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Advancements in Crop and Soil Management Practices of Faba Bean in Ethiopia: A Review

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Abstract: Faba bean is the most important pulse crop in Ethiopia in terms of area coverage and total annual production. It is a source of food, feed and cash to the smallholder farmers and plays a significant role in soil fertility restoration. The productivity of this crop is far below the potential due to several biotic and abiotic yield-limiting factors. However, since the commencement of crop management research efforts dated back to 5 or 6 decades, several recommendations had been made. For example, improved drainage practices markedly increased the productivity of faba bean grown on *Vertisols*. Similarly, the application of lime contributed to a significant yield increase on acidic soils. Nevertheless, the efforts made so far have not been systematically reviewed and documented despite the importance of such information for further improvement of the crop. Therefore, this paper is intended to review crop and soil fertility management research results made so far on faba bean in Ethiopia based on earlier review articles, the use of secondary data published in journals, progress reports, annual reports and all available information, except experiments conducted at one location for one year.

Key words: Cropping System · Crop Management · Data · Ethiopia · Faba Bean · Seedbed · Soil Fertility

INTRODUCTION

Faba bean (*Vicia faba* L.) is one of the major pulse crops grown in the highlands (1800-3000 m asl) of Ethiopia, where the need for chilling temperature is satisfied [1]. It takes the largest share of the area (about 27.34%) and production (about 30.95%) of the pulses grown in Ethiopia. The national average yield is estimated to be 2.11 t/ha [2] as compared to 1.7 t/ha of the world average [3]. Faba bean is grown in several regions of the country with an annual rainfall range of 700-1000 mm [1]. It is a crop of multifarious merits in the economic lives of the farming communities in the highlands of Ethiopia. It serves as a source of food and feeds with a valuable source of protein. It plays a significant role in soil fertility restoration as a suitable rotation crop that fixes atmospheric nitrogen. It is also a good source of cash for the farmers and generates foreign currency for the country [1, 4, 5]. Despite the importance, the productivity of this crop is far below the potential due to several yield-limiting factors. Among which are soil and seedbed requirements/lack of drainage, erosion, soil acidity, low phosphate availability, inadequate and/or terminal soil moisture, inappropriate seed rates, sowing date, method and depth of sowing, fertilizer and weed control practices, frost injury in some areas, the inherent low-yielding potential of the indigenous cultivars, diseases and insect pests are the major factors affecting the productivity of faba bean [1, 4, 5].

However, since the commencement of faba bean management research efforts dated back to 5 or 6 decades, several recommendations had been made to the farming community. For example, research findings showed that improved drainage practice markedly increased productivity of faba bean grown on Vertisols, faba bean-based rotation also showed a marked reduction in weed density and biomass compared with continuous wheat or rotation with other cereals like barley, application of lime contributed to a significant yield increase on acidic soils. Tillage frequencies are determined, the soil N balance after faba bean production was found to be equal or better than the optimum N rates required for wheat production and other similar recommendations are being made [4-8]. The efforts made so far have not been

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systematically organized/ summarized and documented despite the absolute importance of such information for further improvement of the crop. Therefore, this paper is intended to review crop and soil fertility management research results made so far on faba bean in Ethiopia.

Faba Bean in a Cropping System: By its definition, the cropping system is an important component of a farming system and represents the cropping pattern used on a farm and their interactions with farm resources, other farm enterprises and available technology which determine their makeup [9]. Rising input costs decline in soil quality and the buildup of insect pests, diseases and weeds have threatened the ecological and economic sustainability of crop production. Hence, intercropping and/or rotation of cereals with pulse crops could increase grain production, provide a diversity of products, stabilize yield over seasons, reduce economic and environmental risks common in monoculture systems and thereby enhance sustainability. Enhanced cereal yields following legumes have been attributed to chemical and biological factors for higher levels of biological nitrogen fixation [4]. The cereal may be more competitive than legumes for soil mineral N, but the legumes can fix N symbiotically if effective strains of Rhizobium are present in the soil. Such intercrops exploit the environmental resources more efficiently than the pure crop stands [7]. Similarly, intercropping legumes with cereals may be advantageous compared to cultivating in pure stands, because the components can utilize different sources of N [10].

