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Soil Fertility Management Practices For Faba Bean (*Vicia faba* L.) Production in Wolaita Zone, Southern Ethiopia

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Abstract: Understanding the soil fertility management practices is indispensable to improve faba bean productivity. However, little effort has been made to assess the soil fertility management practices of faba bean producing farmers of Wolaita Zone, southern Ethiopia. The study was conducted in Damot Gale and Sodo Zuria districts in Wolaita Zone to assess farmers' soil fertility management practices for faba bean production, in 2019 on 310 framers. Faba bean productivity in the studied districts is majorly constrained by the scarcity of arable land, poor soil fertility, and soil acidity. These cumulative effects have caused negative consequences on soil fertility and faba bean productivity. In most soil fertility, management practices in faba bean farm did not significantly vary among the studied districts. The soil management practices by farmers were inadequate to improve the soil fertility and to enhance faba bean productivity. Consequently, the average grain productions of both fertilized and unfertilized faba bean farm were far less than the national average. Therefore, intensive soil fertility management interventions such as faba bean residue management, crop rotation, application of sufficient and balanced fertilizers, adequate lime application, screening acidity tolerant varieties are required to improve faba bean productivity. in the studied districts.

Key words: Faba bean, Farmers soil, Fertilizer, Fertile soil, Infertile soil, Production constraint, Yield

1. Introduction

Faba bean (*Vicia faba* L.) is the major crop in Ethiopia, which plays a key role in enhancing soil fertility and improving food security [1]. The average national yield is about 2.12 t ha^{-1} [2], which is very low compared to the average yield of 3.7 t ha^{-1} in major faba bean producing countries in the world [3]. Particularly, in Wolaita Zone farmers harvest an average yield of about 1.2 t ha^{-1}, which is far lower than the national average of 2.1 t ha^{-1} [4]. The major factors usually mentioned for lower yield of faba bean in Ethiopia include climatic, edaphic (soil fertility and acidity), biotic (diseases, pests, and weeds), very few improved varieties, and poor agronomic practices [5, 6,]. In

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Wolaita Zone faba bean production is also constrained by biotic and abiotic factors like disease, soil acidity, and degraded soil fertility [7].

Extensive exploitation and depletion of nutrients occur in Ethiopia due to continuous cropping, less fallowing and limited crop rotation, complete removal of crop residues, minimum or no use of mineral fertilizers and lime on acidic soil [8, 9]. These resulted in macronutrient imbalance, due to the loss of nitrates, phosphates, and potassium from the soils [10, 11]. The report of [12] indicates that the soil management intervention of Wolaita Zone farmers is also inadequate to bring soil fertility improvement and good yield returns. The cumulative effect of nutrient deficiency in the soil has resulted in less productivity of faba bean in Wolaita Zone [7, 13].

Several researchers have studied the soil fertility management practices for faba bean production in a different part of Ethiopia [14, 15, 16]. Those reports revealed that significant improvements in the yield of faba bean can be brought about by proper soil fertility management like crop rotation, crop residue management, fallowing, application of balanced fertilizer, and lime on acidic soil. However, in Wolaita Zone a limited researches work had done on the soil fertility management practices of faba bean producing farmers, thus little information is available. Adequately concrete information is required about farmers' soil fertility management for faba bean production that will enable us to rate the potential and limitations of the soils for faba bean productivity in a zone. In the meantime, the findings enable the formulation of strategies for soil fertility management and forward directions to enhance the crop production of smallholder farmers. Therefore, the present study seeks to investigate the effects of farmers' soil fertility management on faba bean productivity.

2. Results and Discussions

2.1. Faba bean farmers' soil classification

In the study area, faba bean producing farmers locally classify and name the soils in their farm and used them to manage accordingly. Both the Damot Gale and Sodo Zuria districts farmers used similar parameters to classify and name the soils.

The farmers in both Damot Gale and Sodo Zuria districts were characterized and name seven faba bean growing soil types by using *bita as* a suffix, which stands for the soil in Wolaitia language. In general, the soils are *Arrada bita, Lada bita, Kareta bita, Zo'o bita, Gobo bita*, *Chare bita*, and *Talla bita* (Figure 1.). The first six soils are common in both districts, except *Talla bita,* which is found in Damot Gale district only. Among the soil types, *Arrada bita* is predominant in both districts and followed by *Lada bita*. Whereas, *Zo'o bita* is less represented in both at Damot Gale and Sodo Zuria districts (Figure 1.).

