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Participatory Definition of Farmers' Preferences to Guide Plant Breeding for Durum Wheat, Barley, and Lentil

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Abstract

Aligning plant breeders' objectives with farmers' preferences is essential for improving the adoption of new crop varieties. This study evaluated the effectiveness of a Participatory Weighted Selection (PWS) index, previously developed from a survey of 869 Moroccan farmers, by comparing it with biophysical Participatory Variety Selection (PVS) trials conducted on 19 farms across four agroecological zones in Morocco. Novel CWR-derived lines of durum wheat, barley, and lentil were assessed alongside commercial checks, and both male and female farmers were interviewed to gather PVS preferences. The results showed no significant gender differences for the top-ranked varieties across crops, with minor variations in some zones. Jabal emerged as the preferred durum wheat variety overall, while Zagharin2 was favored in favorable zones. Furat-3 was generally preferred for barley, except in certain mountain and favorable zones, and Bakria was the top lentil variety across most sites. Farmers' PWS responses clustered into three groups, emphasizing consistent prioritization of high yield potential, abiotic stress tolerance, and good nutritional quality. Comparison of biophysical performance with PVS and PWS revealed strong alignment for durum wheat; however, the highest yielding genotypes for barley and lentil were not always the most preferred. Overall, these results demonstrate that the PWS approach effectively captures farmers' preferences and provides a reliable tool for guiding breeding decisions. These findings reveal that integrating PWS with on-farm biophysical and PVS evaluations provides a robust, farmer-informed framework for prioritizing genotypes and improving the relevance of breeding decisions across diverse agroecological contexts.

Keywords: participatory varietal selection; participatory weighted variety selection; crop wild relatives; on-farm trial; gender preference; variety adoption; Morocco; grain yield; plant breeding

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1. Introduction

Durum wheat (*Triticum durum* Desf.), barley (*Hordeum vulgare* L.), and lentil (*Lens culIinaris* Medik) are major food crops in Morocco. Cultivated as winter cereals, they occupy more than 55% of the country's arable area [1], with durum wheat and barley cultivation respectively covering approximately 20% (≈1 million ha) and 35% (≈1.8 million ha) of

this area. Lentil in Morocco is a rainfed crop in rotation with cereals, covering about 14% of the national legume area and ranking third after faba bean and chickpea, with around 50,000 ha cultivated and 38,200 t produced annually [2]. The replacement of traditional landraces by modern cultivars, which has been ongoing since 1950, has led to satisfactory increases in the average productivity of the three crops [3]. However, the varietal replacement rate in Morocco slowed down considerably after 1990, with most farmers currently cultivating varieties released over two decades ago [4,5]. Although breeding programs have consistently released improved cultivars with higher yields and better resistance to abiotic and biotic stresses, their adoption by farmers remains extremely low [6].

Within Morocco's traditional agroecosystems, smallholder farmers largely rely on the informal seed sector through farmer-to-farmer exchange, purchase from unlicensed village-based seed producers, and reuse of saved seed [7]. Adoption of newly released wheat cultivars remains limited, with only 16% and 41% of Moroccan producers cultivating varieties released within the past 10 and 20 years, respectively. The results of a survey conducted in 2014 indicated that out of 40 wheat varieties grown by local farmers, only eight (20%) were released in the previous decade, covering less than 10% of the total cultivated area [6]. Subsequently, under the Green Morocco Plan, large investments and subsidies were introduced, aimed at tripling the area under cultivation with certified seeds of durum wheat, bread wheat, and barley (the three main cereals) [8]. While these investments have favored the overall turnover of cultivated varieties, most of the novel ones also date back more than 15 years. Moreover, the absence of on-farm demonstration trials, lack of participation in field days, and location outside favorable production zones together reduce the likelihood of adopting newly released varieties by 51% [7], highlighting a persistent and systemic lag in varietal uptake. This slow adoption is further influenced by diverse farmer conditions and substantial agroecological heterogeneity. In addition, this trend is driven by a weak extension system that struggles to communicate the benefits of recent releases to smallholder farmers, as well as by the fact that not all novel varieties are properly tailored to meet all farmers' diverse needs. Together, these constraints highlight a disconnect between technology development and end-user priorities, contributing to persistently low adoption rates. To address this gap, participatory approaches were developed to enhance farmer engagement in varietal decision-making and to improve their access to the latest technological and genetic innovations [9–11].

Participatory varietal selection (PVS) is a distinctive approach for integrating farmers' considerations within the breeding process [12,13]. Their engagement is elicited in the final stages of the breeding process by selecting, among a short list of candidates, those that should be promoted for variety release [14]. This procedure can be simplified by inviting farmers to visit demonstration plots at a station to conduct their selection, or it can be made more powerful by asking farmers themselves to grow the candidates in their fields. The latter strategy tends to significantly improve the trust of farmers in the final results; hence, it fosters adoption and, in many cases, also boosts diffusion by farmer-to-farmer seed exchanges [15,16]. Through PVS, communities are empowered to evaluate and select the best-performing, cost-effective varieties with desirable traits in their own fields, improving farmers' access to improved varieties, enhancing food security and increasing genetic diversity [17,18]. The PVS method also provides opportunities for breeders to obtain feedback directly from their target users, which, in turn, can inform future rounds of breeding [19].

However, as noted by Alary et al. [3], the PVS approach entails several limitations. First, PVS happens at the end of the breeding cycle, delaying farmers' engagement until after breeders have already made many decisions. Second, the number of farmers who can

participate in the process is limited. Third, on-farm planting is logistically and economically challenging. Finally, a discussion with a group of farmers tends to favor the loudest voices, masking the individual opinions of the smallest and most vulnerable growers. From this perspective, the participatory weighted variety selection (PWS) approach was proposed by Alary et al. [3] as a more objective, scalable, and integrative strategy for capturing farmers' preferences. It entails the use of socioeconomic surveys to gather the opinions of many farmers about the traits that compose their ideal variety. Farmers are then clustered based on their preferences, and their combined values are converted into "weights" for each trait. The sum of all the weights for all the traits makes a "selection index" [20], which breeders can then apply to measure the overall value of their candidates and promote those that better fit farmers' preferences. The greatest advantages of PWS are that it can be applied very early in the breeding cycle and that it is supposedly capable of capturing more farmers' opinions than PVS, at a fraction of the cost. However, to date, the true difference between PVS and PWS has not yet been tested.

Hence, the present study integrates farmers' assessment and preference analyses for three crops, namely, durum wheat, barley and lentil, evaluated independently. The study aims to (i) assess the performance of candidate lines in on-farm trials across diverse agroecological zones in Morocco; (ii) investigate gender-specific varietal preferences using participatory varietal selection (PVS); and (iii) compare biophysical field performance with outcomes generated through PVS and Participatory Weighted Selection (PWS) methods.

2. Materials and Methods

2.1. Germplasm

A collection comprising 25 durum wheat entries, 28 barley entries, and 25 lentil entries was previously evaluated in Morocco, Senegal, Ethiopia, and Lebanon [21]. A subset of entries for each crop was selected for on-farm participatory assessment (Table S1). Selection was based on prior multi-environment evaluation, focusing on entries that consistently exhibited superior yield potential and yield stability, high biological yield, and enhanced nutritional quality. These criteria were used to ensure that only agronomically competitive and nutritionally promising materials were advanced to participatory testing, thereby maximizing their relevance to farmers and other stakeholders. It is worth mentioning that the novel candidates used in this study were derived from crop wild relatives (CWRs), as this germplasm was identified as superior to the commercial checks when tested across stations [21]. Four CWR-derived lines were selected for durum wheat to grow in farmers' fields alongside Karim, a widely cultivated national cultivar (cv.) as the check. Similarly, farmers planted four CWR-derived barley entries against the commercial cv. Furat-3. In addition, three CWR-derived lentil entries were planted against the cv. Bakria, an officially released commercial variety widely used as a national check.

2.2. Study Area

The selected entries were assessed in 12 districts of Morocco over two seasons (2018–2019 and 2019–2020) (Figure 1). These districts were grouped into four agroecological zones: "mountains" > 900 m.a.s.l. (Boulmane, Midelt, and Sefrou), "favorable" areas with annual water inputs exceeding 400 mm as rainfall or irrigation (El Kelaâ Des Sraghna, and Fkih Ben Salah), "intermediate" areas with annual moisture not exceeding 400 mm (Khemisset, Settat, and El Jadida) and "unfavorable" areas with annual moisture not exceeding 300 mm (Youssoufia, Safi, Rhamna, and Khouribga). These areas were grouped into four Köppen climate zones [22,23], as shown in Table S2.

