Chapter

Faba Bean Agronomic and Crop Physiology Research in Ethiopia

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Abstract

Faba bean is an important pulse crop in terms of protein source, area coverage, and volume of annual production in Ethiopia. The aim of this paper is to assess the agronomic and crop physiology investigations in the past two decades in Ethiopia. The production limiting factors of this crop are low input usage, natural disasters, depletion of macronutrients, and unavailability of essential nutrients. Phosphorus is among the main limiting nutrients in soil systems in Ethiopia. Seed yield and biomass yield of faba bean were increased from 1338 to 1974 kg/ha and from 3124 to 4446 kg/ha when phosphorous was changed from 0 to 52 kg/ha, respectively at Holeta whereas application of 40 kg P $ha-^{1}$ resulted in higher grain yield (6323 kg ha^{-1}) and 3303 kg ha^{-1} at Lemu-Bilbilo and Bore highlands, respectively. The highest grain yield of 32 kg ha^{-1} was obtained from the application of 92 kg P_2O_5 ha^{-1} at Sekela district while application of 46 kg P_2O_5 ha^{-1} resulted in a substantial increase in seed yield over unfertilized plots on vertisols of Ambo. On the other hand, the results suggest that using starter nitrogen from 0 to 27 kg/ha has marginally increased faba bean yield but, a farther increase of nitrogen has indicated deteriorate of yield at Arsi zone. Proper plant populations play a crucial role in enhancing faba bean production. Planting faba bean at 30 cm × 15 cm spacing gave the highest grain yield in Duna district while it was 30 × 7.5 cm at vertisols of Ambo University research farm. Significantly higher seed yield (4222 kg/ha) was observed in the 40 cm inter-row spacing as compared to 50 cm inter-row spacing, which gave the lowest seed yield per hectare (3138 kg/ha) on fluvisols of Haramaya University. Intercropping and crop rotation are cropping systems that can increase soil fertility and crop yield. Intercropping of faba bean with barley at Debre Birhan increased land equivalent ratio than both crops when planted as sole. An additional income of 18.5% and 40% was gained than planting sole faba bean and wheat, respectively at Kulumsa. Faba bean can fix about 69 kg/ha nitrogen in Northern Ethiopia. Generally, the current review results showed that only limited studies in organic and bio fertilizer, plant density, and cropping systems were done on faba bean in Ethiopia. Hence, studies regarding soil acidity, organic fertilizer, and secondary plus micronutrient impacts on faba bean production and productivity along soil types and weather conditions need great attention in the future in Ethiopia.

Keywords: seed yield, biomass yield, fertilizer, plant population, row spacing, intercropping, crop rotation, soil fertility

1. Introduction

Faba bean (*Vicia faba* L.) is an important legume crop that contains a high protein amounting to 33% and is consumed worldwide as protein source by humans [1]. It is also a crop of considerable importance as a low-cost food rich in carbohydrates [2]. In addition to its great nutrition content, faba bean plays an essential role in crop rotation. It has the ability to fix nitrogen, and provide a significant level of nitrogen from the soil air using a symbiotic relationship with Rhizobium bacteria [3]. Depending on the plant density and the field management, this plant is able to fix nitrogen up to 40 kg ha^{-1} annually [4]. Like the other members of *Fabaceae*, *V. faba* also increases the humus of soil [5].

Faba bean production occupied nearly 2.1×10^6 ha worldwide [6]. Its global production is 4.4 million tons [7]. The main faba bean global producers are China (1.64 Mt), Ethiopia (0.92 Mt), Australia (0.34 Mt), France (0.27 Mt), and Sudan (0.16 Mt) [7].

Faba bean is an important pulse crop in terms of area coverage and volume of annual production in Ethiopia [8]. The crop takes the largest share of the area under pulses production [9]. The annual area coverage of the crop in Ethiopia is 492,271.60 hectares with a total production and productivity of 1.04 million tons and 2.1 tons/ha respectively [9]. It is a major staple food crop among pulses and it is mainly grown in the mid and high altitude areas of the country with an elevation ranging from 1800 to 3000 meters above sea level [10]. Some limiting factors of faba bean production are climatic conditions, edaphic factors, disease problems and agronomic practices [11].

