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Current State, Challenges and Opportunities to Improve Faba Bean Cultivation in Morocco: A Review

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ABSTRACT

Faba bean (*Vicia faba* L.) is a leguminous crop renowned for its millennia-long cultivation driven by its highly nutritious seeds. Rich in minerals, bioactive carbohydrates, fiber and protein with a complete amino acids profile, faba beans serve as vital components in both human and animal diets. In Morocco, faba bean is crucial for food security, sustainability and rural economy. After stable cultivation in the 1960s-70s and subsequent expansion, recent years have seen a decline in cultivated areas due to market volatility, climate challenges, traditional farming methods, pests and limited research. Addressing these multifaceted challenges requires a comprehensive approach. Key strategies include the adoption of alternative agricultural practices such as no-till farming to enhance soil quality and reduce labor costs. Implementing effective weed management strategies and increasing mechanization are crucial for reducing labor requirements and improving overall productivity. Additionally, breeding programs focused on developing drought-tolerant and high-yielding faba bean varieties are essential. Preparing solutions for emerging pests like aphids and pod borers, which thrive in the shifting hotter and drier climate, is critical. Adopting regional/agroecological varieties and developing open-pollinated and synthetic varieties for the national catalog are important considerations. To combat crenate orobanche, extensive screening of accessions and developing herbicide-resistant varieties should be prioritized. The integration of molecular tools, such as marker-assisted selection and genomic prediction, is crucial for accelerating the breeding process and enhancing precision in developing resilient varieties. Finally, emphasizing scientific research to optimize agronomic practices and reinforce crop resilience stands as a critical priority. This review evaluates the current status of the faba bean sector in Morocco, identifying the obstacles faced by farmers amidst economic, environmental and market fluctuations. It proposes essential strategies aimed at advancing faba bean production in Morocco, serving as a fundamental resource and reference for stakeholders including farmers, researchers, seed producers and policymakers.

Key words: Crop resilience, Faba bean challenges, Food security, Legumes, *Vicia faba*.

Faba bean (*Vicia faba* L.), belonging to the Fabaceae family, is a dicotyledonous plant native to Eurasia and the Mediterranean basin, cultivated for millennia for its nutritious seeds (Duc *et al.,* 2015). This diploid annual plant (2n = 2x = 12) is known for its seeds rich in proteins and starch, used in human and animal nutrition. Faba bean has various morphological types, with pods containing seeds of various sizes, suitable for different food and feed applications. Mature faba bean seeds (dry seeds) contain between 20 and 40% protein, which is approximatively twice that of cereals, making them a valuable source of plant-based protein in both human and animal diets (Dhull *et al.,* 2022). The amino acids profile of faba beans is complete, including essential amino acids such as lysine, phenylalanine, isoleucine, leucine, valine, methionine, tyrosine, tryptophan, histidine and threonine, as well as non-essential-amino-acids-such as aspartic acid, glutamic acid, alanine, arginine, glycine, proline and serine (Labba *et al.,* 2021; Pirman *et al.,* 2001). Carbohydrates are the second most important nutrient, with contents ranging from 47 to 68%, the majority of which is starch (42 to 52%) (Augustin and Cole, 2022). Faba beans are also an excellent source of dietary fiber (15 to 30%), which may reduce gastrointestinal disorders, coronary heart disease and type 2 diabetes (Karataş *et al.,* 2017; Kshirsagar *et al.,* 2020; Singh *et al.,* 2013). Faba bean seeds are also rich in minerals such as sodium, potassium, calcium, copper, zinc, iron, manganese, magnesium, phosphorus and sulfur (Khazaei and Vandenberg, 2020) and contain various bioactive compounds with notable antioxidant properties (Alam and Najam, 2022; Poonia *et al.,* 2022). Thus, faba bean seeds can be consumed as green, dried, fresh, or cooked form and are used in various traditional dishes

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such as *Falafel* and *Bissara* (Pasqualone *et al.,* 2020). They are also used to enrich various food products such as bread and biscuits with protein (Hill, 2022). However, faba beans also contain antinutritional factors, such as phytates, vicine, convicine, saponins, lectins, oligosaccharides (raffinose, stachyose), condensed tannins and trypsin and protease inhibitors. These components can pose risks to some people, causing disorders such as favism or abdominal discomfort (Saha *et al.,* 2022). Seed treatments, such as germination and cooking, can reduce these antinutrients, improving its nutritional quality (Abbas and Ahmad, 2018). Selecting varieties with low antinutrient content remains an effective method to overcome these challenges.

Moroccan agriculture plays a crucial role in the national economy, representing 38% of the country's total employment, 74% of which is in rural areas (Economic and Financial Statistics - The Ministry of Economy and Finance - Morocco, 2023). Faba bean cultivation in Morocco offers a significant opportunity to improve food security, agricultural sustainability and the rural economy. The faba bean market, mainly traditional and located in rural souks, involves various actors such as small and medium-sized farmers, intermediaries, resellers and direct consumers, helping to maintain affordable sales prices. Faba bean plays a vital role in crop rotation systems, improving soil fertility through nitrogen fixation and reducing the need for synthetic fertilizers (Maalouf *et al.,* 2021; Rfaki *et al.,* 2018). Crop rotations and associations with cereals, palms and olives in different regions of Morocco, such as Saïs and Drâa-Tafilalet, offer significant agronomic and economic benefits, increasing the average gross margin by 50% compared to monoculture (Boutagayout *et al.,* 2023; Daoui and Fatemi, 2014; El Janati *et al.,* 2021). Moroccan agriculture, employing a large part of the population and contributing substantially to gross domestic product (GDP), faces several challenges to maintain and improve faba bean production. Farmers face economic and environmental constraints, as well as fluctuations in the international market. Effective management of faba bean cultivation requires an integrated approach, including research to develop resilient varieties and sustainable management strategies.

This review article aims to diagnose the current situation of the faba bean sector in Morocco and propose prospective strategies to overcome challenges and improve production. This work constitutes a crucial and pioneering platform for farmers, researchers, seed producers and policymakers, thus contributing to the sustainable development of this sector in Morocco.

Faba bean cultivation overview

Importance of faba bean

Faba bean, a specie of great antiquity in Morocco, remains an essential component within agricultural production systems, playing diverse roles on the agrobiological and socio-economic levels. Beyond its major agro-economic impact, faba bean stands out as one of the main sources of protein, for both human food and animal feed.

