27).

The study of the Portuguese case is interesting for several reasons. First, it adds knowledge to a scientific problem that, as already mentioned, is still little studied, but is of fundamental importance for the evolution of global agriculture. Second, it is pertinent to place Portugal, a peripheral European country, within the wider biotechnological developments from the 19th century onwards. Although, the improvement of crops is as older as agriculture itself, since the late 19th century the rediscovery of Gregor Mendel's works exponentially increased the investments on seed selection processes in the USA, the European core (Kloppenburg, 2004, pp.4-5), and also in the peripheries[4]. After the World War II, the globalisation of the so-called Green Revolution (GR) model gave even more relevance to biotechnology, which became the key to achieving the desired increases in productivity of each sown seed[5]. Considering the discussions around the agricultural modernization itineraries and the regional impacts of GR, it remains necessary to explain how the influence of the USA spread across Europe[6]. The Portuguese case shows that even though it continued to be governed by a fascist-inspired dictatorship, the country was included in the Marshall Plan and in international scientific networks led by the USA[7]. In fact, as the collaboration with the USA was not integrally assumed by the dictatorship at the time (Rollo, 2007), there are many aspects that continue to require a detailed historical analysis, as is the wheat improvement[8].

Given its historical border stability, Portugal is a relevant case study for understanding long-term dynamics as are the dissemination and adaptation of certain species and varieties, and the process that led to the selection of some of them over others. Revealing the past motivations behind such issues also enables the spacetime identification of rejected seeds and their characteristics, building knowledge that may hold high value in current or future food scenarios.

As the title of this article suggests, not all wheat is the same. Within the same genus – *Triticum* L. – there are several different species – *Triticum aestivum* L., *Triticum durum* Desf., *Triticum diococcum* L., etc. – and hundreds of varieties. For instance, in just the database constructed for this study, we identified over 250 varieties of wheat within two species – *Triticum aestivum* L. and *Triticum durum* Desf[9]. A significant portion resulted from breeding experiments that may have little or no implementation in Portuguese agriculture. However, out of the 255 varieties, 77 were identified being cultivated in at least two distinct locations within the Portuguese territory, thus highly suggesting their use for food production during a given historical period.

Each one of these seed wheat has different characteristics regarding productivity; resistance to weather extremes (as heat, cold, drought, wind); adaptation to different harvesting solutions; quality and quantity of straw; ease of making flour and bread. Historically, the previous characteristics had an impact on the variation of the consumption choices and also

on the social construction around them. As it would be impossible to have a single variety combining the all-best aspects, since specific characteristics are more or less valued depending on the time and place, this article highlights the changing geography of wheat species and varieties in Portugal since the 16th century. This analysis is done considering the three essential factors that influence agriculture: agroecological conditions, human actions, and the seeds genetic characteristics[10]. These are co-evolution factors that interact with each other and change continuously over time, because none of them is constant.

It is not entirely surprising that there is a scarcity of articles on biotechnology changes, especially for chronologies prior to the 20th century. As almost all of authors who have studied the subject acknowledge, the lack of sources is enormous and even the agricultural statistics often ignore it (Brunt, 2004; Atack, Coclanis and Grantham, 2009; Martín-Retortillo and Pinilla, 2015; Pfister and Kopsidis, 2015). Therefore, this study required a methodological approach that would allow overcoming the gaps already identified and developing a long-term analysis. At a time when the state had no specific agricultural public services, the research was focused on the records of the large landowning organizations of the *Ancien Régime*, such as monasteries, churches or noble houses. Then, from mid-19th century onwards, the sources become more abundant and are related to the first public agricultural organizations, private agricultural associations, and some of the main landowners and producers. The data collected in written sources produced since the 16th century was crossed with the information obtained through interviews carried out in various regions of Portugal[11]. This methodological approach required the examination of thousands of records to reach at no more than a little over three hundred. In fact, the vast majority of the records only referred to the species of grain, rather than the specific variety, thus being unsuitable for this article. Anyway, connecting the written and the oral sources enabled the research to extend back several centuries, since, as we will see, it was possible to identify wheat varieties that were cultivated in Portugal from the 16th century until the mid-20th century.

In order to achieve the established goals, this article is organized as follows. This introduction is followed by a review of the state of art on the importance of seed selection and improvement in agrarian development. The third section is dedicated to a brief explanation of the agroecological conditions for wheat growth and the main differences between the hard and soft wheat species. Then, an historical changing geography of wheat varieties through Portuguese territory is presented. After that, the main part of the article discusses the reasons that led to the evolution of the distribution of wheat species and varieties in the Portuguese territory. Finally, the conclusions are presented. The data suggest that, from the second half of the 19th century, the dissemination of soft wheat landraces (Kloppenburg, 2004, p. 5) took place in the regions with the highest production, located in southern Portugal, due to the greater ease in breadmaking. Until then, the local agroecological conditions allowed only hard wheat. Soon after, especially since the *Campanha do Trigo* (*Wheat Campaign*), between 1929 and 1938, imported and/or improved soft wheat varieties began to replace landraces within the framework of the GR. Thus, in the 1960s, soft wheat landraces were reduced to those areas where GR met more difficult social, economic and agroecological conditions for

its expansion. Despite being peripheral, it is also shown that the state investment in wheat formal biotechnological development in Portugal was not chronologically far behind the central western countries.

2. Biotechnology innovation in Western agriculture

Over the past two centuries, global agricultural productivity has increased several folds. In the USA, for example, agricultural productivity gains more than doubled from the 1930s to the 2000s, and at least half of that was due to biotechnological improvements (Kloppenburg, 2004, p. 5). Similarly, agronomic research in many European countries (Great Britain, France, Germany, Norway, Hungary) and Canada has concluded that innovations in wheat varieties account for about 50% of the yield increases during the second half of the 20th century (Pujol-Andreu, 2011, p. 76). In fact, the changes possibilities within the same variety subjected to a simple mass selection process – the method used since the Neolithic – are easily visible. The Figure 1 shows two wheat fields of the same variety. The one on the left was subjected to human intervention by technicians from the *National Plant Improvement Station* in Elvas (Alentejo, southern Portugal), while the one on the right is an untouched landrace. It can be seen that the selected wheat is shorter, thus more resistant to the wind, better adapted to the mechanical harvester, less prone to lodging, and even, although it cannot be seen in the image, more productive. Conversely, it produces less straw, thus reducing a wide range of applications that have historically been based on the use of this raw material (fodder, mattresses, twine, etc.).