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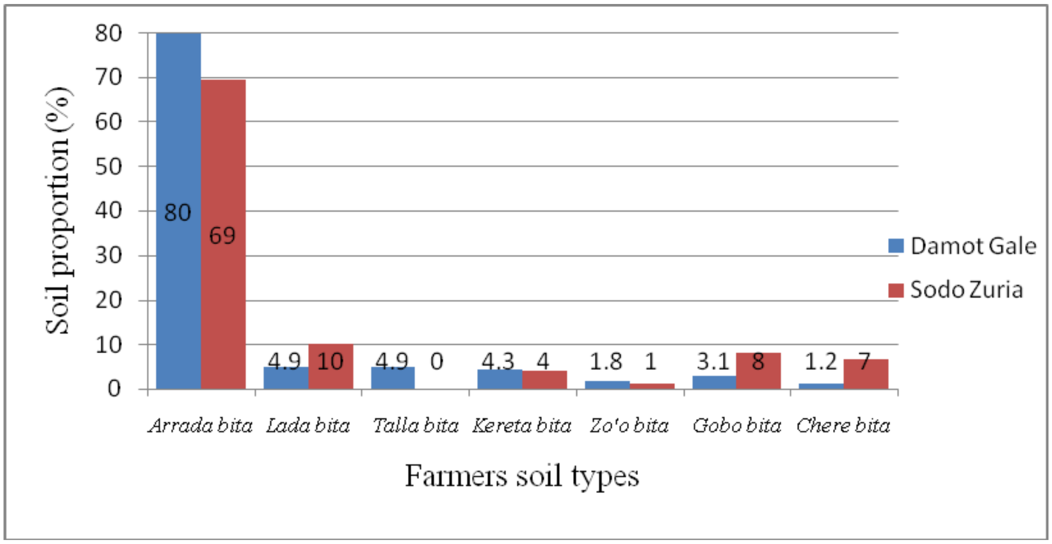

Figure 1. Farmers soil types for samples collected from Damot Gale and Sodo Zuria districts.

Most farmers used soil color, soil fertility, workability, and water permeability as the criteria for classification (Table 1.). Accordingly, farmers considered black/dark soil as fertile and suitable for faba bean productivity. While the brown/red soil is considered as low fertility and less productive.

[23] and [24] who reported that the darker soil is more fertile than the brown one also reported the related perception of farmers. The related perception of farmers was also reported by [23] and [24] who reported that the dark soil is more fertile than brown. In general, farmers ranked *Arrada bita* in the highest to medium fertility status. Also, the most faba bean farmers preferred *Arrada bita* for enhanced productivity . On contrary, *Lada*, *Gobo*, *Zo'o* and *Chere bita* ranked as low fertility and less preferred for faba bean. Farmers rank *Talla* and *Kareta bita* under medium to low soil fertility class (Table 1.). Overall, as noticed from the interview, the majority of the farmers' plant faba bean on fertile soil (*Arrada bita*).

Table 1. Faba bean farm soil classifications and commonly perceived soil characteristics at Damot Gale and Sodo Zuria districts of Wolaita Zone, Southern Ethiopia

Soil classified	Common soil name (FA0, 1984)	Textural class (Fanuel *et al*.,2016)	Farmers' parameter to classification			
			Color	Fertility	Workability	Permeability
Arrada bita	Eutric Nitosols	Silty Clay	Black/dark	High to Medium	Easy	High
Lada bita	Haplic Alfisols	Clay	Red	Low	Moderate	Moderate
Talla bita	Haplic Alisols	Clay	Reddish brown	Medium to low	Difficult, due to stickiness	Low
Kareta bita	Humic Nitisols	Silty Clay Loam	Black/dark	Medium	Difficult	Moderate
Zo'a bita	Vertisols	Clay	Brown	Low	Moderate	Moderate to low
Gobo bbita	Vertisols	Clay	Red	Low	Moderate	Moderate to

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						low
Chere bita	Orthic Luvisols	Silty Clay	Brown	Low	Difficult, due to water logging problem	Very low

"*bita*" literally mean soil in Wolaita language (Source: Survey result, 2019).

