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Review

Barley History and Breeding in Spain

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Abstract: Barley has been and continues to be a crucial field crop in Spain, with approximately 2.4 million hectares planted annually and a production ranging 7–10 million tons. It is a crop well adapted to shallow soils and the harsh winters of the high central plains of the country. Traditionally, animal feed has been the main use for this crop, while an important brewing industry developed throughout the 20th century. This article reviews the most important milestones of this crop in Spain, including its uses, historical yield, barley price, and barley–wheat price relationship. With respect to the collection of Spanish landraces currently preserved in the CRF (Plant Genetic Resources Center) seed bank, two main genetic groups distributed in northern and southern Spain were distinguished. The landraces of both groups are mostly six-row and winter types, but they differ in vernalization requirements, which are lower in southern landraces. The trends in barley production, the most planted cultivars in Spain over the last 70 years, and the past and present-day breeding programs in the country are also reviewed.

Keywords: *Hordeum vulgare*; landraces; agricultural history; plant breeding history

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1. Introduction

Barley (*Hordeum vulgare* L. ssp. *vulgare*) is a significant crop in the world and is the fifth most planted crop, with 47.1 Mha (million ha) and an annual production of approximately 154.9 Mt (million tons) in 2022–2023 [1]. Interestingly, wheat has been the most important crop in Spain for centuries, dating back at least to Roman times. However, in the 1975–1976 season, the area dedicated to barley surpassed that dedicated to wheat for the first time. Since then, barley has remained the most cultivated crop for 45 years [2]. In the past seasons, the barley area has been slightly decreasing and approaching that of wheat and has been recently surpassed by that of the olive tree (first in 2018–2019 and then since 2021–2022) (Figure 1, Table S1). As Spain is a country with a Mediterranean climate, barley production in Spain fluctuates from season to season. For example, during the 2021–2022 and 2022–2023 seasons, 2.5 and 2.4 Mha of barley were planted, with grain production rates of 8.9 and 6.7 Mt, respectively [2].

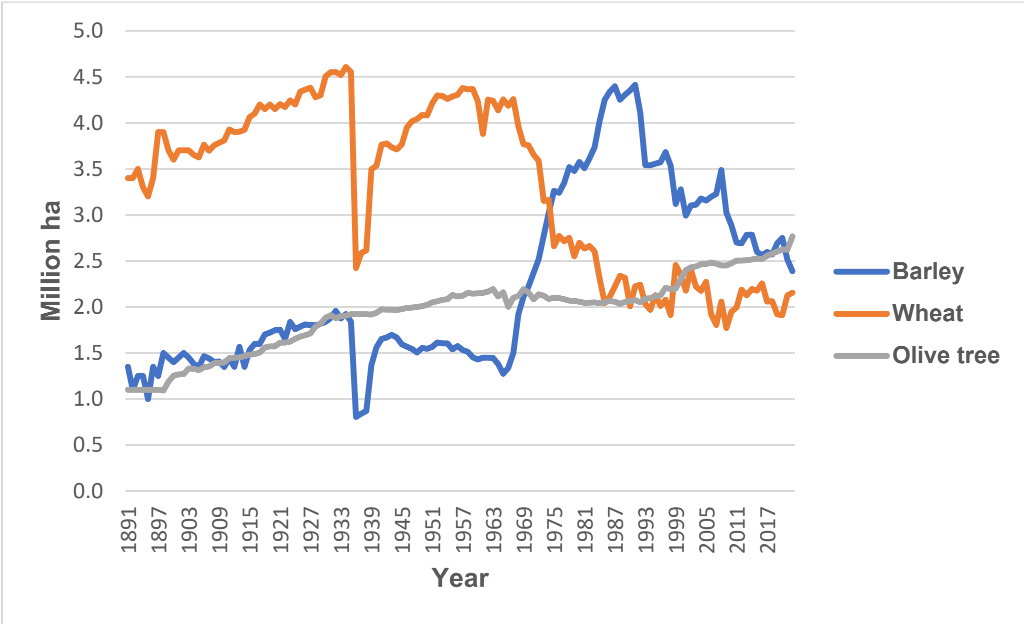

Figure 1. Historical barley, wheat, and olive tree areas in Spain (1891–2022) [2].

2. Origin and Historical Evolution

Barley and wheat were the first cultivated plants. Domestication occurred on the left side of the Fertile Crescent (Southwest Asia) from its wild ancestor *Hordeum vulgare* L. ssp. *spontaneum* (C. Koch) Thell. approximately 11,000 years BP (before the present). The oldest remains of barley with tough rachis have appeared at the archaeological sites of Tell Abu Hureyra (Syria) circa 9000 years BP, Tell Aswad (Syria) from 8900 to 8600 years BP, and Jarmo (Iraq) approximately 8,400 years BP [3]. The first domesticated barley presented a tough rachis (due to the presence of recessive alleles at either *brt1* or *brt2* loci) [4,5]. The first domesticates also presented reduced dormancy in the seeds, in addition to being tall, with two-row spikes, hulled grains, white or clear glumes, vernalization requirements (winter type), and sensitivity to the photoperiod. During the expansion of cultivation to the East (Central Asia, India, and China) and the West (Mediterranean Basin and Europe), several mutations appeared that gave rise to other phenotypes: six-row spikes, naked grain, short culm, purple or black seed caryopsides, lack of vernalization requirements (spring type), and insensitivity to the photoperiod. Different quantitative profiles of seed proteins and amylases also arose in this expansion, leading to future feed and malting barley types. This genotypic differentiation increased the diversity of the crop and led to the emergence of new landraces adapted to different climates, soils, and human needs [6].

From the Fertile Crescent, two independently domesticated populations of barley gave rise to two genetic pools: landraces that spread westward (with greater genetic diversity) and those that spread eastward. During the westward expansion, genetic exchange occurred with wild barley populations from Libya and some islands in the eastern Mediterranean Sea. Eastern branch barley also experienced admixture similar to that of Central Asian wild barley [7].

The first barley arrived in Spain at approximately 7400 years BP when the Neolithic Revolution entered Spain from the east. The remains found in the Balma Margineda cave, Pyrenees (actually in Andorra), date back to that time [8]. Approximately 5000 years BP, archaeological barley remains on the Mediterranean coast (e.g., Can Sadurní, Barcelone), and in southern Spain, such as in Cueva de Nerja (Málaga) and Cueva de los Murciélagos (Córdoba), are frequently found [9].

3. Historical Area, Production, and Yield: Barley–Wheat Price

3.1. Barley Area and Production

Barley adapts quite well to the shallow soils and the cold and dry climate of the Spanish Central Plateau (Meseta). The largest barley area in Spain has extended for centuries through the inland areas of the southern sub-plateau although it has also been planted in the cold mountainous regions of the north (e.g., the Central System and the Pyrenees) [10]. The national barley area remained at approximately 1.3 Mha throughout the 19th century although production doubled (from 0.6 Mt in 1800 to 1.2 Mt in 1900). From 1900 to 1935, the acreage expanded from 1.3 Mha to 1.9 Mha, while production increased to 2.5 Mt, which contributed to the expansion of livestock farming in both periods [10] (Figure 2). After the Spanish Civil War (1936–1939), the barley cultivation area decreased to approximately 1.5 Mha and stayed that way in the 1940s, 1950s, and 1960s.