As biotechnology is as old as agriculture itself, for millennia, each year armies of farmers have selected and improved the seeds with the most desirable characteristics from their crops. A recent key moment was the so-called *Columbian Exchange* that expresses the global spread of agricultural crops since the 15th century (Crosby, 1972). As was seen in the Iberian Peninsula, farmers around the world tried to adapt new seeds to local agroecological conditions, albeit at very different rates depending on the crop. Productivity was not the only goal for choosing the best seeds to grow. Depending on the local context, other characteristics were important, such as resistance to pests and diseases, shortening the vegetative cycle, adaptation to cultivation and harvesting methods, physical characteristics such as size, use of production factors such as water or fertilizers.

Since the beginning of the 19th century, biotechnological development has been regulated by public and private organizations. What was left behind were millennia of seemingly unstructured biotechnological progress, at least as long as historiography does not prove otherwise. If from the Neolithic, farmers kept the seeds with the characteristics they value most for the next year's crop (Mazoyer and Roudart, 2006, p.92-93), this was a method of seed selection that has probably persisted throughout time and space. For instance, the first books with agricultural instructions published in Spanish (1513) and in Portuguese (1749) explain

the best practices at the time for this seed selection (Herera, 1513; Garrido, 1749). It is also known that in 17th century England, farmers used the highest yielding seeds for sowing, while reserving the poorest for personal consumption and animal feed (Brunt and Cannon, 2013). However, the scarcity of research in this area does not allow us to know in depth the influence of seed selection and improvement in pre-industrial Europe. The problem is not only that economic historiography underestimates the importance of biotechnology (Pujol-Andreu, 2011), but also the difficulty in obtaining historical information (Martín-Retortillo and Pinilla, 2015; Pfister and Kopsidis, 2015).

FIGURE 1. **Experimental wheat fields of the National Plant Improvement Station, Elvas, Portugal, 2021**

SOURCE: Author's picture, 2021.

The USA seems to have led the way of structured biotechnological progress, establishing a germplasm collection in 1835. Shortly thereafter, in 1839, Congress appropriated money to the Department of Patents to establish a seed collection and distribution system. Foreign seeds began to be imported into the USA: wheat from Poland, Turkey and Algeria; rye from

France; sorghum from China; cotton from India and Mexico; pepper and corn from Peru; rice from Japan (Kloppenburg, 2004, p. 12). These seeds were then subjected to millions of experiments carried out by thousands of farmers using the old method of simple mass selection. At the same time, the improved varieties were mailed to farmers across the USA by the Postal Service, which preceded the mailing of any other item by 5 years (Kloppenburg, 2004, p. 56). By the end of the 19th century, the government was sending out more than 23 million free seed packets annually (Kloppenburg, 2004, p. 63).

During the late 19th and early 20th century, public breeding stations were established all over Central Europe, using the then-new method of hybridization (Hardwood, 2012, pp. 9-10) – Switzerland in 1898, Austria in 1902, Germany in 1902, and Italy in 1905[12]. In Germany, for example, hybridization was used in almost all crop development, and by the early 20th century there were already more than 500 German wheat varieties (Hardwood, 2012, p.37). In Spain, during the first decade of the 20th century, wheat hybridization was also carried out in public institutions, such as *Estación Agronómica de Madrid* and *Granja Experimental de Badajoz* (Pujol Andreu, 1998, pp. 172-173). As we will see in more detail, at least for wheat, Portugal is also included in this seminal European chronology, since by late 19th century experiments were being made both by public and private organizations.

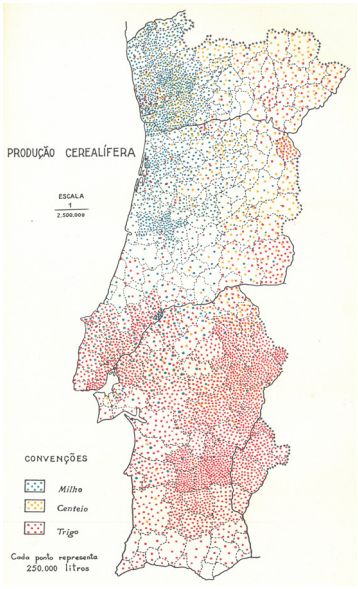
3. Agroecological conditions for wheat growth and main differences between hard and soft wheats

Wheat is harvested in the most diverse latitudes, from the highlands of the tropics to the southern border of the Arctic Circle. In the northern hemisphere, however, it is between the 49th and 58th parallels that wheat finds the better environmental conditions for its development, especially since the high temperatures of the warmer south are harmful in the final stages of the vegetative cycle (Sampaio, 1990, p. 63). It seems that in Portugal wheat production was pushed to the warmer south as it was replaced by the more productive irrigated corn further north, since the 17th century[13]. The main exception is the Northeast, which is also arid and colder. Figure 2 shows the described geography of wheat production in Portugal for the 1930s, but this picture could easily be replicated with some little differences, at least as far back as the mid-19th century (Martins, 2005), when the first official agricultural statistics were compiled (Freire and Faísca, 2021). Thus, wheat was produced and continued to be produced until the early 1980s (Faísca, 2019), in areas where the agroecological conditions were not the best for its productive success.

This apparent paradox, which has political-economical motivations that have long been described in economic historiography (Reis, 1979), has certain consequences. For example, at the productivity level, which is much lower in Portugal than in Central and Northern Europe, but also in the varieties grown. In the northwestern regions, the colder and wetter climate, as

well as in the more fertile soils, allowed the cultivation of soft wheat, while in the south, the heat, dryness and thinner soils led to the use of hard wheat (Castro, 1893).

FIGURE 2. **Regional distribution of grain production in Portugal, 1935**



SOURCE: Girão, 1941, 325.

The hardness of the grain under the pressure of the millstone during the baking process is one of the simplest ways of distinguishing hard from soft wheat. The latter were more easily crushed, thus consuming less energy (Guarienti, 1996, pp. 15-17) and producing a whiter and softer flour that made a more socially and economically valuable bread (Castro, 1893, p. 31)[14]. However, soft wheat absorbs less water, so its flour yield is lower. On the contrary, hard wheat is less suited to breadmaking, even though it is cheaper, which was an important factor in low-income economies such as the Portuguese one until the mid-20th century (Lains, 2003, pp. 125-166), and presents a higher yield when transformed into flour. For these reasons, soft wheat was usually and historically preferred for breadmaking and hard wheat for pasta and cookies. Despite this general picture, southern populations consumed harder bread due to the scarcity of soft wheat, mixing it with some soft wheat flour where possible (Castro, 1893, p. 31).