2.2. Cropping history of faba bean farm

Crop intensity

The number of crops grown each year on a faba bean production field varies from one to three, depending on the soil fertility and moisture. The cropping intensity varied significantly among districts ($\chi2 = 22.93$, $p < 0.001$) (Table 2.). Also, the intensity was in the order of two crops > one crop > three crops per land per year (Table 2.). About 54% and 63.3% of interviewed farmers have grown two successive crops a year in the same field at Damot Gale and Sodo Zuria districts, respectively. Whereas, 42.3% and 22.5% of the sampled farmers have grown only crop a year on a plot of land at Damot Gale and Sodo Zuria districts, respectively. However, very few Damot Gale (3.7%) and Sodo Zuria districts (14.2%) farmers had grown three successive crops a year in the same field (Table 2.). Overall, the majority (58.4%) of the interviewed farmers had grown more than one crop each year (Table 2.).

The sampled farmers indicated poor soil fertility, expensive price of inorganic fertilizer, and the limited number of labor challenged to grow more than one crop each year on a field. Hence, most of the study area farmers economically poor and lead hand to mouth living style. Similarly, soil fertility constraint, limited moisture availability and financial problem were reported in different parts of Ethiopia [25, 26]. In general, cultivating only faba bean each year per plot plot would reduce overexploitation of nutrients and would increase grain production. Nevertheless, higher cropping intensity had a relative yield advantage than single cropping. Increased cropping intensity requires better soil fertility management [26]. In this regard, the sampled faba bean fields were not mange adequately. Therefore, increased cropping intensity would result in large nutrient exploitation, unless balanced by proper soil management practices.

Table 2. Faba bean farmers' cropping practices on sampled agricultural fields at Damot Gale and Sodo Zuria districts of Wolaita Zone, Southern Ethiopia

Cropping practices	Sampled farmers	Districts		
		Damot Gale(%)	Sodo Zuria(%)	Total (%)
Crop intensity per a year	χ^2	N=163	N=147	N=310
One		42.3	22.5	32.9
Two	22.93^{***}	54	63.3	58.4
Three		3.7	14.2	8.7
Varieties planted		N=163	N=147	N=310
Local	0.98^{NS}	65.6	64	64.8
Improved verity		34.4	36	35.2

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N = number of sampled farmers who involved in faba bean cropping practices, ***= 0.001 and NS=Not significant

Faba bean varieties used in studied districts

The number of farmers who grow improved varieties did not show statistical differences among districts (Table 2.). The local faba bean variety was dominant over-improved varieties and covered about 65.6% and 64% at Damote Gale and Sodo Zuria districts, respectively (Table 2.). Different research conducted on acidic soils of Ethiopia showed that the improved varieties had a significantly higher grain yield over the local variety [27, 28]. However, the result in the present finding indicated that very few numbers of farmers grow improved varieties(Table 2.). Also, as noticed from the discussion, farmers were used only "Dosha" as the improved faba bean variety. Thus, the predominantly growth of the local variety might be among the reasons for far lower productivity in the studied districts.

2.3. Faba bean production constraints

Land shortage

The number of faba bean grower farms that challenged land shortage did not significantly vary among Damote Gale and Sodo Zuria districts (Table 3.). The survey work recognized that the vast majority of the farmers have less than a "Timad'' or 0.25 hectare of land per household. In line with the findings of this study, [29] indicated that 60% of households in Wolaita Zone possessed less than 0.25 hectares of farmland that is smaller than the national average of 1.01 hectares [6]. Overall, 85.3% and 78.9% of farmers interviewed in Damot Gale and Sodo Zuria districts, respectively, indicated the farm size as a constraint for faba bean production (Table 3.). Consequently, the abandonment of fallowing in the studied districts was recorded, which resulted in low soil fertility and faba bean productivity. Similarly, different studies conducted in Ethiopia also indicated the small farmland size as a reason for continuous cultivation and less crop productivity [25, 26]. In general, continuous cultivation without fallowing due to small farm size might affect the soil fertility and faba bean productivity in studied districts. Hence, maintenance of the soil fertility status through fertilizer application and using different soil management interventions are required to restore the soil and faba bean productivity.