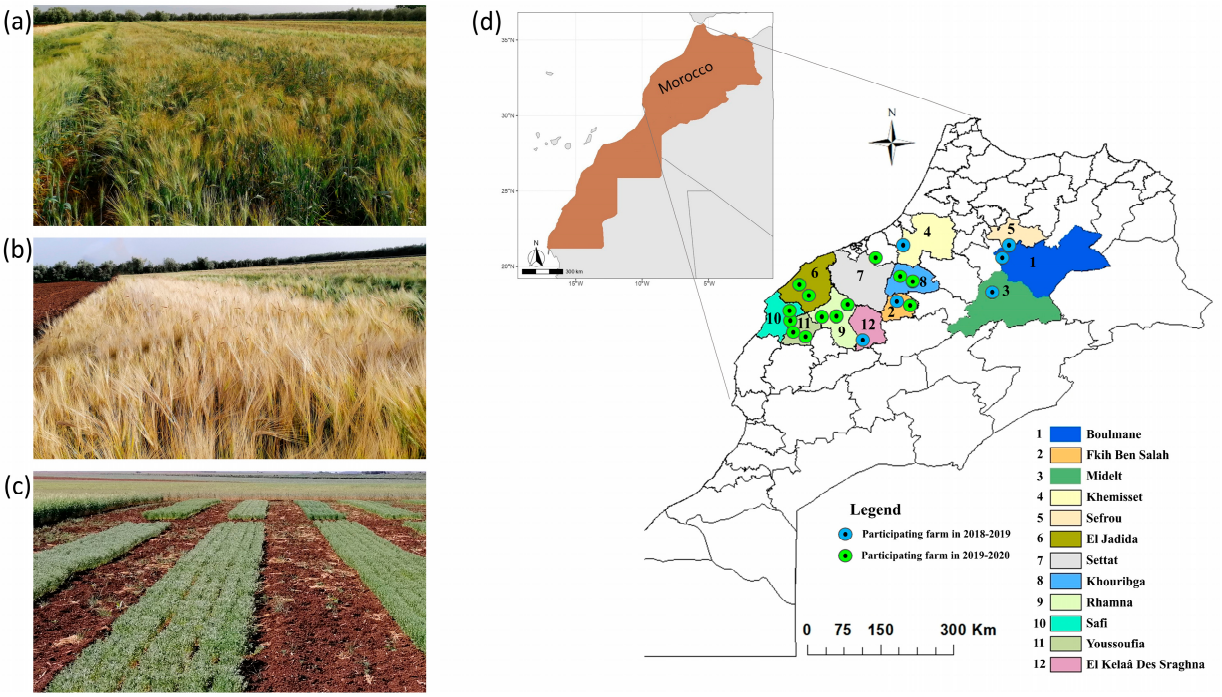


Figure 1. Demonstration of the on-farm trials in Morocco: (**a**) durum wheat, (**b**) barley, (**c**) lentil, and (**d**) geographical distribution of participatory on-farm trials (dotted circles) during the 2018–2019 and 2019–2020 seasons displayed on the map of Morocco, the engaged provinces are color-coded and numbered as per the legend.

Nineteen farms in total participated within the study districts. Barley and durum wheat were planted in 200 m^2 plots, whereas lentil was grown in 40 m^2 plots. A timely planting date was used for all trials, occurring between 15 November and 15 December during both seasons. Each crop trial was maintained by farmers, who followed local agricultural practices. Agroecological information for all the test sites is presented in Table S3. Plant height in cm, grain yield in kg ha^{-1}, and biomass yield in kg ha^{-1} were recorded in each trial plot. In addition, 1000-seed weight expressed in g was determined by weighing 500 randomly selected grains and doubling the value.

2.3. Farmers' Surveys

During the field season, each farm was visited when crops were nearing maturity. At that time, a "selection by stone" process [24] was implemented for PVS, where host farmers were given two stones and neighboring farmers were given one. Each participant was then asked to place their stones in front of their preferred entry. Accordingly, each farmer's preferred entry via PVS was determined. In addition, the farmers were asked to convince each other (i.e., peer-to-peer) why their selected variety was superior, which provided a valuable opportunity for the attending scientists to gather key information. Given the cultural norms prevailing in these Moroccan rural communities, women farmers' involvement in PVS was mainly centered around their preference for food processing of the harvested grains. After harvest and post-harvest processing, both men and women were consulted to confirm their final declared preferences during the PVS process. For PWS, the same consultation was used to conduct a structured survey capturing participants' evaluations and perceptions of the tested germplasm. The survey questions drew on insights that emerged during the open conversations held during the "selection by stone" process. Male farmers were asked to rate the importance of 20 suggested traits from low to high using values ranging from 1 to 10 (Table S4). Scores were assigned in response to the following question: "How much does this trait influence your preference to cultivate

a variety?" These 20 traits were grouped into six broad categories (yield potential, yield stability, biotic stress resistance, abiotic stress tolerance, industrial quality, and household use) following the approach of Alary et al. [3].

2.4. Statistical Analysis

The on-farm data were treated as unreplicated, with each farm's mean performance defined using two values obtained from 1 m^2 samples. Farms within the same agroecological zone were considered replicates, and an analysis of variance (ANOVA) was conducted using the Genstat program, version 17 [25]. Multiple comparisons were made using Fisher's least significant difference (LSD) at a significance threshold level of $p < 0.05$. These results were used to compare the performances of the CWR-derived entries in on-farm trials with those of the main check.

The scores assigned to PVS by each farmer were recorded as a single unreplicated mean value. The Chi-square (χ^2) test was employed to compare male and female preferences. The results of the six broad categories collected for each farmer were clustered by principal component analysis (PCA) performed with the *Factoextra* and *FactoMineR* packages in R (version 4.4.1) and RStudio (version 2024.04.2+764) [26]. Following Alary et al. [3], within each cluster, the farmers' weighted index was defined as the average of farmers belonging to the same cluster and converted into overall ratios (percentages) defined as PWS. The scores reported by Alary et al. [3] were used as a reference framework to assess farmers' preferences for the tested durum wheat germplasm, without reanalysis of the original data.

2.5. Definitions of Indexed Values for Tested Germplasm

The conversion of field data into six broad criteria was conducted following the approach suggested by Alary et al. [3] and using the dataset developed by El Haddad et al. [21] (Table S5) to define the actual values. The broad criterion of yield potential, considered as the ability of a genotype to maximize its productivity, was obtained from the best linear unbiased estimation (BLUE) for grain yield across all sites. Yield stability was determined using the additive main effects and multiplicative interaction (AMMI)-wide adaptation index (AWAI), which measures the capacity of a cultivar to remain stable across environments [27]. The main diseases considered under biotic resistance were leaf rust (*Puccinia triticina*) for durum wheat and net blotch (*PyrenopIhora teres*) for barley. This broad criterion was not applied to lentil, as it had not been screened for any disease; therefore, a uniform resistance score was assigned to standardize the evaluation across genotypes. Abiotic tolerance was defined by farmers as heat and drought stress tolerance. Those were assessed as the yield performances at the most heat-affected station (Fanaye 20 in Senegal), where temperatures exceed 40 °C, and at the most drought-affected station (Sidi El Aidi 20 in Morocco), as well as kernel size at the lowest-yielding site. Industrial quality mostly refers to the harvest's suitability for conversion into food within the processing industry. Durum wheat industrial quality was evaluated according to gluten strength using the sodium dodecyl sulfate protocol and the colorimeter yellow scale using the b* value measured with a chromameter (model CR-400, Konica Minolta Inc., Osaka, Japan). Beta-glucan content was the industrial quality criterion used for barley across all sites, while protein content and micronutrients (zinc and iron) were used for lentil across all sites. The broad criterion of household use assessed a cultivar's ability to meet the demands of a farming system characterized by partial or complete household consumption of the harvest and use of by-products (mainly straw and stubble) as livestock feed. It was measured as biomass yield, plant height, and average 1000-seed weight (BLUE) across all trial sites. Ideally, further measurements should have been considered to meet the farmers' expressed

requirements of straw and grain palatability and storability. However, these values are difficult to measure and could not be obtained for the specific set of lines used here.

Because individual traits were measured in different units, direct comparison was not possible. Therefore, each trait was normalized by dividing its observed value by the maximum value recorded across all genotypes, resulting in normalized scores ranging from 0 to 1, with the best-performing genotype assigned a value of 1. For each genotype, normalized trait values were then averaged to obtain a single composite score for each broad criterion.