Another important difference between these two species of wheat is related to the straw. Typically, hard wheat produces pithier and more nutritious straw, which was used to feed livestock, an essential factor in organic farming that lasted until the mid-20th century. It is always important to remember that this agricultural model was based on manure fertilizer and ani-

mals as the main labor force (Pujol-Andreu, 2011, p. 78). In the southern regions, where the large estates predominate, this proved to be an important asset, as there were economic conditions to maintain large livestock contingents. In the northwest, not only were there fewer livestock, but the cooler and wetter climate produced more grasses and hay to feed the animals (Coutinho, 1884, pp. 73-81), making the production of straw less important.

4. Changing wheat varieties in Portugal from 16th to 20th centuries

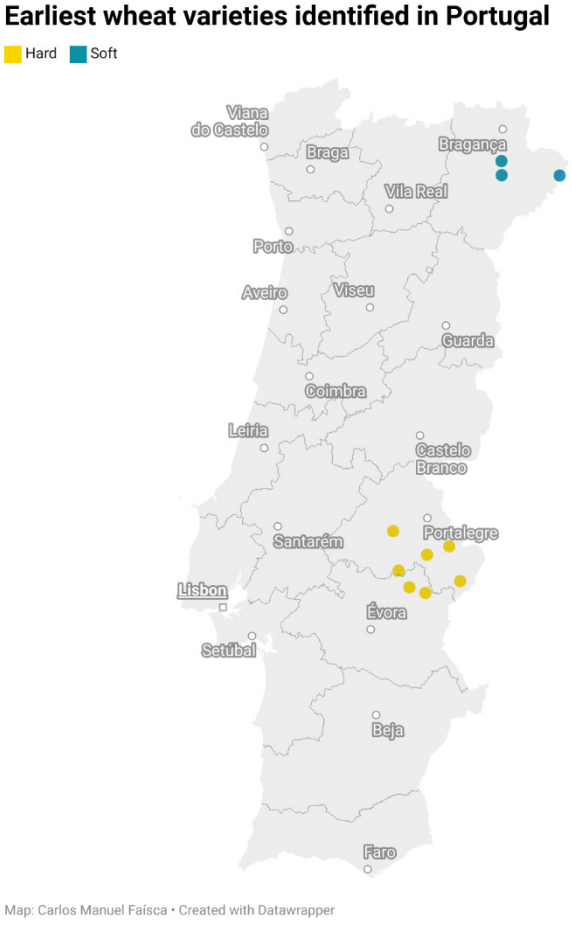
Records from the 16th to the 18th centuries show a clear division in the wheat species with *Triticum aestivum* L. (soft wheat) varieties in the colder and wetter north of Portugal, and *Triticum durum* Desf. (hard wheat) varieties in the warmer southern regions. Figure 3 shows the earliest wheat varieties within the soft and hard wheat species identified in Portugal, with the north/soft-south/hard division already present, which is confirmed by the next 93 records that could be collected with a time span from the 16th to the early 19th century. From the 19th century, this difference is also well documented in agricultural reports that underly mainly the agroecological conditions (climate and soil) between the two regions (Coutinho, 1884; Castro, 1893).

This situation was then considered a problem for Portuguese agriculture whose main goal was to guarantee the food sovereignty of a growing population (Freire, 2011; Branco and Silva, 2017) which, since 1889, had chosen wheat production as one of the main crops for achieving this (Reis, 1979). Since soft wheat is more suitable for making high quality bread, but the vast majority of national production was based on the vast southern plains where hard wheat predominates (75% by late 19th century), Portugal produced mainly the cheaper and less suited hard wheat for breadmaking (Castro, 1893). Politicians, agronomists, landowners and tenants wanted to change this situation. Thus, by mid-19th century, several attempts had been made to introduce soft wheat on a large scale in the southern fields, as confirmed by some records. In fact, in 1862, several soft varieties were found on the northern borders of the southern regions – *Barbela* in Santarém, *Caxudo* in Portalegre (Lapa, 1862). However, reports claim that, in these cases, the farmer had to "(...) fight against the environment and usually lost" (Castro, 1893, p. 33).

Nevertheless, efforts continued, and by the early 20th century, soft wheat varieties such as the northern *Barbela* were spreading further south and becoming increasingly well-established there. This wheat variety was found in Évora in 1906 (Silva, 1906), in Beja in 1907 (Fialho, 1907), and by 1930 it was one of the dominant varieties in Portugal, spread all over the

country and representing more than 10% of the total national wheat production (Monteiro, 1935, pp. 41-42; Franco and Amaral, 1964, p. 114). However, *Barbela* was not the only soft wheat present in the south between the second half of the 19th century and the beginning of the 20th century, as can be seen in Figure 4 and Table 1. In the early 1930s, in the southern wheat-producing region of Alentejo, the soft varieties were already dominant, since "(...) the milling industry preferred them to the hard ones (...)" (Estação Agrária Central, 1934, p. 192). It was also noted that although foreign varieties were already present, they were still in a clear minority, estimated at just over a third of the regional wheat production area (Estação Agrária Central, 1934, p. 192).

FIGURE 3. Earliest wheat varieties within hard (*Triticum durum* Desf.) and soft (*Triticum aestivum* L.) species identified in Portugal (16th and 17th centuries)