Food

Broad beans (*Vicia faba* L.) have stood as a fundamental dietary pillar for millennia, thriving primarily in the Mediterranean region and also encompassing continental areas. The richness of digestible proteins and starch present in their seeds constitutes the main driver of their widespread food use (Rahate *et al.,* 2021). Broad beans are acclaimed as a crucial source of protein, fiber, vitamins, minerals, antioxidants and many other essential nutrients (Carbas *et al.,* 2020). However, various factors may restrict their exploitation as a source of protein in human food (Sharan *et al.,* 2021). Furthermore, the cotyledons of *Vicia faba* L. seeds contain glucopyranosides, in particular, vicine and convicine (Marquardt, 2023; Ramsay and Griffiths, 1996). Consumption of these seeds may lead to the risk of favism, an enzyme deficiency characterized by hemolytic anemia prevalent in the Middle East and the Mediterranean basin (Dhull *et al.,* 2022). Therefore, studies have been intensively directed towards improving the nutritional quality of the seeds (Khazaei *et al.,* 2021; Labba *et al.,* 2020; Santos Neto *et al.,* 2012). In Morocco, faba beans are a staple in traditional cuisine, featured both as a main dish and as an ingredient in a variety of recipes, whether as fresh, ripe seeds or dried. As a cold-season crop, faba beans thrive in Morocco's interior regions, where they are cultivated and consumed in both their green and dried forms.

Moreover, the broad bean dish, whose preparation is similar to *Ful medames* but involves the use of dried broad bean seeds, is *Bissara* (Pasqualone *et al.,* 2020). *Bissara* can be eaten in Morocco as either a dip or a soup. Due to its richness in essential amino acids, the bean is an appropriate food to complement the Moroccan diet, largely based on cereals, for a well-balanced essential amino acid intake to better meet the needs of the human body (Khayour *et al.,* 2023).

Socio-economic

Morocco, pays an additional income from the financial transfer to North Africa, with a GDP per capita of US$ 120.44 and a GINI index of 38.5 (World Bank Open Data, 2024). There have been many levels of the rural population in the past year, with a much better income of US$. Agriculture, a pivotal sector highly responsive to environmental conditions, accounts for approximately 38% of Morocco's total employment and up to 74% in rural areas. It also contributes to a higher rate of 13% of GDP, including various regions, depending on the effectiveness of this activity (Economic and Financial Statistics - The Ministry of Economy and Finance - Morocco, 2023). About 80% of 14 million residents are exposed to the agricultural sector. The trade-in food legumes in Morocco is structured around two distinct markets, namely the traditional market and the "organized" market (ONICL, 2010). The traditional market,

operating mainly at the level of rural souks, involves various actors such as small and medium-sized farmers, intermediaries, resellers and direct consumers or restaurateurs. Oriented towards local demand, it meets the needs of local markets and households, with sales prices fluctuating considerably, sometimes varying from 1 to 15 dirhams per kilogram (MAD/Kg) during the season (El Janati *et al.,* 2021). These fluctuations may discourage some farmers from engaging in growing fresh beans. On the other hand, by promoting crop diversification, faba beans help strengthen the economic stability of farmers, thereby reducing their dependence on a single crop and exposing them less to the inherent risks.

Incorporating faba beans into the diet is essential for combating malnutrition, especially among vulnerable populations. Moreover, cultivating and processing these beans stimulates local economic activities, fostering rural development and reducing socio-economic disparities. The cultivation of faba beans generates substantial employment opportunities, particularly during planting and harvesting seasons, providing vital support to local farming communities and creating manual labor opportunities due to limited mechanization.

In this context, the creation of producer groups or cooperatives emerges as a potentially beneficial solution. These groupings could provide producers with increased profitability and security in the marketing of their production (via the establishment of a minimum purchase price) and strengthen their position on the market by reducing dependence on screw intermediaries.

Agronomic

Nitrogen remains a determining factor for both the yield and quality of agricultural production, but it is often limited in many regions of the world due to its high cost in the form of fertilizer. Faba beans, like other food legumes, contribute significantly to enriching the soil with fertilizing elements (Meena *et al.,* 2018). The roots of faba bean establish a symbiosis with bacteria of the *Rhizobium* genus, allowing the fixation of atmospheric nitrogen and, thus, enriching the soil with nitrogen. This association reduces farmers' dependence on chemical fertilizers (Mabrouk *et al.,* 2018).

In intercropping, when combined with cereals, faba bean helps control weeds by increasing competition between cereals and weeds for water and nutrients (Silberg *et al.,* 2019). This capacity (symbiosis) contributes significantly to the supply of protein for human and animal nutrition, while significantly reducing dependence on energy-intensive mineral nitrogen fertilizers (Mabrouk *et al.,* 2018).

Experiments carried out under Moroccan conditions over two years demonstrated the advantages of including faba bean in the crop cycle (Yigezu *et al.,* 2019). In this study, legume–cereal rotations have clear economic advantages over cereal monocropping. Assuming a biennial rotation – the fastest cycle possible in a rainfed dryland system, the study demonstrated that joint adoption of rotations and improved faba bean varieties leads to a two-year average gross margin that is US$ 537/ha (48%) higher than wheat monocropping (US$ 277/ha). In another study, the importance of olive tree and faba bean crop association in the Saïs region was determined (Daoui and Fatemi, 2014). The results indicated that planting legumes, such as faba beans and lentils, near olive tree trunks can harness biological nitrogen fixation benefits. In the Drâa-Tafilalet oases, rotating cereals with faba beans and incorporating palm trees not only supports farmers' subsistence and provides livestock feed from grains and crop residues but also enhances soil fertility and reduces water evaporation. This practice is particularly valuable in the region's arid climate (El Janati *et al.*, 2021).

Moreover, in a field study conducted in the Meknes region over two successive cropping seasons, which included monocultures as well as two- and three-species intercropping arrangements, it was observed that the practice of faba bean-oat intercropping (1:2) could be employed in an ecological weed management program to enhance yield parameters under low-input production systems in the Meknes region (Boutagayout *et al.,* 2023). Another study in Haouz (Morocco) demonstrated that the mixed cropping or wheat-faba bean rotation systems have a positive impact on the soil's microbial functionalities, thereby enhancing crop production (Wahbi *et al.,* 2016).

Furthermore, three years of field experiments revealed that intercropping faba bean with mustard in a 2:5 row ratio resulted in higher productivity, improved net returns and reduced crop failure risks (Ouji *et al*., 2022).

Global and national faba bean production

Global production

In terms of global legume production, faba bean ranks sixth, following the common bean (*Phaseolus vulgaris* L.), chickpea (*Cicer arietinum* L.), field pea (*Pisum sativum* L.), cowpea (*Vigna unguiculata* L.) and lentil (*Lens culinaris* Medik.) (FAOSTAT, 2024).

The global landscape of faba bean production is dominated by China, which leads with an annual output of 1,723,598 tons. Ethiopia follows as the second-largest producer, contributing 1,070,637 tons annually. In this global context, Morocco holds the 19th position, with an annual production of 48,973 tons (Fig 1) (FAOSTAT, 2024). This ranking underscores the potential for Morocco to increase its faba bean production and highlights the crop's importance in diverse agricultural systems worldwide.

Morocco's faba bean sector

Cultivated and harvested area

In 2022, faba bean cultivation covered 105,000 hectares in Morocco, accounting for 42% of the main legume area (Ministry of Agriculture of Morocco, 2024). Three-quarters of national food legume production concentrates in the Center-North, particularly in Tangier-Tétouan, Taza-El Hoceima, Fès-Boulmane, Chaouia-Ouardigha and Abda-

Doukkala (Ministry of Agriculture of Morocco, 2024). These regions receive over 300 mm annual rainfall, favoring rainfed faba bean cultivation.

