American Journal of Plant Biology
2026, Vol. 11, No. 3, pp. 113–119
https://doi.org/10.11648/j.ajpb.20261103.19

Research Article

Comparative Effects of Fenugreek Rotation with Bread Wheat to Enhancing Wheat Productivity at Highland and Mid-altitudes of Bale, South-eastern Ethiopia

Chala Gutema*

Oromia Agricultural Research Institute, Sinana Agricultural Research Centre, Bale-Robe, Ethiopia

Abstract

In the Bale zone, the farmers dominantly rely on the monoculture of wheat, which currently imposes its detrimental consequences on the depletion of soil fertility and has a high risk of low crop production. Therefore, an on-farm experiment was conducted to determine the importance of rotating fenugreek with bread wheat there; to determine the effects of fenugreek rotation with bread wheat on the yield components and yield of bread wheat varieties at Bale; and to study the compatibility and productivity of the fenugreek and bread wheat rotation system under the Bale highlands and mid-altitudes of East Bale. The growth and agronomic traits of fenugreek and bread wheat were affected by rotations. The highest plant height of fenugreek (50.67 cm) was recorded from the Burqa variety when grown, followed by the Senate variety of bread wheat. The highest bread wheat plant height (108.0 cm) was recorded when the Senate variety was grown, followed by the Hundaol variety. The number of primary branches per plant in fenugreek was observed to be high when it was planted after bread wheat. The maximum number of pods per plant (21.80) was obtained when Hundaol planted the following Senate variety. The maximum spike length (6.50 cm) was recorded when the Galan variety was planted after the Hundaol varieties of fenugreek, and the highest number of seeds per pod (12.87) was obtained from the Burqa variety of fenugreek when grown with the Senate variety of bread wheat. The highest number of seeds per spike (53.70) was obtained when wheat grew after a wheat-fenugreek-wheat rotation. The maximum seed yield of fenugreek (1647 kg ha^{-1}) was recorded when it grew after wheat. On the other hand, the maximum grain yield (6232 kg ha^{-1}) in wheat was gained when Senate grew after fenugreek. The minimum seed yield of fenugreek and wheat grain yield was obtained from monocropping. This experiment revealed that the first wheat following a fenugreek precursor crop in rotation resulted in superior grain yields of bread wheat. Low grain yields were obtained from the continuous wheat rotations at Bale. The result indicates the need to encourage the adoption of appropriate wheat rotations by farmers in the highlands of the Bale zone and similar agroecologies.

Keywords

Rotation, Fenugreek, Bread Wheat, Primary Branches, Spike

*Correspondence: Chala Gutema (chalagutema@gmail.com)

Received: 15 June 2026; **Accepted:** 6 July 2026; **Published:** 11 August 2026

1. Introduction

Fenugreek (*Trigonellafoenum-graecum*L.) is an annual herb which belongs to the family Fabaceae [1]. It is a multipurpose spice crop; every part of the plant is being used as leafy vegetable, fodder and condiment [2]. Fenugreek is one of the oldest known medicinal plants that have been documented in ancient herbal publications, religious scriptures, travel records and anecdotes dating back in human history [3]. Beyond fixing nitrogen, it covers the surface soil and suppresses weeds and reduces soil erosion.

Crop rotation is thought to be a useful means of minimizing the risks of agricultural production. Legumes in crop rotation systems play a significant role in improving soil fertility [4]. Pests and diseases are major constraints, and their effect would be managed using rotation crops such as potatoes, cereals, and legumes. The inclusion of legumes in a cropping sequence has the potential to improve soil quality, porosity, and structure [5, 6] and influence specific microorganism populations in the rhizosphere [7, 8] for the benefit of the subsequent crops. Intensive cultivation under one crop may leave compacted soils for the next, while late harvesting may impede preparation for the follow-up planting. Previous studies have shown significant yield advantage of crop rotation as compared to mono cropping [9]. Farmers in Bale dominantly relied upon monoculture of cereals (mainly wheat), which currently imposes its detrimental consequences like depletion of soil fertility, greater risk during crop and/or market failure, abandonment of crop diversity that caused development of herbicide-resistant noxious-weeds, diseases and insect pests associated with single cropping. Fenugreek is one of the potentials "break-crops" for the ever-increasing cereal monocropping system in Bale. Information on crop rotation system in Bale zone is not practiced well by farmers. Thus, there is a need to study such type of crop rotation system in the Zone.