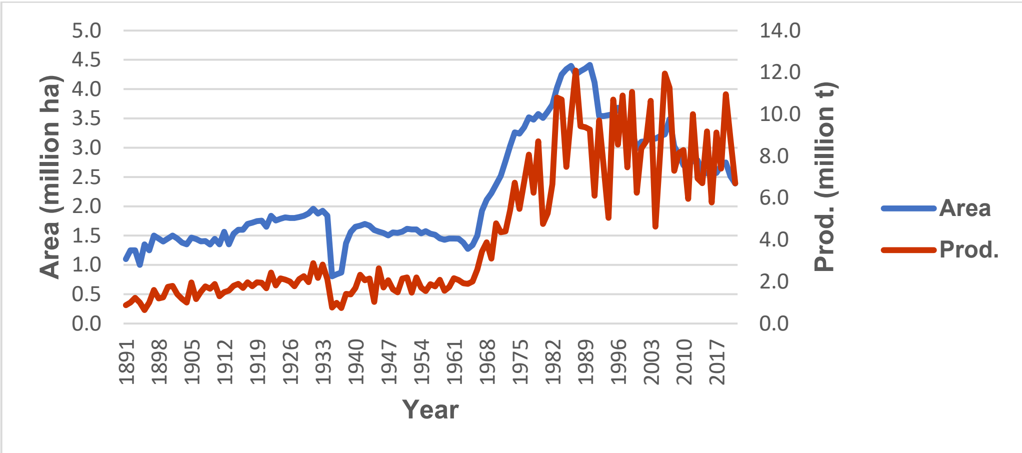

Figure 2. Historical barley area and production in Spain (1891–2022).

From the late 1960s, the barley area greatly increased, and the crop somewhat shifted north, primarily to the Castilla y León region. In the 1940s and 1950s, the national primary objective regarding food was self-sufficiency of wheat, and the National Wheat Service (Servicio Nacional del Trigo) even implemented a guaranteed (minimum) price to foster wheat grain production. However, in the 1960s, the standard of living of the Spanish people increased, and a need arose to promote crops for livestock feed. Maize and barley were the main crops selected to increase the amount of the so-called 'cereal pienso' (feed cereal). Furthermore, since 1965, a surplus of wheat has appeared in the market. Higher-yielding wheat cultivars were released at this time, better crop management was applied, bread consumption decreased, and the improvement of the national railway and road network permitted an easy wheat grain supply to nonproducing locations [11]. Starting in 1968, the government raised the guaranteed price of barley, which remained above the market price, to promote its cultivation. As the wheat price decreased because of the surplus, barley achieved a competitive price, approximately 80% of the wheat price. Furthermore, growing costs were lower for barley than for wheat, and the yield was slightly higher. These properties favored the rapid substitution of wheat with barley in terms of the cultivated area. In 1975–1976, already a larger area was planted with barley (3.3 Mha) than with wheat (2.7 Mha). Barley production grew so much that even some of the production was exported to other countries in some seasons, such as 1969, 1970, 1973, and 1975. While the average production in 1960–1966 was 1.9 Mt, in 1968–1973 it was 4.0 Mt. In addition, the costly wheat surpluses of the late 1960s and early 1970s were widely reduced. In short, internal livestock development generated a demand for barley, which promoted its expansion from 1968 to 1972 and after 1972 when the Spanish agri-food trade was liberated [12].

In the 1980s and 1990s, the national area rose sharply, exceeding 4 Mha in 1984–1992. The record seasons were 1990–1991 and 1991–1992, at approximately 4.4 Mha, with the country (in the latter season) earning the second position in the barley area in the world, after only the former USSR and above Canada (Table 1). In the past hundred years, Spain has always been among the top nine barley-growing countries in terms of cultivated area and production, but since the 1990s, it has reached the top five (next to Russia, Australia, Canada, Ukraine, or Turkey) [1]. Since then, the cultivated area has slowly decreased to approximately 3–3.3 Mha in the 2000s, 2.6–2.8 Mha in the 2010s, and currently, it ranges from 2.3 to 2.5 Mha. Regarding grain production, the average in the 1980s and 1990s was 8.5 Mt, exceeding 10 Mt in five seasons. In the 2000s, national production was 8.8 Mt, and since 2010, it has dropped to about 8.0 Mt, due to the decrease in the cultivated area [2].

Table 1. Historical international position of Spain regarding barley cultivated area and production.

Rank	Season/ Country	Area/ Prod. *	Season/ Country	Area/Prod.	Season/ Country	Area/Prod.	Season/ Country	Area/Prod.	Season/Country	Area/Prod.
	1950/51		**1970/71**		**1990/91**		**2010/11**		**2022/23**	
1	USSR	8.2/6.4	USSR	21.3/35.1	USSR	26.2/52.5	Russia	4.9/8.4	Russia	7.9/23.4
2	China	6.2/6.8	Canada	4.0/8.9	Canada	4.5/14.0	Australia	4.4/7.9	Australia	5.1/14.4
3	USA	4.5/6.6	USA	3.9/9.1	**Spain**	4.4/9.4	Ukraine	4.3/8.5	Turkey	3.2/8.5
4	India	3.1/2.4	France	2.9/8.2	Turkey	3.3/7.3	Turkey	3.0/7.3	Canada	2.6/10.0
5	Canada	2.4/3.6	India	2.8/2.7	USA	3.0/9.2	**Spain**	2.9/8.2	**Spain**	2.4/6.7
6	Morocco	2.0/1.1	Turkey	2.6/3.3	Syria	2.7/0.8	Canada	2.4/7.6	Kazakhstan	2.2/3.3
7	Turkey	1.9/2.0	China	2.4/2.7	Iran	2.6/3.5	Morocco	1.9/2.6	France	1.9/11.3
8	**Spain**	1.5/1.5	UK	2.2/7.5	Germany	2.6/14.0	Germany	1.6/10.3	Ukraine	1.7/5.6
9	Algeria	1.1/0.8	**Spain**	2.2/3.1	Australia	2.5/4.1	Iran	1.6/3.3	Iran	1.7/3.0
10	France	1.0/1.6	Germany	2.1/6.7	Morocco	2.4/2.1	France	1.6/10.1	Germany	1.6/11.2
	46.2/~50		66.1/119.4		73.7/179.1		47.6/123.5		47.1/154.9	

* Data ordered by area. The data from the 1950 season are from [13], and those from 1970, 1990, 2010, and 2022 are from FAOSTAT [1]. The area is in Mha (million ha), and production is in Mt (million tons).