Table 3. Major faba bean production constraints on sampled agricultural fields at Damot Gale and Sodo Zuria districts of Wolaita Zone, Southern Ethiopia

Production constraints	Sampled farmers	Districts		
		Damot Gale(%)	Sodo Zuria(%)	Total (%)
Land shortage	χ^2	N=163	N=147	N=310
Yes	2.15^{NS}	85.3	78.9	82.3
No		14.7	21.1	17.7
Poor soil fertility	χ^2	N=163	N=147	N=310

Yes	1.12^{NS}	54.6	60.5	57.42
No		45.4	39.5	42.58
Soil acidity	χ^2	N=163	N=147	N=310
Yes	0.11^{NS}	35.6	37.4	36.5
No		64.4	62.6	63.5
Soil erosion	χ^2	N=163	N=147	N=310
Yes	4.93**	39.9	27.9	33.9
No		60.1	72.1	66.1

N represents the number of farmers who involved in cropping practices, **= 0.01 NS=Not significant (Source: Survey result, 2019).

Poor soil fertility

Farmers used the soil color, workability, water permeability, and water holding capacity as criteria to judge the soil fertility status. [23] and [24] also reported similar perceptions of farmers to classify the soil fertility status.Thus, the dark soil, which has high water retention and it is easy to plow, is classified as fertile soil by faba bean growers in both districts. Accordingly, the farmers' perception about the soil fertility status had not significantly varied among Damot Gale and Sodo Zuria districts (Table 3.).

About 54.6% and 60.5% of the interviewed farmers at Damot Gale and Sodo Zuria districts complained about the poor soil fertility as a faba bean production constrain (Table 3.). In line with the findings of this study, [7] indicated poor soil fertility as faba bean production constrains in Wolaita Zone. Though poor soil fertility is constraining faba bean growers, farmers had limited capacity to improve the soil fertility by applying adequate mineral fertilizer, liming and residue management. Thus, soil fertility interventions require special attention.

Soil acidity

The short structured questionnaire was used to verify whether the soil acidity is a constraint for faba bean production or not in the studied districts. Most of the interviewed farmers did not know what soil acidity means. However, those few who indicated the soil acidity as a constraint used the wilting of leaves and stunted growth inadequate fertilizer applied condition as the criterion to judge. The chi-square statistic revealed a non-significant difference in the number of farmers, who perceive the soil acidity as a constraint among Damot Gale and Sodo Zuria districts (Table 3.). About 35.6% of Damot Gale and 37.4% of Sodo Zuria district farmers complained of soil acidity as faba bean production constraints (Table 3.). [7] also reported the soil acidity as a serious constraint for faba bean production in Wolaita Zone. Hence, the soil acidity is a problem for optimal faba bean productivity, even on a fertilized faba bean soil. Therefore, identifying the proper lime rate and timely application is required to reduce the soil fertility problem and to improve faba bean productivity.

Soil erosion

The number of farmers, who complained the soil erosion as faba bean production constraint had shown significant ($\chi2$ =4.93, $p < 0.01$) variation among districts (Table .3). Out of the interviewed farmers, 39.9% and 27.9% indicated soil erosion as a production constraint at Damot Gale and Sodo Zuria district, respectively (Table 3.3). This implied that soil erosion is among the major constraint for faba bean production. The erosion problem is more serious at Damote Gale than Sodo Zuria districts. The higher erosion in Damot Gale district may be due to steeper slopes than in Sodo Zuria district [30]. In general, intensive crop cultivation, complete crop residue removal, and high nutrient depletion may intensify erosion in faba bean [31, 7].

2.4. Soil fertility management practices for faba bean production

Mineral fertilizer application

The mineral fertilizer application practice significantly varied among districts ($\chi2$ = 0.50, $p < 0.05$) (Table 4). Only 29.5% and 25.9% of the sampled farmers applied mineral fertilizer in Damot Gale and Sodo Zuria districts, respectively (Table 4.).

The farmers have raised the limited financial capacity and the rising price of mineral fertilizer as the reason for limited fertilizer application. Other researchers also mention financial capacity and the expensive price of mineral fertilizer as a challenge for applying an adequate amount of fertilizers [32, 33]. A significant number of farmers are skeptical of the application of mineral fertilizers. Those farmers believed that a crop does not require inorganic fertilizer. However, the previous study in the neighboring district (Boloso Sore), Wolaita Zone by [7] indicated a significant yield improvement in faba beans when fertilizers are applied. Farmers' perception of fertilizer use should be correct to improve faba bean yield. Identifying the type of fertilizer and refining the best rate is required for optimum economic return of faba bean.

