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Breeding and Genomics Status in Faba bean (*Vicia faba* L.) Production: Review Article

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Abstract

The production of the faba bean, a crucial legume crop, increased by 21% in 2014 despite a decline in its global acreage. Nutrients, protein, and bioactive compounds abound in its seeds. The foundation of Ethiopia's faba bean (Vicia faba L.) breeding program is the diversity of exotic germplasm that was primarily introduced from local collections (PGRC/E) of native landraces and ICARDA. Creating improved, high-yielding cultivars suitable for high- and mid-altitude environments is the main goal of breeding. In addition to desired agronomic and seed quality characteristics, the specific breeding objectives were based on the biological, biotic, and abiotic constraints that Ethiopian faba bean production faces. To lessen genetic vulnerability, variant releases should have a wider genetic basis.

Keywords: Plant breeding; Faba bean; crops.

1. Introduction

The faba bean, or Vicia faba L., is one of the most significant legume crops in the world. Between 1980 and 2014, its global acreage decreased to 2.1 million ha, and yields within individual countries vary greatly [20]. 4.1 million tons of faba bean grain were produced worldwide in 2014, a 21% increase from 1994 [20]. Human consumption involves both fresh and dry faba bean seeds, which are very nutritious due to their high protein content (up to 35% in dry seeds) and good source of various nutrients, including K, Ca, Mg, Fe, and Zn [1, 2]. Soil fertility is increased when faba beans are incorporated into cropping systems. Because of its great effectiveness in creating symbiosis with particular Rhizobium bacteria and the resulting biological nitrogen fixation (BNF), arable lands require less fertilizer input and have higher soil biological activity [16].

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The main obstacles to the commercial production of faba beans are outlined, along with an overview of their resilience to various abiotic stresses and cultivation techniques that could increase their yield and nutritional value. It is stressed how crucial it is to search for and develop new cultivars with heightened resistance to biotic and/or abiotic stress. High self-fertility selection may be a significant benefit for streamlining breeding and advancing seed production technology.

Ethiopia's faba bean (Vicia faba L.) breeding program is built on the diversity found in the local collections (PGRC/E) of native landraces and exotic germplasm that was primarily introduced from ICARDA. Creating improved, high-yielding cultivars that are suited to high- and mid-altitude environments is the main goal of breeding. In addition to desirable agronomic and seed quality characteristics, the specific breeding objectives were based on the limitations facing Ethiopian faba bean production, including biological, biotic, and abiotic constraints. To mitigate genetic vulnerability, varietal releases should have a wider genetic base. The Ethiopian faba bean improvement program's future directions are suggested.

Aiming to increase productivity, the Ethiopian pulse research program has released several improved pulse cultivars, including 34 faba bean cultivars [8,37]. Farmers hardly ever use certified improved seeds, even with the widespread release of improved cultivars. In 2010, improved seeds covered only 3.5 percent of the total yearly arable land coverage by major food crops [7]. In a similar vein, it was discovered that during the 2017–18 growing season, improved seed was only used on 0.8% of the total area planted to pulse crops. The limited use of improved faba bean seed can be attributed to a number of factors, including the inefficient and ineffective seed industry, the unavailability of quality seeds at the appropriate time and location, and inadequate promotion systems [7].

Objective

To review the current breeding and genomics status in fababean variety development.

To recommend the future perspective on the basis of this review.

2. Literature review

2.1. History, Origin, And Distribution

The family Fabaceae includes the genus Vicia L. There is little and conflicting information regarding the genus's wild progenitor, its place of origin, and the subsequent stages of the domestication of its most significant member species, V. faba L. According [12], the Near East is the faba bean's center of origin, whereas China appears to be a secondary center of genetic diversity in faba beans 65. [45], found seeds of a possible faba bean ancestor close to Mount Carmel, Israel; the remains were C-dated to 14,000 years BP (before present), which lends support to Cubero's findings. Furthermore, [46] found that in the Lower Galilee of Israel, the faba bean was already domesticated approximately 10,200 years ago. All things considered, faba beans can be regarded as among the first domesticated crops because of a number of early Neolithic archeological discoveries made in Africa and Eurasia [24].