According to Central Statistical Agency [12] report, in Ethiopia about 4.34% of the grain crop area of land was covered by faba bean with annual production of about 3.94% of the total grain production and yield of 1.84 t/ha. Despite the importance, the productivity of the crop is far below the potential and is constrained by several limiting factors [13, 14]. Even though the availability of high-yielding varieties, the productivity of faba bean under smallholder farmers is less than 1.89 t ha^{-1} [15]. The low yield of faba bean was related to the vulnerability of the crop to biotic and abiotic stresses [16]. Among the abiotic category, declining soil fertility and low pH (acidity) are the most determinants for the low productivity of most crops [17]. Most of the reports revealed significant improvements in the yield of faba bean due to chemical fertilizers applications [18, 19].

1.1 Socio-economic significance of faba bean

Broad beans are one of the most popular legumes in Ethiopia. It is a crop of manifold merits in the economy of the farming communities in the highlands of Ethiopia. It serves as a source of food and feed and a valuable and cheap source of protein. Faba bean also plays a significant role in soil fertility restoration in crop rotation through the fixation of atmospheric nitrogen [13, 14]. It is tightly coupled with every aspect of Ethiopian life. It is mainly used as an alternative to peas to prepare flour which is used to make a stew used widely in Ethiopian dishes. Its boiled broad bean (*nifro* in Amharic) is also common in Ethiopia. It is also a crop of high economic value [20]. Ethiopia's faba bean export has moved northward since the year 2000 and the major destinations are Sudan, South Africa, Djibouti, Yemen, Russia, and USA, though its share in the countries pulses export is small [21].

1.2 Main constraints for faba bean production or general production constraints

Despite its importance, the productivity of faba bean is far below the potential and is constrained by several limiting factors [14]. It was also mentioned that the productivity of faba bean is far below the expected potential due to low input usage, natural disasters like a snow storm, depletion of macronutrients from cultivable land, and unavailability of essential nutrients [22]. There are also other limiting factors of faba bean production like climatic conditions, edaphic factors, disease problems, and agronomic practices [11].

2. Research achievements

2.1 Fertilizer study

Soil fertility is an important factor affecting crop productivity in general and faba bean in particular. All plants have their own type and amount of nutrient requirements from the soil. Excess nutrients in the soil cause toxicity to the plant and deficient nutrients cause nutrient deficiency symptom. Nitrogen, phosphorus, and sulfur are among the essential elements determining soil fertility.

2.1.1 Phosphorus

Phosphorous has a great role in the growth and development of crops. It plays a prime role in the growth of roots, nodulation, dry matter production, N fixation, and protein synthesis of leguminous crops [23]. Phosphorous is implicated in speeding up maturity and enhancing the root-shoot growth ratio. It is involved in many metabolism activities [24]. Phosphorous exerts many and varied functions in plant metabolism and hence inadequate phosphate supply to the plant seriously affects numerous metabolic processes. This is the reason why it is called the key to life because it is directly involved in the most life process. Thus, faba bean being a legume it needs phosphorus for better root and nodule development, which is often neglected by farmers. Hence, balanced nutrition of legumes gains significance to harvest better yields, especially under rain-fed cropping conditions, where rainfall quantum and its distribution controls the total crop production system [24].

Phosphorus is among the main limiting nutrients in soil systems in Ethiopia that create high yield gaps [25]. The application of diammonium phosphate to faba bean resulted in either lack of response or negative effects on some on-farm trials in the past in Ethiopia [18]. It was also reported that there was no response to phosphorous fertilizer at Holetta [26]. But, [18] stated that phosphorous fertilization resulted in a significant quadratic response at this location. This study further reported that there was no significant effect on seed yield at Burkitu and Debre Zeit. They reason out that the lack of significant response to the phosphorous application at Debre Zeit is possible since the research field has been fertilized with N and P fertilizers during the past three decades. Seed yield and biomass yield of faba bean was increased from 1338 to 1974 kg/ha and from 3124 to 4446 kg/ha respectively, when phosphorous was changed from 0 to 52 kg/ha at Holeta [27].