Role of Faba Bean in Biological Nitrogen Fixation: As discussed above food legumes in cropping systems are known to enhance the nitrogen content of the soils. As a result, N_2 fixation by leguminous crops is a relatively low-cost alternative to N fertilizer for small-holder farmers in developing countries [6]. Among which faba bean (*Vicia faba* L.) is a major grain legume widely cultivated in many countries for food and feed purposes. It contributes to sustainable agriculture by fixing atmospheric nitrogen in symbiosis with soil *rhizobia* [11]. Hauggaard-Nielsen *et al*. [12] reported the presence of a difference between faba bean and other typical grain legume species in their proportion of shoot N derived from fixation (Ndfa) in the order faba bean > lentil = soybean > pea > chickpea > common bean. The same authors noted that from a quantitative point of view faba bean and soybean fixes around the same amount of N (120 kg N/ha) followed by pea and lentil (85 kg N/ha) and chickpea and common bean (50 kg N/ha). According to Anteneh *et al*. [13], Ethiopia is considered as the center of diversity for faba bean with the presence of high *rhizobia* diversity where the crop derives more than 80% of its nitrogen (N) from the symbiotic association while N remains to be the major yield-limiting nutrient in the country. In an experiment conducted at three sites (Asassa, Bekoji and Kulumsa in southern Ethiopia), the amount of N_2 fixed by faba bean ranged from 139-210 kg N/ha. This in turn resulted in a substantial mean soil N balance that ranged from 12 to 58 kg N/ha after the seed had been removed and all faba bean residue components were incorporated with the soil. In contrast, the mean soil N balance in wheat after wheat was at a deficit (- 9 to - 44 kg N/ha) indicating the need for the high rate of fertilizer N application in a continuous wheat production system [6]. Similar authors indicated that soil NO_3 analysis showed higher soil NO_3 in wheat-faba bean rotations (10.43 mg) relative to wheat-rapeseed rotations (7.30 mg), which could be attributable to N contributed by the faba bean precursor crop as a result of N_2 fixation. According to the results of an experiment conducted at Alaje areas of Tigray; faba bean, field pea, dekeko and lentil accumulated a surplus soil N of 37, 21, 26 and 13 kg/ha, respectively, over the wheat plot. In this study, faba bean accumulated a higher amount of soil N and the combination of 20 kg N/ha and 20 kg P/ha increased the nodulation, biological nitrogen fixation and yield of legumes [14]. From the study conducted to evaluate the effect of locally isolated *Rhizobium leguminosarum bv. vicieae* on the nodulation, yield and yield-related traits of faba bean, NSFBR-30 is recommended as a candidate isolate for faba bean bio-fertilizer production in eastern Ethiopia [13].

Impact of Faba Bean in Succeeding Crop Performance: Crop rotation with legumes is one of the cheapest methods for soil fertility maintenance [4]. Legumes are universally regarded as beneficial to crop rotation, on the general assumption that they improve soil fertility by adding nitrogen to the soil. In several studies, faba bean as a precursor showed superior performance than other legumes both by nitrogen fixation and in enhancing the yield of the subsequent crop. According to a review of Getachew *et al*. [7], from the study conducted in northern Shewa to identify the best combination of precursor crops for barley production, faba bean showed a significant ($P<0.01$) effect on straw and grain yields of barley where grain yield of barley increased by 20-117% compared to continuous barley. Likewise, the yield of wheat after faba bean was higher by about 69% compared to the yield of wheat after wheat. It was assumed that N is largely responsible for the yield jump compared with cereal after cereal since the legume crop uses less soil N [7]. Similar results at Kulumsa, in southern Ethiopia, showed that the yield response of wheat to fertilizer N after faba bean production was very low as compared with wheat following rapeseed and continuous wheat due to the adequately available N as a result of atmospheric N_2 fixation by faba bean [6]. According to a review of Amanuel and Daba [6], soil sample analysis showed that the organic matter and available nitrogen contents of faba bean field were superior to that of field pea precursor plots and greater grain yields were also obtained in wheat after faba bean than wheat following field pea. Similarly, production of maize varieties following faba bean precursor crop without and with rhizobium inoculation by the application of half-recommended nitrogen fertilizer found optimum for sustainable maize production in highlands of western Ethiopia [15].

In a crop rotation experiment done using seven different six-year rotations, wheat after faba bean gave the largest yield increment relative to monoculture wheat (1396 kg/ha or 75%; 1451 kg/ha or 114%) at Kulumsa and Arsi Robe, respectively, in southern Ethiopia [16]. In another experiment, a long-term effect indicated that faba bean as a precursor crop increased mean grain yield of wheat by 660 to 1210 kg/ha and 350 to 970 kg/ha at Kulumsa and Asassa, respectively, as compared to the continuous wheat [6].