In Chaouia-Ouardigha, legumes occupy 4% of usable agricultural area, with faba beans comprising 27.8% of food legume area (Abdelali Martini and Dey De Pryck, 2015). Abda-Doukkala dedicates 45.78% of its food legume area to faba beans (Abdelali Martini and Dey De Pryck, 2015). Faba beans dominate food legume rotations in Fez-Meknes at 52.25%. In Taza-Hoceima, irrigated faba beans cover 12% of Morocco's crop area. Tangier-Tétouan grows faba beans as the dominant species on 8,300 hectares.

Data on Morocco's harvested area for dry and fresh faba beans reveals significant trends (Fig 2) (FAOSTAT, 2024). Dry bean area remained stable at 150,000-160,000 hectares in the 1960s-1970s. Green bean area ranged between 9,000-14,000 hectares during this period. The 1970s saw expansion, reaching 259,000 hectares for dry beans in 1972 and 18,000 hectares for green beans in 1980, due to growing demand and production incentives.

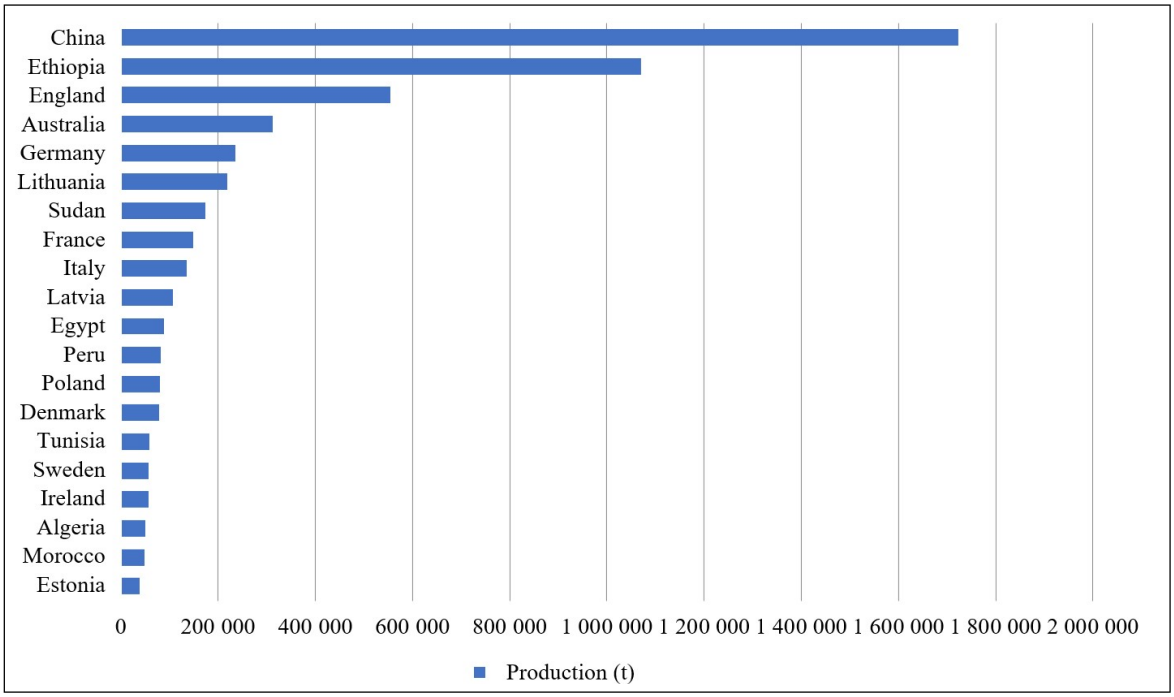


Fig 1: Distribution of global faba bean production among the top 20 producing countries during the 2020/2021 growing season (FAOSTAT, 2024).

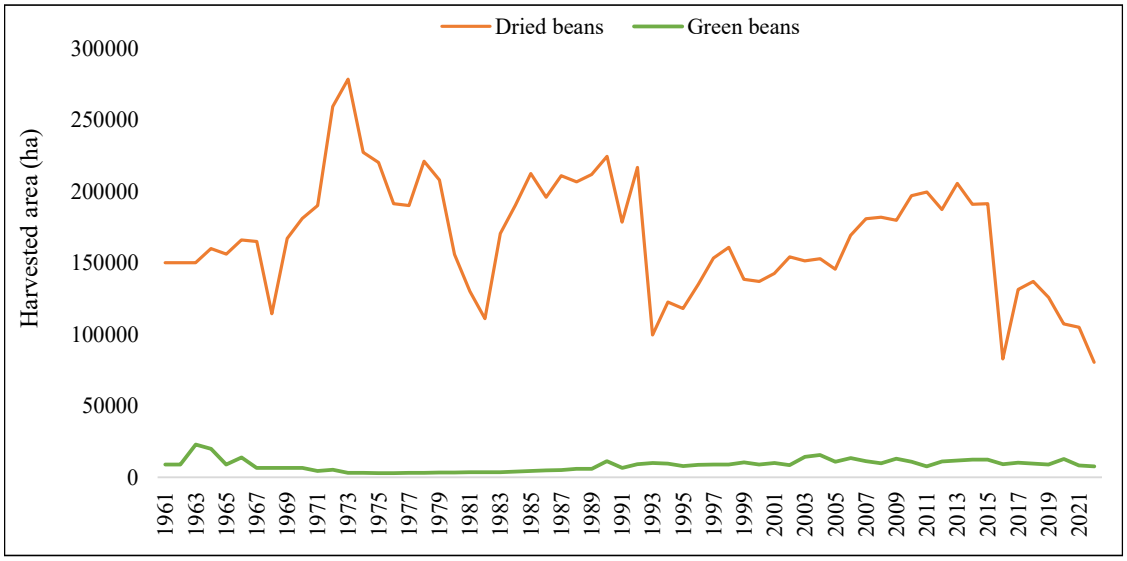


Fig 2: Evolution of harvested area of green and dried faba bean in Morocco between 1960 and 2022 (FAOSTAT, 2024).

The 1980s-1990s experienced fluctuations, with dry bean area varying from 99,500 hectares (1993) to 224,400 hectares (1990). From the 2000s, areas stabilized at lower levels. Green bean area fluctuated between 6,600 hectares (1967) and 18,425 hectares (1990). Dry bean area declined to 104,927 hectares in 2021, while green bean area reached 12,352 hectares in 2015 and 8,390 hectares in 2021.