2.6. Calculation of PWS Preferences

For the calculation of PWS, the relative importance assigned by each farmer cluster to the different broad criteria was expressed as a weight (w), reported as a percentage that summed to 100% within each cluster. These weights were multiplied by the corresponding normalized broad criterion scores (x) for each genotype and summed according to Equation (1):

$$PWS = \sum w_{ni} \times x_{nv}, \quad (1)$$

where w is the weight in percentage assigned to criterion n by a farmer cluster i and x is the field-measured value for the entry v and criterion n. In this formula, a perfect genotype matching the preferences of a given farmer cluster would obtain a PWS score of 100%; the score would be 0% if there is no match at all.

3. Results

3.1. Performance of CWR-Derived Entries in Farmers' Fields

3.1.1. Durum Wheat

On-farm trials were clustered according to four agroecological zones (intermediate, mountain, favorable, and unfavorable). The combined ANOVA results revealed statistically significant differences ($p < 0.05$) for zone and genotype × zone interactions for most traits, with the genotype factor differing significantly for plant height and grain yield (Table S6). Furthermore, the genotype × zone interaction explained most of the variation in all traits, reaching 37.40% for grain yield. In the intermediate zone, Jabal, an entry harboring introgression from *Aegilops speltoides*, was the top-yielding line, with a significant ($p < 0.01$) yield advantage twice over the check cv. Karim (Figure 2a), with an average grain yield of 3668 kg ha^{-1} (Table S7). Icaverve (*T. araraticum*) and Nachit (*T. dicoccoides*) were the top yielders in the favorable zone, with grain yields of 5268 kg ha^{-1} and 5583 kg ha^{-1}, respectively, surpassing ($p < 0.01$) the check's grain yield (1230 kg ha^{-1}). In the mountain zone, Jabal and Zagharin2 recorded the highest yields of 5601 kg ha^{-1} and 5743 kg ha^{-1}, respectively, generating a yield advantage that was 30% over Karim. Jabal was also the top yielder in the unfavorable zone (3828 kg ha^{-1}), providing a significant yield advantage of 68% over Karim.

3.1.2. Barley

A total of 16 on-farm trials were carried out for barley. The ANOVA results revealed highly significant differences ($p < 0.01$) between zones for all the traits (Table S6). Significant variations ($p < 0.05$) in plant height, biomass yield, and grain yield were observed among genotypes. Most of the total variation in plant height, biomass yield, grain yield, and 1000-seed weight was explained by the zone factor. The highest average biomass yield (10,495 kg ha^{-1}) and grain yield (4989 kg ha^{-1}) were recorded in trials located in the favorable zone, and the lowest values were recorded in the unfavorable zone at 4617 kg ha^{-1} for grain yield and 1816 kg ha^{-1} for biomass yield. In the intermediate zone, ENT-19-1 recorded the highest yield (4174 kg ha^{-1}) and generated a 3% yield ad-

vantage over the check cv. Furat-3 (4040 kg ha^{-1}) (Table S7). In the mountain zone, the yields of ENT-19-1 and ENT-19-8 were significantly superior ($p < 0.05$) to that of the check (Figure 2b). However, Furat-3 achieved the highest yield (averaging 5428 kg ha^{-1}) in the favorable zone, followed by ENT-19-8 (5.103 kg ha^{-1}). The ENT-19-8 plants were more than 25% taller than those of the check, generating 12% more biomass. In the unfavorable zone, ENT-19-8 was the top yielder, with a yield advantage above 30% over the check.

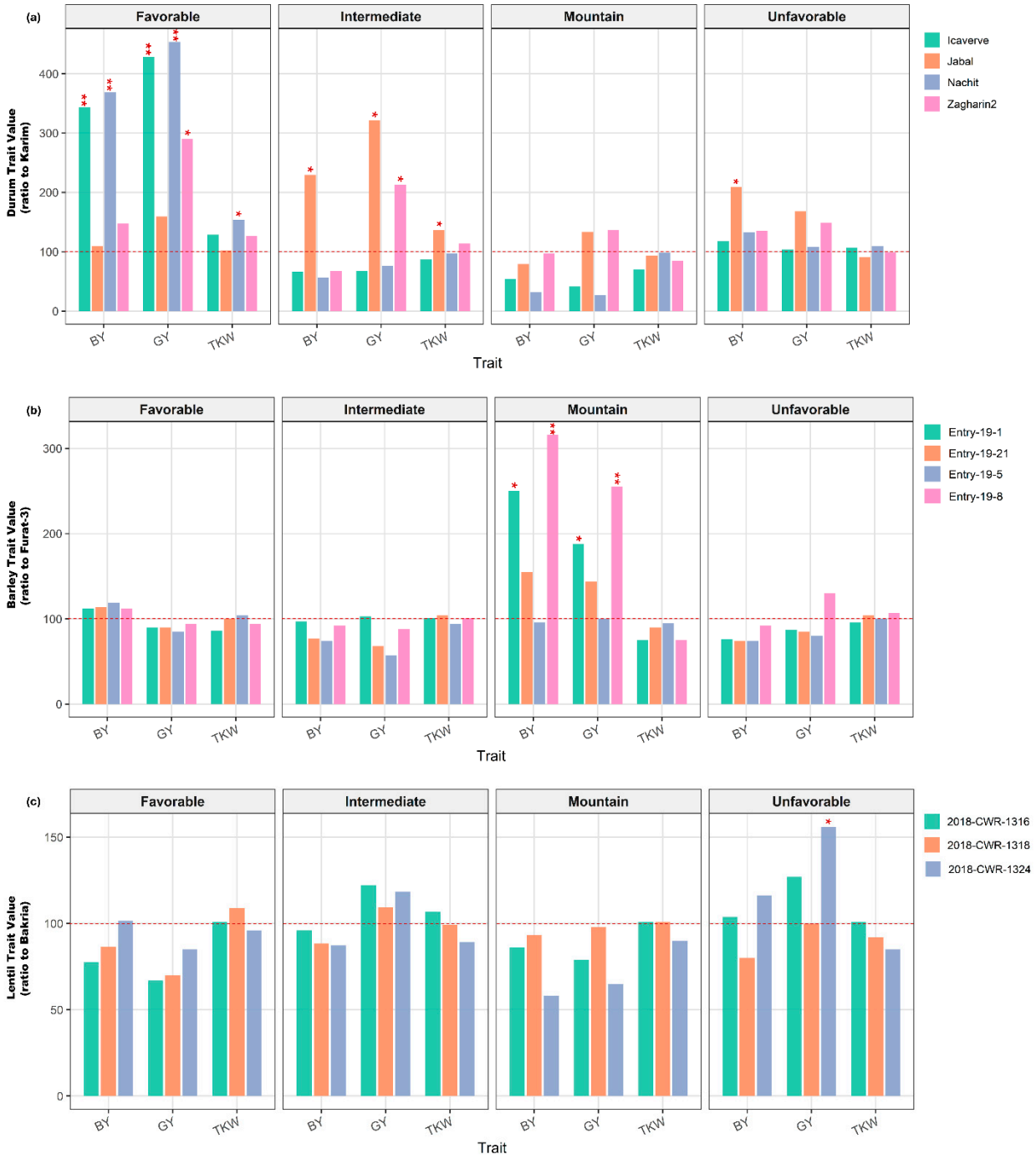


Figure 2. Plant height (PLH), biological yield (BY), grain yield (GY), and 1000-seed weight of (**a**) durum wheat, (**b**) barley, and (**c**) lentil in each agroecological zone expressed as ratios to those of the commercial check. Significant superiority is reported at * $p < 0.05$ and ** $p < 0.01$ over the check (cv. Karim for durum wheat, cv. Furat-03 for barley, and cv. Bakria for lentil), according to the results of Fischer's least significant difference.

3.1.3. Lentil

Data on lentil were gathered from 13 on-farm trials across the two seasons. The ANOVA results showed significant differences ($p < 0.01$) between zones for all traits. Significant variations were also found among genotypes relating to plant height, biomass yield, and 1000-seed weight (Table S6). Most of the variance in plant height, biomass yield, and grain yield was explained by the zone factor. The genotype factor mostly explained variations in 1000-seed weight, accounting for 20.56% of the total variation. The highest average grain yield (1092 kg ha^{-1}) was recorded in the favorable zone and was significant ($p < 0.05$). In the intermediate zone, the entry 2018-CWR-1316 had the highest yield, averaging 660 kg ha^{-1} (Table S7), with a yield advantage of 22% over the check cv. Bakria (Figure 2c). However, in the favorable zone, the check was the top yielder, with an average yield of 1356 kg ha^{-1}, followed by 2018-CWR-1324 (1551 kg ha^{-1}). In the mountain zone, the check had the greatest yield, averaging 433 kg ha^{-1}, followed by 2018-CWR-1318 (423 kg ha^{-1}). The entry 2018-CWR-1324 generated the highest yield in the unfavorable zone with a yield advantage of 56% over Bakria.