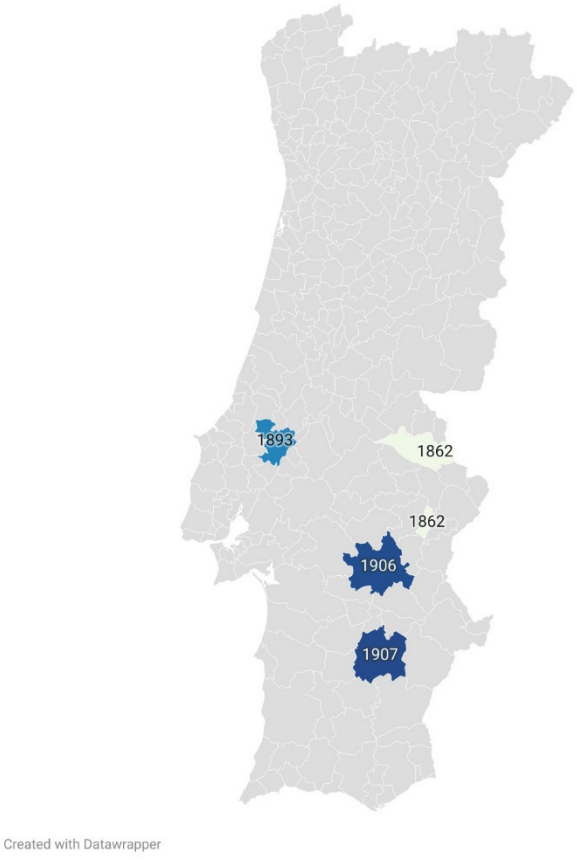


SOURCE: Author's elaboration from the ReSEED database

Then, from the 1930s, a major change occurred in the history of biotechnology in Portugal. Although the experiments date back to the end of the 19th century and the first legislative initiatives to the beginning of the 20th century, the selection, improvement and distribution of wheat seeds by public bodies became much more effective (Franco and Amara, 1964, p.11; Saraiva, 2010) with the *Wheat Campaign* launch (1929), the creation of the *Federação Nacional de Produtores de Trigo* (*National Federation of Wheat Producers)*, in 1933, and later the Estação Nacional de *Melhoramento de Plantas* (*National Breeding Station*), in 1942[15]. For example, in 1929, the rural extension service of the Beja district, one of the centers of Portuguese wheat production, was unable to provide seeds or any technical assistance to local farmers beyond 10 km from the Beja town due to financial constraints (Estação Agrária do Alto Alentejo, 1929, p. 415). But in 1942, only 13 years later, 600 tons of selected wheat seeds were distributed to the farmers, especially in Alentejo, through the *National Federation of Wheat Producers* network. This amount rose to 18,500 tons in 1959, which meant 25% of the total wheat seeds sown each year in the Portuguese fields (Saraiva, 2010, pp. 490-491).

In 1939, a new law established the official certification of both Portuguese and foreign wheat varieties, and the official tables were dominated by improved hybrid varieties, most of which were still imported from Italy (Silva, 1959). In fact, the influence of the Italian wheats developed by the plant breeder Nazareno Strampelli and massively used during the Italian *Battaglia del grano*, launched in 1926 and promoted by Mussolini, extended beyond the end of the fascist regime[16]. The result was the gradual disappearance of many landrace varieties with local names, especially in the areas where the public services and private companies were more established and distributed these seeds directly to farmers on a massive scale. At least since 1942, when the *National Breeding Station* were created, both the wheat varieties improved in Portugal and the already imported hybridized varieties were widely distributed. Alentejo was at the center of this movement, as large local landowners enthusiastically embraced the introduction of imported and/or hybrid varieties that were linked to different forms of state privileges, given the importance that public policies attributed to the region for the production of Portuguese wheat (Rosas, 1994, pp. 259-262; Saraiva, 2010, p. 482).

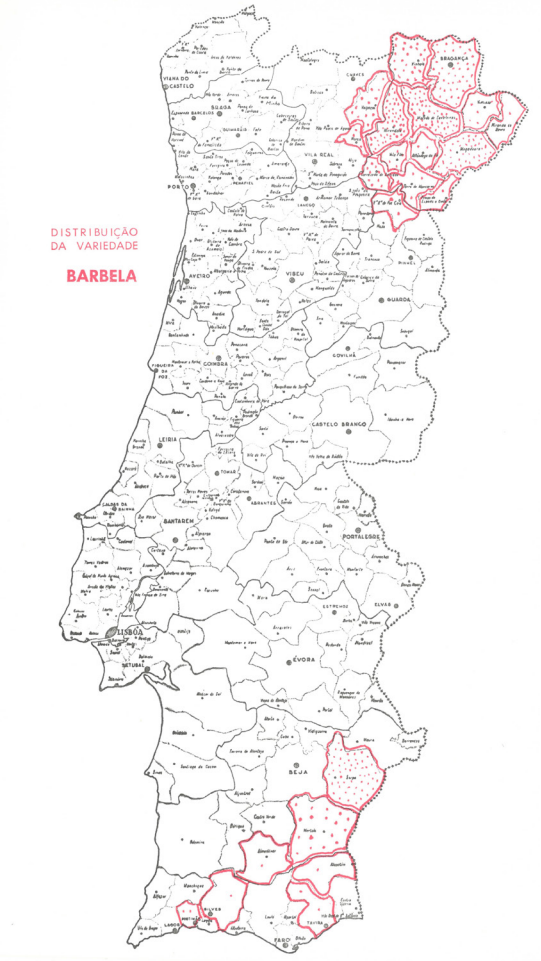
FIGURE 4 AND TABLE 1. **Identified soft wheat varieties in the south of Portugal**



Soft wheat variety	Location	Date
Galego	Crato	1862
Da Terra	Borba	1862
Caxudo	Portalegre	1862
Barbela	Santarém	1893
Ribeiro	Santarém	1893
Canoco	Santarém	1893
Cascalvo	Santarém	1893
Sete	Santarém	1893
Barbela	Évora	1906
Ribeiro	Évora	1907
Galego	Évora	1907
Barbela	Beja	1907

SOURCE: Author's elaboration from the ReSEED database.