Increasing the rate of phosphorus from nil to 40 kg P ha^{-1} changed the seed yield from 1939 to 3303 kg ha^{-1} at Bore highlands, Guji zone [28]. Significantly higher mean dry biomass yield (14,158 kg ha^{-1}) and seed yield (6323 kg ha^{-1}) were produced with the application of 40 kg P ha^{-1} that was at par with 20 kg P ha^{-1} and 30 kg P ha^{-1} at Lemu-Bilbilo. The results also showed that the grain yield of faba bean was significantly increased with P fertilizer application rates over the control whereas the application of 30 kg P ha^{-1} resulted in a higher number of effective tillers $plant^{-1}$ (1.53), which was at par with all other P rates application except the unfertilized plots [29]. The highest grain yield of 3.2 t ha^{-1} was obtained from the application of 92 kg ha^{-1} P_20_5 at the Sekela district of West Gojam [30]. According to [31] fertilization of faba bean with 46 kg P_20_5/ha resulted in a substantial increase in biological yield (8172 kg/ha) over no fertilizer check (5602 kg/ha haulm yield). Fertilization of faba bean with 46 kg P_20_5/ha resulted in a substantial increase in seed yield (3531 kg/ha) over no fertilizer check (2654 kg/ha seed yield) on vertisols of Ambo University research farm. Harvest index tended to improve with P nutrition (49.7) over no phosphorus (47.4) [31].

On the other hand, the research conducted on phosphorus fertilizer rate at Bore Highlands, Guji Zone revealed that application of 40 kg P ha^{-1} resulted in the highest plant height of faba bean which was significantly higher by 11.8% than the unfertilized and gave the highest nodule dry weight (170.90 mg/plant) and seed yield (3303.0 kg ha^{-1}), but the faba bean plant height difference between 10, 20, 30 and 40 kg P ha^{-1}, as well as seed yield difference between 30 and 40 kg ha^{-1} P rate, were statistically the same (**Table 1**). Increasing the rate of phosphorus application from nil to 10 kg P ha^{-1} did not affect the number of pods produced per plant. However, further increasing to 30 kg P ha^{-1} application rate resulted in significantly higher numbers of pods per $plant^{-1}$ than by plots fertilized with 20 kg ha^{-1}, 10 kg ha^{-1}, and nil rates [28].

Faba bean exhibited a significant response in terms of pod weight/plant with the application of 46 kg P_20_5/ha (24.0 g) compared to 21.7 g obtained with no phosphorus (**Table 2**). Test seed weight has a linear relationship with phosphorus fertilization. Phosphorus fertilization at 46 kg P_20_5/ha significantly improved the test seed weight (520 g) over no phosphorus (492 g) at Ambo University research farm vertisols [31].

The total number of nodules per plant increased significantly in response to increasing the rate of phosphorus application. The application of mineral phosphorus fertilizer at the rate of 40 kg (the highest rate) phosphorous ha^{-1} resulted in the highest number of nodules (94.52) per plant [28].

2.1.2 Nitrogen

Nitrogen is an essential nutrient for plant growth, development, and reproduction. It is so vital because it is a major component of chlorophyll, amino acids, energy-transfer compounds, such as ATP (adenosine triphosphate), and significant component of nucleic acids such as DNA, the genetic material that allows cells (and eventually whole plants) to grow and reproduce. Adequate amounts of nitrogen in the plant are also essential for the absorption of other nutrients [32]. It is involved in cell multiplication, giving rise to the increase in size and length of

P-rate (kg ha^{-1})	Plant Height (cm)	Number of Pods $Plant^{-1}$	Nodule Dry Weight (mg $plant^{-1}$)	Seed yield (kg ha^{-1})
0	104.20b	8.50c	105.50c	1939.00c
10	112.60a	9.40bc	127.80bc	2318.00b
20	113.10a	10.36b	147.50abc	2570.00b
30	114.60a	14.46a	165.70a	3105.00a
40	118.10a	13.08a	170.90a	3303.00a
LSD (5%)	6.69	1.80	23.95	354.13
CV (%)	10.40	28.80	29.10	23.40

Source: [28].