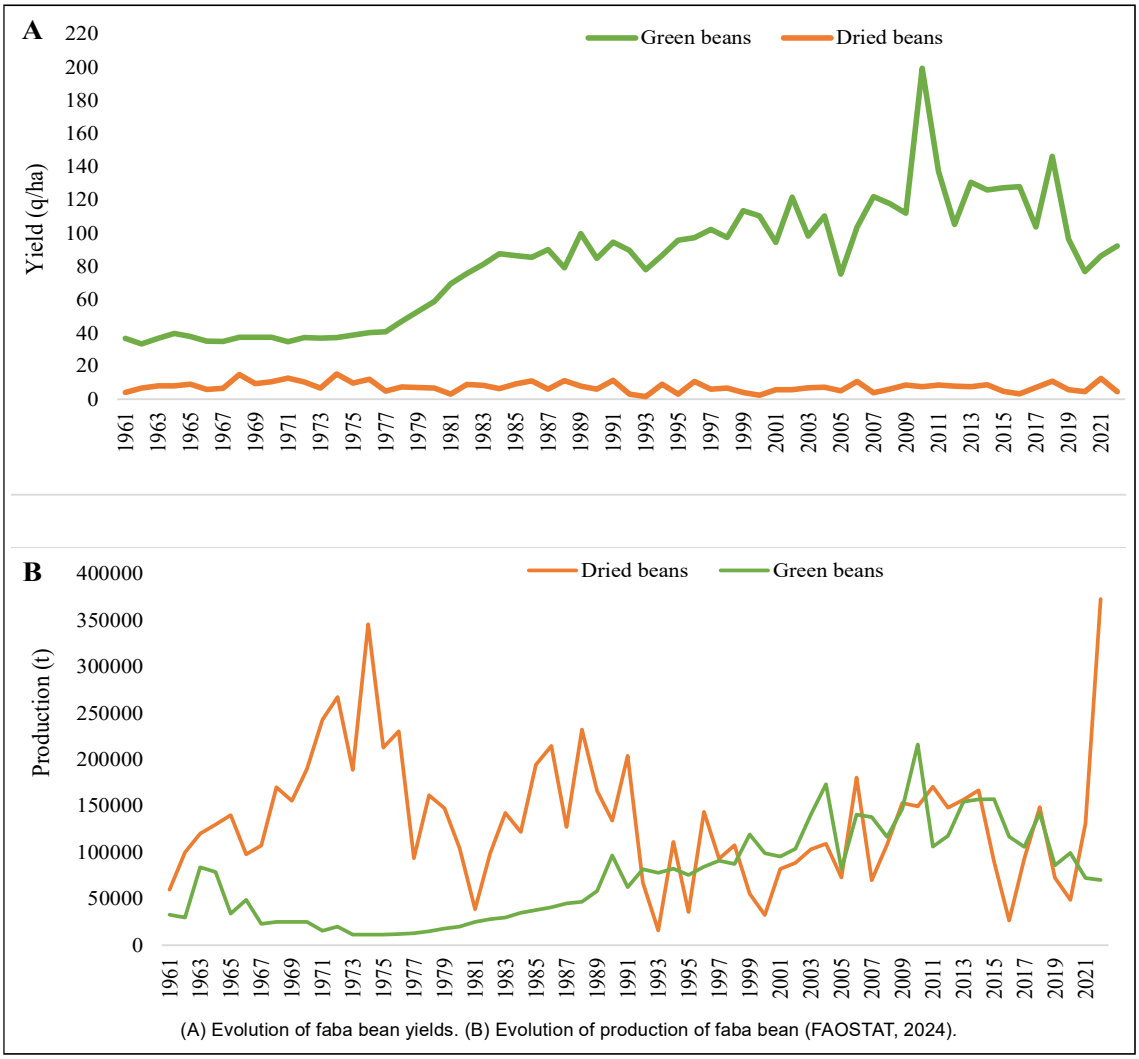
Harvested area data for faba beans and green beans in Morocco suggests varying production trends over the decades. The recent reduction in harvested area for both types of beans may reflect changes in farmer preferences, environmental challenges, or market opportunities. It is crucial to carefully monitor these trends to adapt agricultural strategies and meet market needs while ensuring sustainable management of agricultural resources.

Yield and production

Analysis of Morocco's faba bean yields over 61 years reveals distinct patterns for dry and fresh green beans. Dry bean yields average 7.56 q/ha with high variability and no clear long-term increase (Fig 3A). This instability, despite technological advancements, indicates persistent production challenges. Green bean yields, however, increased from 36.67 q/ha in 1961 to 92.16 q/ha in 2022, averaging 85.51 q/ha. This disparity highlights the need for targeted dry bean cultivation interventions.

Factors affecting dry bean performance likely include drought sensitivity (Abid *et al.*, 2017), pest pressures (particularly *Orobanche crenata*) (Rubiales *et al.*, 2016), limited adoption of improved varieties and possible soil depletion (Dahan *et al.*, 2012). Morocco's dry bean yields (4.56 q/ha in 2020) fall significantly below the global average of 19 q/ha (FAOSTAT, 2024). Green bean production success demonstrates yield improvement potential with appropriate management and growing conditions, possibly including better irrigation access.

Analysis of *Vicia faba* L. production in Morocco from 1961 to 2021 shows significant trends (FAOSTAT, 2024).



(A) Evolution of faba bean yields. (B) Evolution of production of faba bean (FAOSTAT, 2024).

Fig 3: Evolution of yield and production of green and dry faba bean yields in Morocco between 1960 and 2022.

Dry bean production grew from 60,000 tons in 1961 to 267,170 tons in 1972. Green bean production increased from 33,000 tons in 1961 to 84,000 tons in 1963, due to expanded cultivation areas and increased market demand (Fig 3B).

The 1970s-1980s saw notable fluctuations. Dry bean production peaked at 345,490 tons in 1974 before declining to 38,790 tons in 1981. Green bean production remained relatively stable between 11,420 and 46,700 tons. From 1980 to 2010, both varieties showed stability with a slight upward trend. Dry bean production oscillated between 38,790 and 231,980 tons in the 1980s, gradually increasing to 166,680.3 tons by 2014. Green bean production recovered to 215,976 tons in 2010 after declining in the 1980s-1990s.

From 2010 to 2021, both types declined notably. Dry bean production reached 131,208.3 tons in 2021. Green bean production fluctuated significantly, ranging from 26,564.45 tons (2016) to 157,236 tons (2015). This decline coincides with the "Green Morocco" program implementation in 2010, which encouraged more lucrative crops and supported oilseed production to reduce oil imports (Ministry of Agriculture of Morocco, 2024).

These production trends reflect various factors: traditional agricultural practices, pest and disease pressures, lack of production valorization, market instability, climatic hazards, increasing production costs and insufficient agronomic research investment. Sustainable faba bean production in Morocco depends on effective crop management, variety diversification, climate change resilience and strategic alignment with market trends.

Exportations and importations quantities

Until the late 1970s, Morocco was the world's second-largest food legume exporter after the United States, exporting 1.2 million quintals. However, repeated droughts, biotic attacks, export suspensions and competition from Turkey, Australia, Mexico and Canada transformed Morocco from an exporter (1992) to a net importer (Ministry of Agriculture of Morocco, 2024).