FIGURE 5. **National distribution of *Barbela* wheat by 1960**

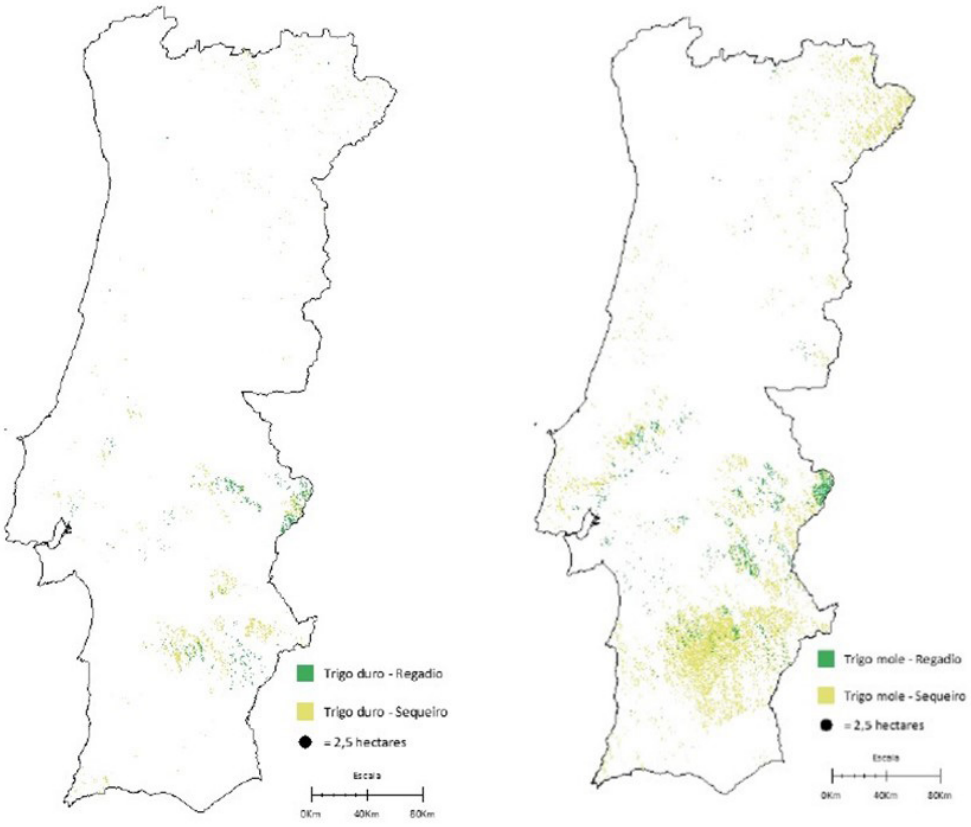


SOURCE: Franco, Amaral, 1964, p. 115.

Thus, by the beginning of the 1950s, the soft landrace varieties brought earlier from the northern regions, such as the *Barbela*, began to disappear in the southern wheat-producing areas and were replaced by other varieties, many of Italian origin, such as the *Quaderna*, *Rieti*, *Roma* and *Pirana*, the latter one already a hybrid between an Italian and Portuguese wheat[17]. Nevertheless, soft wheat landraces varieties survived in the peripheral northern areas and also in some peripheral areas of the south, especially in the poorest lands, as shown in Figure 5 and confirmed by other sources and oral interviews[18]. In fact, in the northern regions where this variety was historically established, it has remained until today, even after it was removed from the *National Catalog of Wheat Varieties* in 1987, making it impossible to buy its seeds (Car-

valho, 1993, p. 57)[19]. Currently, in the few areas where wheat is still cultivated in Portugal, hard wheat continues circumscribed to the south. While soft wheat, after being introduced in the southern regions in the mid-19th century, is present in both the north and the south, as shown in Figure 6.

FIGURE 6. **Distribution of hard and soft wheats in Portugal (2016)**



SOURCE: Barreiros, 2018, p. 20.

5. Explaining the historical changes of wheat varieties in Portugal

Given that the success of agriculture is inseparable from geography, the location of wheat varieties in Portugal can be explained by the agroecological conditions of each territory. Although

the recognition of these connections spans centuries, from the 18th century onwards, scientific arguments challenged previous explanations. For instance, the relevance of the agroecological conditions, as well as the fact that soft wheat is easier to bake, are explained in a manuscript kept in the *Academia das Ciências de Lisboa* (*Lisbon Academy of Sciences*), dated 1800: "(...) fine or soft wheat is proper in cold and wet northern countries. Its characteristics are to be soft and flexible between the teeth and inside presents a very white material. Hard wheat is produced in dry and hot climates (...) when it is broken it shows a grey color, its tone is less clear and the mill does not crush it easily" (Cabral, 1800, p.7). This north-soft/south-hard wheat division was maintained until the late 19th century and several agronomic reports stated that this was in keeping with the climate of each region (Portugal. Direcção-Geral de Agricultura, 1890, p. 1184).

However, by the end of the 1800s, the population was growing rapidly (Rodrigues, 2009, p. 328), wheat imports were becoming more difficult due to the protectionist policies adopted from 1889 (Reis, 1979), and consequently the importance of national wheat production was increasing. It is important to emphasize that at the beginning of the 20th century, wheat was estimated to be the basis of food consumption for almost half of the Portuguese population, ranging from just over 10% in the northern regions to 95% in the southern ones, including the capital and largest city, Lisbon (Fialho, 1907, pp. 23-24). In this scenario, the milling industry demanded large quantities of soft wheat, which could only be met if cultivated in the vast plains of southern Portugal (Fialho, 1907, pp. 23-24; Monteiro, 1935, pp. 189-192).

Thus, in the 1890s, farmers were actively trying to disseminate soft wheat varieties in the southern fields, but they faced major difficulties because they had to bring in new seeds every two years as the previous ones hardened due to the hot and dry climate (Castro 1893, p. 33). Human action increasingly sought to interact with seeds and agroecological conditions to achieve the goals set for Portuguese wheat production, but still with poor outcomes. However, the continuation of experiments introducing soft wheat varieties in the south, along with subsequent selection of the best-adapted ones, and very likely the changes observed in southern agriculture, may explain the success that began to be noticed. In fact, there was an improvement in livestock until the beginning of the 20th century, with an increase in the availability of organic manure, while novel fertilization solutions were slowly adopted by farmers, particularly during the last quarter of the 19th century. There was also an increase in mechanization; one of the best-documented cases concerns the introduction of the steam harvester. All these new technologies and techniques were adopted first by the large farmers concentrated especially in Alentejo region and surrounding areas where latifundia predominates (Branco and Silva, 2017, pp. 224-236). Irrigation, on the contrary, cannot explain it, as its expansion only occurred starting in the mid-second half of the 20th century (Faísca, 2023).

For instance, in the Santarém district, on the northern border of the Alentejo region, soft wheat was already being produced, with the existence of some soft wheat landraces as early as 1893 (such as *Galego*, *Ribeiro* and *Barbela*) (Castro, 1893, p. 31). Later, by early 20th century, soft wheat varieties were already fairly present in southern wheat agriculture. In the Évora district, 9 out of 14 municipalities produced soft wheat, and the Beja district 7 out of 14

municipalities had soft wheat production (Fialho, 1907, p. 23). Meanwhile, the first public agricultural organizations and large landowners also tried to introduce foreign soft wheat seed varieties from various places in Europe: France, Belgium, Great Britain and Italy. All initial experiments gave poor results and these varieties did not seem to thrive (Coutinho, 1889, p. 127 and 281; Castro, 1893, p. 34; Silva, 1906, pp. 8-9).

However, this was about to change. Following the first legislative guidelines regulating public wheat hybridization, published in 1901, the 1910s saw an increased effort by the Portuguese state to import, improve and maintain "new" wheat varieties (Pires, 1946, p. 217), as well as other grains, such as rice (Faísca, Freire and Viana, 2021). It was expected that the new varieties, once adapted to the agroecological conditions of the south, could exponentially increase national wheat production and thus close the remaining gap to food self-sufficiency. In this context, a group of twelve agricultural stations was created in 1915, with the main objective of importing and improving agricultural seeds. Nevertheless, the early 20th century was a period of permanent economic difficulties for Portugal, and although the main macroeconomic indicators show a growing economy, it was at a very slow pace, exacerbating the economic divergence between Portugal and the most developed countries (Lains, 2003, pp. 125-166). This was reflected in the strained public finances, which did not allow adequate investment in the development of agricultural seeds varieties, as in many other planned public policies (Lopes, 2005, pp. 265-286; Amaral, 2019, pp. 78-87).