The provinces with the largest historical barley areas in the four different periods are depicted in Figure 3 (Table S2). The province of Murcia stood out with approximately 150,000 hectares (~10% of the national surface) from 1898 to 1904 (first recorded data), followed by Seville, Ciudad Real, and Jaén, with approximately 80,000 ha each, and Badajoz. All were southern provinces where the barley-planted area is currently limited. Interestingly, approximately 28,000 ha in the Canary Islands are used for feed and gofio (a kind of Canarian porridge for human consumption), but currently, these areas are almost null. In 1955–1961, the province that grew the most barley was Ciudad Real, with an annual mean of 127,000 hectares, followed by Badajoz (108,000 ha), and then, by Albacete, Toledo, and Murcia. Barley production has moved steadily northward over time (from Andalusia and Castilla-La Mancha regions to Castilla y León and Aragón), being replaced in the south by wheat, olive trees, vineyards, other fruit trees, vegetables, etc. During 1985–1990, when barley production in Spain was booming, the main province was Valladolid, with more than 400,000 ha planted in that period (405,000 ha), next came Burgos (288,000 ha), followed by Huesca, Zaragoza, and Albacete. In the recent period of 2015–2020, the provinces of Cuenca (260,000 ha) and Valladolid (188,000 ha) were the most important in terms of barley cultivation, followed by Huesca, Zaragoza, and Burgos [2].

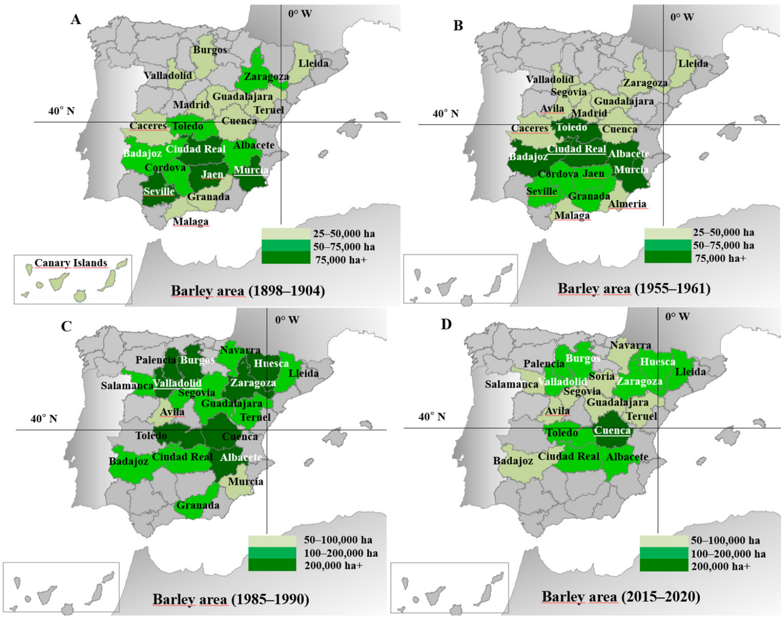

Figure 3. Provinces with the largest historical planted area of barley in Spain. Note the scale change for the area of (**A**,**B**) (smaller) with respect to (**C**,**D**). The five provinces with the largest planted area are white-lettered, and the main province is underlined [2].

3.2. Barley Yield

As barley is a crop that is well adapted to most of the country's climates and soils, yields are approximately 25% higher than those of wheat. Compared with wheat, barley is established faster because the embryo is larger, covers the soil faster, and flowers earlier [14]. For example, in 1751–1753, the national wheat yield was 470 kg/ha, whereas that of barley was 600 kg/ha (Table 2). These differences were even greater in the interior of the country (e.g., the plateau lands of Castilla-La Mancha and Castilla y León) and were smaller in the main river valleys of Duero, Tajo, Guadiana, and Guadalquivir where the deep clay soils favor wheat growth over barley growth. In fact, throughout the 19th century, barley yields in Spain were quite close to those in the rest of Europe. While the wheat yield in Spain was 43% lower than the European average, that difference was only 21% in the case of barley [15].

Table 2. Historical wheat and barley yields (kg/ha) by decade in Spain.

Decade [1]	Barley Yield	Wheat Yield	Difference	Difference (%)
1750	600	470	130	27.7%
1810	620	490	130	26.5%
1890	822	715	118	14.2%
1900	1069	898	171	18.3%
1910	1114	889	225	25.6%
1920	1136	903	233	26.0%
1930	1119	857	262	30.9%
1940	1176	846	330	37.9%
1950	1207	975	232	24.2%
1960	1524	1139	385	34.0%
1970	1942	1575	367	24.3%
1980	2097	2204	−108	−4.5%
1990	2400	2386	15	−0.3%
2000	2711	2840	−130	−5.4%
2010	3004	3216	−212	−6.9%

[1] Data from the decades 1750 (actually 1751–1753) and 1810 (actually 1818–1820) from [15]. Data from 1890–2020 from [2]. The difference between the barley yield and wheat yield was calculated, and the percentage was divided by the wheat yield. The decades start from year 01 and end in the next 00 (e.g., the decade of 1960 is 1961–1970).

By the 1910s, the wheat yield had risen to 889 kg/ha, and the barley yield had increased to 1114 kg/ha. Fertilization has improved, and seed selection has become more systematic, but the difference in barley–wheat yield has remained [15]. Barley production, like that of wheat or any other dryland crop in the Mediterranean climate, depends heavily on annual rainfall, especially spring rains, which are variable; therefore, extensive variations in national production occur between years (Figure 2, Table S1). At the local level, these variations are even greater since barley is planted throughout Spain, and differences (especially north–south) in the rainfall pattern occurred during the growing season. In the 19th–early 20th centuries, wheat was far more cultivated than barley (approximately 4.5 vs. 1.3 Mha), and wheat was often sown in locations not suitable for its cultivation but necessary for bread production [10].

Starting in 1975, barley was the most cultivated crop in Spain but, paradoxically, aroused little interest in terms of breeding, agronomy, and technical management. Many farmers used reduced seed rates and applied less fertilizer and phytosanitary treatments than recommended, which was reflected in relatively low yields (1500 kg/ha in the 1960s, 1900 t/ha in the 1970s, 2100 t/ha in the 1980s, and 2400 t/ha in the 1990s) for a crop well adapted to most soils and the climate of Spain [16]. From the 1980s onward, national wheat yields started to be approximately 5% higher than those of barley (Table 1). In the 1980s, 1990s, and 2000s, a greater cultivated area of barley than of wheat (almost double, 3–4 vs. 2 Mha) was observed, and while barley occupied the plateau lands, wheat was established in the more favorable fertile soils of the large river valleys. This situation could partially explain the difference in yield, together with less careful agronomic management of barley [2].