Table 1.
Effect of mineral phosphorus fertilizer application rate on plant height, number of pods $plant^{-1}$, nodule dry weight and seed yield of faba bean during 2015 and 2017 main cropping season at bore.

Phosphorus rate (kg ha^{-1})	Effective tillers $plant^{-1}$	Dry biomass yield (kg ha^{-1})	Seed yield (kg ha^{-1})
0	1.18b	10970c	5076c
10	1.36ab	12092b	5693b
20	1.49a	13178a	6008ab
30	1.53a	13962a	6248a
40	1.44a	14158a	6323a
LSD (0.05)	0.21	1019	463
CV (%)	15.30	8.2	8.17
Source: [29].			

Table 2.
Main effects of phosphorus rates on effective tillers $plant^{-1}$, dry biomass yield, and seed yield of faba bean in Lemu Bilbilo district of Arsi zone.

leaves and stems and especially the stalks of grains and grasses; increases chlorophyll, giving the leaves their dark green color, plays a part in the manufacture of proteins in the plant, and is part of many compounds in the plant including certain types of basic acids and hormones [33]. Therefore, the application of nitrogen below optimum has a profound influence on crop growth and may lead to a great loss in grain yield [34].

Nitrogen is among the main limiting nutrients in soil systems in Ethiopia that create high yield gaps [25, 31]. Applying starter nitrogen from 0 to 27 kg/ha has slightly increased faba bean yield but, a further increase of nitrogen has indicated a decline of yield. The highest biological yield was recorded at the highest nitrogen level at Arsi zone [35]. Faba bean seed yield increased at Adet, Holeta, and Sheno when nitrogen increased from 0 to 36 kg/ha [18].

2.1.3 Sulfur

Sulfur is another important nutrient required by plants essentially required to form proteins and coenzymes [36]. Sulfur as a protein component is an essential element. Soil sulfate may originate from atmospheric deposition, fertilizer addition, or mineralization of soil organic S, which is the main sulfur fraction. In recent years the importance of appropriate nourishment of plants with sulfur has grown, which is chiefly related to a decrease in the deposition of this element in soils because of a reduction in industrial emissions [37]. The shortage of this component in the soil reduces the yield level and quality of leguminous plants [38, 39]. Sulfur fertilization, moreover, improves the yield quality, increasing the content of protein and sulfur amino acids in seeds [40, 41].

3. Plant population and patterns

Plant density is a major determinant of proper plant development and growth [42]. It has a remarkable capacity to exploit the environment with varying competitive stresses [43]. Both high and low crop densities reduce yield and total revenue. When planting density is too low, each individual plant may perform at its maximum capacity, but there are not enough plants as a whole to reach the optimum yield. If the planting density is too high, plants may compete against each other, known as intra-specific competition. Under those conditions, the performance of individual plants becomes a limiting factor for maximum crop yield [44].

It has been reported that among a various package of improved production technology proper plant population with appropriate adjustment of inter and intra-row spacing play a key role in enhancing faba bean production [45]. Optimum plant density differs from each variety and location since the different location has different soil type, soil moisture, soil fertility, and relative humidity [46]. In line with these findings, the research conducted on plant densities on faba bean varieties at Lemu-Bilbilo district of Arsi zone, Ethiopia indicated that the highest seed yield of faba bean (4649, 4594, and 4162 kg ha^{-1}) was obtained at 90, 70, and 50 plant m^{-2} for Degaga, Moti and Gora varieties, respectively [47]. The authors also stated that the highest total biomass of 9 t ha^{-1} was recorded from the highest plant population (90 m^{-2}), but did not show significant differences to the total biomass obtained from 70, 50, and 25 (control) plants m^{-2}. It was reported that 25 plants population density m^{-2} was economically recommended for Degaga and Moti varieties whereas, 50 plant population density m^{-2} was for Gora variety at the study site and similar agro-ecologies.