3.2. Farmers' Preferences for the Candidate Varieties

A total of 19 farms from 12 districts were used for this study, with the male and female heads of the household participating in both PVS and PWS. Demographic characteristics of the surveyed participants are summarized in Table 1. The average age of the male farmers was 52 years, with 31.60% aged above 60 years. The females' average age was 47.8 years, with 36.8% aged between 30 and 40 years. In terms of education, 36.8% of the men had completed middle school, 31.6% had primary school education, and 5.30% had university-level education. For the women, 42.1% had a primary school education, 26.3% were illiterate, 15% had attended middle school, and 5.30 had university-level education. Regarding agricultural training, 57.9% of the males and 68.4% of the females had received formal training. Farm sizes varied, with 36.8% smaller than 20 ha, 15.8% between 21 ha and 60 ha, and 10.5% larger than 60 ha. On average, households comprised 7.5 male members (ranging between two and 12) and 5.2 female members (ranging between two and 16). Sheep were the most raised livestock on these farms, with an average of 33.60 sheep heads per flock, followed by cows (9.40 on average) and goats (1.10 goats on average).

The PVS data revealed that male farmers' preferences mostly focus on field performances, while female farmers mostly expressed preferences for food transformation aspects. Gender did not significantly influence variety preferences across the three crops for PVS (Table S8). Similarly, there was no significant difference between zones in male and female preferences for durum wheat and lentil; however, the results highlighted a significant impact of zones on barley variety preferences. In addition, our findings indicated that the durum wheat variety Jabal was consistently preferred in intermediate and unfavorable zones by both men and women (Figure 3a). Similarly, Zagharin2 emerged as the top choice for both genders in favorable zones. In mountainous regions, male farmers exhibited equal preferences for Jabal, Nachit, and Zagharin2, whereas female farmers predominantly favored Jabal. Overall, the CWR-derived variety Jabal garnered the highest preference scores among both the male and female respondents.

In barley, the PVS results revealed that the check variety Furat-3 was the most preferred in favorable zones for males, unfavorable zones for females, and intermediate zones for both genders (Figure 3b). Males in unfavorable zones showed equal preference for Furat-3 and ENT-19-8. In mountainous areas, the entry ENT-19-8 was favored by both males and females. Overall, Furat-3 received the highest scores among both the male and female participants, followed by ENT-19-8. For lentil, the check variety Bakria emerged as the preferred choice across all zones for both males and females, except in mountain zones,

where male farmers favored the entry 2018-CWR-1316 (Figure 3c). Overall, Bakria achieved the highest scores among both genders.

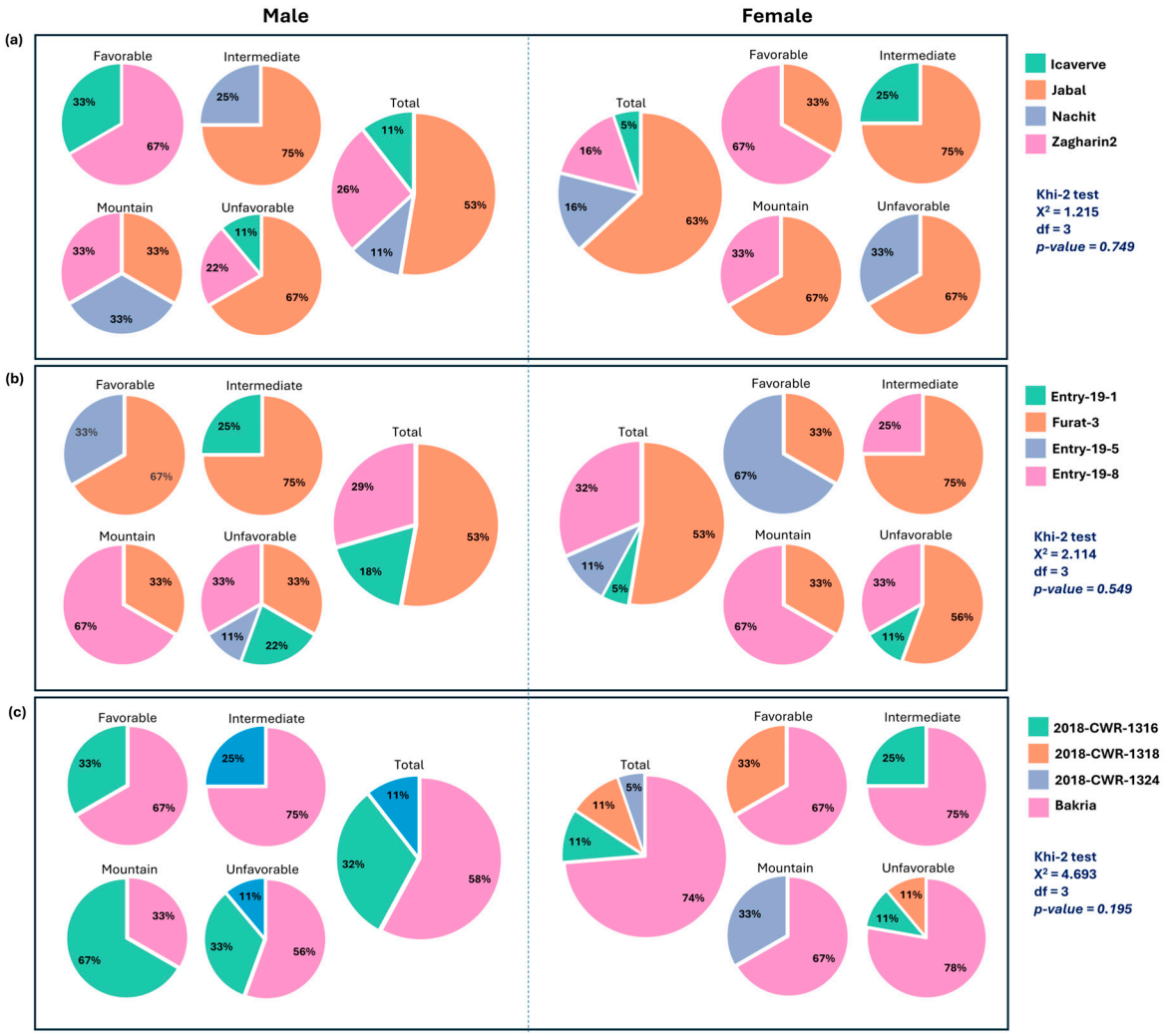


Figure 3. Male and female preferences through the PVS approach for (**a**) durum wheat, (**b**) barley and (**c**) lentil. The Khi-2 test on gender preferences was performed, and its values are presented.

Table 1. Demographic profile of the participants involved in the assessment of the CWR-derived entries during on-farm trials in Morocco.

Household Characteristics		Frequency (%)		Mean	
		Male	**Female**	**Male**	**Female**
Age (years)	30–40	26.3	36.8	52.5	47.8
	41–50	15.8	26.3		
	51–60	26.3	15.8		
	>60	31.6	21.1		
Education level	Illiterate	5.3	26.3		
	Primary school	31.6	42.1		
	Middle school	36.8	15.8		
	High school	21.1	10.5		
	University	5.3	5.3		
Training	Yes	57.9	68.4		
	No	42.1	31.6		

Table 1. *Cont.*

Household Characteristics		Frequency (%)		Mean	
		Male	Female	Male	Female
Farm size (ha)				24.9	
	<10	36.8			
	10–20	36.8			
	21–60	15.8			
	>60	10.5			
Household size (persons)		41.1	58.9	5.2	7.5
Farm animals	Sheep	0–105		33.6	
	Cows	0–40		9.4	
	Goats	0–20		1.1	

3.3. Farmers' Preferences for Candidate Lines Using the PWS Approach

The PWS value was calculated using data from 19 farms. Heatmaps illustrate the relative intensity of the weighted index for the six broad criteria across the four agroecological zones for durum wheat, barley and lentil (Figure 4a–c). Furthermore, PCA was performed to investigate relationships among the preferences expressed across all farms for the three crops. For durum wheat, PC1 and PC2 together explained 66.79% of the total variation (Figure 4d), with yield stability, biotic stress resistance, abiotic stress tolerance, and household as the discriminating traits contributing to PC1, whereas yield potential and industrial quality contributed to PC2. Farms were clustered into three groups based on hierarchical cluster analysis (Figure S1a). Cluster 1 comprised eight farms located in the unfavorable zone. Cluster 2 was mixed, comprising three farms from the favorable zone, three from the mountain zone, one from the intermediate zone, and one from the unfavorable zone. Cluster 3 included three farms, all situated in the intermediate zone.