Faba bean import and export data show significant changes over time (Fig 4) (FAOSTAT, 2024). In the 1960s, exports far exceeded imports, peaking at 107,714 t in 1974. From the 1980s, exports declined sharply, reaching zero in some years. Imports fluctuated moderately, with peaks in 1985, 1995 and 2020. The 1990-2010 period saw steady import growth. Recent years, particularly 2016, 2018 and 2020, showed exceptionally high imports, while exports remained relatively stable. In 2022, imports reached 23,227.39 t, while exports totaled 122.58 t.

These trends indicate significant changes in faba bean trade dynamics over decades, likely influenced by market demand, trade policies and agricultural conditions.

Exportations and importations values

Export and import values generally follow the trends in exported and imported quantities. In the 1960s-1970s, dried bean exports dominated, peaking at US$2,339,500 in 1973 (Fig 5A) (FAOSTAT, 2024). From 1973 to 1993, dried bean export values declined significantly, falling below US$100,000 in 1985. Between 1986 and 2022, values fluctuated with an overall downward trend, dropping from US$471,700 to US$20,500. Green bean exports, initially negligible, increased from 2013, reaching US$414,100 in 2021 and US$117,000 in 2022. This data shows a shift in export preferences from dry to green beans in recent years.

Import data were absent from 1960 to 1990, suggesting national self-sufficiency in dried bean production (Fig 5B) (FAOSTAT, 2024). From 1990 to 2015, import values fluctuated markedly, peaking at US$641,700

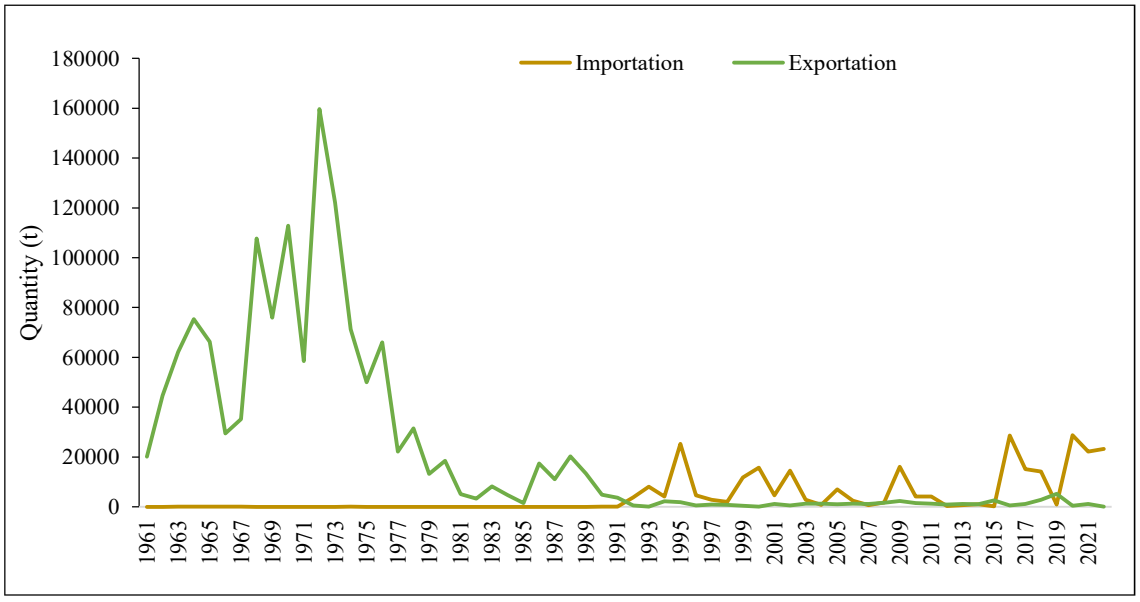


Fig 4: Evolution of imported and exported quantities of faba and broad bean in Morocco between 1960 and 2022 (FAOSTAT, 2024).

in 1995. Between 2015 and 2022, imports grew exponentially from US$28,900 to US$1,775,600. This trend indicates growing national market interest in dried beans, potentially influenced by changing dietary preferences, increased demand for plant-based proteins and evolving global trade dynamics.

Characteristics of Moroccan faba bean

Cultivated varieties

The official catalog of faba bean varieties encompasses 27 faba bean *major* and 10 faba bean *minor* varieties registered in List A. This list includes species and varieties whose seeds or plants are eligible for certification and marketing within Morocco or internationally (Table 1). However, one *major* faba bean variety is included in List B, designated for multiplication in Morocco for export purposes only. This brings the total number of faba bean varieties within the species to 38, which is comparatively low when contrasted with the number of varieties available for main rotation species such as cereals. For instance, durum wheat alone has 110 varieties registered, bread wheat has 94 and barley has 72 (ONSSA, 2024).

Nutritional proprieties

Research on Moroccan faba bean seed nutritional quality is limited. A comparative study analyzed nutrients and

Table 1: List "A" and "B" of bean varieties listed in the official catalog.

	Botanical variety	Variety - Code	Origine	Year of registration
List "A"	Faba bean *major*	Agrex very long pod	ACSGM	1985
		Agrex very early	ACSGM	1985
		Aguadulce supersimonia	ACSGM	1985
		Aguadulce very long pod	ACSGM	1985
		DeFes (111)	INRA MOROCCO	1985
		Extra early	ACSGM	1985
		Extra early with purple grains	ACSGM	1985
		Karabiga (f213)	INRA MOROCCO	1985
		Lobab (f269)	INRA	1985
		Riviera with purple grain	ACSGM	1985
		Superagrex	ACSGM	1985
		Carmen	SEMILLAS BATTLE	2002
		Acualonga	SEMILLAS BATTLE	2002
		Superlonga	AGRIN	2003
		Reina mora	SEMILLAS FITO	2004
		Reina blanca	SEMILLAS FITO	2005
		Luz de otono	SEMILLAS FITO	2005
		Claro de luna	SEMILLAS FITO	2015
		Tanyeri	BIOTEK TOHUMCLUK	2016
		Sora (sifb0213)	SEMINNOV	2017
		Nour (sifb103413)	SEMINNOV	2017
		Comendador	ZAYIN TECHNOLOGY	2017
		Sifb0114	SEMINNOV	2018
		Hiba (fv1031)	INRA MOROCCO	2018
		Sofia	SEMILLAS FITO	2019
		Yasmine	INRA MOROCCO	2022
		Raeda	INRA MOROCCO	2023
	Faba bean *minor*	Alfia 17 (f317)	INRA MOROCCO	1986
		Alfia 21 (f321)	INRA MOROCCO	1986
		Alfia 5 (f305)	INRA MOROCCO	1986
		Alto	ETS TOURNEURS FRERES	1986
		Talo	ETS TOURNEURS FRERES	1986
		Icarus	SEED CO AUSTRALIA	1997
		Prothabon101	SEMILLAS BATTLE	2004
		Nejma (sifb0513)	SEMINNOV	2017
		Zina (fv705)	INRA MOROCCO	2018
		Vinicius (rutabon)	SEMILLAS BATTLE	2020
List "B"	Faba bean *minor*	Flep	COOP.AG.SANTA LUCIA	2000

antinutrients in dry seeds of six *Vicia faba* varieties: 'Karabiga', 'Alfia 321', 'Defes', 'Aguadulce', 'Alfia 317' and 'Lobab'. Results showed significant differences in dry matter (88.69-89.51%), ash (2.64-3.06%), crude fiber (8.92-12.33%), protein (25.26-28.54%), total sugars (0.40-0.71%) and reducing sugars (2.04-3.09 mg GE/g). Bioactive compounds were also evaluated: total phenolics (3907.27-4823.92 µg GAE/g), tannins (19.89-36.76 µg EC/g) and flavonoids (173.82-369.54 µg QE/g) (El Kabous *et al.*, 2022).