On the other hand, [48] reported that the significantly highest seed yield (2495 kg ha^{-1}) of faba bean was obtained at the combination of 30 cm × 15 cm spacing (the lowest and highest inter and intra-row spacing, respectively). The lowest grain yield (1329 kg ha^{-1}) was recorded at 30 cm × 5 cm spacing (**Table 3**). They also reported that significantly the highest dry biomass yield (8738 kg ha^{-1}) was recorded at the combination of 30 cm inter by 5 cm intra-row spacing. This was statistically similar with the dry biomass obtained due to 40 cm by 5 cm inter and intra-row spacing combination, and the lowest dry biomass yield (3812 kg ha^{-1}) was obtained at 50 cm × 15 cm inter and intra-row spacing interaction in the Duna district of Hadiya zone [48].

According to [49] significantly higher seed yield (4222 kg/ha) was observed in the 40 cm inter-row spacing as compared to 50 cm inter-row spacing which gave the lowest seed yield per hectare (3138 kg/ha) at fluvisols of Haramaya University. Seed yield (kg/ha) is significantly affected by inter and intra-row spacing. The higher seed yield was observed in the narrowest as compared to the wide spacing which gave the lowest mean seed yield at vertisols of Haramaya [45]. Another experiment conducted to see the effect of plant spacing on faba bean at Ambo University vertisols research farm revealed plant spacing had a significant effect on seed yield of faba bean [48]. Plots sowing by 30 × 7.5 cm spacing resulted in greater faba bean seed yield (3814.8 kg/ha) than that sowing by 40 × 5.0 cm (3074.1 kg/ha) and 60 × 5.0 cm (2388.9 kg/ha), respectively.

Inter-row spacing (cm)	**Intra-row spacing (cm)**					
	5	10	15	5	10	15
	Seed yield (kg ha^{-1})			**Dry biomass yield (kg ha^{-1})**		
30	1329.0a	2169.0c	2495.0e	8738.0 g	7678.0e	7187.0c
40	1545.0b	2378.0d	1966.0f	8656.0 g	7594.0e	5549.0b
50	1606.0b	2154.0c	1365.0a	8184.0f	6579.0d	3812.0a
LSD (0.05)		99.3			276.4	
CV (%)		7.2			13.8	

Source: [48].

Table 3.
Interaction effect of inter and intra-row spacing on seed and dry biomass yield of faba bean at Duna district of Hadiya zone in 2015.

Further research accompanied on plant spacing at fluvisols of Haramaya University also indicated that significantly the highest numbers of seeds per pod and seed yield per plant were obtained in wider row spacing [48]. At the same location, but different soil types (vertisols) also reported that an increase in the number of seeds per pod with wider plant spacing could be due to less competition for nutrients and water [49]. This is consistent with the results of [45] who stated wider spacing tended to improve the seeds/pod as compared with narrow spacing. These results might be due to the fact that widely spaced plants suffer less from competition than closely spaced plants.

Many literatures report that as plant density decreases (inter and intra-row spacing increases) number of pods/plant increases. For example [45] found a significant increment of the number of pods per plant by increasing inter and intra-row spacing in which the highest number of pods/plant (28.6) was obtained from the widest (50cm × 12cm) inter and intra-row spacing on vertisols at Haramaya University. The authors also state that a decrease in inter and intra-row spacing increases competition which eventually leads to a reduction in the number of pods on the individual plant. An increase in the competition for light and nutrients in high population leads to a decrease in photosynthesis and so more abscission and lower pods per plant.