Table 4. Faba bean farmers' soil management practices on sampled agricultural fields at Damot Gale and Sodo Zuria districts of Wolaita Zone, Southern Ethiopia

Management practices	Sampled farmers	Districts Damot Gale(%)	Sodo Zuria(%)	Total (%)
Number of plow	χ^2	N=163	N=147	N=310
Plough once	0.18^{NS}	35.6	35.4	35.4
Plough twice		33.1	31.3	32.3
Plough three times		31.3	33.3	32.3
Mineral fertilizer application	χ^2	N=163	N=147	N=310
Yes	0.50^{*}	29.5	25.9	27.7
No		70.5	74.1	72.3
Type of fertilizer applied	χ^2	N=48	N=38	N=86
DAP	0.46^{NS}	48	52.3	51.1
Urea		0	0	0

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DAP + Urea		52	47.7	48.9
Amount of fertilizer applied	F-test	N=48	N=38	N=86
DAP (kg ha^{-1})	0.66^{ns}	81.5±3.5	84.5±1.0	82.7±2.3
Urea (different kg ha^{-1}) + DAP(100kg ha^{-1})	4.22*	147.1±2.9	144.0±2.9	146±3.0
Farm yard manure (FYM)	χ^2	N=163	N=147	N=310
Yes	0.48^{NS}	31.3	33.3	32.3
No		68.7	66.7	67.7
Amount of FYM applied	F-test	N=51	N=49	N=100
FYM applied (tha^{-1})	23.65***	1.4±0.2	1.2±0.1	1.3±0.3
Lime applied	χ^2	N=163	N=147	N=310
Yes	0.23^{NS}	3.1	4.1	3.5
No		96.9	95.9	96.5
Amount of lime applied	F-test	N=5	N=6	N=11
Lime application (tha^{-1})	0.21^{NS}	1.6±0.1	1.5±0.1	1.6±0.6
Faba bean residue management	χ^2	N=163	N=147	N=310
Remain on field	0.02^{NS}	1.8	2	1.9
Incorporate in soil		0	0	0
Clearing		98.2	98	98.1
Faba bean rotation	χ^2	N=163	N=147	N=310
Yes	3.49*	31.3	41.5	36.1
No		68.7	58.5	63.9
Fallowing	χ^2	N=163	N=147	N=310
Yes	0.25^{NS}	2.5	3.4	2.9
No		97.5	96.6	97.1

N represents the number of farmers who involved in cropping practices *, ** significant at p<0.05, 0.001, respectively and NS=Non significant difference (Source: Survey result, 2019).

The type of fertilizer applied

The type of inorganic fertilizers used among farmers did not show statistical differences among districts. The mineral fertilizer user farmers applied either di-ammonium phosphate (DAP) alone and/or DAP and urea together at a different time (Table 4.). However, farmers in both districts were not applied urea fertilizers alone for faba bean production.

Overall, about 48% and 52.3% of the sampled faba bean fields were managed with DAP fertilizer alone at Damot Gale and Sodo Zuria districts, respectively. The remaining 52% (Damot Gale) and 47.7% (Sodo Zuria) sampled fields were managed with DAP and urea fertilizers together (Table 4.). Those farmers who used urea and DAP in combination applied DAP at the time of sowing and urea at the active vegetative stage.

The amount of fertilizer applied

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The amount of combined application of urea and DAP fertilizer significantly varied (4.22, $p < 0.05$) among districts (Table 4.). Those sampled farmers applied 100 kg ha^{-1} DAP and 50 kg ha-1 Urea at planting and active vegetative stage, respectively. The rate is in line with [34] blanket recommendations of 100 kg ha^{-1} DAP and 50 kg ha^{-1} for all legume crops. However, due to the differences in inherent soil properties and spatial variation, the blanket management approach could not address yield-limiting nutrients in the soils and enhance faba bean productivity. Thus, adequate site-specific fertilizer recommendation is required for improved crop productivity [35].

The rate of combined application of urea and DAP was significantly higher in Damot Gale (147.1$\pm$2.9) than Sodo Zuria district (144.0$\pm$2.9) (Table 4). [20] also reported that more urea and DAP fertilizer application for crop production in Damot Gale than Sodo Zuria district. Generally, the use of small and non-balanced nutrients would lead to depletion of nutrients and reduced faba bean productivity.