An older study of faba bean seeds from various Moroccan regions found mean values per 100 mg: 3.1 mg ash, 123 mg Ca, 327 mg phosphorus, 146 mg Mg, 1298 mg K, 28.2 mg Na, 5.6 mg Fe, 2.81 mg Zn, 1.22 mg Cu, 37 ìg Cr and 46 ìg Pb (Sika *et al.*, 1995).

A recent study evaluated Moroccan faba bean pod extracts' nutritional quality (Kalili *et al.*, 2022). The results revealed that these pods, traditionally integrated into the diet, are rich in macro and micronutrients as well as bioactive substances, thus highlighting their potential contribution to the human diet and nutritional security. Fresh bean pods contained 87.31±0.25% moisture, 4.67±1.03% ash and 29.11±3.20 g/100 g protein, with notable amounts of potassium (1946.8±4.61), phosphorus (483.8±3.14) and calcium (399.6±2.25) mg/100 g.

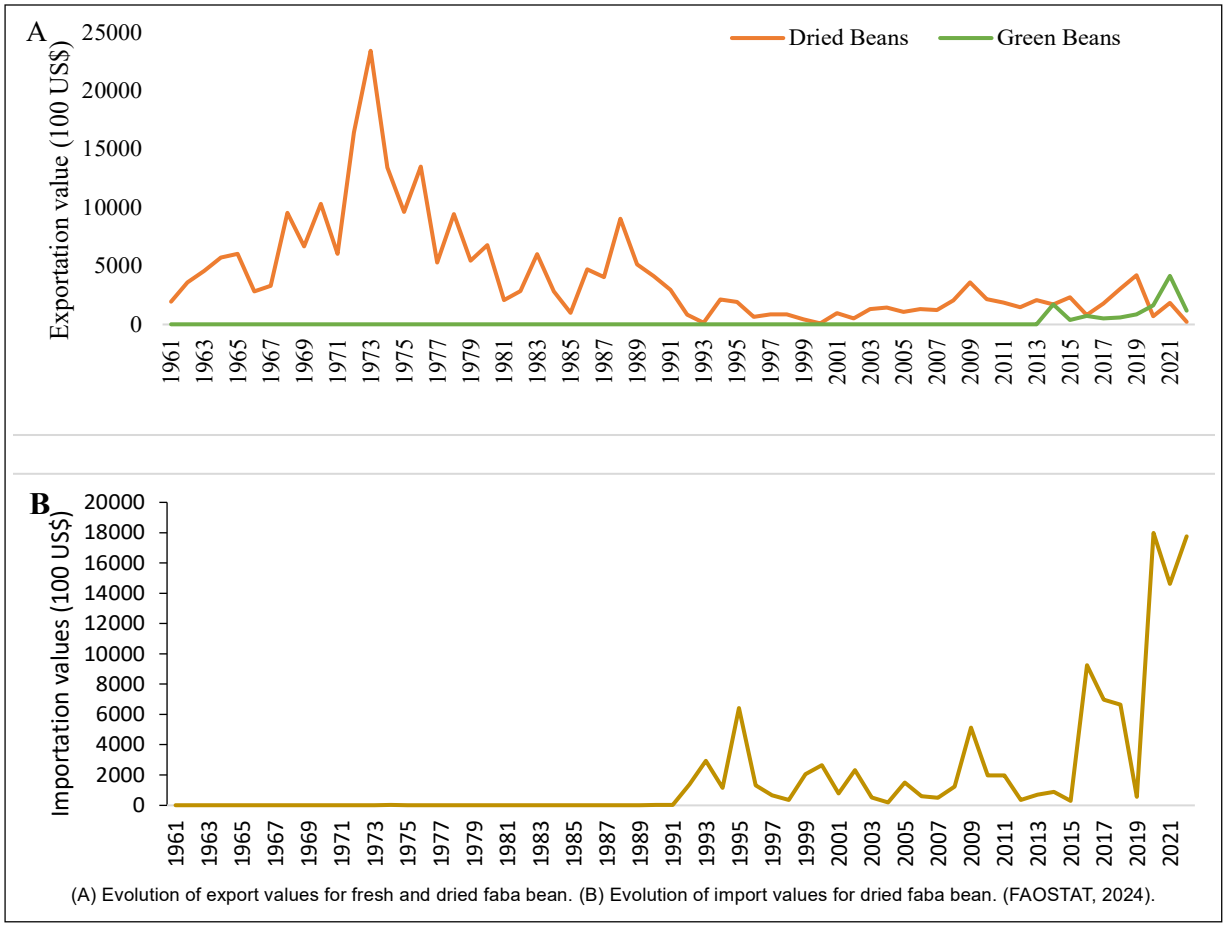
Extract content varied: 49.5-594.4 mg GAE/g for total phenols, 0.7-3.4 mg QE/g for flavonoids and 4.9-73.91 mg TAE/g dry weight for tannins. Antioxidant activity evaluation revealed optimal activity (IC_{50}=491.2-642.67 µg/mL) in various extracts.

Challenges in faba bean cultivation

Disease and pests

Faba bean suffers from numerous pests and diseases, including rust (*Uromyces fabae*), chocolate spot (*Botrytis fabae*), ascochyta blight (*Ascochyta fabae*), faba bean zonate spot (*Cercospora zonata*), faba bean root rot (*Fusarium solalli*), faba bean galls (*Olpidium viciae*), faba bean beetle (*Brnchus rnfimanus*), medic aphid (*Aphid medicaginis*) and faba bean root nodule weevil (*Sitona amurcnsis*). Additionally, the adverse impacts of climate change further exacerbate these issues, underscoring the urgent need for effective management strategies.

In Morocco, fungal diseases like chocolate spot (*Botrytis fabae*) and ascotchyta blight (*Ascochyta fabae*) were once significant threats to faba bean crops, particularly in cooler regions where spores survived between seasons. Continuous faba bean cultivation leads to the accumulation of plant residues in fields, escalating



(A) Evolution of export values for fresh and dried faba bean. (B) Evolution of import values for dried faba bean. (FAOSTAT, 2024).