While numerous initiatives aimed at promoting wheat production had been undertaken by large landowners and their organizations since the mid-1920s (Saraiva, 2010, p. 478), significant changes only began to occur with the consolidation of the dictatorship regimes, since 1926. These changes were primarily driven by increased financial resources (Lopes, 2005, pp. 270-271) and, especially, the adoption of the longstanding concept of wheat self-sufficiency as a cornerstone of the new regime (Saraiva, 2010). In fact, dictatorship governments were based on economic autarky and on achieving food self-sufficiency, especially in grains such as wheat. For these reasons, following the fascist Italian *Batalla del Grano* (1926-1937), the Portuguese state launched the *Wheat Campaign* (1929-1938). The campaign was based on seven actions, which can be grouped into propaganda and education, financial support, and technical and technological support, as summarized in Table 2. The sixth action relates to fertilization and seeds, and it is critical to determine what varieties were distributed, where, why, and whether previous wheat varieties and landraces were still cultivated.

The distribution of selected and improved seeds, however, was not uniform throughout the Portuguese territory. The greatest investments were made in the southern areas, which were politically designated for wheat production and where, not by coincidence, the *National Plant Breeding Station* is located. Thus, by the late 1950s, farmers from Alentejo and other southern areas were using a higher proportion of selected wheat seed, as shown in Table 3. This was again confirmed by oral interviews. When asked if they had received any specific public incentives for wheat production, and in particular for selected seeds, all the informants from northern (Trás-os-Montes mountains) and the southern (Algarve mountains) peripher-

al areas denied any significant intervention by public or private organizations in this regard[20]. The interviewees from Alentejo express the opposite. They remember how they were invited to the *National Plant Breeding Station* every May, where, in addition to attending training sessions, they received improved selected seeds[21].

TABLE 2. ***Wheat Campaign*** **actions to support production in Portugal**

Type of	Description
1. Propaganda	Emphasize the importance of wheat to farmers and educate them on the latest cultivation methods
2. Technical assistance	Agricultural stations, schools and the National Institute of Agronomy will help farmers to improve their wheat yields
3. Financial assistance	Subsidized access to agricultural credit
4. Reduction of uncultivated land	The Ministry of Agriculture will provide technical support to expand wheat production on uncultivated land
5. Lease of agricultural machinery	Several public organizations will lease modern agricultural machinery
6. Distribution of fertilizers and seeds	Fertilizer and selected seeds will be distributed at low cost in the major cities of the wheat production regions
7. Subsidies	The production will be subsidized according to the cultivated area and the previous use of the land

SOURCE: Federação Nacional de Produtores de Trigo, 1954.

TABLE 3. **Total seeding and selected seeding by region, 1957-1961**

District	Region	A – Total seed sown (Kg)	B – Total selected seed sown (Kg)	% of selected seed sown (B/A)
Portalegre	Alentejo (South)	9,000,000	3,600,000	40%
Évora	Alentejo (South)	12,000,000	3,360,000	28%
Beja	Alentejo (South)	21,000,000	3,150,000	15%
Lisboa	Lisboa (Center-South)	4,500,000	1,575,000	35%
Santarém	Ribatejo (Center-South)	4,000,000	1,160,000	29%
...				
Faro	Algarve (South)	5,500,000	275,000	5%
Bragança	Trás-os-Montes (North)	5,500,000	27,500	0.5%

SOURCE: Franco, Amaral, 1964, p. 20-21.

This public effort was also accompanied by private companies whose ultimate goal was to sell agricultural inputs – such as fertilizer and machinery – that the hybrid and imported varieties needed to achieve the productivity gains for which they were known (Carranza Gallego, 2019). Just as they remember the workshops held at the *National Breeding Station*, the farmers in the Alentejo emphasize the importance of the agronomists of the *Companhia União Fabril* (*União Fabril Company*), or CUF, service in changing agricultural techniques and introducing imported and hybrid varieties of soft wheat. "Engineer Canelas taught us a new way of growing wheat that changed the density of sowing from night to day", said Francisco Carapinha, born in 1930[22]. The company, for which the agronomist Manuel Canelas worked, has its roots in an important chemical company that, since the early 20th century, had the production of fertilizers as one of its main assets. By the 1930s, the CUF employed thousands of workers and was soon the most important business group in Portugal[23]. The company had a strong I&D department, including experimental fields in a joint venture with important farmers from the wheat growing regions[24]. As Table 4 shows, Alentejo was also the main region for CUF's wheat I&D activities.

TABLE 4. **CUF wheat experimental fields by region, 1932**

Region	Number of wheat experimental plots	Wheat experimental field ratio (Number/Km²)
Trás-os-Montes (North)	5	0.0008
Beira Baixa (Center-North)	3	0.0004
Areias da Borda d'Água (Center-South)	5	0.0007
Alentejo (South)	36	0.002
Algarve (South)	5	0.001

SOURCE: Seabra, 1937, p. 77-86

As the Alentejo was flooded with the more productive improved and/or hybrid varieties, especially those imported from Italy, the landraces persisted only in the most peripheral regions, as shown in Figure 4 for *Barbela* wheat. Several factors may have driven this situation, since the Trás-os-Montes and Algarve mountains, although separated by almost 700 kilometers, have several similarities. First, in both regions the property structure of is made up of small and medium landowners (Rodrigues and Matos, 1952, pp.61-62; Pires, 1984, p. 60), which increases the difficulty of introducing the usual inputs associated with GR, due to the lack of investment capital: intensive use of machinery and fertilizers, and the constant purchase of improved seeds, since hybrids become sterile after the first harvest.

Second, the orography also made the use of heavy machinery unprofitable, as confirmed by oral interviews. For example, Francisco Pereira, an 87 years old farmer, and Joaquim Rosa Gomes, 84-years old, both from Furnazinhas village, Castro Marim (Algarve), stated that until the mid-1960s, the use of tractors was out of reach for local farmers[25]. They did not have

the financial resources to purchase and maintain a tractor, and the uneven landscape did not allow for the proper return of such investment. In fact, even in 1979 only 58% of farmers in the region used mechanical traction (Pires, 1984, p. 88). Similarly, in Rebordãos village, Bragança (Trás-os-Montes), Augusto Encarnação Benides, born in 1949, and who cultivated *Barbela* variety, states that he only acquired a tractor in 1975 and with the aid of public financing assistance[26].