There is a lot of genetic diversity in Vicia faba. Over 38,000 accessions of faba bean germplasm are conserved worldwide in multiple gene banks and at the International Center for Agricultural Research in Dry Areas (ICARDA), according to [18]. Numerous additional genotypes may be locally available in Europe at farms and in breeders' collections, according to research conducted by the EUROLEGUME consortium [38]. Numerous investigations and marker systems have evaluated the genetic diversity of V. faba accessions [5,24]. It is difficult to achieve a distinct differentiation between varieties in practice, as most morphological, (eco-) physiological, and chemical traits exhibit continuous variation. According to a study by [34], genotyping faba beans using multiple barcoded samples and NGS (next-generation sequencing) is a workable technique. The distance matrix produced by the author reveals that although some V. faba clades were formed exclusively by accessions from a particular nation, others were interspersed, suggesting that genetic and geographic distances are not always correlated.

2.2. Morphological Description and Botanical Characterization

The faba bean is an annual legume of the cool season that grows to a height of 0.1 to 2 m. It forms coarse, upright, hollow, and unbranched stem(s) from the base [18, 24]. There is no set rate for stem growth, and certain cultivars are more likely to lodge. The pinnate, alternating leaves have two to six leaflets that can reach a maximum length of eight centimeters without the need for tendrils. The flowers are grouped in inflorescences and have a characteristic papilionaceous structure. They can be pure white or have diffuse anthocyanin pigmentation on all petals, with black spots frequently seen on the wing petals [18, 24]. The seeds are oblong to broadly oval in shape, with a prominent hilum at the end. They can be yellow, green, brown, black, or violet in color, and occasionally they have spots [18]. Faba bean plants have a strong taproot that frequently branches out into lateral roots from the top; both the tap and lateral roots have rhizobia-containing nitrogen-fixing nodules.

Although most faba beans are thought to be day-neutral, certain accessions need long days in order to flower. However, thermal time—roughly 830–1000°C days above 0°C are necessary for faba bean flowering to progress—is the most significant factor; winter faba bean genotypes necessitate vernalization. Bodner [23] have reported 650°days and a 0°C base temperature prior to flowering for cropping systems in northern Europe; this may indicate a photoperiodic sensitivity to long-day conditions in faba beans.

2.3. Adaptability of Faba Bean to Abiotic Stress

In Europe, heat and drought are regarded as the two main obstacles to faba bean growth and production. The degree to which faba bean varieties withstand drought varies greatly [19]. Proline accumulation is one of the mechanisms that distinguish drought-tolerant genotypes or varieties [5, 22]. Recent studies, however, have identified some frost-tolerant genotypes, which could be used in breeding programs.

Of the cool-season grain legumes, faba beans are thought to be the most resilient to flooding. Furthermore, at salinity levels of 80 and 120 mM NaCl, respectively, nitrogen accumulation in the shoots decreased by 36 and 63%. Pseudomonas fluorescens inoculation or the foliar application of silicon are two methods used to mitigate the detrimental effects of salinity on faba bean plants [43]. There are genotypes of faba beans that are tolerant to salinity; one such genotype is "VF112," which has been described as salt-tolerant due to the fact that salt stress did not affect its growth or ability to fix nitrogen.

2.4. Agronomy

2.4.1. Crop Sowing and Rotation

In regions of Europe with mild winter temperatures,faba beans are typically planted in the fall. To avoid frost damage, sowing is delayed until the end of winter or early spring in cooler agroclimatic zones [6, 15]. The earliest varieties can be sown at the end of summer in some parts of the Mediterranean Basin, with the goal of harvesting them by the end of autumn [11].

Moldboard plowing (20–40 cm depth) and harrowing are the primary tillage operations during the sowing period. Light duty plowing, which is typically done with a rotary tiller, comes next. Reduced tillage and no-tillage are also effective substitutes for conventional tillage in faba bean crops, according to several studies [10,13].

When used as a break crop in cereal production, faba beans have been shown to increase the yield and seed protein content of subsequent cereal crops when rotated with cereals [66]. In some Mediterranean countries, faba beans are also included in vegetable crop rotations; for example, they can be used as a pre-crop of some summer crops, like those in the Cucurbitaceae or Solanaceae families. Adekiya [3] state that adding faba beans to rotation systems can also improve the physical properties of the soil, maintain soil fertility, and break the cycles of disease and pests.