In the case of barley, PC1 and PC2 explained 64.00% of the total variation in farmers' preferences, with abiotic stress tolerance, biotic stress resistance, and household use being the main factors along the PC1 axis, whereas yield stability and industrial quality primarily contributed to differentiation along the PC2 axis (Figure 4e). Hierarchical cluster analysis (Figure S1b) showed that seven farmers from the unfavorable zone grouped together in cluster 1. Cluster 2 included two farmers from the favorable zone and one from the mountain zone. Cluster 3 consisted of four farmers from the intermediate zone, two from the mountain zone, two from the unfavorable zone, and one from the favorable zone.

For lentil, the first two PCs explained 58.73% of the total variation. Yield potential, biotic stress resistance, industrial quality, and household use contributed primarily to PC1, while yield stability contributed to the PC2 axis (Figure 4f). Cluster analysis identified three groups of farmers (Figure S1c). Cluster 1 included two farmers from the mountain zone and one each from the favorable and unfavorable zones. Cluster 2 comprised six farmers from the unfavorable zone, two from the intermediate zone, two from the favorable zone, and one from the mountain zone. Cluster 3 consisted of five farmers, including three from the unfavorable zone and two from the intermediate zone.

The combined results shown in Table 2 indicate that yield potential was the most desirable trait across clusters for all three crops, apart from cluster 1 farmers growing durum wheat, who ranked abiotic stress tolerance highest. The broad criterion of industrial quality was the second preferred trait among all cluster 3 farmers growing durum wheat (21.65%) and barley (19.37%). However, abiotic stress tolerance was ranked second among all cluster 2 farmers growing durum wheat (18.74%) and among all cluster 1 and cluster 2 farmers growing barley (19.85 and 17.81%, respectively). Yield stability and biotic stress resistance were of low interest among all clusters of farmers growing barley (12.74 and

13.19%, respectively) and durum wheat (14.54 and 9.47%, respectively). Household use was identified as the third most desirable trait among all cluster 1 barley-growing farmers (16.18%). For lentil, abiotic stress tolerance consistently ranked second across all clusters, followed by industrial quality, while biotic stress resistance was the least valued criterion among all lentil-growing farmer groups.

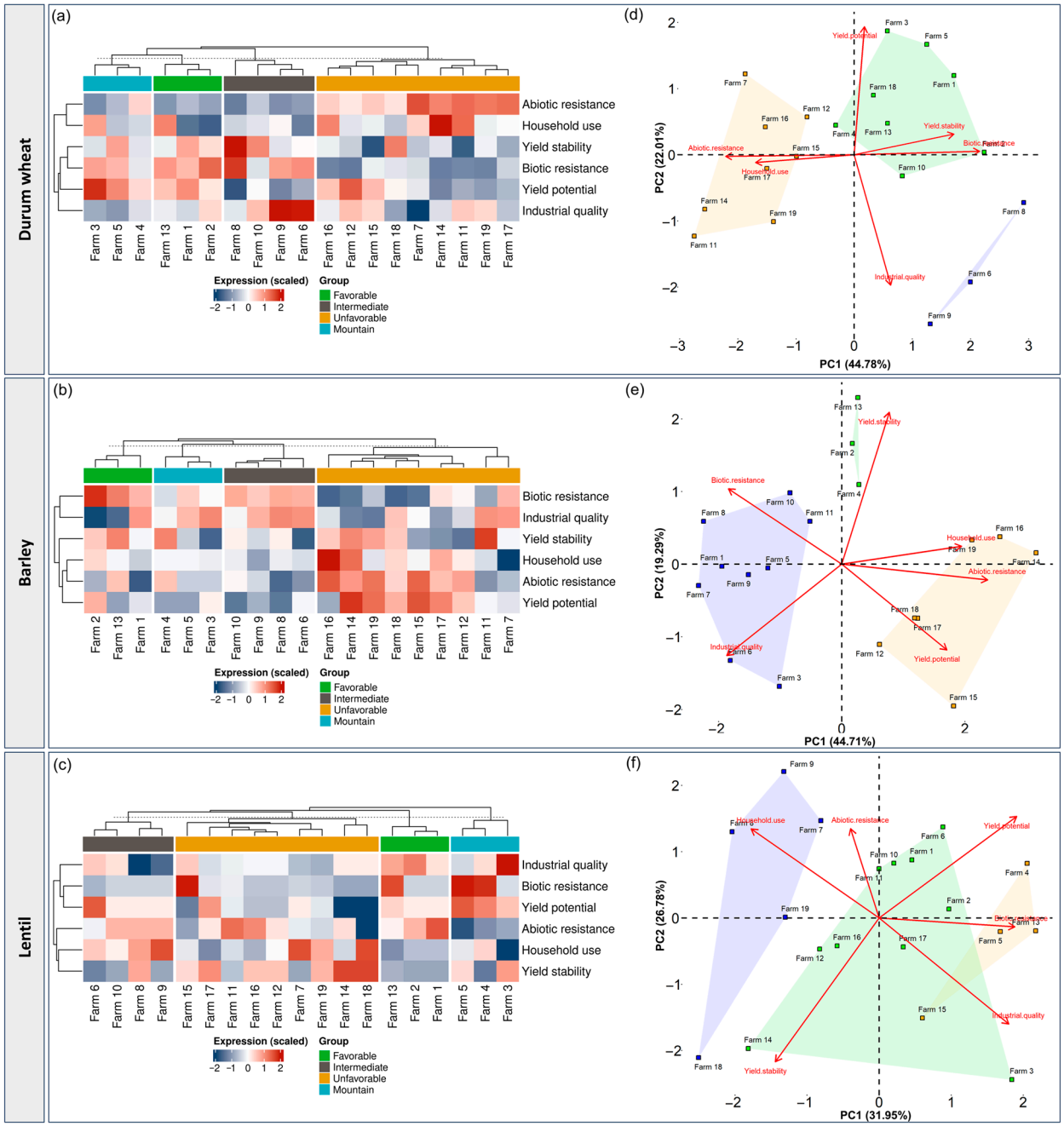


Figure 4. Heatmaps showing the intensity of the six broad selection criteria across the four agroecological zones for durum wheat (**a**), barley (**b**), and lentil (**c**), and PCA biplots (first two axes) illustrating the relationships among the weighted selection criteria for durum wheat (**d**), barley (**e**), and lentil (**f**). PCA clusters are represented in orange (cluster 1), green (cluster 2), and blue (cluster 3).

Table 2. Weighted index (±SD) of farmers' preferences per cluster for durum wheat, barley, and lentil.

Crop	Cluster	Yield Potential	Yield Stability	Biotic Stress Resistance	Abiotic Stress Tolerance	Industrial Quality	Household Use
Durum wheat	Cluster 1	24.00 ± 1.67	13.02 ± 1.11	6.50 ± 1.29	24.33 ± 1.87	18.72 ± 1.68	13.44 ± 0.96
	Cluster 2	25.41 ± 1.11	15.03 ± 1.05	10.00 ± 1.62	18.74 ± 2.11	18.37 ± 1.15	12.45 ± 1.03
	Cluster 3	22.07 ± 0.81	15.56 ± 2.62	11.92 ± 1.18	16.55 ± 0.61	21.65 ± 2.67	12.24 ± 0.75
	Average	23.83 ± 1.67	14.54 ± 1.34	9.47 ± 2.75	19.87 ± 4.01	19.58 ± 1.80	12.71 ± 0.63
Barley	Cluster 1	26.62 ± 1.51	12.34 ± 1.52	10.00 ± 2.46	19.85 ± 0.99	15.00 ± 2.24	16.18 ± 1.16
	Cluster 2	24.46 ± 1.61	13.80 ± 0.55	15.55 ± 3.42	17.81 ± 1.75	12.92 ± 3.13	15.46 ± 0.29
	Cluster 3	24.18 ± 0.97	12.09 ± 1.48	14.01 ± 1.69	15.65 ± 1.37	19.37 ± 1.19	14.70 ± 0.93
	Average	25.09 ± 1.33	12.74 ± 0.92	13.19 ± 2.86	17.77 ± 2.10	15.76 ± 3.29	15.45 ± 0.74
Lentil	Cluster 1	26.35 ± 1.21	12.51 ± 1.43	8.11 ± 0.15	21.94 ± 1.30	18.91 ± 0.81	12.18 ± 1.23
	Cluster 2	25.95 ± 0.93	13.17 ± 1.78	5.74 ± 0.22	24.37 ± 1.20	19.06 ± 1.24	11.73 ± 1.38
	Cluster 3	25.60 ± 0.91	13.59 ± 1.94	5.69 ± 0.20	23.07 ± 1.89	16.73 ± 1.58	15.33 ± 0.86
	Average	25.97 ± 0.37	13.09 ± 0.54	6.51 ± 1.38	23.12 ± 1.21	18.23 ± 1.31	13.08 ± 1.96

The PWS values shown in Table 1 were subsequently applied to the actual performances of the tested entries to determine the theoretical preference of each cluster of farmers. The performances of durum wheat, barley, and lentil candidates were estimated with reference to El Haddad et al. [21].