Barley-based long-term crop rotation experiments were conducted at different areas to determine the effect of crop rotation and fertilizer on the yield of barley. At Sheno, in northern Shewa, results of the three rotation cycles indicated that the mean grain yield of barley following faba bean without fertilizer gave about 22% more grain than barley monoculture produced with the application of 18/20 kg N/P/ha. Thus, faba bean as a break crop could help small-scale farmers to save 18/20 kg N/P/ha in the form of di-ammonium phosphate (DAP) [8]. At Bekoji, in southern Ethiopia, barley grown after faba bean resulted in a grain yield increment of 62 and 46% as against barley after cereals in 1993 and 1994, respectively. A two-course rotation resulted in a 31% higher grain yield of barley than a three-course rotation [6]. In a similar experiment conducted on malt barley; the highest grain yield, kernel plumpness, protein content and sieve test were obtained for malt barley grown after faba bean, followed by rapeseed and field pea [17].

The tillage frequency of barley was reduced when barley was planted after faba bean and the grain yield of barley increased by about 66% when plowed once; 122% when plowed twice; 77% when plowed three times and 81% when plowed four times when barley was planted after faba bean compared barley-barley monoculture [8]. Review of Amanuel and Daba [6] pointed that the crop rotation system is one of the most effective and inexpensive practices for maintaining weed species equilibrium and avoiding competition in subsequent cereal crops. Accordingly, in a crop rotation trial conducted at Kulumsa, southern Ethiopia, faba bean as a break crop decreased Andropogon and total grass weed density more than rapeseed precursor crop.

The Proportions of Faba Bean in the Inter-and Mixed Cropping System: Most faba bean crops in the industrialized countries are sole cropped, but in other parts of the world (like China) intercropping of faba bean with maize or other cereals is a common practice [18]. Mixed cropping of faba bean with other cereals and field pea is a common practice in some parts of Ethiopia. Studies on mixed cropping of barley (*Hordeum vulgare* L.) with faba bean (*Vicia faba* L.) showed that the total yield and total land equivalent ratios (LERs) of mixtures exceeded those of sole crops, especially when the faba bean seed rate in the mixture was increased to 75 kg/ha (37.5%) or more (Table 1) [19]. The grain yields of faba bean decreased with a decreased proportion of faba bean in the faba bean wheat mixture (Table 2). Wheat grain yields were also affected by an increased proportion of faba bean in the mixture. Similar to barley, the highest total yield and land equivalent ratio (LER) was obtained when faba bean was mixed at a rate of 37.5% with the full seed rate of wheat [7].

Faba bean and field pea as mixed crops resulted in higher production per unit area than a monoculture of either crop. The higher LER values for field pea than faba bean indicate the dominance of field pea over faba bean in all mix proportions. The total LERs for mixed cropping were always greater than unity ranging from 1.12 to 1.47 in weeded and 1.15 to 1.30 in un-weeded treatments indicating yield advantage from mixing faba bean and field pea. From the results, a proportion of 75:25 faba bean and field pea were found the most suitable for mixing both

Table 1: Effects of mixed cropping of barley and faba bean on grain yields of component crops, barley yield equivalent and partial and total land equivalent ratios (LERs) at Holetta, 2001-2002, Ethiopia

	Grain yield (kg/ha)			Partial and total LER values		
Treatment (Mix proportion (%)	Barley	Faba bean	Total	Barley	Faba bean	Total
Pure barley	2396a	-	2396	1.00 a	-	1.00c
Pure faba bean	-	2521a	2521	-	1.00a	1.00c
Barley (100%) + F. bean (12.5%)	2237ab	312e	2549	0.93b	0.12e	1.05c
Barley (100%) + F. bean (25%)	2036bc	576d	2612	0.85c	0.23d	1.08b
Barley (100%) + F. bean (37.5%)	2042bc	945c	2987	0.85c	0.38c	1.23a
Barley (100%) + F. bean (50%)	1831cd	1023c	2854	0.76d	0.41c	1.17a
Barley (100%) + F. bean (62.5)	1762d	1203b	2965	0.73d	0.48b	1.21a
LSD (%)	271.1	178.4		0.12	0.07	0.13

Source: Abraham Feyissa, Getachew Agegnehu and Adamu Molla, [19].