4. Cropping system

4.1 Intercropping

Intercropping is the agricultural practice of cultivating two or more crops in the same land at the same time [50]. It is intensive management for crop production which aims to match efficiently crop demands to the available growth resources and labor [51]. It is relatively common in tropical and temperate areas because of the effective utilization of water [50], nutrients [52, 53], and solar energy [54]. The most common advantage of intercropping is the production of greater yields on a given piece of land by making more efficient use of the available growth resources. This could be due to different rooting characteristics, canopy structure, height, and nutrient requirements or resource use at different times [55].

In Ethiopia, food production for a rapidly growing population from a continually shrinking farm size is a prime developmental challenge. Researches indicated that inter-cropping is a good way of using land efficiently. A 3 years study of sorghum/groundnut and sorghum/soybean intercropping in Asosa (Ethiopia) showed that sorghum/groundnut intercrop had the highest sorghum yield at all growing seasons. The gross income and land equivalent ratio indicates greater economic benefit with intercropping of groundnut in 1: 1 proportion and simultaneous planting than sole planting [56].

The spatial arrangement of faba bean with barley around Debre Birhan area revealed that a significantly greater land equivalent ratio (LER) was obtained in intercropping than both crops when planted as sole. The 2B:1FB (one row of faba bean intercropped in two rows of barley) was more productive than other planting patterns (1B:1FB and 1B:2FB). All spatial arrangements had the LER values of more than one (LER > 1). It indicated that intercropping had economic advantages in land-use efficiency [57].

Mixed intercropping of wheat with faba bean was compared with sole culture of each species in 2002 and 2003 at Holetta Agricultural Research Center, in the central highlands of Ethiopia, and intercropping increased the land equivalent ratio by +3% to +22% over sole cropping [58]. The authors' findings showed that as faba bean seed rate in the mixture increased from 12.5 to 62.5% the wheat grain yield was reduced from 3601 kg/ha to 3039 kg ha^{-1} whereas faba bean seed yield was increased from 141 kg ha^{-1} to 667 kg ha^{-1}. However, the maximum total grain yield of 4031 kg ha^{-1} of wheat, gross monetary value of US$ 823, system productivity index of 4629, and crowding coefficient of 4.70 were obtained when wheat at its full seed rate was intercropped with faba bean at a rate of 37.5%. The field research conducted on planting ratio in faba bean and wheat intercropping at Kulumsa showed grain yield of faba bean was significantly affected by planting ratio plus wheat intercropping and additional income of 18.5% and 40% was gained than planting sole faba bean and wheat, respectively [59].

4.2 Crop rotation

Crop rotation is the most among factors significantly increased soil organic matters [60]. Legumes contribute to the maintenance and restoration of soil fertility by fixing N_2 from the atmosphere [61]. The input of fixed N from grain legumes may be a significant contributing factor in relation to sustaining productivity in smallholder systems [62]. The researches findings so far indicated that faba bean can enhance the yield of the following crop and increase the economy of the farmers [63]; can mark residual phosphorus available that otherwise would remain fixed [64] and may indirectly make more phosphorus and potassium available for subsequent crops [65] and the rotational benefit of faba bean to improve the P availability for subsequent crops also is considered to be closely related to the mineralization of its P-rich crop residues rather than to residual effects of root exudates on soil chemistry.

Faba bean improve the structure of poorly structured soil by stabilizing soil aggregates compared to continuous cotton and cereals as pre-crops [66]. Its roots and stubble contributed 44–50 kg N ha^{-1} to the requirements of the following crop in a temperate climate [67]; produce high levels of rhizome deposition which will improve the soil N balance which assists in maintaining soil organic fertility, and appear to provide an important source of N for following crops in the rotation [20].

Other findings revealed that yields of malting barley were greater with some pulse rotations than with continuous barley at Jeldu and Holetta [58]. Mean grain yield advantages of malting barley over the two locations after faba bean, field pea, and rapeseed were greater by 67, 43, and 53%, respectively, than malting barley after barley indicating that the lack of crop rotation has already been manifested in the continuous barley plots. The authors also showed that the highest biomass yield of 7348 (kg ha^{-1}) and protein content (11.3%) of malting barley were recorded from malting barley following faba bean which was 9.5% protein content greater than that of following malt barley.