Nachit and Jabal were identified as the best candidates among the durum wheat lines with the highest yield potentials (100%), followed by Zagharin2 and Icaverve (99% each) (Table S9). Jabal and Zagharin2 evidenced the most stable yields at 90 and 100%, respectively. The entries most resistant to biotic stress were Nachit and Jabal (both 100%). Zagharin2 and Nachit demonstrated the greatest tolerance to abiotic stress (98 and 100%, respectively). The most suitable entries for industrial quality were Zagharin2 (100%), followed by Nachit and Jabal (98% each). Jabal ranked highest for household use (100%), followed by Nachit and Zagharin2 (99% each). The results of applying PWS indexes of farmers' preferences to this set of candidates revealed that Zagharin2 had the highest score, followed by Jabal (95.65%) and Nachit (95.58%), among farmers in cluster 1, for whom abiotic stress tolerance was the top-ranked broad criterion. Jabal best matched the preferences of farmers in clusters 2 (96.07%) and cluster 3 (96.19%), followed by Zagharin2 (95.55 and 95.00%, respectively) and Nachit (94.92 and 94.78%, respectively) (Figure 5a). The commercial check cv. Karim obtained the lowest score (77%) for the three farmer clusters, given that its yield stability, biotic stress resistance, and abiotic stress tolerance were low.

The PWS scores for farmers' objectives in cultivating a variety obtained by Alary et al. [3] were used to validate the performance of the durum wheat candidates in our trials. Following the same procedures used in this study, Alary et al. grouped farmers into four classes according to shared preferences and similar rankings of traits. The PWS scores for four farmers' preferences were applied to the set of durum wheat lines assessed in our study. The results indicated that Nachit achieved the highest score, fulfilling 85% of the criteria across all classes of farmers. Nachit had the best matching score for Class 1, meeting 90% of preferences, followed by Zagharin2 (86%) and Jabal (84%). The main preferences of Class 1 farmers were high yield potential (34%) and industrial quality (31%). For Class 2 farmers, of whom more than one-third were located in the favorable zone, Jabal and Nachit scored highest, respectively meeting 81% and 86% of their preferences. Nachit also met 85% of the preferences of Class 3 farmers, who were mostly located in the mountain zone, followed by Jabal (82%) and then Zagharin2 (79%). Similarly, Nachit had the top score for

Class 4 farmers, who live in extremely poor rural areas affected by drought and disease epidemics. It matched 85% of their preferences, while Zagharin2 and Jabal respectively met 79 and 81% of their preferences. The commercial check cv. Karim attained the lowest PWS score for all the farmers' classes.

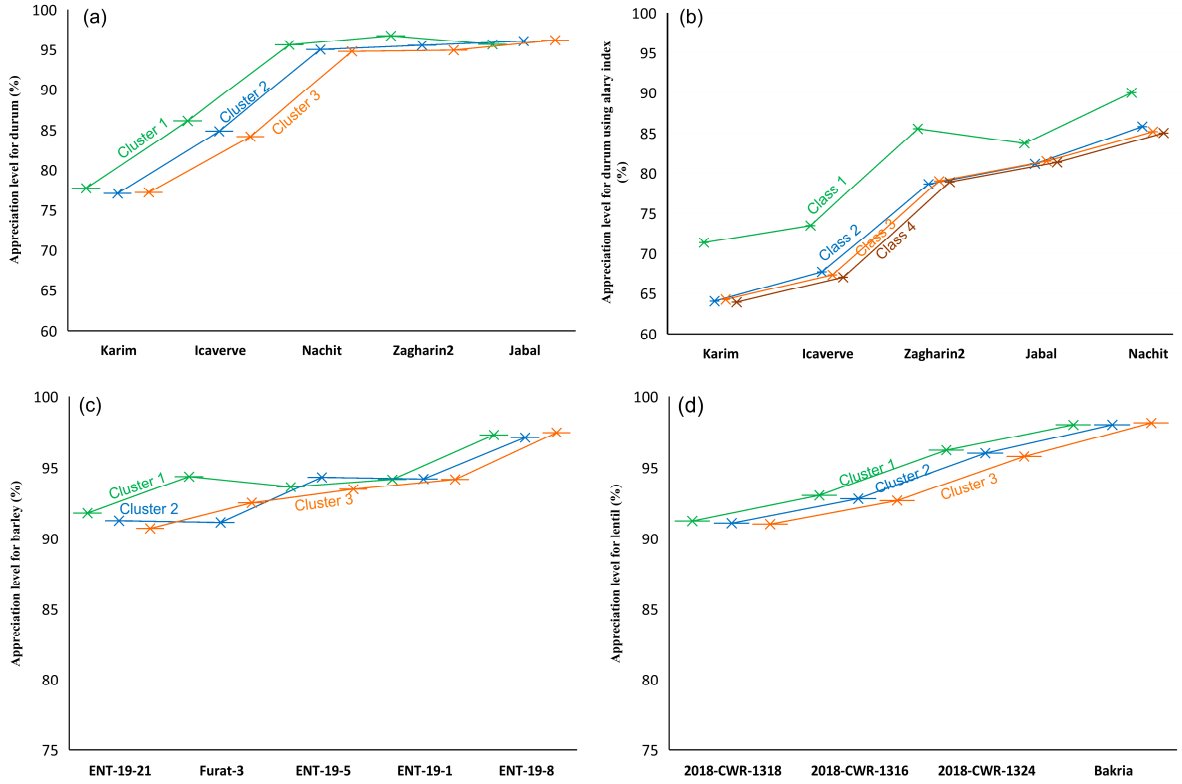


Figure 5. Distribution of matching preferences for CWR-derived lines of durum wheat (**a**), the Alary weighted index for four farmers' classes (**b**), barley (**c**), and lentil (**d**), as assessed using a selection index. The plots present matches by percentage.

The results for barley showed that ENT-19-8 was the candidate with the greatest yield potential (100%), followed by ENT-19-1 (99%) and then the check cv. Furat-3 (97%) (Table S9). ENT-19-5 had the most stable yield (100%), followed by ENT-19-21 (97%). Three of the CWR-derived entries (ENT-19-1, ENT-19-5, and ENT-19-8) were identified as highly disease resistant (100%), while the disease resistance ranking of Furat-3 and ENT-19-21 was 80%. Abiotic stress tolerance was highest for cv. Furat-3 (100%), followed by CWR-derived ENT-19-8 (97%). ENT-19-8 also evidenced the highest industrial quality and was the most suitable entry for household use (100%). The results showed that the ENT-19-8 entry best met farmers' preferences across all three clusters (Figure 5c), covering up to 97% of preferences given its high yield potential, biotic resistance, industrial quality, and household use. The check cv. Furat-3 met 91–94% of the preferences of all three farmer clusters.

In the case of lentil, the CWR-derived entries 7978/ILWL118/5-4 and 7978/ILWL118/2-7 had the best yield potential at 99% and 100%, respectively (Table S9). The most stable yields were recorded for the entry 7978/ILWL118/2-1 and the check cv. Bakria (96% and 100%, respectively). All the tested entries had high resistance to biotic stress, while Bakria was the most tolerant to abiotic stress. The entry 7978/ILWL118/2-7 showed the best industrial quality characteristics (100%), followed by the check (95%), which was also the most suitable for household use. As expected, Bakria was preferred by all three farmer clusters, meeting up to 98% of the criteria, given its high yield stability, resistance to abiotic stress, and high industrial quality (Figure 5d). The CWR-derived entry 7978/ILWL118/2-7 could

also be a good choice due to its high yield, resistance to biotic stress, and high industrial quality, meeting approximately 96% of farmers' preferences across the three clusters.