Table 2: Effects of mixed cropping on grain yields of wheat and faba bean and land use efficiency at Holetta, 2001-2002, Ethiopia

	Grain yield (kg/ha)			Partial and total LER values		
Treatment (Mix proportion (%)	Wheat	Faba bean	Total	Wheat	Faba bean	Total
Pure wheat	3813a	-	3813	1.00a	-	1.00c
Pure faba bean	-	1832a	1832	-	1.00a	1.00c
Wheat (100%) + F. bean (12.5%)	3601ab	139d	3740	0.94b	0.08e	1.02b
Wheat (100%) + F. bean (25%)	3394bc	352c	3746	0.89bc	0.19d	1.08b
Wheat (100%) + F. bean (37.5%)	3482b	542b	4024	0.91b	0.30c	1.21a
Wheat (100%) + F. bean (50%)	3198cd	574b	3772	0.84cd	0.31be	1.15a
Wheat (100%) + F. bean (62.5)	3039d	667b	3706	0.80d	0.36b	1.16a
LSD (5%)	301.2	141.3		0.06	0.07	0.10

Source: Getachew Agegnehu, Asnake Fikre and Ayalew Tadesse, [7]

crops resulting in higher seed yield and total land equivalent ratio (LER). In addition, all mixing proportions resulted in a substantial monetary advantage over each of the monoculture crops [4, 6]. In another field experiment conducted in northwestern Ethiopia, the highest LERs, 2.0 at Mota and 1.5 at Adet and the highest monetary advantage at both locations were obtained when a planting pattern of 1:1 maize:faba bean alternate rows were used with the application of 96-46 N-P_2O_5 kg/ha [20]. In the study conducted to evaluate the effect of time of single hand-weeding in mixed cropping of faba bean and field pea, the weed density in all single hand-weeded plots between 2 - 6 weeks after emergence (WAE) was found low to influence the combined grain yield of the test crops and the density of late-emerging weeds was significantly low in treatment weeded between 4 - 6 WAE. However, a single hand-weeding at 6 WAE was found more preferable in controlling late-emerging weed species and reducing weed interference during the early crop growth stage and time of harvesting [21].

Crop and Soil Fertility Management

Studies on Plant Density and Seeding Rates of Faba Bean: For most crops, including grain legumes, the choice of sowing rate is an important agronomic practice that influences plant density and crop establishment [22, 23]. According to Lyon [24], many factors influence the optimum plant population of a crop; availability of water, nutrients and sunlight, length of the growing season, potential plant size and the plant's capacity to change its form in response to varying environmental conditions (morphological plasticity). In addition, Islam *et al*. [25] stated that plant population or seed rate is influenced by row width, crop species, soil and climatic variables and crop use. Some of the available literature related to the response of faba bean to plant density indicates that a wide range of densities is commonly used depending on the cultivar, environmental conditions and the sowing date [26-32]. Accordingly, the optimum plant density to obtain high productivity for different faba bean cultivars under different management systems can range from 15 to 130 plants per square meter and/or a seed rate of 150 kg/ha to 370 kg/ha. These findings indicate that the faba bean crop can alter plant size and canopy structure in response to changes in plant density. In Ethiopia, farmers use lower seed rates than research recommendations which result in lower grain yields [7]. Depending on the seed size, agro-climatic conditions and soil types several recommendations have been made across the country. Amare and Adamu [26] recommended a seed rate of 175 and 200 kg/ha or 35 – 40 plants per square meter for mid and high altitude areas, respectively. The same authors indicated that a seed rate of 250 kg/ha as a broadcast on Nitosols and 350 kg/ha as drilling on the cambered bed on Vertisols resulted in the highest faba bean grain yield. Also, Zewudu [33] reported that the grain yield of faba bean significantly increased with increasing a seed rate from 170 to 260 kg/ha and the presence of a significant variety by seed rate interaction around Sheno to Debre Brehan areas. Similarly, a seed rate of 250 kg/ha was found agronomically optimum for faba bean production in Shambo areas of western Ethiopia [4]. On the other hand, Mandefro *et al*. [34] recommended 40 cm row-to-row and 5cm plant-to-plant spacing for row planting and 150-200 kg/ha for broadcast planting of faba bean. In southern Ethiopia, an inter-and intra-row spacing of 40cm x 10cm or a seed rate of 200 kg/ha for variety 'Gebelicho' (large seed size) and 150 kg/ha for variety 'Degega' (medium seed size) was found optimum for row planting against the national blanket recommendation of 40cm* 5cm [35]. Kissi *et al*. [36] recommended a seed rate of 175 kg/ha with early sowing highlighting the need for further research using seed rates lower than 175 kg/ha for conclusive recommendations at Sinana, southern Ethiopia. Depending on the agronomic parameters of faba bean, 25 plants per square meter were found optimum for verities Degaga and Moti whereas, 50 plants per square meter for variety Gora in the highlands of Arsi Zone, Southeastern Ethiopia [37]. Similarly, Getachew and Missa [30] did an experiment using three different seed-size varieties of faba bean on different soil types. From the results, the small-seeded variety gave economic optimum yield at a density of 50 plants per square meter at Adadi and Jeldu (light vertisol) and 40 plants per square meter at Holetta. The medium seed size variety resulted in optimum yield at a density of 40 plants per square meter at Adadi and 50 plants per square meter at Holetta and Jeldu. The large-seeded variety gave optimum yield at a density of 50 plants per square meter at all locations. Mebrate *et al*. [38] recommended a seed rate of 217.1 to 289.4 kg/ha (30 - 40 plants per square meter) for '*Hachalu*' (large seeded) and a seed rate of 110.1 to 220.1 kg/ha (30 - 60 plants per square meter) for '*Lallo*' (small seed size) for a broadcast sowing of faba bean on the highland *Vertisols*. In a similar experiment, 40 plants per square meter (40cm x 6.25cm row-to-row and plant-to-plant spacing, respectively) were found optimum for row planting of both large and small-seeded varieties under broad bed and furrow production system on heavy *Vertisols* (Mebrate *et al*., in press).