Finally, several agronomists mention the better adaptability of landrace varieties such as *Barbela* to the agroecological conditions of both regions (Reis and Ferreira, 1950, p. 24; Carvalho, 1993, pp. 37-40), and indeed, they have clear similarities. Both regions present thin soils predominantly composed of schist, prone to high erosion due to steep slopes and containing little organic matter (Reis and Ferreira, 1950, p. 93; Rodrigues and Matos, 1952, pp. 1-2). The rainfall levels and distribution, and warm air amplitude show some parallel. Although Trás-os-Montes has a colder climate, it was in the lower areas of this region where wheat was cultivated, between 500 and 800 meters above sea level, while the *Barbela* cultivation areas in the Algarve were in the highest areas of the region, between 400 and 600 meters above sea level (Pires, 1984, p.12; Carvalho, 1993, p.60). Even the number of frost days, for example near Cachopo village, was 20 to 25, something almost absent from the rest of Algarve (Pires, 1984, p. 12). In Trás-os-Montes, in areas where, in addition to frost, it snows every winter, rye was cultivated. In fact, in this northern district of Portugal above 800 meters in altitude only rye was produced, with no cereal cultivation in the higher mountains above 1.000 meters (Carvalho, 1993, p. 60). So, despite the differences, the agroecological conditions of the higher areas in the Algarve mountains resemble those of the lower ones of Trás-os-Montes.

Under these conditions, local farmers continued to use the soft wheat landraces because they were the most suitable for bread production compared to the hard wheat varieties, and they were the "ones that the weather and the soils allowed"[27]. This idea of a match between agroecological conditions and the chosen wheat variety chosen is consistent among all three dozen elderly farmers interviewed in Trás-os-Montes and the Algarve. Another factor that seems to be essential is the production of straw. In organic agriculture, as it was practiced in these regions until the second half of the 20th century, straw was essential for feeding animals, among other uses[28]. This has already been observed for the pre-GR wheat production in Spain (Pujol-Andreu, 2011). In fact, Table 5 proves the ability of the *Barbela* landrace variety, compared to other improved/hybrid varieties, to produce straw and even grain when grown in the agroecological and social-economic conditions of the Algarve mountains.

Today, wheat production has almost disappeared in Portugal, with only some areas remaining in the Alentejo for both hard and soft wheat, and in the northeast of Trás-os-Montes for soft wheat, as shown in Figure 5. Nevertheless, the regional division between hard wheat (southern areas) and soft wheat (since the late 19th century in both the north and the south) is maintained. However, the varieties grown are no longer landraces, except in very isolated cases, and are all hybrids/improved varieties developed by the public official services or sold by seed private companies[29].

TABLE 5. **Results of the experiments made in 1941-1942, by the *Experimental Station of Dryland Agriculture* in Caldeirão Mountain (Algarve)**

Variety	Grain production (Kg/Ha)	Straw production (Kg/Ha)	Grain/straw ratio
Barbela (landrace)	1,046	2,234	1:2.13
Ideal (improved)	886	1,870	1:2.10
Português (landrace)	788	1.656	1:2.10
Mentana (improved, of Italian origin)	904	1.248	1:1.38
Quaderna (improved of Italian origin)	1,080	1,460	1:1.35
Riafle (improved, of Italian origin?)	1,008	1,556	1:1.54
Temporão Coruche (landrace)	762	1,534	1:2.01

SOURCE: Posto Experimental de Culturas de Sequeiro de Caldeirão, 1941-42.

Thus, looking at the theoretical framework that explains agricultural innovation, which links agroecological conditions, human action and the genetic characteristics of seeds, it is possible to conclude that, until the 19th century, wheat production in Portugal was mainly determined by agroecological conditions[30]. This model relates these three elements: agroecological conditions, such as climate, topography, and soil; the genetic characteristics of seeds, which better adapt to certain features of the previous factor; and human action, which, by combining the previous factors, seeks to influence them according to the objectives established for agricultural production. Depending on the historical period, although these factors are always present, their importance varies. Thus, for example, the rice production increase in southern Portugal, where water scarcity is one of the characteristics of the agroecological conditions, was impossible without human action improvements, namely, in the construction of large irrigation systems from the mid-20th century onwards (Faísca, Freire and Viana, 2023).

In fact, it was not until the late 19th century that it was possible to introduce soft wheat varieties into the south, when human action on seeds succeeded in selecting the characteristics necessary for soft wheat to thrive in the regional environment conditions, likely supported by the increased use of fertilizers and machinery. Later, the same occurred in an even more significant way with the introduction of improved and/or hybrid varieties, many of which were imported from countries such as Italy, which spread throughout the main wheat producing regions in Portugal. However, due to the demanding requirements of the varieties developed within the GR, this meant a significant increase in agricultural investment. So, in the poorest peripheral regions of Portugal, dominated by smallholdings, landraces varieties were only abandoned much later.

This research also highlights that the first modern Portuguese attempts to develop wheat biotechnology, both public and private, were a few years behind the European core and the USA. In fact, if in 1873 the French company Vilmorin produced its first hybrid wheat, the Dattel, the available records confirm its cultivation in Portugal as early as 1907, and once again in the Alentejo region (Fialho, 1907). But even more important is the fact that by 1880s sever-

al experiments were conducted in wheat improvement and hybridization using landraces and imported varieties. They were carried out since 1885 by the state-paid agronomist António Filipe da Silva in the northern Alentejo area, and simultaneously by the private landowner D. Luiz de Castro, and future Minister for Public Works, Commerce, and Industry, who was responsible for Agriculture (1909-1910), on his estates a little more than 60 km north of the Alentejo (Castro, 1893). This suggests that Portugal, considered to be on the periphery of Europe for economic development (Lains, 2003, pp. 33-60), was not in the biotechnological issues[31]. In fact, Portugal followed closely the chronology of the Western model of agricultural development, based on the intensification of production factors with a strong focus on seeds. Future research based on other agricultural crops, and, above all, on what has actually happened in its national agriculture, will allow Portugal to be placed in the international framework of modern agricultural development.