Fig 5: Evolution of faba bean (*Vicia faba* L.) trade values in Morocco, 1960-2022.

disease inoculum levels and facilitating rapid disease spread, especially in cooler production regions where uredospores act as crucial survival mechanisms between cropping seasons (Shifa *et al.,* 2011). However, with Morocco's climate shifting towards hotter and drier conditions, these previously prominent diseases are now less prevalent. This shift in climate has favored the escalation of new challenges. Pests like aphids and pod borers thrive in low humidity and are further spurred by rising temperatures, leading to earlier infestations. Studies have established a direct link between higher spring temperatures and earlier aphid hatches (Li *et al.,* 2003; Shi *et al.,* 2014; Wilkaniec *et al.,* 2016), intensifying pressure on faba bean cultivation, especially with earlier flowering now occurring as early as February. Moreover, the ongoing climate change, characterized by rising temperatures and erratic precipitation patterns, is expected to heighten the susceptibility of faba beans and promote the development of rust disease (*Uromyces fabae*) (Terefe *et al.,* 2016).

Weed

Faba bean is very sensitive to weed competition (Wakwey et Dargie, 2017). Weed infestation is a major constraint in production and can reduce yield by up to 50% (Karkanis *et al.,* 2018) and even up to 80% (El-Metwally and Dawood, 2017).

In 2001, Tanji identified a total of 191 weed species in 25 rainfed faba bean fields (Tanji, 2001). Among these, 169 species were dicotyledons, representing 88% of the total and 166 species were annuals, making up 87%. Additionally, seven perennial monocotyledons and 18 perennial dicotyledons were observed. The 22 monocotyledon species were classified into five families: *Poaceae* (15 species), *Liliaceae* (3), *Araceae* (2), *Cyperaceae* (1) and *Juncaceae* (1). The 169 dicotyledons belonged to 32 families, with the most species-rich families being *Asteraceae* (41 species), *Fabaceae* (23), *Brassicaceae* (14), *Caryophyllaceae* (12) and *Apiaceae* (12). On average, each field contained 45 weed species, with a range of 28 to 63 species per field. This diversity illustrates the rich flora in faba bean fields without adequate weeding (Tanji, 2001).

In a study on weeds in faba bean fields during 2018-2019 growing season, researchers identified a diverse range of weeds (Boutagayout *et al.,* 2020). Over 20 different species were found, belonging to 13 distinct plant families. Broadleaf weeds (dicots) were the most common type, with species like *Polygonum aviculare* and *Papaver rhoeas* being particularly dominant. Grasses (monocots) were less prevalent, with only two species identified. Interestingly, the *Asteraceae* family, had the most representatives in the field, followed by the *Fabaceae* family (Boutagayout *et al.,* 2020). These findings underscore the significant weeding challenges faced by farmers. In fact, Zimdahl *et al.* (1992) found that small farmers spend 124 hours weeding one hectare of faba beans, compared to 35 hours per hectare for medium-sized farms and 46 hours per hectare for large farms. Chafai Elalaoui (2000) observed that a single manual weeding with a hoe requires an average of 39 hours of male labor per hectare. Despite these efforts, many weeds remain associated with the crop until maturity.

Chemical weed control in food legumes is challenging because selective herbicides do not effectively control dicotyledonous weeds. Several herbicides can be applied after sowing but before crop and weed emergence (Baye, 2012; Tanji, 2013; Bouhache and Benmansour, 2014; Baye, 2015; Tanji, 2015). These herbicides act on the seeds of germinating grass and broadleaf weeds under specific application conditions, including adequate soil moisture, well-worked soil (in the case of tillage) and properly adjusted application equipment. Irrigation or rainfall after application may improve the effectiveness of these treatments (Hajjaj *et al.,* 2016).

Beyond weeds, broomrapes, particularly *Orobanche crenata*, a parasitic weed, pose the most significant threat to faba bean cultivation, with substantial economic and agricultural impacts. In Morocco, the infestation has escalated from 12% in 1981 to 51% in 2003, resulting in average yield losses of 37.4% in 1998 (Labrada, 2008). The infestation forced farmers to abandon cultivation of heavily infested crops, thereby restricting rotation choices and negatively affecting both food security and local economies. Consequently, the Moroccan government imposed a regulation in 1992 to prevent faba bean export to ensure food security (Labrada, 2008).

The severity of broomrape infection is highly influenced by environmental factors such as temperature and soil moisture, as well as the density of the parasitic seedbank (Fernández-Aparicio *et al.,* 2016). In fact, the seeds can remain viable in the soil for over ten years, creating a persistent seed reservoir. A single Orobanche plant produces up to 100,000 seeds, facilitating rapid re-infestation and making it challenging to cultivate host crops continuously (Musango *et al.,* 2022; Labrada, 2008). According to established equations for yield loss estimation, an average presence of four broomrapes per plant can reduce the yield by half (Mesa-García and García-Torres, 1991; Fernández-Aparicio *et al.,* 2016). Moreover, crenate broomrape, now further accelerated by elevated temperatures, complicates the plight of legume farmers. Climate change scenarios, including rising temperatures and increased drought stress, are predicted to create a favorable environment for crenate broomrape growth, while simultaneously weakening host crops (Mohamed *et al.,* 2006). Interestingly, soil moisture plays a complex role in this dynamic. While moderate soil moisture levels can favor parasite infection (Pérez-de-Luque *et al.,* 2016), Parker (2014) suggests that crenate broomrape can inflict even greater damage under moisture stress and poor soil conditions, factors likely to become more prevalent with climate change. This vulnerability is likely exacerbated by low atmospheric humidity, which increases transpiration

rates in host plants, potentially enhancing the movement of water and nutrients towards the parasite (Parker and Riches, 1993). This potential synergy between climate-driven environmental stress and increased parasite virulence highlights the need for effective control strategies. While various control methods have been explored (Abbes *et al.,* 2019), none offer complete success. Chemical control using glyphosate is a common practice, but its effectiveness is limited. Thus, breeding for resistance is considered the most promising approach due to its economic and environmental benefits (Amri *et al.,* 2019). Research has identified resistance sources in several crops, including faba bean, along with chickpea, sunflower and tomato (Kharrat *et al.,* 2010; Nefzi *et al.,* 2016; Amri *et al.,* 2019; Bai *et al.,* 2020; Cvejić *et al.,* 2020). However, developing resistant cultivars remains challenging due to limited resistance sources and the complex genetics involved, mainly because the low heritability of the genes and QTLs associated with that resistance (Pérez-De-Luque *et al.,* 2005; Amri *et al.,* 2021).

Drought

Faba bean requires consistent soil moisture throughout its growing cycle for optimal development. Regular water supply, either through well-distributed rainfall or irrigation, is crucial, especially during flowering and pod formation stages (Loss and Siddique, 1997). Water requirements peak about 9-12 weeks after germination (Subash and Priya, 2012). Compared to other legumes like common bean, pea and chickpea, faba beans show particularly high sensitivity to drought (Basheer-Salimia *et al*., 2021), making them unsuitable for severe drought regions despite their high protein content. The crop is especially vulnerable during its critical growth stages of flowering, podding and grain filling (Karkanis *et al.,* 2018).