Farmyard manure application

The use of cows farmyard manure (FYM) for faba bean did not show significant variation among districts (Table 4.). However, only 31.3% of Damot Gale and 33.3% of Sodo Zuria district farmers applied farmyard manure for faba bean production (Table 3. 4).

It was noticed that most farmers who applied FYM did it near to their residence rather than to distant faba bean plots. Also, growers indicated the farm distance from their residence and a shortage of manure are the major reasons for lower manure application. Similarly, [24] also reported in Tigray a higher FYM rate near the residence than on distant plots due to difficulty in transportation. However, the application of an adequate amount of FYM for faba bean production has substantial importance to improve the productivity of small-scale farmers [15].

Farmyard manure application rate

The FYM applied rate for faba bean indicated significant (23.65***) variations among the studied districts (Table 4.). The FYM application rate is significantly greater in Damot Gale than Sodo Zuria district (Table 4.).

The amount of FYM applied both in Damot Gale and Sodo Zuria ranges from 1 to 2 t ha^{-1}. Among FYM applying farmers, 59.2% and 81.6% were applied 1 t ha^{-1} in Damot Gale and Sodo Zuria districts, respectively and the remaining farmers applied 2 t ha^{-1}. The average application rate for faba bean varies 1.4$\pm$0.2 t ha^{-1} and 1.2$\pm$0.1 t ha^{-1} in Damot Gale and Sodo Zuria districts, respectively (Table 4.). Whereas, [7] study in the neighboring district (Boloso Sore) in Wolaita Zone, revealed that faba bean required 4 t ha^{-1} for optimum growth. Furthermore, yield improvement on faba bean was reported in different parts of Ethiopia due to FYM application, in which pH, available P, and CEC of the soil increased [36, 15, 37]. Thus, the FYM rate used in the studied districts is very low and affects the soil fertility status negatively, unless replenishment of nutrients takes place.

Lime application

Faba bean farmers, who applied lime in the study used $CaCO_3$ as the liming material.

The lime application had no significant statistical differences among the districts (Table 4.). About 3.1% and 4.1% of the farmers applied lime in Damot Gale and Sodo Zuria districts, respectively (Table 4.). Similarly, the previous work of [10] and [7] had shown limited knowledge of farmers to apply lime in Woliata Zone. However, different researchers have reported soil acidity as a serious problem for crop productivity in Wolaita area [10, 7, 11, 38]. For instance, [11] reported pH of 4.4 and 4.6 at Kokate and Areka in Wolaita Zone, which is very strong [39]. Though soil acidity is a serious constraint, most farmers did not solve the problem adequately. Therefore, the soil acidity might lead to further grain yield reduction, unless additional research is conducted to identify the optimum lime rate and soil acid-tolerant faba bean variety.

The rate of lime application

The rate of lime application on faba bean farms did not show significant variation among districts (Table 4.). The lime applied on faba bean farm varied from 1 to 2 t ha^{-1} with an average rate of 1.6±0.1 t ha^{-1} and 1.5±0.1 in Damot Gale and Sodo Zuria district, respectively (Table 4.). [31] indicated the soil of Wolaita Zone requires 4 t ha^{-1} for improved common bean production. Overall, the average lime applied rate (1.6±0.6 t ha^{-1}) on faba bean field in the studied districts is not sufficient to mitigate the soil acidity. Therefore, to secure higher faba bean production in the studied districts, further research is required to reclaiming the soil by using optimum lime and balanced fertilizer.

Faba bean residue management

Faba bean residue management did not show significant differences among the districts (Table 4.). Farmers were not well aware of the advantage of retaining and incorporating faba bean residues in the soil. Overall, faba bean residues were removed from 98.2% of Damot Gale and 98% on Sodo Zuria districts (Table 4). Correspondingly, [20] also reported crop residues removed for varied purposes in Wolaita Zone. Furthermore, southeastern Ethiopia farmers clear the crop residues for construction material, fuel, and animal feed [9]. Hence, faba bean residue retaining and/or incorporating into the soil is required special attention to restore the soil fertility and improve crop productivity in the studied area.

Faba bean rotation

Faba bean rotation with different crops significantly ($\chi 2 = 3.49$, $p < 0.05$) varied among districts (Table 4.). Overall, Sodo Zuria (41.5%) showed significantly higher

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faba bean rotation than Damot Gale district (31.3%) (Table 4.). Thus, in Sodo Zuria the soil fertility is maintained significantly better than Damot Gale district, through crop rotation.