Objectives:

1) to determine the effects of fenugreek rotation with bread wheat on the yield components and yield of bread wheat varieties in wheat growing districts of Bale Zone, and
2) to evaluate the compatibility of fenugreek and bread wheat in a rotation system under wheat growing districts of Bale Zone.

2. Materials and Methods

2.1. Description of Study Area

The experiment was conducted at on-station at Sinana and Gololcha in Bale and East Bale Zones, Oromia Regional State, in 2021 to 2023. The experiment was conducted only at Sinana on-station. Sinana is located 07o 07’10.837” N latitude and 040o 13’32.933” E longitude; and 2400 m a.s.l.) and it is found 463 km south east of Finfinnee and 33 km East of Robe, the capital of Bale zone while Gololcha is is located 540 km away from Addis Ababa to Southeastern.

These area follows a bimodal rainfall patterns and has two separate cropping seasons locally called *bona* and *gana*. The main season *bona* extends from September to November and *gana* from March to May. The soil type of both areas is *Vertisol*s and cereals, pulses, vegetables are mainly grown under rain fed and irrigation.

2.2. Treatments and Experimental Design

The improved bread wheat varieties “Gelan and Sanate” was used as main crop and the improved fenugreek variety “Burqa and Hundaol” was used as precursor crop were used as a planting material and grown on the selected site and plots except the control plots. The experiment was laid out in a randomized complete block design in three replications. The treatment arrangement was given in Table 1.

Table 1. *Treatment arrangements used in the study.*

S. N	Year 1	Year 2	Year 3
1	Burqa	Burqa	Burqa
2	Hundaol	Hundaol	Hundaol
3	Gelan	Gelan	Gelan
4	Sanate	Sanate	Sanate
5	Burqa	Gelan	Burqa
6	Burqa	Sanate	Burqa
7	Hundaol	Sanate	Hundaol
8	Hundaol	Gelan	Hundaol
9	Gelan	Burqa	Gelan
10	Gelan	Hundaol	Gelan
11	Sanate	Hundaol	Sanate
12	Sanate	Burqa	Sanate

2.3. Experimental Procedure and Field Management

The experimental field was ploughed by oxen except the first year of the experiment establishment which is ploughed by tractor and the soil was pulverized to a fine tilth by hand digging. Site demarcation and Blocking were done and fixed for the experimental year. The gross plot size of 1.8 m × 3 m (5.4 m^2) was used for both crops. The spacing of 30 cm and 10 cm for fenugreek and 20 cm and 10 cm for wheat between rows and plants respectively was used. The four middle rows were used for data collection for fenugreek, and 7 rows were used for data collection for wheat. Fertilizer application and other management practices were done for both crops as per recommendation.

2.4. Data Collection

The Yield and yield related parameters such as plant height, number of primary branches per plant, number of pod per plant, number of seed per pod and total seed yield were taken for fenugreek and the Yield and yield related parameters such as plant height, number of tillers per plant, spike length, number of seed per spike and total grain yield were also taken for bread wheat. The collected data was subjected to analysis of variance (ANOVA) procedure using [10] software.

2.5. Soil Sampling and Analysis

Soil sample was collected from the entire experimental plot before planting using zigzag pattern to determine the soil status. Additionally, soil sample was taken from each experimental plot after harvesting and was analyzed for their physico-chemical properties.

3. Results and Discussion

3.1. Pre-Soil Physico-chemical Properties of the Experimental Site

The important physicochemical properties of the experimental soil were taken following the standard methods and procedures. Composite soil samples were initially taken just before starting the study at the depth of 0-30 cm. Accordingly, the textures of the soil of both locations were dominated by the clay fraction (Table 2). The clay texture indicates the degree of weathering, nutrient availability, and water-holding capacity of the soil. The pH was neutral, organic carbon was low, total nitrogen was medium, and available phosphorus was medium for Sinana. At Gololcha, the pH was neutral, organic carbon was medium, total nitrogen was low, and available phosphorus was medium (Table 2). The pre-sowing soil analysis indicated that external application of nutrients or amendments to the experimental sites.

3.2. Post- Soil Physico-chemical Properties of the Experimental Site

The post-harvest physiochemical characteristics of the soil for bread wheat with fenugreek rotation are presented in Table 3. Post-harvest soil analysis of soil revealed soil organic matter and total nitrogen increased when fenugreek is used as a precursor crop, and available phosphorus increased when wheat was used as a precursor crop.

The saturation of crop rotation systems with cereals results in a reduction of TN in the soil [11]. The noted reduction in the TN soil content under continuous growing of crops usually corresponds to the reduction in the soil organic carbon content [12, 13]. The soil sampled from crop rotation contained higher amounts of available P than the soil from the field of continuous wheat cropping [14].