3.3. Barley–Wheat Price Volatility

Another interesting aspect of barley history is its price compared with that of wheat, its rival crop. Since antiquity, the price of barley has been approximately half that of wheat, as occurred in Roman times in most regions [17]. Bread-making ability made wheat the preferred crop, and this preference increased its cultivation over that of barley, up to three times in Spain. In a study on barley and wheat prices between 1524 and 1546 in Seville (Spain), Borrero [18] explained that at that time, the barley price was approximately half that of wheat, which was a normal situation in Spain [19] and Europe [20,21]. However, in times of wheat deficit, its price rose much more than that of barley (which also rose but less), as occurred in this city during 1529–1530 and 1538–1542 (Table 3). Shortly afterward, the price of wheat dropped sharply, and it was just slightly more expensive than barley was, as in 1533 when the price of barley was as high as 88% with respect to that of wheat. This barley–wheat price volatility pattern has been repeated in many instances. The most likely explanation is not agronomic but commercial. Wheat grain was imported to a large extent, and when its supply rose, prices fell. Grain prices were and are a result of the level of production and the outside market, which is quite dynamic in the case of wheat and much lower in the case of barley whose imports are limited [18]. Therefore, barley prices were more stable, and wheat prices fluctuated more. This barley–wheat price relationship was maintained in Spain even at the beginning of the 20th century (Table 3) where the ratio ranged between 50% and 60%. As of 2024, the barley–wheat price has ranged from 80 to 90% in Spain, approximately 200–207 vs. 210–235 EUR/t [22].

Table 3. Barley and wheat price volatility in Seville (1524–1546) and Spain (1890–1907).

Year	Barley Price [1]	Wheat Price	Barley-Wheat (%)	Year	Barley Price [2]	Wheat Price	Barley-Wheat Ratio (%)
1524	72	145	50	1890/91	12.5	19.4	65
1525	70	114	61	1891/92	12.6	21.0	60
1526	85	179	48	1892/93	11.3	22.2	51
1527	70	114	61	1893/94	10.9	20.8	52
1528	nd	nd	nd	1894/95	10.0	17.4	57
1529	187	425	44	1895/96	10.4	17.3	60
1530	136	323	42	1896/97	12.5	21.0	59
1531	102	255	40	1897/98	11.1	23.6	47
1532	80	175	46	1898/99	10.6	23.2	46
1533	120	136	88	1899/1900	12.1	22.2	54
1534	127	167	76	1900/01	12.6	21.9	58
1535	136	180	76	1901/02	11.4	20.7	55
1536	136	221	62	1902/03	11.8	20.3	58
1537	85	170	50	1903/04	13.1	21.3	62
1538	95	230	41	1904/05	14.4	23.8	61
1539	128	247	52	1905/06	14.2	23.5	60
1540	204	374	55	1906/07	10.4	19.5	53
1541	148	425	35				
1542	148	388	38				
1543	80	180	44				
1544	140	230	61				
1545	289	493	59				
1546	230	473	49				
Mean	256	130	51	Mean	11.9	21.1	56

[1] Barley and wheat prices in Seville were in August, and the maximum prices (maravedís) are listed [18]. Nd, no data. [2] Prices in Spain are listed in pesetas [23].

4. Uses and Products

The main use of barley is its hulled grain to feed ruminants, especially mules (which are used for plowing), horses, and sheep although it is also used to feed pigs. In fact, the Spanish word for barley, 'cebada', comes from the verb 'cebar', meaning to feed (specifically to fatten) an animal [24]. In addition, its straw is used for livestock bedding. There is also a small amount used for human food in various forms. Sometimes, barley flour is mixed with wheat flour in several proportions to make barley bread. Many of these breads were made in years when wheat grain was lacking. In any case, the natural substitute for wheat in times of scarcity was rye, which is itself a bread-making cereal and the basis of black bread. However, rye, unlike barley, is only planted in the acidic and cold soils of the northern sub-plateau, especially on the west side (Leon and Galicia regions) [10].

Spain has not been a beer-consuming country until recently. It is believed that the brewing tradition began when King Charles I of Spain brought some brewmasters from Flanders to Madrid in 1537. Although several ale beer factories were present in Madrid during the 17th and 18th centuries, it was a scarce and expensive drink, restricted to the upper classes and large cities. It was craft or semi-craft brewed, with markedly seasonal consumption (summer), and it never reached rural areas [25]. More commonly, 'barley water', which is obtained by boiling malted or toasted grains in water (without fermentation), was consumed. This drink (to which lemon juice and sugar could optionally be added) was typical of the Valencia region, especially in Alicante, but reached other places, such as Madrid [11].

The arrival of Pilsen-type beers had an impact in Spain (with some delay). They were beers made with lightly roasted malt and with lager yeast, which gave rise to a clear and light beer. This type of beer, when consumed cold, is suitable for the Mediterranean spring and summer in most of Spain. The first industrial factory was Moritz, established in Barcelona in 1856. Shortly thereafter, the companies Mahou (1889), San Miguel (1890), El Águila (1900), La Cruz del Campo (1904), Estrella de Galicia (1906), and Damm (1910) were founded, each with its own story of beginning, establishment, and success. Interestingly, San Miguel was founded in the then-Spanish colony of the Philippines by Enrique Barreto. Currently, two independent San Miguel brands exist: Filipino (San Miguel Corporation®) and Spanish (which, in 2000, merged with Mahou to form the Mahou San Miguel® Group) [26].

Beer production and consumption grew slowly in Spain throughout the 20th century. In fact, in the first 20 years of the 20th century, national production only ranged between 0.1 and 0.2 Mhl (million hectoliters) per year. However, not until the 1950s did production increase considerably [27]. Prices decreased, and beer became more affordable for the public, penetrating rural communities. In 1970, more than 12 Mhl of beer were produced, and 20 Mhl by 1980. In 1982, beer consumption surpassed that of 'Spanish wine' for the first time, with 55 liters per capita [28]. By 2022, beer consumption in Spain was approximately 95 liters per capita, the sixth largest in the world [29]. At the end of the 20th century, some multinational companies, such as Heineken®, gained a foothold in the Spanish beer market. In 2022, national beer production was 41.14 Mhl, the second highest in Europe behind Germany, and the ninth highest in the world. Table 4 shows the most important brewing companies in Spain in the three seasons of the last 10 years. Few changes were recorded during this period. Mahou San Miguel® is the brewer with the highest production in Spain (with 12.81 Mhl), followed by Grupo Damm® (moving up to the second position) and Heineken España®. The next highest producers are Hijos de Rivera (Estrella Galicia®), Cervecera de Canarias®, and Grupo Ágora (La Zaragozana®). Hijos de Rivera and Grupo Ágora are the only major industrial brewers that remain in local hands. In 2022, national beer turnover represented an added value of EUR 9000 million [30].

Table 4. Main brewing companies in Spain in three years of the period from 2013 to 2022.