Tillage and Weed Management: From the study conducted to evaluate the influence of hand-hoeing and hand-weeding timings on faba bean production at Holetta and Denbi, in western Ethiopia, reduced weed dry matter weight associated with higher grain yield was obtained from hand-hoeing at 2 weeks after emergence (WAE) supplemented by hand-weeding at 5-7 WAE [21]. At Holetta, the treatments with supplementary hand-weeding during 5 or 7 WAE yielded 44.5% or 28.7% more than the check yield (un-weeded). The corresponding efficacy (i.e. % weed biomass reduction) for the 5 or 7 WAE supplementary hand-weeded treatments after the recommended hand-hoeing (2 WAE) was 63.4% and 72.3% compared to the check treatment in that order [21]. The results of another experiment at Wolmera, western Ethiopia, indicated that the treatment with three times tillage and weeding once by hand was economically the best option with a marginal rate of return of 227% [5]. From a similar experiment carried out around Debre Zeit, the optimum mean grain yields of faba bean over three seasons were obtained from plowing once before planting supplemented with one hand-weeding [7]. Similarly, at Shambo (western Ethiopia), thrice oxen plow of the land with "*maresha*" (a local plow) gave a significant yield advantage as compared to the minimum tillage [4].

***Vertisols* Management Through Seedbed Preparation:** As described by different scholars, high moisture level limits faba bean production on *Vertisols* as the crop is highly sensitive to waterlogged conditions. The problem of black root rot (*Fusarium solani*) disease is widely prevalent in the *Vertisols* where it is mainly associated with water-logging. Getachew *et al*. [39] made a diagnostic survey in Ethiopia in areas having a water-logging problem. According to this survey, in most of the areas, farmers' traditional strategies to overcome deficient surface soil drainage have generally not been effective. However, the exception is the handmade broad beds and furrows (HBBFs), which are almost confined to Enewari plateau at 2600 m altitude in central Ethiopia. It is found to be a very effective surface drainage system despite considerable human labor usage and low economic returns to labor [40]. In this practice, raised beds about 80 cm wide with 40 cm wide furrows in between are established each year on about 35, 000 ha. This work is done by hand without the help of any tool (actually oxen are used to open furrows about every 1.2 m wide interval). Studies on *Vertisols* also indicated that draining of excess water by using broad bed and furrow (BBF) in Ethiopia resulted in a moderate control of black root rot

Table 3: NP effects on faba bean grain yield (kg/ha) at eight locations in Ethiopia in 1992-93 (except at Sheno which was in 1993 and 1995)

Treatments	Holetta	Burkitu	Chefa	Sinana	Sheno	Adet	D/Zeit	Alemaya
N rate (kg/ha)								
0	1375	3228	3128	2306	1287	2885	2241	1624
18	1462	2876	2734	2207	1537	3318	2269	1537
27	1474	3557	2865	2184	1506	3602	2410	1389
36	1578	2971	2998	2217	1546	3836	2156	1486
F-test								
Rate	ns	ns	ns	ns	ns	*	ns	ns
Linear	ns	ns	ns	ns	ns	**	ns	ns
P rate (kg/ha)								
0	914	1809	1935	1339	1174	2835	2044	1328
10	1267	2867	2559	1868	1433	3168	2187	1485
20	1584	3510	3369	2596	1541	3669	2453	1519
40	2124	4444	3862	3110	1729	3970	2392	1704
F-test								
Rate	**	**	**	**	**	**	**	**
Linear	**	**	**	**	**	**	**	**
SE	76.8	193.5	117.9	85.8	72.7	208.2	71.9	74.7
CV (%)	29.5	34.7	22.8	21.8	28.0	29.9	17.9	28.0