4. Discussion

4.1. Performances of CWR-Derived Entries in the Surveyed Farmers' Fields

Although a relatively small set of male and female participants was interviewed in this study, they represented a diverse range of ages, educational backgrounds, and farm sizes, providing a suitable sample for analyzing varietal preferences. Given the limited use of farming inputs and the associated costs, selecting varieties that enhance productivity without requiring farm expansion or additional expenditures is both strategic and effective. In this pilot initiative, 19 Moroccan farms across four agroecological zones were selected to identify the most promising CWR-derived entries with potential for varietal release and future commercialization. Results from the on-farm trials showed that agroecological zone and genotype × zone interactions significantly influenced most traits across the three crops. Considering the marked differences among zones, it is unsurprising that these factors accounted for the majority of observed variation, aligning with previous findings on the strong environmental and interaction effects on crop performance in Morocco [28–30].

Among the durum wheat lines tested, Jabal, which carries introgressions from *Ae. Speltoides* in its pedigree, was the best-performing entry in the intermediate and unfavorable zones, areas heavily affected by drought stress. It provided a yield advantage of up to 68%, along with increased biomass production and larger grain size compared with the variety cv. Karim. Similarly, Nachit (derived from *T. dicoccoides*) and Icarverve (from *T. araraticum*) were the top-yielding entries in trials conducted in the favorable zone, whereas Zagharin2 (from *T. dicoccoides*) performed best in the mountain zone, which experiences moderate drought stress. These findings align with previous work [21], in which these entries demonstrated strong performance and broad adaptation across 19 agroecological zones, including drought- and heat-prone environments in four countries (Morocco, Senegal, Ethiopia and Lebanon). Notably, the highest-performing lines originated from top crosses involving *T. dicoccoides* and *Ae. Speltoides*. Several studies have highlighted the value of these wild progenitors for developing elite durum wheat with enhanced yield potential and improved resistance to major biotic and abiotic stresses [31,32].

Of the barley lines evaluated, ENT-19-1, a CWR-derived entry originating from *H. spontaneum*, was the best performer in the intermediate zone, which experiences moderate drought stress, providing a yield advantage of more than 3% over the check cultivar cv. Furat-3. This result supports our previous findings [21], which demonstrated the strong potential of *H. spontaneum* to deliver stable and high grain yield across diverse environments. Numerous studies have also highlighted the value of *H. spontaneum* for enhancing drought and heat tolerance and for conferring resistance to major diseases [33,34]. In addition, ENT-19-8, another CWR-derived entry, was the top-performing line in both the mountain and unfavorable zones, with yields 25–155% higher than those of cv. Furat-3, which remained the highest-yielding variety only in the favorable zone.

Among the lentil lines, the check cultivar cv. Bakria demonstrated the best overall performance in the favorable and mountain zones, where drought stress has an insignificant impact. However, 2018-CWR-1316, a CWR-derived entry originating from *L. orientalis*, outperformed Bakria in districts located in the intermediate zone, where drought stress is moderate, providing a 22% yield advantage. In districts within the unfavorable zone, those most severely affected by drought, the CWR-derived entry 2018-CWR-1324 was the top performer, delivering up to a 56% yield advantage over Bakria. These findings further confirm that selected entries derived from *L. orientalis* can produce higher grain yields under drier conditions compared with Bakria, in agreement with El Haddad et al. [21].

Moreover, *L. orientalis*, the closest wild progenitor of cultivated lentil, has long served as an important reservoir of valuable alleles associated with resistance to diseases, parasitic weeds, and insect pests, as well as tolerance to key abiotic stresses, particularly heat and drought [35–37].

4.2. Trait Preferences of Interviewed Farmers

The PVS survey highlighted a remarkably consistent pattern of variety preferences across genders and agroecological zones for all three crops evaluated. With the exception of a few site-specific deviations, men and women expressed similar preferences, suggesting that gender does not substantially drive varietal choice in these systems. This reinforces the idea that the traits valued by farmers are largely universal within communities, such as yield stability, stress tolerance and household utility, rather than gender-specific. Across crops, Jabal, Nachit, and Zaghrin2 for durum wheat, Furat-3 for barley, and Bakria for lentil stood out as the most preferred varieties, underscoring their broad adaptation and high acceptability among diverse farmer groups.

Interestingly, while agroecological zones had no significant influence on PVS outcomes across crops, barley exhibited a clear zone-specific pattern of preference, indicating that this crop is particularly sensitive to environmental and socioeconomic contexts. Farmers in the unfavorable zone (cluster 1), representing the most resource-poor and drought-prone rural areas, prioritized yield potential, tolerance to abiotic stresses, and household use. This aligns closely with the subsistence-oriented nature of production systems in these zones, where resilience traits are essential for minimizing risk. In contrast, farmers in the favorable and mountain zones (cluster 2) emphasized yield potential alongside both abiotic and biotic stress resistance, reflecting the more balanced production objectives in these environments. The intermediate zone (cluster 3), which encompasses some of the most industrialized regions, showed a distinct preference for industrial quality in addition to yield potential. This pattern strongly suggests that market incentives and the requirements of food-processing industries are shaping farmer decision-making in these areas.

These insights collectively demonstrate that while some genotypes receive widespread acceptance due to their superior performance across multiple environments, preferences for specific varietal traits remain context-dependent, shaped by the interaction between environmental constraints and livelihood strategies. The strong performance and preference for two-rowed CWR-derived barley entries across several zones are particularly important. These lines not only contribute to higher productivity under diverse conditions but also exhibit robust tolerance to key abiotic and biotic stresses and offer favorable industrial-quality traits. Their additional value as a forage resource further strengthens their appeal, particularly in mixed crop-livestock systems. These results are in line with previous reports [38–40] and underscore the considerable potential of CWRs to broaden the genetic base of barley and improve its resilience in the face of climate variability.

In durum wheat, our findings revealed that farmers in unfavorable zones were grouped together in cluster 1, prioritizing abiotic stress tolerance as the most crucial trait, followed by yield potential. Several studies have reported that a succession of extremely severe drought periods in these areas has led to a dramatic reduction in agricultural production, which has considerably impacted socioeconomic conditions in Morocco [41,42]. As a result, farmers operating in such fragile environments logically focus on varietal resilience, seeking genotypes that can withstand water scarcity and mitigate risk before considering yield maximization.

In contrast, yield potential was ranked second by farmers in the favorable and mountain zones (cluster 2), followed by abiotic stress tolerance and industrial quality, while biotic stress resistance was considered the least important. These findings align with earlier

reports by Alary et al. [3], who showed that yield potential, industrial quality, and abiotic stress tolerance are the primary preferences of Moroccan farmers located in the favorable zone. However, their study also noted that smallholders in mountain zones prioritize yield potential, yield stability, and industrial quality, which is relatively consistent with the patterns observed in our study. As in the case of barley, farmers in the intermediate zone (cluster 3) expressed a stronger preference for industrial quality traits compared with other clusters. This trend likely reflects the influence of food-processing industries that operate predominantly in these more industrialized regions, encouraging farmers to meet specific quality standards required by processors. The importance placed on industrial quality by these farmers, therefore, seems to be shaped less by agroecological constraints and more by market-driven incentives.

Across all three clusters of lentil-growing farmers, yield potential and abiotic stress tolerance consistently emerged as the top priorities, followed by industrial quality. This strong emphasis on resilience traits reflects the production realities in Morocco, where lentil cultivation is frequently challenged by drought and high temperatures. Several national and international breeding initiatives have therefore focused on developing robust lentil varieties capable of withstanding harsh abiotic stresses, particularly drought and heat [28,43,44]. However, our findings highlight that industrial quality, although ranked after yield potential and abiotic stress tolerance, remains an important consideration influencing farmers' final choices. This underscores the need for breeding programs to more explicitly integrate industrial quality traits into the selection of new lentil candidate varieties. Enhancing these attributes may not only improve marketability but also increase the likelihood of adoption by farmers seeking varieties that satisfy both agronomic performance and downstream processing requirements.

Our study demonstrates that Moroccan farmers prioritize grain yield, tolerance to drought and heat, and grain quality as the key criteria for varietal selection. In the unfavorable zone, farmers focused primarily on adaptation to water stress in addition to grain yield, reflecting the constraints imposed by harsh environmental conditions. In contrast, farmers in the intermediate zone, with farm sizes ranging from 9 to 210 ha, are better positioned to target both yield potential and industrial quality traits, enabling them to supply higher-quality products to food-processing industries.