Rank \ **Year**	**2013**		**2017**		**2022**	
	Company	**Prod.** [1]	**Company**	**Prod.**	**Company**	**Prod.**
1	Mahou San Miguel	11.97	Mahou San Miguel	12.30	Mahou San Miguel	12.81
2	Heineken	9.62	Heineken	10.52	Grupo Damm	11.34
3	Damm	8.17	Damm	9.66	Heineken España	10.07
4	Hijos de Rivera	1.44	Hijos de Rivera	2.79	Hijos de Rivera	4.81
5	Cervec. Canarias [2]	0.85	Cervec. Canarias	1.08	Cervec. Canarias	1.07
6	La Zaragozana	0.60	La Zaragozana	0.87	Grupo Ágora	0.88
7	Others	0.05	Others	0.40	Others	0.14
Total		32.7		37.6		41.14

[1] Beer production (Prod.) in millions of hectoliters. [2] The actual name is 'CIA. Cervecera de Canarias'.

Historically, the connection between the Spanish barley and beer sectors has been weak. On the one hand, the country's climatic conditions are not ideal for obtaining high-quality malt. The import of barley or malt of European or American quality has been common in Spanish breweries for many years [27]. Fortunately, the situation has improved. Currently, approximately 770,000 t of barley produced in Spain are used to make malt to supply brewers. This amount is obtained from approximately 250,000 ha of cultivated malting barley, and it is expected to increase further in the future. The main malting company in Spain is Intermalta, which has three malting centers in San Adrián (Navarra), Albacete, and Seville. The annual malting capacity of the three centers is 350,000 t [31]. The Cerveceros de España association and the main producing malt company in Spain

(Intermalta) aim to reduce the carbon footprint in the brewing process, and one way to achieve this goal is by planting barley near large malt production centers [30,32]. The "Comisión Mixta" (Mixed Committee) of Maltsters and Brewers of Spain publishes a sheet with the cultivars recommended by the industry (good field performance and industrially approved by both the malthouse and the brewers and already good selling cultivars) and cultivars in development (with good field performance and industrially validated or in an advanced stage of doing so but not yet planted in ample acreage) biannually. For the 2023–2024 and 2024–2025 seasons, the recommended varieties are RGT Asteroid, LG Belcanto, Fandaga, KWS Fantex, and RGT Planet, whereas Lexy, RGT Orbiter, and KWS Thalis are under examination [33].

5. Breeding of Barley in Spain

5.1. The Spanish Barley Landraces

Landraces were cultivated until the early 1980s, especially the six-row winter barley used for feed (e.g., Caballar, Mazuela, Del país), which occupied approximately 95% of the cultivated area of the landraces, and the two-row (e.g., Ladilla, Pamula) or naked landraces (e.g., Mondada) constituted the remaining 5%. The use of barley for horse and mule feed was so frequent that 'Caballar' barley (from horse) is still a synonym in Spanish for any six-row barley, retaining the old Latin denomination. Adaptability and yield stability are their main assets, whereas a tall culm (and high lodging), low yield, and low test weight are the main issues [34]. A study comparing Spanish landraces and modern cultivars at low- and high-production sites revealed (surprisingly) that at low-production sites, some landraces outperformed all cultivars. However, at high-production sites, the cultivars outperformed the landraces, as expected, indicating the potential of landraces for breeding under low-productivity conditions [35].

Fortunately, most landraces are preserved due to several collection missions, such as the one conducted by Enrique Sánchez-Monge's group in the 1950s. The collection of landraces is currently preserved at the CRF (Centro de Recursos Fitogenéticos, Plant Genetic Resources Center) seed bank of Finca La Canaleja (Madrid). The list of barley accessions maintained at the CRF shows 1756 landraces of Spanish origin (under the name 'cultivar primitivo o tradicional'). The landraces were collected throughout Spain, especially in the provinces of the interior. Valladolid, Zaragoza, Badajoz, Palencia, Soria, and Zamora are the provinces in which the most accessions were collected [36]. From that collection, a smaller core collection of 175 accessions was sampled. It comprised three groups: successful old cultivars (16), two-row landraces (11) and six-row landraces (148). The accessions were sampled proportionally to the historic importance of barley cultivation in different agroecological regions of Spain. This core collection has been phenotyped and genotyped in several studies [37–39]. In addition, Harry Harlan visited Spain in 1923 where he collected material as did Nicolai Vavilov in 1927. According to Harlan, the Spanish barley types (from the northern sub-plateau, which he explored) were similar to those from the silty soils of the basin of the Danube (Germany, Austria, Hungary, etc.). Generally, they were six-row landraces adapted to semiarid climates, with cold winters and some vernalization [40]. Several genetic studies of Spanish landraces have classified them into two main groups and two smaller groups:

- The two small groups are the most similar to other European barley populations. One comprises spring two-row barley, which grows in areas where late (winter) sowings are common. The other comprises six-row barley, which is close to the current European six-row cultivars from France or Germany [41].

The two main groups, comprising more than 90% of all Spanish landraces, denominated for the purpose of this review as Group 1 and Group 2, are as follows:

- Group 1 is composed of six-row landraces, mostly with a winter habit, hulled grains, and sensitivity to the photoperiod. The vernalization needs of these landraces are 2/3 those of a true winter type [42]. It represents the barley populations of northern inland Spain, especially Castiles [41]. This group seems to be related to some barley types from Central and Western Europe (France, Germany, Austria, northern Italy, etc.) [43], although more recent studies point to a differentiation of this group from others, probably due to a long period of isolation [44].

- Group 2 comprises six-row landraces with a facultative habit, which are sensitive to the photoperiod (with some exceptions), and a few have naked grains. They settled in southern and eastern Spain (Andalusia, Murcia, Valencia, Catalonia, and Aragon) [41]. The vernalization needs of facultative landraces are approximately 1/3 of those of true winter barley [42]. This group seems related to others from the Mediterranean Basin since they are similar to landraces from southern Italy, Greece, Cyprus, the Balkans and northern Africa (Morocco, Algeria, and Libya) [43]. A special feature of this group is that in the western branch of the Fertile Crescent, they may have undergone genetic admixture with wild barley from Libya and Cyprus [7].

These two groups actually settled in rather different agroecological niches. The comparison of climates between the areas occupied by the two groups revealed that Group 1 is found in areas with more severe winters and more moderate evapotranspiration than areas occupied by Group 2, with a higher evapotranspiration demand and mild winters [44]. One main distinction between these groups was the allele carried for the main vernalization gene *VrnH1*. Most Group 1 accessions carried the *VrnH1-6* allele, whereas most Group 2 accessions carried the *VrnH1-4* allele. These alleles are likely responsible for the different vernalization requirements of the groups [44,45]. Another clear genetic differentiation in Spanish landraces was the stark latitudinal gradient exhibited for the alleles at the *HvFT1* locus. This locus is one of the main determinants of earliness and presents four alleles in Spanish barley populations, with alleles for earliness in the northern half of Spain and for lateness in southern Spain [46].