5. Biological nitrogen fixation

Many studies conducted in Ethiopia and elsewhere in Africa have suggested that biological nitrogen fixation in different legume crops supplies sufficient N for optimum and sustainable crop production [39, 68]. Many studies also confirmed that different legumes have different nodulation and biological nitrogen fixation potentials [69]. Faba bean can fix about 69 kg/ha nitrogen in Northern Ethiopia [70].

5.1 Rhizobium inoculation

Inorganic fertilizer is an immediate supply of nitrogen, but by far the most important source of fixed nitrogen derives from the activity of certain soil bacteria that absorb atmospheric N_2 gas and convert it into ammonium. According to [71] soil bacteria reduce approximately 20 million tons of atmospheric nitrogen to ammonia. Integration of multipurpose, N-fixing legumes into farming systems commonly improves soil fertility and agricultural productivity through symbiotic associations between leguminous crops and Rhizobium [8]. They also suggested that the contribution of N fixation to soil fertility varies with the types of legumes grown, the characteristics of the soils, and the availability of key micronutrients in the soil to facilitate fixation, and the frequency of growing legumes in the cropping system.

It is widely acknowledged that inoculation of legumes with effective rhizobia can improve yields and provide a substitute for inorganic fertilizers. Research has recognized inoculation with effective and appropriate rhizobial strain is necessary to improve symbiotic nitrogen fixation and optimize faba bean productivity [72]. These authors also revealed that inoculation affects microbial community by increasing desired rhizobia strain population in the rhizosphere and for successful establishment, inoculants strain must be able to survive in the soil environment and take advantage of an ecological niche to be offered by the roots of the host plant.

Since the soil may harbor certain ineffective nodule forming native rhizobia, effective nodule formation largely depends upon the competitiveness of inoculants strain. This upholds that strain competitiveness is key for successful inoculation under field conditions. Therefore, symbiotic performance depends on the abundance of effective rhizobia strain and its competitiveness for nodulation. It is evident that there are diversified faba bean cultivars in Sub-Saharan Africa that are likely to be accompanied by symbiotically effective nitrogen-fixing indigenous Rhizobium strains [72].

Rhizobium inoculation resulted in significantly taller plants (55 cm) compared to not inoculated plants (43 cm). No significant difference in grain yield and biological yield of faba bean were recorded among not inoculated and inoculated faba bean with strain FB-1017 at Arsi Zone [35]. Faba bean grain yield was decreased from 2.65ton/ha to 2.55ton/ha when it was inoculated with rhizobium across locations (Agarfa, Farta, and Sinana) [73].

6. Prospects of agronomic research for enhancing sustainable intensification in Ethiopia

- The influence of secondary and micronutrients on faba bean production was not thoroughly studied in Ethiopia.
- No research has been conducted on faba bean physiology to improve its productivity in Ethiopia.
- Rhizobium inoculation study should be carried out across locations.
- The advantage of crop rotation with faba bean was not studied across locations

7. Conclusion and future outlook

The outcomes of this review revealed that faba bean yield showed an increasing trend as a result of technology improvements by different researchers. Among different fertilizers study phosphorus is a very important nutrient for faba bean production. To know the optimum amount of this nutrient research study should be conducted across locations, soil types and also repeated based on soil test results. Applying a small amount of nitrogen which is different across locations as starter nitrogen is required for faba bean production and productivity. Intercropping faba bean with cereals can increase income by about 50% over sole cropping component crops. On the other hand, rotating faba bean with cereals increased soil fertility which is can increase the yield of the subsequent crop. A slight decrease of faba bean grain yield was observed when it was inoculated with rhizobium at Agarfa, Farta, and Sinana. In general, it was revealed that there was still a drawback of research done on faba bean yield improvement in Ethiopia. Therefore, further studies on soil acidity, secondary and micronutrients, organic fertilizer study should need focus on across locations, soil type, and weather conditions in Ethiopia.

Conflict of interest

There is no conflict of interest among authors.

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