Faba bean is often rotated with cereals and infrequently rotates with roots and tubers (potato, sweet potato, and yam). Most farmers implemented the rotations as maize - faba bean – cereals and/or root and tubers - faba bean - cereals. FARM Africa (2005) also reported related faba bean rotation practices in Wolaita Zone. In contrary to this, a crop rotation in Tigria is dominated by cereals [24]. However, including legumes at least once in the rotation cycle influence the soil microbial activities [9]. These enable the soil to increase OM, which is creating an ideal condition for crop productivity [40]. Thus, including grain legumes in crop rotation provides multiple environmental, agricultural, and economic benefits, such as fix the atmospheric nitrogen, release in the soil high-quality organic matter, and facilitates soil nutrients' circulation and water retention. Moreover, the type of legume species used for rotation purposes affects the mineralization process and the amount of fixation. Especially, faba bean is the best preferable legume for rotation purposes, due to its powerful nitrogen-fixing (177–250 kg ha^{-1} $crop^{-1}$) nature [14]. In line with this, [40] reported faba bean-rape-wheat rotation as a suitable crop rotation to improve soil fertility status. In general, farmers are well aware of the merits of faba bean rotation with other crops to improve soil fertility. Most farmers indicated their preference for faba bean rotation than fallowing, due to limited farmland size.

Fallowing

The interviewed farmers revealed that the practice of fallowing did not significantly vary within the studied districts (Table 4.). In this regard, only about 2.5% of Damote Gale and 3.4% of Sodo Zuria farmers were practicing fallowing. Overall, the fallowing practice is very limited (2.9%) (Table 4). The farmers are well aware of the significant role of fallowing in reclaiming soil fertility. However, the small farmland size in the studied districts is forcing farmers to practice limited fallowing. Thus, the problem of abandonment of fallowing is very common in Wolaita Zone [41, 20]. Similarly, the limited practice of fallowing due to small farmland size was reported in different parts of Ethiopia [9, 24, 42, 43]. Thus, the abandonment of fallowing negativity affects soil fertility and grain yield productivity [43]. The soil fertility constraint due to continuous cropping required immediate attention for sustaining faba bean production in the studied districts.

2.4. Faba bean grain yield production

From 2016 to 2018, faba bean grain yield production had shown statistically significant differences ($P < 0.001$) due to fertilizer application. Overall, in all three years fertilized and unfertilized faba bean farms had 1.8 ± 0.8 t ha^{-1} and 0.62 ± 0.3 t ha^{-1}

average grain yield, respectively (Table 5.). In line with this, CSA (2018) reported average grain production of as 1 t ha^{-1} in Wolaita Zone, which is far less than the national average (2.1 t ha^{-1}).

In 2016 the yield (t ha^{-1}) of fertilized faba bean was 1.80±0.6 and 1.72±0.7 in Damot Gale and Sodo Zuria district, respectively. However, in the same year, the yield of the unfertilized farm was very low both in Damot Gale (0.52±0.2 t ha^{-1}) and Sodo Zuria (0.50±0.1 t ha^{-1}) districts (Table 5.). The fertilized faba bean farm in 2017 was 1.88±0.7 t ha^{-1} and 1.74±0.6 t ha^{-1} in Damot Gale and Sodo Zuria district, respectively.

Table 5. Grain yield production of faba bean on sampled agricultural fields at Damot Gale and Sodo Zuria districts of Wolaita Zone, southern Ethiopia.

		Mean yield (t ha^{-1})		
Year of production	Fertilizer application	Damot Gale(N=163)	Sodo Zuria(N=147)	F-test
Production in 2016	No	0.52±0.2	0.50±0.1	4.05*
	Yes	1.80±0.6	1.72±0.7	1.73*
	t-test	***	***	
Production in 2017	No	0.77±0.3	0.71±0.3	5.9**
	Yes	1.88±0.7	1.74±0.6	0.01**
	t-test	***	***	
Production in 2018	No	0.63±0.3	0.61±0.4	6.73*
	Yes	1.84± 0.12	1.84±0.11	0.84 NS
	t-test	***	***	

N represents the number of farmers who involved in cropping practices; *,**,*** significant at $p \leq 0.05, 0.01, 0.001$, respectively; NS=Not significant