The landraces of the two groups may have arrived in Spain during several periods. Barley has been in Spain since approximately 7400 BP, but recent genetic findings point to a large wave of human migration arriving at the Iberian Peninsula in the Bronze Age, approximately 4500 BP, with a population coming from the Pontic Steppe (current northern Caspian and Black Sea basins) through continental Europe [47]. The beer remains in the old beakers in the Ambrona Valley (Soria) at approximately 4400 BP and from Genó (Lleida) at 3100 BP could be a consequence of this arrival [11]. These people may have brought their own crops, adapting to colder and continental climates, which may have contributed to the cereals adapted to the inland plateaus of Spain. At the time of the Greek and Phoenician expansion in the Mediterranean Basin, new landraces surely arrived with the settlers in the coastal colonies of eastern and southern Spain, respectively. However, during the Roman expansion in the Iberian Peninsula, new landraces from the shallow soils of southern Italy and the eastern Mediterranean (e.g., Greece) most likely replaced the old ones that existed previously. This outcome could be the case for the landraces of Group 2, as occurred with plant material of other crops, such as durum wheat and olive trees [48]. The Hispanic Roman agronomist Columella (first century ACE, after the common era) wrote about the varieties of barley cultivated in the Roman Empire. He wrote about six-row barley, which he named 'hexastica' (meaning six rows) or 'caballuna' (meaning from horses). Columella continued by stating that this barley had to be sown in autumn (i.e., a winter type), and it seemed to be the dominant type. He also described two-row barley, named 'distica' (meaning two rows) or 'galatica' (from Galatia, an inner region of Turkey). Columella highlighted the great weight of its grain (namely, a high test weight) and recommended sowing in January (i.e., a spring type). In addition, the coarsely ground barley grains have several uses, and sometimes they are boiled in water to make 'ptisana', a drink (similar to barley water) with allegedly medicinal properties. The use of the barley plant as a green forage was also mentioned [49].

At the time of Islamic expansion in Spain (Al-Andalus), many crops, including barley material from the eastern Mediterranean, also arrived. Thus, Andalusian agronomist Al-Awwam cites barley cultivation several times in his Kitab al-Filaha (the book of agriculture) and refers to the similarity of the naked-grain barley from Al-Andalus to those from

Cappadocia (Turkey) and some other barley varieties to those from Nabatea (Jordan) [50]. Romans and Muslims, with broader knowledge of the barley material, likely brought their own landraces, which, competed with extant local landraces, increased genetic diversity and resulted in a process of admixture and/or replacement of unknown proportions. As landraces from Group 2 share genetic similarities with landraces from North Africa, they were likely introduced in different population waves, including the Islamic expansion in Spain during the 8th–11th centuries, and remained in the country for centuries. The consensus among barley historians and geneticists is that six-row types of barley were predominant in Europe in prehistoric times. Two-row barley varieties were less common in ancient times, and they are assumed to have been extensively introduced in Europe by returning crusaders from the states of Outremer (in the Mediterranean Levant) during the 12th and 13th centuries [51].

Therefore, the successive arrivals of landraces from prehistoric times through the Roman and Islamic eras allowed them to adapt in isolation with some admixture between groups [44] and be subjected to selection by farmer preferences and agroclimatic conditions. This situation occurred to a much lesser extent in wheat, which is basic for human nutrition in the Mediterranean Basin. During a wheat grain deficit (for example, due to drought, conflict, or population growth), grain was imported from another location or another country. In the Middle Ages, this situation was quite common in Spain, and new grain was brought to Spanish ports from North Africa or Sicily (mostly durum wheat) (the so-called sea wheat or 'Trigos de la mar'). As part of this grain was used to sow the following season, a mixture of genotypes was produced, which is typical of the wheat landraces in Spain [48]. However, when a location in Spain faces a feed shortage (e.g., due to a drought), barley grain, which is used for animal feed, is rarely imported. Animal demand is not always met properly, and imports of barley grain are not as common as those of wheat. Barley is less favorable for transportation and trade than wheat because of its lower price and lower test weight (20% less, therefore occupying more space) [52]. The barley deficit could be compensated for by feeding on natural pastures, reducing the amount of grain provided to each animal, or sacrificing some of them. This strategy was already shown in the barley–wheat price relationship in Seville in the period from 1524 to 1546 when wheat prices rose in times of crisis but plummeted when grain was imported, while barley prices remained relatively stable [18].

However, the internal circulation of barley grain, although less frequent than that of wheat, did occur. For example, in Spanish warehouses (Pósitos), the majority of preserved grain is wheat, but the storage and sale of barley grain do occur [53]. Therefore, if a neighboring population needed grain, wheat was given preference over barley. As part of the grain was used for planting the following year, it affected the composition of the seeds planted the following year. In any case, barley grain movements between localities in the Spanish Middle Ages have been mentioned, such as one from Elche (Alicante) to the General Council of Orihuela (Alicante) in 1449 [54]. These findings have important implications for the composition and evolution of landraces. The small number of barley grain imports (in contrast to those of wheat) increased the stability of the genetic composition of the landraces over space and time.

5.2. Barley Breeding and Varietal Deployment in the 1950s–1980s

The cultivar Albacete was selected from a Group 2 landrace of the homonym province in 1955 by E. Sánchez-Monge's group at the Estación Experimental de Aula Dei (Zaragoza). It is a six-row winter type adapted to semiarid land and has enjoyed great success for more than 30 years. Almunia was another cultivar (less successful) also obtained via landrace selection and was adapted to irrigated or high-precipitation areas [55]. Pané 01 was another important cultivar selected from a Catalonian landrace in the 1950s by Josep Pané. Nevertheless, by 2002, almost 70% of the barley in the drylands of Aragon was sown with Albacete [35]. In the 1950s and 1960s, together with the Spanish landraces and Albacete, seeds of some cultivars were imported from abroad, especially from France. Hâtif de Grignon (a selection from a French landrace developed at the Grignon experimental station in 1937) and Barbarrosa (as Barberousse was known in Spain) are six-row winter barley varieties for feed adapted to northern Spain where they have been cultivated for more than 20 years. Beka, Etoile de Velay, Foma, Pallas, and Sonia are two-row spring malting barley cultivars that were also popular in Spain [11].

The varietal scene at that time (1970s and 1980s) was rather complex. The landraces were still in the fields, but they were vanishing over time, whereas Albacete (and to a lesser extent Almunia) continued to perform well. The presence of foreign cultivars increased. With the entry of Spain into the former European Economic Community (now European Union) in 1986, many European cultivars (French, British, Dutch, etc.) entered the barley market. On the one hand, the cultivars offered greatly increased; on the other hand, national breeding programs suffered from the competition of these high-yield cultivars in a crop with reduced sales of certified seeds (approximately 10–12% in the 1980s) [34]. At this time, the presence of more two-row cultivars became more common. For example, the French cultivars Alpha and Reinette were winter feed and two-row barley (Table 5). In the 1950s, 1960s, and 1970s, successful barley breeding programs occurred in many European countries, driving a type of barley 'Green Revolution' (similar to that of wheat), but in Central and Western Europe, instead of Mexico. The UK and Germany focused on breeding two-row spring malting barley, whereas in France and the Netherlands, both spring malting and winter feed barley types were bred. The main traits for breeding were dwarfism and resistance to lodging to allow for better barley fertilization and harvesting. This breeding was achieved by natural mutant plants or by artificial mutation [56,57]. Resistance to the most important diseases of the crop, such as powdery mildew (caused by the fungus *Blumeria graminis* f. sp. *hordei*), leaf rust (*Puccinia hordei*), scald (*Rhynchosporium commune*), and net blotch (*Pyrenophora teres*), was also introduced in the new cultivars. In any case, more resources were available to breed spring cultivars with high malting quality. An example of the success of barley breeding at this time was the cultivar Trumpf, which was obtained in East Germany by 1973. The malting cultivars were so good and high-yielding that they were also used as parents in barley breeding programs for feed, modifying the quality and percentage of protein [58]. However, the cultivars that were successful in Spain were French cultivars that were better adapted to the Spanish climate, such as the Beka, Alpha, or Dobla cultivars, or even Swedish cultivars, such as Pallas [16]. National breeding programs were scarce, but the team of J.L. Molina-Cano released brewing cultivars adapted to southern Spain, such as Zaida (Union × Adora) while working for the brewing company La Cruz del Campo in approximately 1982 [59].