*, **Significant at P < 0.05 and P < 0.01, respectively; NS = Not significant

Source: Getachew Agegnehu [5]

(*Fusarium solani*) and a dramatic yield increment compared to production under flatbeds [34]. Accordingly, an alternate broad bed of 80 cm with a furrow of 20 cm on either side has been recommended [34] against 40 cm drainage furrows reported by Getachew *et al*. [40]. As a review report of Getachew *et al*. [7], similar works carried out at Sheno (northern Shewa) and Holetta (western Shewa) resulted in substantial increments of faba bean grain yields under drained conditions compared to flatbeds. At Holetta, cumber beds increased grain yields of faba bean over flatbeds by 49 and 50% under no fertilizer and fertilizer conditions, respectively. Experimental findings at Sheno and Angolela areas of northern Shewa also showed that highland pulses performed best on well-drained black clay soils. This was confirmed from research results in which faba bean sown on the broad bed and furrow gave 31 and 71% mean grain yield advantages in the 1997 and 1998 crop season, respectively, over flatbed with 3 m wide open drainage furrows.

Soil Fertility Management Through Chemical Fertilizer Application: From the study conducted on the effect of phosphate fertilizer rate on grain yield of faba bean, the application of 18/20 kg N/P/ha or DAP at the rate of 100 kg/ha was found optimum on dila (medium fertile) soils [5, 7]. On the other hand, application of N fertilizer did not result in a significant yield difference at seven out of eight locations (Table 3). Nitrogen fertilization resulted significantly in linear response only at Adet with seed yield advantages of 15, 25 and 33% over the control [5]. Similarly, from earlier research results response to N was noted at Holetta in Nitisols [7]. P fertilization increased faba bean seed yield significantly (P < 0.01) in linear response at all locations (Table 3). It was reported that the response of faba bean to phosphorus fertilizer application is dependent on the residual P fertility level of the soil. Hence, the authors recommended further study involving the determination of critical levels of soil available P for optimum faba bean yield [5].

According to Minale *et al*. [4], considerable research has been carried out on the nitrogen and phosphorous requirements of faba bean on red-brown soils of Yilmana-Denssa, Farta and Dabat and Kon, in northern Ethiopia, where cereals (wheat/barley) are as precursor crops. The results indicated that there was a progressive increase in faba bean grain yield with incremental levels of phosphorous at all the locations, whereas the responses to nitrogen were low probably due to the nitrogen-fixing capacity of the crop. It was reported that faba bean fixed more nitrogen (135 kg N/ha) than lentil and chickpea. The economic analysis results showed that 18/23 kg N/P_2O_5/ha was more profitable in Yilmana-Denssa, Dabat and Kon areas, whereas 27/69 kg N/P_2O_5/ha was more economical in Farta areas. Results of soil-test-based trials at Wolmera areas (West Shewa) on Nitisols showed that the application of phosphorous fertilizer at different rates increased faba bean grain yield up to 58% over the control. According to Girma *et al*. [41], extractable soil P concentrations (Bray II, 0- 20 cm depth) three weeks after

Table 4: Effect of phosphate fertilizer and lime application on the grain yield of faba bean at Holetta, 1998-2000

	Seed yield (kg/ha)			
Factor	1998	1999	2000	Mean
N/P kq/ha (F)				
0	978b	713b	1489b	1073b
18/20	1464a	1188a	1527a	1380a
F test	***	***	NS	***
LSD (5%)	132.3	115.4	314.1	135.6
Lime (L) (t/ha)				
0	918b	615c	904c	813c
1	1238a	944b	1364b	1182b
3	1364a	1076ab	1879a	1439a
5	1364a	1167a	1886a	1472a
F-test				
Rate	* * *	* * *	** *	* * *
Linear	* * *	* * *	** *	* * *
Quadratic	**	*	*	**
LSD (%)	187	163.2	444.3	191.7
FxL	NS	NS	NS	NS
CV (%)	14.7	16.5	28.3	27.2

*, **, ***= Significant at 0.05, 0.01 and 0.001 probability level, respectively, NS = Not significant, "Means in a column with different letters are significantly different ($P < 0.05$).