6. Conclusions

As in other European countries, from the end of the 19th century both public and private Portuguese organizations systematically sought to change the genetic characteristics of cultivated seeds. In this regard, the Portuguese agronomists and some landowners tried to closely follow the innovations that were practiced in more developed countries. Since wheat was one of the main products of Portuguese 19th century agriculture, it was heavily exposed to this type of experiments. They allowed the dissemination of soft wheat landraces in the main wheat-growing regions of the south by the end of the 19th century. Until then, soft wheat landraces were limited to the northern areas, as they were not adapted to the southern agroecological conditions. Thus, until the end of the 19th century, agroecological conditions were the main factor explaining the geography of wheat varieties in Portugal.

The specific context of the end of the 19th century strongly stimulated the introduction and successful dissemination of soft wheat landrace varieties in the southern regions. Political grain protectionism and population growth meant that the milling industry had to be satisfied with national soft wheat suited for breadmaking, which coincided with the period of strong international development of biotechnology. The demand for food in the form of bread was the main reason for the spread of soft wheat varieties throughout Portugal. At this point, human action intensified its impact with the systematic realization of experiments for introducing seeds of soft wheat varieties in the south, along with the respective selection of the best-adapted ones, and simultaneously with the increased use of fertilizers and mechanize agriculture techniques in the main southern wheat-growing regions.

Soon after, improved and/or hybrid varieties were either developed or imported due to their increased productivity. Their distribution became the task of the state agricultural services from the beginning of the 20th century and, after a slow start, they spread rapidly. Drawing on the Italian experience, with more financial stability, technical expertise, and also ideological

motivation, public organizations massively distributed seeds of hybrid and imported wheat varieties, in a process where private companies also participated with commercial objectives. Thus, after the mid-20th century, landrace varieties remained only in the more peripheral regions, where they were better adapted to the local agroecological conditions, but also to the socio-economic environment of organic agriculture. Human action seems also to better explain the geography of wheat varieties in Portugal in the 20th century, both in the areas where hybrid and/or imported varieties have become dominant, as in the poorest areas. In these areas, as previously stated, were the small farmers who continued to use, for instance, the *Barbela* landrace even after its removal from official catalogs in the late 1980s.

It should be emphasized that Portugal's biotechnological development, at least chronologically, was not far behind from that of the more advanced economies such as that of Europe and of the USA. Subsequent studies, including also other agricultural crops and focusing on what actually happened regarding Portuguese plant breeding, will contribute to reposition Portugal within the global framework of modern agricultural development.

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Notas

1. In this article, the concept of variety is as follows: a proven variant that is distinct, uniform and stable, thus the definition being no different than a cultivar, according to the *International Code of Nomenclature for Cultivated Plants*, see Brickel, 2016, p. 6.
2. For the concept of European periphery and its applicability to Portugal, see Lains, 2003.
3. Following Kloppenburg, 2004, this definition includes selection, improvement, and introduction of "new" wheat varieties.
4. About the Iberian Peninsula, see Freire, forthcoming.
5. In order to understand the chronologies of the GR, see Hardwood, 2012 and Picado 2022.
6. About the Iberian Peninsula, see Lanero and Freire, 2011.
7. For interpretations of the GR chronology and the political objectives of both the USA and the other countries were implemented, see Hardwood, 2012; Picado, 2022
8. For example, in addition to the fight against malaria, the Rockefeller Foundation's intervention in Portugal is still little known, see Faísca, Freire, Viana, 2021.
9. The ReSEED database is under construction within the scope of the ReSEED project, it includes information on species and varieties of plants cultivated in the Iberian Peninsula since the 16th century, see Gomes and Freire, 2023.
10. About the exploration of this analytical framework, which is being developed under the ReSEED project, see Gomes and Freire, 2023; Faísca, Freire and Viana, 2023; Gomes, González Remuiñán and Freire, 2023.
11. The fieldwork took place in 19 villages of Trás-Os-Montes, Alentejo and Algarve. Twenty-one semi-structured interviews were conducted. The interviews were audio and video recorded (20 h and 32 min). Following the data protection requirements of the European Union, all participants consent authorising the interviews and the use of their content for scientific purposes, including publication. The material collected is still under analysis within the ReSEED project and will be transcribed. Only preliminary results are presented here.
12. About Strampelli's hybridization experiments, see Saraiva, 2010, pp. 465-468.
13. The maize dissemination in Portugal is still under discussion. However, by the early 18th century maize had already become a dominant cereal in the northeast regions (see Serrão, 2017), close to the Galician (Spain) border, see Pérez García, 1992, and Pegerto Saavedra, 2018.
14. This is also why soft wheat is sometimes called bread wheat.
15. About *Wheat Campaign* distribution of selected seeds, see Saraiva, 2010.
16. Initially the Portuguese authorities though self-sufficiency was to be accomplished through the wheat varieties developed by Strampelli, Saraiva, 2010, p. 482.
17. Testimony from Francisco Carapinha, Montargil, Ponte de Sor (Alentejo), October 2022
18. Testimonies from Belmiro, Rebordãos, Bragança (Trás-os-Montes), 19 April 2022; José Sebastião Gomes, Cachopo, Tavira (Algarve), 10 August 2022; Reis, Ferreira, 1950.
19. In November 2022, we were offered a portion of *Barbela* wheat by a farmer in Cedea, Zamora,

Spain, a small village just a few kilometers from the Portuguese border.

20. Testimonies from Sebastião Gomes, Custódio Campos, both taken in Cachopo, Tavira (Algarve), 10 August 2022, among several others taken in northern Trás-os-Montes.
21. Testimony from Francisco Carapinha, Montargil, Ponte de Sor (Alentejo), 21 December 2022.
22. Testimony from Francisco Carapinha, Montargil, Ponte de Sor (Alentejo), 21 December 2022.
23. On the history of CUF and its economic importance, see Silva, Amaral, Neves, 2016.
24. The only exception was the *Tavira Experimental Camp* (Algarve), which was publicly owned and was part of the network directly dependent on the *National Plant Breeding Station* (Elvas, Alentejo).
25. Testimony from Francisco Pereira and Joaquim Rosa Gomes, Furnazinhas, Castro Marim (Algarve), July 2022.
26. Testimony from Augusto Encarnação Benides, Rebordãos, Bragança (Trás-os-Montes), 19 April 2022.
27. Almost every interviewee says this or something similar when asked why they sow *Barbela* wheat.
28. In Cachopo, barley straw was even used to build roofs.
29. In one of the interviews, an old farmer gave us seeds of the *Serôdio* wheat landrace, which he maintains by reproducing the old logic of saving the best seeds from one harvest to the next.
30. For this framework, see Faísca, Freire and Viana, 2023, Gomes, Freire, 2023; Gomes, González Remuiñán and Freire, 2023.
31. Confirming this perception, for a Portuguese and Spanish overview, see Freire forthcoming.