Interestingly, on farms with fewer women, predominantly located in the favorable and mountain zones, farmers prioritized yield potential and abiotic stress tolerance over industrial quality. Conversely, in the intermediate and unfavorable zones, where households generally have a higher proportion of women, greater emphasis was placed on industrial quality traits. This pattern suggests that women play a more active role in varietal adoption decisions in these zones, shaping the selection of varieties that balance household needs with market requirements, consistent with findings reported by Nchanji et al. [45].

4.3. Comparison of the PWS and PVS Approaches

PWS and PVS are pivotal tools in agricultural research and development, enabling farmer-centered evaluation of crop varieties. PWS engages farmers in scoring candidate varieties across multiple traits, such as yield, disease resistance, and industrial quality, assigning weights according to their preferences to generate context-specific selection indices. In contrast, PVS allows farmers to directly evaluate and test varieties in their fields, empowering them to identify the most suitable options for local conditions.

In our study on durum wheat, Jabal emerged as the top yielder in the intermediate, unfavorable, and mountain zones, consistently ranking highest in PVS assessments across both genders. Similarly, Nachit, Icaverve, and Zagharin2 performed best in the favorable zone, aligning closely with PVS results, which showed Zagharin2 as the preferred variety

for both genders, Icaverve as the second choice among males, and Jabal as the second choice among females. Overall, these results indicated no gender distinction for the topmost preferred entry in each zone; however, differentiation occurred occasionally for the second and third preferences. PWS scores, calculated using the Alary et al. [3] index, were largely consistent with PVS results and biophysical on-farm trials, highlighting Nachit, Jabal, and Zagharin2 as the most preferred entries. Some variation was observed in the second preferences, suggesting that even a relatively small number of farmer surveys can generate robust PWS values for the top-ranked variety. It also indicates that overall preferences are much less important than agroecological preferences.

For barley, the check cv. Furat-3 exhibited the highest grain yield in the favorable zones and was the top choice among males in the PVS assessment, whereas females favored ENT-19-5. In contrast, PWS identified ENT-19-8 as the preferred variety in these zones, reflecting farmers' prioritization of yield potential and tolerance to abiotic stress. This discrepancy highlights a difference between in-field PVS selection and PWS-derived preferences. On the contrary, ENT-19-8 emerged as the top yielder in both the mountain and unfavorable zones, where farmers primarily sought high yield potential and industrial quality. These findings were well-aligned with the PWS results, while Furat-3 remained the preferred variety under PVS for both genders. In the intermediate zones, Furat-3 was ranked highest in PVS, whereas PWS indicated ENT-19-8 as the optimal choice across all sites. Meanwhile, ENT-19-1 recorded the highest biophysical yield in the intermediate zones, illustrating occasional mismatches between field performance, PVS, and PWS assessments.

For lentil, the check cv. Bakria produced the highest grain yield in the favorable and mountain zones and was also ranked highest in PVS assessments. A similar pattern was observed with the PWS approach, confirming Bakria as the preferred choice in these zones, where farmers primarily target yield potential, abiotic stress tolerance, and industrial quality. Our study revealed a remarkable alignment between PWS and PVS across all agroecological zones, with Bakria consistently ranked as the top choice. Exceptions were noted in male preferences in the mountain zones, where 2018-CWR-1316 was initially favored over Bakria. Additionally, 2018-CWR-1316 performed best in the intermediate zones, while 2018-CWR-1324 was the top yielder in the unfavorable zones, highlighting occasional discrepancies between biophysical performance and farmer-preference assessments via both PVS and PWS.

Overall, for durum wheat, the highest-performing genotype in on-farm trials was consistently identified as the most preferred variety through PWS. However, for barley and lentil, the highest-yielding variety was not always the most preferred genotype when farmers' preferences were integrated. This discrepancy is likely related to the strong influence of environmental conditions on genotype performance. These observations are supported by the variance partitioning analysis (Table S6), in which agroecological zone effects explained 44.93% and 58.31% of the total variance for barley and lentil, respectively, compared with a lower environmental contribution for durum wheat (6.31% of the total variance). These results indicate that, particularly for barley and lentil, farmer preferences are shaped by environmental stability and multiple trait considerations rather than yield performance alone.

Our study demonstrates that the PWS method offers a distinct advantage in capturing farmers' varietal preferences, often surpassing the PVS approach, which can be more challenging to implement. PWS is particularly valuable for its objectivity, scalability, and logistical and economic efficiency, providing a cost-effective alternative that reduces the need for extensive on-farm trials. Consequently, PWS has the potential to accelerate the adaptation and dissemination of new varieties more effectively than both PVS and conventional approaches. This is supported by Alary et al. [3], who emphasized that PWS

indices not only increase the likelihood of adoption of new releases but also account for farmers' specific needs that may be overlooked by traditional, non-participatory breeding methods. Nonetheless, combining the PWS and PVS approaches offers a complementary framework that enables breeding programs to balance field performance with farmer-defined preferences, thereby enhancing varietal adaptation and adoption.

5. Conclusions

This study evaluated the performance of CWR-derived lines of durum wheat, barley, and lentil across four diverse agroecological zones in Morocco. Biophysical assessments showed that several novel CWR-derived entries outperformed the control varieties in one or more zones. Comparisons among the biophysical performance, PVS, and PWS approaches revealed strong overall alignment for durum wheat, confirming that all three methods are effective for identifying candidate varieties that align with farmers' preferences. However, the top-yielding genotypes were not always the most preferred for barley and lentil. Nevertheless, combining the PWS and PVS approaches provides a complementary framework that enables breeding programs to balance agronomic performance with farmer-defined preferences. By integrating both scientific evaluation and local knowledge, this approach not only improves varietal adaptation and adoption but also highlights the critical role of selecting appropriate evaluation criteria for food sustainability. In particular, for smallholder farmers, such a framework can support the development of cropping systems that are more resilient to climate variability and environmental stresses, contributing to a more stable and sustainable agricultural ecosystem. While PWS emerges as the more practical and impactful tool for guiding breeding selection, owing to scalability, objectivity, and capacity to capture weighted farmer preferences, both PVS and PWS effectively connect breeders with farmers.

Expanding PWS to incorporate the perspectives of other actors along the food value chain, such as processors, traders, and policymakers, could further enhance its strategic value and support more holistic varietal adoption. Ultimately, addressing the complex interactions among crop diversity, production environments, food systems, and socioeconomic factors will require integrated participatory approaches. Nevertheless, the key traits and participatory methods highlighted in this study provide an actionable foundation for developing the next generation of varieties better tailored to farmers' agronomic, household, and market needs, thereby promoting sustainability and resilience, particularly in small farming systems.

Supplementary Materials: The following supporting information can be downloaded at https://www.mdpi.com/article/10.3390/su18125994/s1: Figure S1: Hierarchical clustering analysis based on weighted indices for (a) durum wheat, (b) barley, and (c) lentil, derived from participating farmers' responses; Table S1: Details of durum wheat, barley, and lentil lines used in trials conducted in farmers' fields during the 2018–2019 and 2019–2020 seasons; Table S2: Description of the farm sites in Morocco; Table S3: Maximum and minimum temperatures and moisture and irrigation systems at the on-farm experimental sites in Morocco; Table S4: Alignment between surveyed traits and traits to criteria; Table S5: Conversion of field measurements into broad criteria traits; Table S6: Analysis of variance and mean values for plant height, biological yield, grain yield, and 1000-seed weight of durum wheat, barley, and lentil entries across farmer clusters. The value of each source of variation (zone and genotype and their interaction) is expressed as a ratio to the total variation; Table S7: Plant height, biological yield, grain yield, and 1000-seed weight of durum wheat, barley, and lentil lines tested in farmers' fields across four agroecological zones of Morocco during the 2018–2019 and 2019–2020 seasons; Table S8: Khi2 and fisher tests on the PVS preference varieties for durum wheat, barley, and lentil; Table S9: Estimated performances of durum wheat, barley, and lentil entries using selection criteria converted from field data into ratios relating to the best genotype (0–100%).

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Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The datasets generated during the present study are available on the Germinate Platform. All data can be accessed at https://ics.hutton.ac.uk/cwr/diiva/ (accessed on 20 February 2023).

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Abbreviations

The following abbreviations are used in this manuscript:

CWR	Crop wild relative
GID	Germplasm identifier of entries
PVS	Participatory Variety Selection
PWS	Participatory Weighted Selection

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