2.4.2. Soil Fertilization and Inoculation

Although "starter" nitrogen fertilization at a rate of 20 kg ha-1 does not always seem to be necessary, it does appear to facilitate the nodulation process in faba bean plants. Furthermore, the production of legume BNF uses a lot of energy and phosphorus (P). Accordingly, fertilizing with phosphorus at a rate of 40 kg ha-1 can frequently improve the nodulation process, fix nitrogen, and raise yield. Numerous additional investigations demonstrate that faba bean crops react to S and K fertilization as well [11]. Deficits in micronutrients, such as zinc and boron, are uncommon and are readily remedied with foliar sprays. However, because faba beans are grown as a low-input crop, S and K fertilizers are rarely used. Moreover, deficiencies in micronutrients, such as zinc and boron, are uncommon and are readily remedied with foliar sprays.

It is not necessary to inoculate faba bean fields or seeds with Rhizobium in traditional cultivation areas. In regions where faba beans or other legumes have not been grown for a number of years, it is prudent to test the soil for their presence. It has been reported that, especially in alkaline soils, dual inoculation with Rhizobium and arbuscular mycorrhizal fungi is more effective than Rhizobium alone for promoting faba bean growth. This finding is likely due to the synergistic relationships between the two inoculants [32].

2.4.3. Irrigation

Except for crops grown in extremely arid and hot climate zones, beans are typically grown without irrigation. The production faba bean is thus highly dependent on the quantity and variation of rainfall during the growing season. Given that faba beans are sensitive to drought [40] climate change may have an impact on the growth and efficiency of water use in semiarid regions [17, 25]. If faba bean cultivation occurs during the cold season, it may be feasible to produce beans without irrigation in the Mediterranean region and other arid and hot climate zones. Alternatively, to prevent yield penalties during drought, faba bean crops can be irrigated at the seed filling stage. Furthermore, [10] note that irrigating spring crops during the flowering stage and early podding usually increases faba bean production. For faba bean dry biomass production to reach 3–4.4 t ha-1, 231–297 mm of water are needed. One of the main obstacles to reaching higher and more consistent production levels is the creation of faba bean varieties resistant to drought [26]. In breeding programs, a number of genotypes that are thought to be drought-tolerant can be used to create drought-tolerant cultivars [8, 31].

2.4.4. Weed Control

A significant impediment to faba bean production is weed infestation, which can cut yield by as much as 50% [4]. Consequently, in order to achieve a high yield, weeds must be removed as soon as possible, ideally between 25 and 75 days after sowing. The broadleaved species Anthemis arvensis L., Chenopodium album L., Papaver rhoeas L., Sinapis arvensis L., Fumaria officinalis L., Veronica spp., Lamium amplexicaule L., Cirsium arvense (L.) Scop., and the grass species Avena sterilis L., Phalaris spp., Lolium rigidum Gaud., and Alopecurus myosuroides Huds. are the 12 main weeds that compete with faba bean in Europe, much like other winter pulse crops and cereals. Furthermore, Orobanche crenata Frosk, also known as bean broomrape, is the primary species infesting faba beans in this region.

Because of its more vigorous early growth and larger plant height, the faba bean outperforms other pulse crops, like chickpea, in terms of weed competition [4]. However, one of the main strategies used in conventional faba bean production to manage weeds is the application of herbicides. To the best of our knowledge, the European Union has registered the herbicides bentazon, pendimethalin, clomazone, quizalofop-p-ethyl, and propaquizafop for use on this crop. Quizalofop-p-ethyl and propaquizafop are applied post-emergence to control grass weeds like Phalaris spp. and Lolium spp., while bentazon is applied post-emergence to control broadleaved weeds. The first two are applied pre-emergence to control both grass and broadleaved weeds. In fields where aminopyralid (pyridine carboxylic acids) and chlorsulfuron (sulfonylureas) have been applied previously, residual herbicides can harm faba beans planted there.

For the time being, the best way to stop broomrape infestation seems to be to develop resistant faba bean varieties.

2.5. Disease and Insect Management

2.5.1. Diseases

Fava bean crops are particularly vulnerable to fungal diseases, particularly during rainy seasons. The three primary pathogens affecting faba bean crops worldwide are rust, chocolate spot, and ascochyta blight [2,47] One of the most dangerous pathogens, Ascochyta fabae Speg. (teleomorph Didymella fabae Jellis and Punithalingam) is the cause of Ascochyta blight, which can result in a 30% reduction in yield [43]. Integrated management techniques, such as crop rotation, the use of resistant varieties, and late sowing, are essential to successful control of ascochyta blight infection, even though the application of fungicides, such as azocystrobin and chlorothalonil, significantly reduces infection [43].