While early-season drought is problematic, it is less detrimental compared to terminal drought (Chetto *et al.,* 2024). Interestingly, unlike small-seeded crops such as wheat and rapeseed, which require minimal moisture to germinate, faba bean seeds can remain dormant in the soil until sufficient moisture is available for germination and growth. This characteristic means that early-season drought may force cereal farmers to reseed, leading to significant increases in production costs, while faba bean farmers might avoid this issue.

In the Middle East and North Africa (MENA) region, Marrou *et al.* (2021) demonstrated that in the driest areas (receiving less than 200 mm of rainfall during the growing season), applying just 50 mm of supplemental irrigation could reduce the risk of crop failure by up to 34% and increase yields sufficiently to meet average farm household needs. For more humid areas, the same amount of irrigation could boost faba bean yields by up to 1 ton per hectare, a significant increase compared to the average yield of 3.5 tons per hectare. Importantly, the study found that restrictive irrigation (providing only 50 mm of water) was nearly as effective as full irrigation in most cases.

Labor costs

Faba bean cultivation is labor-intensive, as it involves several manual processes: sowing, weeding, harvesting and threshing. This reliance on manual labor significantly contributes to the crop's demanding nature in terms of workforce. Over the years, the cost of labor has increased, yet the profitability of faba bean cultivation has not improved. On the contrary, the cost of farm inputs has risen along with abiotic and biotic challenges, further straining the economic viability of this crop.

In Morocco, the Daily Guaranteed Minimum Wage for agricultural workers (SMAG) has increased from 66.56 MAD/day ($6.70) in 2014, to 73.22 MAD/day ($7.37) in 2019 (Achour et Chafik, 2019) and was approved to rise to 88.58 MAD/day ($8.91) in 2023 (Bulletin Officiel, 2022). This increase in labor costs is a significant burden for farmers, especially when compared to neighboring countries in the MENA region. For example, in US dollar terms, the monthly minimum wage in Morocco stands at approximately $287, which is substantially higher than in Egypt ($142.5), Jordan ($176) and Algeria ($231) (Danish Trade Union Development Agency, 2020).

Strategies and perspectives for overcoming challenges in faba bean cultivation in morocco

One of Morocco's most important strategies for addressing climate change and drought is the adoption of no-till systems, to convert 1,000,000 hectares of cereals to no-till by 2030 as part of the Green Generation 2020-2030 initiative (Moussadek *et al.* 2024). However, crop rotation in no-till systems presents challenges, particularly in selecting seeds compatible with the same no-till machinery used for sowing cereal seeds. To support the one million-hectare no-till expansion, it is necessary to breed small-seeded varieties of faba bean and other legumes to maintain proper rotation and soil health. While no-till systems favor small-seeded varieties due to their compatibility with existing machinery, large-seeded cultivars like 'Sbaai' and Aguadulce remain popular in northern mountainous regions for their fresh market value (Yigezu *et al.,* 2019). To address this diversity in needs, the Moroccan catalog could benefit from adopting regional/agroecological varieties rather than relying on national averages. Additionally, it is essential to consider developing and registering open-pollinated and synthetic varieties in the national catalog, instead of the pure lines. In fact, research has shown that such varieties often outperform pure lines (Maalouf *et al.,* 2018; Chetto *et al*., 2023). By including these diverse options, the catalog can better meet the specific needs of different regions and agricultural practices, enhancing resilience and productivity in varying environments.

To address the significant threat posed by crenate orobanche in faba bean cultivation, a comprehensive approach is essential. Extensive screening of accessions, landraces and lines for tolerance should be conducted in both controlled and field environments to account for the

parasite's environmental dependence (Fernández-Aparicio *et al.,* 2016). Developing herbicide-resistant varieties, such as the imazapyr-resistant PBA Bendoc developed through EMS mutagenesis in South Australia (Mao *et al.,* 2019), can significantly reduce cultivation costs and enhance profitability. Given the efficacy of imidazolinone herbicides in controlling Orobanche (Labrada, 2008), integrating these technologies alongside breeding efforts to enhance tolerance is beneficial. Considering the critical attributes conferred through mutagenesis, this approach should be prioritized for rapid enhancement.

Genetic improvement offers significant opportunities to address drought and other climate change challenges. Strategies include exploiting genetic diversity, marker-assisted and genomic selection, gene editing, root system architecture improvement and physiological trait-based breeding. The recent publication of the first high-quality faba bean genome sequence marks a milestone, opening new avenues for crop improvement through enhanced understanding of genetic mechanisms and more efficient breeding programs (Jayakodi *et al.,* 2023).

To further advance faba bean cultivation in Morocco, several complementary strategies offer promising opportunities. Value chain development can improve market access and profitability for farmers. Precision agriculture techniques can optimize resource use and increase yields (Gebbers and Adamchuk, 2010), while farmer participatory breeding ensures that new varieties meet local needs and preferences (Ceccarelli and Grando, 2020). Implementing climate-smart agricultural practices can enhance resilience to environmental stresses (Lipper *et al.,* 2018) and biofortification can increase the nutritional value of faba bean, addressing malnutrition concerns (Bouis and Saltzman, 2017).

The integration of the aforementioned approaches with a comprehensive integrated pest management (IPM) strategy is important for optimizing faba bean cultivation. This IPM strategy should synergistically combine genetic resistance mechanisms, judicious application of chemical controls and culturally appropriate agronomic practices, all adapted to local agroecological conditions (Stoddard *et al.,* 2010). To ensure the efficacy and sustainability of these initiatives, it is imperative to maintain a robust continuum of research and development, coupled with extensive knowledge dissemination through farmer education and training programs. Moreover, the implementation of supportive policy frameworks and strategically designed economic incentives is crucial to mitigate adoption barriers and promote sustainable agricultural practices. The successful execution of this multifaceted approach has the potential to revitalize faba bean cultivation in Morocco, thereby enhancing agricultural biodiversity, strengthening food security and promoting environmental sustainability in alignment with national agricultural objectives.

Conclusion

In conclusion, the faba bean sector in Morocco faces multifaceted challenges that hinder its growth and stability. While historically significant to the country's agricultural landscape and dietary diversity, the sector now faces declining cultivated areas, exacerbated by international market volatility, adverse climatic conditions and persistent pests and diseases such as crenate broomrape, weeds and fungal infections. These obstacles are further amplified by the effects of climate change, including drought, alongside the absence of mechanization in critical operations like sowing, weeding, harvesting and threshing, which not only necessitates substantial labor inputs but also escalates production costs, making the crop less profitable for farmers. This review underscores the urgent need for a comprehensive approach to revitalize Morocco's faba bean sector. Priority should be given to developing Moroccan varieties resistant to *Orobanche crenata* and tolerant to drought, leveraging the recently sequenced faba bean genome to accelerate breeding programs. These efforts should also anticipate and address emerging pest pressures associated with the changing climate. Concurrently, research should focus on reducing labor-intensive practices through improved mechanization and the development of herbicide-resistant varieties, offering more efficient weed management options. By addressing both biotic and abiotic stresses through genetic improvement and agronomic innovations, Morocco could enhance the resilience and productivity of its faba bean crop.

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Conflict of interest

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