The yields in an unfertilized farm in 2017 reduced in Damot Gale (0.77±0.3 t ha-1) and Sodo Zuria (0.71±0.3 t ha-1) districts (Table 5.). The fertilized field in 2018 yielded about 1.84± 0.12 t ha-1 and 1.84± 0.11 t ha-1 in Damot Gale and Sodo Zuria districts, respectively. In 2018 the yields of the unfertilized farm were reduced at Damot Gale (0.63±0.3) and Sodo Zuria (0.61±0.4) districts (Table 5.). Scarcity of arable lands, poor soil fertility, erosion, soil acidity, abandoned following and poor residue management is the reason for reduced faba bean yield.

3. Conclusion

Understanding the soil fertility management practices is indispensable to improve faba bean productivity. Production of faba bean in the studied districts was mainly constrained by the scarcity of arable land, poor soil fertility, erosion, soil acidity, and lack soil acidity tolerant improved faba bean varieties. These cumulative effects have caused negative consequences on soil fertility and faba bean productivity. In general, the soil management practices by farmers were inadequate to improve the soil fertility status and to enhance faba bean productivity. Therefore, intensive soil fertility management interventions like faba bean residue management, crop rotation, application of sufficient and balanced organic and inorganic fertilizers, adequate lime application, screening the soil acidity tolerant varieties are required to improve faba bean productivity in the studied districts.

4. Materials and methods

4.1. Description of the study area

The study was conducted in Damot Gale and Sodo Zuria woredas (districts), Wolaita Zone, Southern Ethiopia during the 2019 cropping season. The districts were selected based on their high faba bean production potential. The Damot Gale district is located between 060 55' 22" - 070 05' 00" N latitudinal and 370 45' 31" - 370 59' 58" E longitudinal positions. The elevation of Damot Gale district ranges from 1501 to 2950 meters above sea level [17]. On the other hand, Sodo Zuria district is located at 6°46'60" - 6°56'45" N and 37°38'10" - 37°50'60"E at an elevation from 1500 to 3500 meters above sea level [18]. According to AEZE (1998) classification, faba bean producing areas of both Damot Gale and Sodo Zuria districts predominantly characterized by cool sub-humid (Woinadega).

The last ten years (2010 – 2019) mean annual precipitation was 1,151 mm and 1,346 mm were experienced at Damot Gale and Sodo Zuria district, respectively. The districts have a bimodal rainfall pattern, which consists of belg and meher or main cropping season precipitation occurs [19]. According to [20] the belg cropping season rains in Wolaita Zone during autumn (March-May) and in meher season rains during summer (June - August). At Damot Gale district, about 32% and 38.19% precipitation are observed during the autumn and summer seasons, respectively. The last ten years' mean monthly temperature of Damot Gale district ranged from 18 °C to 21 °C with an average of 19.3 °C [21]. .

On the other hand, at the Sodo Zuria district, about 37.56 and 39.13% of precipitation occurs during the autumn and summer seasons, respectively. The mean monthly temperature of the Sodo Zuria district ranged from 19 °C to 23 °C with an average temperature of 20.5 °C (NMA, 2020). The agricultural practices in the study area are predominantly small-scale mixed subsistence farming. The cropping system is mainly based on continuous cultivation without any fallow periods [20].

4.2. Farmers sampling method and sample size

The sample size for each district was fixed according to [44] simplified formula to calculate the sample size. Accordingly, n = $\frac{N}{1+N(e^2)}$ was employed; where n is the sample size, N is the population size, and e is the level of precision at 95% confidence level. The number of samples varied in the sub-districts depending on the number of the human population residing in the areas. Hence, 310 household heads (163 from Damot Gale and 147 from Sodo Zuria) were interviewed about the soil management practices for faba bean production.

4.3. Data collection

The short structured questionnaire used to record the soil fertility management practices included cropping history, crop rotation practices, fallowing, cropping intensity, production constraints, soil fertility management practices, crop residue management, and fertilizer use (types and rates). The altitude and latitude of each farm recorded by using the GPS (global positioning system).

4.4. Method of data analysis

To analyze the data a descriptive statistics were employed. Mean and percentage computed for different variables. Pearson chi-square, t, and F tests also were calculated. Data analysis was carried out using a statistical package for social sciences (SPSS) software version 20 [22].

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Conflict of Interest

The authors declare that they have no conflict of interest.

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