The fungi Botrytis fabae Sard. and Botrytis cinerea Pers. cause chocolate spot, and Uromyces viciae-fabae (Pers.) J. Schröt causes rust disease in faba beans. Yield losses from rust and chocolate spot infections can range from 22–42% and 36–68%, respectively. Procymidone is also very effective against B. fabae, and frequent applications of mancozeb [43], intercropping with cereals like barley, oat, triticale, and wheat, low crop density, and wide row spacing all reduce the severity of chocolate spot in faba beans.

2.5.2. Insects

Faba beans may become infested by a variety of insects. Aphids fabae Scop., commonly known as black bean aphids, are a common pest [29]. Aphids infest faba bean plants' new leaves [29]. Sprays of foliar insecticides, such as fenvalerate and thiacloprid, work wonders against these pests. The black bean aphid parasitoid Lysiphlebus fabarum Marshall (Hymenoptera) may be effective as a biological control [41]. According to [36], pea leaf weevil (Sitona lineatus L.) and broad bean weevil are additional insects that cause damage to faba bean crops. According to, S. lineatus adults feed on foliage, while larvae feed on faba bean and pea root nodules, which affects their capacity to fix nitrogen.

2.6. Harvest, Processing, Nutritional Value, and Use of Faba Bean

Faba bean crops cultivated for fresh seed consumption may be harvested either manually or mechanically once the pods are filled, but before they start to dry. Pods are harvested by hand two to three times during the harvesting period in crops cultivated in small areas for fresh consumption. When faba bean plants are cultivated for their dry seeds, they can be harvested using a conventional cereal combine harvester. Similar to other pulses, proper selection of the harvest stage is critical if seed loss is to be minimized; seeds should be harvested when the moisture content is 14–15% [33].

The seeds of faba beans also contain antinutrient substances. The primary processing techniques used to lower the concentrations of these chemicals in faba bean seeds and limit their harmful effects on human health are soaking, dehulling, boiling, pressure-cooking, autoclaving, and extrusion cooking [58].

Human health benefits from the consumption of plant-based proteins in diets [47]. Additionally, faba beans are an excellent source of amino acids, with up to 67 g kg-1 dry matter of the essential amino acids leucine, lysine, and arginine. The faba bean has been identified as having potential as a functional food because it also contains macro-, micro-, and non-nutrient phytochemicals.

3. Plant breeding for faba bean

3.1. Breeding for Resistance to Foliar Diseases

3.1.1. Ascochyta Blight

In many nations, including those in Europe, Canada, the Middle East, and Oceania, ascochyta blight is a deadly illness [48]. There have been reports of disease resistance sources, but the resistance mechanism appears to be complicated [39]. Two pathotypes of the fungus have been found in Australia, which worries breeders more. The availability of closely related molecular markers should make it feasible to pyramid multiple QTLs and increase resistance [48].

3.1.2. Chocolate Spot

Many types of chocolate spot-resistant faba bean varieties have been released by the Ethiopian Institute of Agricultural Research (EIAR). Through direct selection from ICARDA-supplied germplasm or by transferring high levels of resistance from ICARDA germplasm into locally adapted varieties, EIAR researchers were able to release several high-yielding faba bean varieties. The faba bean varieties "Moti" (ILB 4432 × Kuse-2-27-33), "Gebelcho" (ILB 4726 × "Tesfa"), "Obsie" (ILB 4427 × CS20DK), and "Walki" (ILB 4615 × Bulga 70) are among those that have been released with partial resistance to chocolate spot. More recently, 'Gora' (ILB2717-1 × R878-1), a variety with larger seeds and more resistance to chocolate spot than traditional cultivars, was released in Ethiopia, the annual rate of genetic gain resulting from the breeding efforts in these released cultivars was 8.07 g/1,000 seeds and −0.27% for chocolate spot severity. According to studies by [44, 48], gall disease can impact faba bean productivity up to 100%, rust disease up to 30%, and chocolate spot up to 61%.