5.3. Barley Situation and Varietal Deployment from the 1990s to Present

The importance of the six-row cultivars continued to decrease from 1990 to 2010 despite the presence of Albacete and Hâtif de Grignon in Aragon. However, two-row winter and spring cultivars (Beka, Pallas, Hassan, Alpha, Kym, etc.) prevailed in Castilla y Leon. Both types of barley were cultivated in Castilla-La Mancha. Since the percentage of certified seeds was still low (10–12%), the cultivars with the highest sales of certified seeds were not necessarily the most cultivated in the field. The multiplication, outside of the seed market, of feed varieties in the semiarid and low-yield areas of Aragon and Castilla-La Mancha was high [11].

By 2009–2010, the rate of certified seed use was close to 15%, and the most important cultivars were foreign (especially French), such as the cultivars Hispanic (probably the most successful cultivar in Spain this century, winter feed), Meseta (winter feed), and Pewter (spring brewing) (Table 5) [11]. A national breeding program that integrated resources from several regional research institutions (INIA-IRTA-ITA-CSIC-ITAP) started in 1995, producing the high-yield cultivars Cierzo, Estrella, and Yuriko (Orria × Plaisant) until 2010 (Figure 4). In 2022, the program released six-row cultivars, Arba and Júcar, both with a Spanish landrace in their pedigrees combined with elite parents. They are the result of a strategy to increase the diversity of the crop and introduce better adaptations from local landraces while maintaining high agronomic standards. Currently, the national program comprises only the CSIC and ITACyL and is devoted mostly to pre-breeding activities to expand the genetic base of the crop [60].

Figure 4. Barley pre-breeding trial at El Vedado (Zaragoza, Spain) in 2024.

Yuriko is a six-row winter cultivar for feed with good adaptability, and it is expected to replace Albacete in the semiarid winter cold areas of Aragon and surrounding provinces. In fact, to date, Yuriko sales of certified seeds are close to 70% of all six-row certified seeds commercialized in Spain. During this period, approximately 92% of the barley area was devoted to feed, and 8% was devoted to brewing, despite the high consumption of lager beer in Spain [61]. In general, the climate of most of Spain is not the most suitable for producing high-quality malt. Grain filling occurs too fast due to the high heat–drought conditions of May and June in most of the country (especially in the south), which decreases the starch/protein ratio, affecting malt quality (Figure 5) [62]. This outcome can be partially corrected by several measures. The main recommendation for a malting barley farmer is to select a two-row cultivar of adequate malting quality (with a high Q index) and with an early heading period for warm climate areas (e.g., Andalusia) or a semilate heading period in cool climates (e.g., Castilla y León, or highlands of Aragon). Other recommendations include early sowing (autumn or winter) and early and limited nitrogen fertilization. Notably, the malting industry requires barley grain with a low level of protein (9.5–11.5%), given that the malt extract is relatively high, and the liquid is less cloudy. However, the protein content must not be too low since several proteins, such as amylases, are needed for a good malt and brewing. Cultivars resistant to scald and especially net blotch should also be chosen, and/or phytosanitary treatments should be performed if the disease exceeds the damage threshold, since these diseases are present in many areas of Spain and impair grain filling [58]. In addition, barley farmers saw no benefit in planting malting barley since the price disparity with feed barley is not as high as might be expected, and the growing conditions are very strict. In Spain, the premium for malting barley is low and generally unattractive. The Spanish malting sector alleges that in France and other European countries, the premium includes classification at the origin and other services, such as a steady supply. The historical disconnection between barley farmers and the malting industry, although it has improved, still exists.

Figure 5. A barley breeding trial was conducted at Ecija (Seville, Spain) in 2024.

By 2015–2016, the varietal situation had changed, and the percentage of certified seeds had risen to 25%. In the last recorded season (2022–2023), the use of certified seeds was 38%. French companies (RGT, Florimond Desprez, and Limagrain) are dominating (still stronger than before) the Spanish market of seeds [63]. Five of the most sold cultivars are brewing spring cultivars, which are on the list of preferred cultivars, such as RGT Planet, RGT Asteroid, and KWS Fantex [33], and have a long heading period and cold tolerance, therefore enabling broad adaptation (Table 5). Crop management is now more technical, and the yield has surpassed 3 t/ha in many seasons. The malting quality is also high, and approximately 10% of barley grains are brewed. In the past, malting cultivars yielded slightly lower yields than did feed barley. However, current malting barley varieties are as productive as the best feed cultivars, due to intensive breeding efforts promoted by a booming malting industry. For this reason, many growers now take their chances with malting cultivars, and if the conditions of the season are not favorable for producing malt quality grain, they are marketed as feed.

Table 5. Most certified barley seed cultivars in Spain in the four different seasons of 1989–2022.