Source: Getachew Agegnehu, Asnake Fikre and Ayalew Tadesse [7]

planting significantly responded to the P fertilization. Correlations of relative yield with Bray-II soil test phosphorous values showed that the soil test phosphorous levels greater than 12.5 mg/kg (critical phosphorous concentration) were found to be sufficient for faba bean production. Similarly, the average phosphorous requirement factor (Pf) calculated from soil test phosphorous values of all treatments for the study area was 7.02 [41]. From an experiment conducted to evaluate the effect of mineral phosphorus fertilizer, the highest nodules per plant (91.6), nodule dry weight per plant (165.6g), plant height (125cm) and seed yield (3242 kg/ha) was obtained in response to phosphorus application at the rate of 40 kg/ha and was found economically optimum in the Bore highlands of southern Ethiopia [42].

Integrated Soil and Crop Management: Adamu [43] reported that sowing faba bean from the last week of May (25^{th} of May) up to the first week of June (10^{th} of June) gave better seed and straw yield accompanied with one hand weeding, after five weeks from emergence. For well-prepared seedbeds, a seed rate of 260 Kg/ha was found to be optimum. However, at Sheno where the seed is covered and buried unevenly by plowing with the local plow and where the temperature is low, 370 Kg/ha of seed was discovered to be optimum. Similarly, on the Nitisols of Holetta, west Shewa, the effect of mineral fertilizer (DAP) and lime in the form of calcium carbonate showed no interaction, however, the application of 23/20 kg N/P/ha increased the mean seed yield of faba bean by 29% over the control. Similarly, the application of lime at the rate of 1, 3 and 5 t/ha resulted significantly in linear response with mean seed yield advantages of 45, 77 and 81% over the control (Table 4) [7]. On the other hand, Mandefro *et al*. [34] recommended a blanket of 100 kg DAP/ha where necessary or application of 4 t/ha of farmyard manure with 26 kg P/ha on acidic nitosols.

Weeding once six weeks after crop emergence and application of 20 kg P/ha produced the highest marginal rate of return (200.3%) on nitisols of west Shewa [5]. Application of either 100 kg DAP/ha or lime at the rate of 4 t/ha is advised around Gedo highlands in western Ethiopia [44]. However, the introduction of new *rhizobium* strains to the area did not significantly increase both nodule number and grain yield [44]. Integration of farmyard manure (FYM) and phosphorus fertilizer showed a positive influence on the seed yield of faba bean at Holeta west Shewa [5]. From this experiment, the application of 8 t FYM/ha and 39 kg P/ha produced the highest marginal rate of return (2027%) [5]. In another experiment, combined use of bio-fertilizer (FB1018, FB1035 strains), liming the soil with $CaCO_3$ at a rate of 3 t/ha and band application of DAP fertilizer at the rate of 100 kg/ha gave the highest benefit through increased yield, profit and improving soil fertility for the following crop in the Gurage zone [35]. Similarly, the integrated application of Rhizobium and vermicompost at the rate of 6 t/ha boost the productivity of faba bean without negatively affecting the N_2 fixation at Haramaya, eastern Ethiopia [45]. On the other hand, the integrated use of vermicompost, *rhizobia* inoculation and NP fertilizer did not bring any significant increase in the yield and yield components of faba bean at Kulumsa. Hence, application of 18-46 kg N-P_2O_5/ha from either inorganic or equivalent amounts from vermicompost or other organic sources of nutrient sources needs to be continued for sustainable production of faba bean under Kulumsa (southern Ethiopia) condition [11]. The study conducted using the CROPGRO-faba bean model indicated that using a higher plant population of 450000 plants per hectare combined with 45 kg/ha nitrogen fertilizer resulted in higher faba bean grain yield in most of the tested locations. The results showed that there is an opportunity to harvest a high grain yield using the available land and water resources and integrating different management practices [46].

Table 5: Main effects of agronomic and nutrient management options on grain yield, frost injury and germination efficiency after harvest of faba bean at Faji (north Shewa) in 2017, 2018 and combined over years