3.1.3. Faba bean gall disease

Physioderma viciae, the cause of faba bean gall [35] is a relatively new disease that is currently common in Ethiopia. Olpidium viciae Kusano is not the cause, despite what was previously suggested. In Ethiopia, recent attempts have been made to determine which faba bean accessions are resistant to the novel Gall disease. "Degaga" and "Nc 58," two of the 14 cultivars examined in Ethiopian conditions, were found to have a moderate level of resistance to gall disease [49]. A recent focus of breeding programs has been to develop faba bean lines with multiple disease resistance [44]. These lines are currently used in the ICARDA breeding program to develop multiple disease resistant cultivars for target environments, despite the fact that most breeding programs concentrate on developing resistant genotypes for a single disease of economic importance [50].

3.1.4. Viral Diseases

The most common viral diseases that can infect faba beans are Faba bean necrotic yellows virus (FBNYV), Alfalfa mosaic virus (AMV), Bean yellow mosaic virus (BYMV), Broad bean mottle virus (BBMV), Broad bean stain virus (BBSV), Bean leaf roll virus (BLRV), and True broad bean mosaic virus (TBBMV). Since the majority of viral diseases are not host-specific, they can infect a wide range of plant species, which makes it possible for them to spread from one species to another throughout the seasons and survive.

Typically, insects like aphids and/or seeds are used as vectors for virus diseases. Although seeds can spread non-persistently transmitted viruses like BYMV and Pea seed borne mosaic virus (PsbMV), the spread of faba bean seeds in Australia is essentially nonexistent.The only method of managing viral diseases in plants is prevention, as once a plant becomes infected it cannot be healed. According to [37]. FBNYV is the main virus affecting faba bean production in North Africa and West Asia, causing up to 90% yield loss in Egypt. The most common viruses in Australia are BYMV, BLRV, and PsbMV, where viral diseases occasionally result in losses. But according to van Leur's personal communication, in 2020 BYMV reduced grain yields in northern New South Wales by as much as 70%. This indicates that BYMV poses a greater threat than fungi-related illnesses that are manageable with fungicides. Newer cultivars that are resistant to BLRV include "PBA Nasma" and "PBA Nanu" in Australia; however, effective resistance to BYMV has not yet been discovered.

3.1.5. Parasitic Weeds

The most practical way to decrease yield loss and weed seed bank over time is to use partially resistant cultivars and apply one to two sublethal doses of glyphosate during the flowering stage Faba bean crops in Mediterranean Europe, West Asia, and North Africa can be severely damaged by root-parasitic plants called Orobanche and Phelipanche (broomrapes); as a result, the crop area is drastically reduced [53]. These parasitic weeds are entirely reliant on their host plant and lack both chlorophyll and functioning roots. Orobanche crenata Forsk. and O. foetida Poir. are the most pernicious and common broomrape species that can infect faba beans [53]. Farmers are being forced to stop growing faba beans in many areas of the nation as a result of these weeds' ongoing ecological range expansion into Ethiopia and Sudan (Abebe and his colleagues 2013).However, there are some encouraging results with the finding of genotypes resistant to Orobanche [53].

In West Asia and North Africa, dodder (Cuscuta species), another stem parasitic weed, is beginning to pose a significant threat to faba beans and other legumes, alongside Orobanche. While none of the aforementioned lines are completely resistant to Orobanche, they will undoubtedly lessen the parasitic weed burden on faba beans.

3.1.6. Breeding for Heat Stresses

The main abiotic stresses that affect food legume crops, especially faba beans, are heat, drought, waterlogging, and frost. Faba bean plants are especially vulnerable to heat stress during their reproductive stage, as gametophyte damage results in high sensitivity and subsequent fertilization failure [10]. Furthermore, faba bean genotypes' yield components and yield can both be significantly reduced by terminal heat stress [2]. Similar to other legume crops, adverse effect results in the development of a small, short-stemmed crop with few branches and pods [50]. To increase faba bean sensitivity to heat stress, selection criteria could include traits like the number of pods and seeds that showed a strong and positive correlation with yield. Seven accessions were identified at ICARDA that had higher pod number, seed number per plant, and rate of pollen viability below 35°C [50].A major obstacle to the production of faba beans in semi-arid regions receiving rainfed conditions is terminal drought. The identification of early maturing genotypes that are suited for drylands with short rainfed periods and additional irrigation could yield substantial yield benefits. According to [33], two prevalent issues that restrict faba bean production in Ethiopia are acidity of the soil and waterlogging. The "Walki" variety, which was created for vertisol and wet environments, is becoming more and more well-liked in Ethiopia's central highlands.