Rank	Cultivar	Seed *	Use *	Cultivar	Seed	Use	Cultivar	Seed	Use	Cultivar	Seed	Use
	1989/90			**2009/10**			**2015/16**			**2022/23**		
1	Beka	15.8	2-b-s	Hispanic	12.1	2-f-w	Meseta	11.7	2-f-w	RGT Planet	28.0	2-b-s
2	Albacete	9.2	6-f-w	Pewter	10.5	2-b-s	Pewter	11.4	2-b-s	RGT Asteroid	9.2	2-b-s
3	Kym	7.6	2-f-s	Volley	5.2	2-f-w	Hispanic	11.1	2-f-w	Lavanda	7.9	2-f-w
4	Hâtif Grignon	7.4	6-f-a	Meseta	4.5	2-f-w	Volley	5.6	2-f-w	Basic	6.9	2-f-s
5	Alpha	7.0	2-f-w	Graphic	4.1	2-f-a	Shakira	5.5	2-b-s	Saratoga	5.6	2-f-w
6	Zaida	5.0	2-b-s	Scarlett	3.0	2-b-s	Nure	5.2	2-f-w	Meseta	5.3	2-f-w
7	Dobla	4.6	6-bf-w	Culma	2.6	2-f-a	Scrabble	4.5	2-b-s	Nure	5.3	2-f-w
8	Reinette	3.5	2-f-w	Carat	2.4	2-bf-w	Gustav	3.8	2-f-s	KWS Fantex	4.5	2-b-s
9	Plaisant	3.1	6-b-w	Beka	1.6	2-b-s	Traveler	3.7	2-b-s	Traveler	4.2	2-b-s
10	Barbarrosa	2.8	6-f-w	Henley	1.5	2-f-s	Graphic	2.8	2-f-a	Solist	3.9	2-b-s
11	Hassan	2.8	2-bf-s	Quench	1.4	2-b-s	Signora	2.8	2-b-s	Pewter	3.5	2-b-s
12	Iranis	2.7	2-f-w	County	1.3	2-bf-s	Cometa	2.6	2-f-w	RGT Medinaceli	3.4	2-f-w
13	Trait d'Union	2.6	2-b-s	Shakira	1.3	2-b-s	Carat	2.2	2-bf-w	Yuriko	3.2	6-f-a
14	Pallas	2.1	2-b-s	Naturel	1.3	2-f-w	Encarna	1.8	2-f-w	Hispanic	3.1	2-f-a
15	Steptoe	2.0	6-f-a	Albacete	1.2	6-f-w	Icaria	1.6	2-f-a	Gustav	2.6	2-f-s
	Total (Mkg)	67.5			71.7		104.2			145.3		
	National area (Mha)	4.3			3.0		2.6			2.4		
	Certified seed use (%)	10.3			14.8		25.1			38.0		

* Certified seed (sealed and resealed) in Mkg (million kg) (for the 1989–90 season, only sealed seed is included, which represents approximately 95% of the seed), and national cultivated barley area in Mha (million ha) [63]. Barley use key: 2 = two-row, 6 = six-row; b = brewing, f = feed, bf = both; w = winter, s = spring, a = alternative. A seed rate of 160 kg/ha was used to calculate the percentage of certified seed use.

6. Future Perspectives

Determining what the future of barley in Spain will be like in the next 25–50 years is difficult. Most likely, the cultivated area will stabilize at roughly 2 Mha. With better cultivars, irrigation, and farmers with finer technical advice, the average yield may increase to 4 t/ha, resulting in a national production of 8 Mt. The possible negative effects of global warming and a decrease in rainfall are yet to be seen in the drylands of Spain, especially since 2023, which is acknowledged as the worst drought since records have been maintained. One of the challenges of the sector is to support national breeding programs to obtain cultivars adapted to the different agroclimatic conditions of Spain: spring short-heading time cultivars for southern Spain, alternative short- or medium-heading time cultivars for the center (up to the Ebro Valley), and winter long-heading time cultivars for fields north of the Duero and Ebro Valley. The main breeding objectives are increased yield, increased quality (feed or malt), drought and heat tolerance, and resistance to diseases (scald and net blotch). Long-term breeding programs and commercial strategies to release new cultivars and public–private collaborations are necessary to accomplish these goals. Most likely, 2/3 of the area will be feed barley (1.3–1.4 Mha), and 1/3 will be malting barley (0.6–0.7 Mha). Brewing barley will probably be located near large malting centers (Seville, Albacete, and Navarra), and farmers will receive an adequate premium to ensure the security of the supply, with specifications that fit the Spanish dryland.

Another possible use of barley in Spain in the future is the development of new cultivars with healthy properties for human consumption (in the form of bread, biscuits, pasta, couscous, or pearl grain). The barley cultivars used for human consumption are usually kernel-naked (to favor flour) and have high β-glucan content (with healthy properties). In this way, a multilateral collaboration between the University of Lleida (Lleida, Spain) (I. Romagosa's team), Aula Dei Experimental Station-CSIC (Zaragoza, Spain) (L. Cistué's team), the breeding companies Semillas Batlle, Oregon State University (Corvallis, USA) (P. Hayes's team), and the James Hutton Institute (Dundee, United Kingdom) (W. Thomas's team) was established. Three cultivars with high β-glucan contents adapted to Spain have already been registered: Kamalamai, a two-row, hulled grain with a waxy endosperm and high yield; Annapurna, a two-row naked grain with a waxy endosperm; and Rajapani, a six-row and naked grain [64]. The collaboration has recently terminated due to the retirement of most researchers, but the material is ready for commercialization.

Recently, a new niche for barley has appeared. A traditional dryland crop, barley is now one of the most cultivated in irrigated fields in the Ebro Valley. Indeed, it has surpassed maize as the most cultivated in irrigated areas. Just a few years ago, maize and alfalfa were the crops of choice, attaining very high yields. For maize, this goal was achieved using cultivars with a long growing period, which pushed sowing as early as the temperatures allowed. However, water shortages in some years have made it clear that this strategy is too risky and results in enormous yield losses if the amount of water is insufficient in the most sensitive stages of the crop. With this situation becoming more likely with climate change, many farmers choose to reduce their risk, sowing a winter crop with a short growing season first before sowing a summer crop (maize or sunflower), also of a short cycle. The winter crop, which is usually barley because it has a shorter cycle than wheat, needs a smaller irrigation dose because most growth occurs during periods of a low evapotranspiration demand and high rainfall. The second crop also needs less water than long-season maize does, and the farmer may choose the second crop based on water availability expectations for the summer crop. These practices have led to the use of early barley cultivars to be grown under irrigation, but cultivars specific for this agronomic niche have not yet been bred.

Therefore, barley is a versatile crop for Mediterranean dry and irrigated lands and will continue to be a staple in Spanish agriculture. The information contained in this article may also be useful for other Mediterranean barley-producing countries, such as Turkey or Morocco, with similar agroclimatic conditions. Current breeding trends also respond to the push for more sustainable practices, and the requirements of the European

Union mandate. These requirements include less use of agrochemicals; therefore, genetic disease resistance will gain even greater importance as a breeding target. Additionally, the increase in organic farming requires cultivars that are better adapted to particular conditions, with enhanced disease resistance and weed control. Another trend in EU agriculture promotes diversification and less use of fertilizers. In this sense, including the ability to be intercropped with legumes and performing cereal–legume rotations will be necessary as new barley breeding targets for specific agricultural systems.

7. Conclusions

This article reviews the main historical milestones related to barley cultivation and the plant material used in Spain. As a crop with good adaptation to most of the country, the plant material has evolved from traditional landraces to cultivars that have arrived from abroad (especially French) since the 1950s. The few national breeding programs are still overshadowed by these high-yielding cultivars. Currently, yields are adequate and provide a significant amount of grain for the feed industry and the national brewing industry.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/agriculture14101674/s1, Table S1. Barley, wheat, and olive tree area (Mha), and barley production (Mt) in Spain 1891–2022 (to make Figures 1 and 2); Table S2: Barley area (ha) in the main cultivating provinces in Spain in 33 seasons during 1898–2020 (to make Figure 3).

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