	FI (%)			GE (%)			GY (t/ha)		
Treatments	2017	2018	Mean	2017	2018	Mean	2017	2018	Mean
Sowing date (Sd)									
1	51.97[a]	73.78[a]	62.87[a]	61.88(4.09)[a]	72.50(4.27)[a]	67.18(4.18)[a]	3.47[a]	3.75[a]	3.61[a]
2	27.28[b]	43.20[b]	35.24[b]	31.88(3.22)[b]	51.39(3.84)[b]	41.63(3.53)[b]	1.78[b]	1.42[b]	1.59[b]
F-test	**	**	**	**	**	**	**	**	*
Variety (V)									
Wolki (Large seeded)	48.50[a]	58.86	53.68	55.83(3.95)[a]	66.94(4.16)	61.39(4.06)[a]	3.14[a]	2.92[a]	3.02
Dagm (Small seeded)	30.75[b]	58.13	44.43	37.92(3.36)[b]	56.94(3.95)	47.43(3.65)b	2.11[b]	2.25[b]	2.19
F-test	**	ns	ns	**	ns	**	**	**	ns
Potash (K_2O kg/ha)									
0	39.55	58.2	48.87	39.58(3.54)[b]	58.89(4.00)	49.24(3.77)	2.58	2.59	2.59
50	39.59	57.12	48.35	47.92(3.68)[ab]	62.22(4.05)	55.07(3.87)	2.76	2.66	2.71
100	38.77	55.45	47.11	45.83(3.46)[ab]	66.11(4.15)	55.97(3.80)	2.64	2.41	2.53
150	40.59	63.2	51.9	54.17(3.95)[a]	60.55(4.01)	57.36(3.98)	2.52	2.67	2.59
F-test	ns	ns	ns	*	ns	ns	ns	ns	ns
Mean	39.63	58.5	49.06	3.66	4.05	54.41(3.85)	2.63	2.58	2.6
Sd*K_2O	ns	ns	ns	**	ns	ns	ns	ns	ns
V*K_2O	*	ns	ns	ns	ns	ns	ns	ns	ns
Sd*V*K_2O	ns	ns	ns	ns	ns	ns	ns	*	ns
CV (%)	13.83	14.46	14.52	10.02	10.6	10.36	12.64	11.0	11.87

FI=Frost injury, GE=Germination efficiency, GY=Grain yield, CV= coefficient of variation, Means in column followed by the same letters are not significantly different at 5% level of significance

Source: Mebrate Tamrat, Abiro Tigabe and Worku Zikargie [49].

Tolerance to Environmental Stresses: Heat, drought, waterlogging and frost are the major abiotic stresses affecting the faba bean productivity in East Africa [47]. Extreme heat is the major threat to faba bean production in the Ethiopian lowlands. Terminal drought is also the other important constraint to faba bean production, particularly in Ethiopia where it is largely grown under rain-fed conditions. Genotypic variation in the response of faba bean to heat and drought has been documented elsewhere [47], but research works are scanty; if any, in Ethiopian condition. Hence, attention should be given to this context in searching for resistance/management to heat and drought tolerance. According to Asfaw *et al*. [48], high temperatures, particularly at altitudes of 1800m or less, are harmful to faba bean at the reproductive stage and can result in considerable flower and pod drops. According to these authors, faba bean was always vulnerable to frost damage in Ethiopian highlands. This usually occurs at the prime vegetation or early anthesis stage and damages are often irreversible. From a field experiment conducted to evaluate the effect of sowing date, variety and potassium (K_2O) against frost in faba bean, early sowing and variety contributed more to frost protection than K_2O application (Table 5). Large-seeded variety was found more responsive to the application of K_2O than small-seeded variety. Based on the economic analysis results, K_2O at the rate of 50 kg/ha was found economically optimum for large-seeded variety ('*Wolki*') at first/early sowing. However, the time of split application of this level needs further study. On the other hand, early sowing/escaping mechanism found a better option than frost resistance/tolerance for small-seeded variety ('*Dagm*') at Debre Brehan, north Shewa [49]. Similarly, from an observation trial conducted in previous years at Sheno (north Shewa), potassium fertilizer, mulch and seed rate showed a non-significant effect on grain yield, biomass yield and frost scores of faba bean. However, the interaction of faba bean seed rate with potash and mulch had a significant effect ($p<0.05$) only on grain yield and number of pods per plant, respectively [personal communication, unpublished].

CONCLUSIONS

The inclusion of faba bean in a cropping system as a preceding crop contributes much to the productivity of other crop species, particularly cereals, by improving the fertility of the soil through N_2 fixation, breaking the disease cycle and minimizing weed infestation. It also enhances the quality of human nutrition with a protein diet. This is more noticeable in Ethiopia, where the majority of the population cannot afford animal protein.

Faba bean is also a good source of income for smallholder resource-poor farmers. Though faba bean has an important place in sustaining cereal-based cropping systems in Ethiopia, its production and productivity are limited due to several biotic and abiotic factors. Research efforts made so far have had a positive impact on the production system of the crop. However, future research works needs to focus on crop physiology research to overcome environmental stresses; model supported recommendations in cropping system; soil tests and crop response calibrations while recommending fertilizer; climate change is becoming an overwhelming threat, therefore, further studies are required on short- and long-term cropping systems with special emphasis on the sustenance of soil fertility and crop productivity (refining obsolete recommendations); and improved production technologies, such as frequency of tillage, time and frequency of weeding should be developed for different agro-ecologies.

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