4. Genomics

The possibility of expediting selection for complex traits is further enhanced by low-cost genome-wide genotyping and high-throughput phenotyping platforms. By definition, genomic selection is more of a black-box method than it is to examine and track genetic variation candidate gene by candidate gene and locus by locus. Instead, it concentrates on multigenic traits. Recurrent selection within base populations of allogamous crop species that are created as synthetic populations has demonstrated the utility of genomic selection [48]. Generally speaking, accuracy values for grain yield are less than heritability values (or their square roots) derived from multiple yield trials. Genetically estimated breeding values for single plants' grain yield or agronomic performance are far more accurate than the performance heritability of those same single plants. Genomic selection based on single plants is thus possible, and in particular, breeding cycles can be significantly shortened; the laborious process of creating and characterizing inbred lines can be moved from the selection and recombination stage of breeding to the cultivar-making stage. If a highly affordable genome-wide genotyping platform becomes available, then breeding faba beans can benefit greatly from genomic selection.

According to [21,38], proposed a two-part breeding strategy in which population improvement is the primary application of genomic selection. This approach could be a viable means of implementing genomic selection in faba beans. Genetic diversity and elite status are prerequisites for the breeding population, or breeding germplasm. Owing to the partial allogamy, the individuals exhibit a degree of heterozygosity. There are many (representative) individuals in this genotyped population. Rather than using plants for genotyping, [44] report that genotypic data are used to predict varietal ability or line per se performance (see above). In between chipped seeds, selection is made appropriately.

After that, only the chosen chipped seed is sown as a new generation of the breeding population. It is then allowed to continue growing in accordance with its spontaneous, partially allogamous mode through open pollination without going through any sporadic phases of phenotyping, multiplication, or inbreeding. Once more, selection is used, a sizable, representative sample of offspring (seed) from this population is genotyped, genomic estimated values are predicted, and so on. "Cultivar development" or "product development" are two terms that can be used to describe the process of generating inbred lines from the most promising, selected individuals [21].

The faba bean's partially allogamous nature provides the recombination required for self-fertilization, which is necessary for the synchronous and cost-free production of inbred material for cultivar development, and for the fast-cycling recurrent selection. The only requirement to enter the cultivar development with inbred lines is to use genotyping to determine the degree of inbreeding in the breeding population (the population subject to

recurrent genomic selection) and identify the more inbred individuals. The fast-cycling population's individuals need to be genotyped regardless of genomic selection, and as a byproduct, the population's inbred levels rise. The degree of genetic improvement realized in the recurrent population improvement is transferred by the inbred individuals that enter the cultivar development pipeline.
Both phenotypic and genomic selection will be used in cultivar development.
An index value derived from phenotypic data and estimated genomic data will be used to determine selection.
The plan would resemble both synthetic and conventional line breeding quite a bit.
The moment an inbred individual enters the cultivar development process, the maintenance breeding would begi n.
A foundational resource for faba bean research to accelerate genetic gain will be the creation of a reference geno me. Genetic gain will also be accelerated by integrating genomic knowledge with other breeding tools and platfo rms, which will speed up the breeding process and enhance genetic gain for faba beans. Translational research w ill necessitate cooperation and understanding between scientists in the lab and the field, who can act as a bridge between basic research and applied plant breeding.

5. Summary and future perispective

The growth of faba beans will impact cropping schemes that include other pulse crops, necessitating a coordinated breeding strategy utilizing advanced genetic technologies for maximum genetic gain. Improved faba bean technologies aim to boost farm profitability by developing high-yielding, nutritious varieties resistant to pests and climate-smart cultivars. Utilizing biotechnological techniques like marker-assisted selection accelerates breeding cycles, but quantitative trait loci studies have not gained widespread acceptance due to genetic diversity.

Genetic diversity in faba bean accessions is linked to their ecological habitat and geographic origin, indicating a gradual process of diversification and differentiation. Breeders focus on improving these beans through plant breeding techniques, using genetic behavior to resist biotic and abiotic factors.

Abbreviations

CSA	Central Statistical Agency
EIAR	Ethiopian Institute of Agricultural Research
FAO	Food and Agriculture Organization
ICARDA	International Center for Agricultural Research in the Dry Areas
MoA	Ministry of Agriculture
NGS	Next-Generation Sequencing

PGRC/E	Plant Genetic Resource Center/Ethiopia
QTL	Quantitative Trait Loci

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6. Author contribution

Review different journal articles to write this review article

7. Conflicts of interest

I do not have any conflicts of interest.

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