***Table 2.** Selected soil physico-chemical properties of the experimental sites before planting.*

	Sinana		Gololcha		
Properties	**Result**	**Rating**	**Result**	**Rating**	**References**
Physical properties					
Sand (%)	22		20		
Silt (%)	26		25		
Clay (%)	51		55		
Textural Class	Clay		Clay		
Chemical properties					
pH (1: 2.5 H_2O)	6.82	Neutral	6.01	Neutral	[15]
Organic Carbon /OC/ (%)	1.18	Low	1.22	Medium	[15]
Total nitrogen /TN/ (%)	0.16	Medium	0.11	Low	[15]
Available phosphorus /P/ (ppm)	10.23	Medium	12.8	Medium	[16]

***Table 3.** Soil physic-chemical properties over years.*

	Sinana								**Gololcha**			
Treatments	**pH**		**OC**		**TN**		**P**		**pH**	**OC**	**TN**	**P**
Rotation	Y-2	Y-3	Y-2	Y-3	Y-2	Y-3	Y-2	Y-3	Y-2	Y-2	Y-2	Y-2
F1-F1-F1	6.82	6.82	1.18	1.56	0.15	0.15	11.86	11.86	6.01	1.23	0.27	12.8
F2-F2-F2	6.82	6.82	1.18	1.56	0.15	0.15	11.86	11.86	6.01	1.23	0.27	12.8
W1-W1-W1	6.82	6.82	1.18	1.18	0.13	0.13	12.42	12.42	6.01	1.22	0.25	13.0
W2-W2-W2	6.82	6.82	1.18	1.18	0.13	0.13	12.42	12.42	6.01	1.22	0.25	13.0
F1-W1-F1	6.82	6.82	1.18	1.62	0.14	0.14	12.55	12.55	6.01	1.23	0.27	13.0
F1-W2-F1	6.82	6.82	1.18	1.62	0.14	0.14	12.55	12.55	6.01	1.23	0.27	13.0
F2-W1-F2	6.82	6.82	1.18	1.62	0.14	0.14	12.55	12.55	6.01	1.23	0.27	13.0
F2-W2-F2	6.82	6.82	1.18	1.62	0.14	0.14	12.55	12.55	6.01	1.23	0.27	13.0
W1-F1-W1	6.82	6.82	1.18	1.51	0.15	0.15	12.55	12.55	6.01	1.23	0.27	13.0
W1-F2-W1	6.82	6.82	1.18	1.51	0.15	0.15	12.55	12.55	6.01	1.23	0.27	13.0
W2-F1-W2	6.82	6.82	1.18	1.51	0.15	0.15	12.55	12.55	6.01	1.23	0.27	13.0
W2-F2-W2	6.82	6.82	1.18	1.51	0.15	0.15	12.55	12.55	6.01	1.23	0.27	13.0

F1=Burqa variety; F2=Hundaol variety; W1=Galan variety and W2= Sanate variety; Y-2=Year two; Y-3=Year three; OC= Organic Carbon; TN=total nitrogen; P= Phosphorus

3.3. Plant Height

The height of Fenugreek and bread wheat was affected by rotation of fenugreek with bread wheat varieties. The highest of fenugreek (50.67 cm) was recorded from the variety Burqa followed by a bread wheat variety Senate while the least was recorded from continuous fenugreek cropping. Similarly, the tallest bread wheat plant height (108.0 cm) was recorded when Senate variety grow followed Hundaol Variety while the lowest bread wheat plant height was recorded when wheat planted followed wheat repetitively.

3.4. Number of Primary Branches Per Plant

The number of primary branches of fenugreek varieties was affected by rotation of fenugreek with wheat varieties. The more number of primary branches of fenugreek per plant was observed from Burqa variety when planted after Senate variety of Bread wheat. However, lower number of primary branches per plant was observed when fenugreek varieties were planted on their own plot continually (Table 3).

3.5. Number of Tillers Per Plant

The number of tillers per plant of wheat was affected by rotation of fenugreek varieties with bread wheat varieties. The result of study indicated that the number of tillers per plant show the increment trend when wheat grow after wheat (Table 3). The more number of tillers per plant (3.93) was obtained when wheat grow following fenugreek varieties.

3.6. Number of Pod Per Plant

The number pod per plant of fenugreek was influenced by rotation wheat with fenugreek. The result of study indicated that if fenugreek varieties were rotate with wheat varieties the number of pod per plant affected. Thus the maximum number of pod per plant (21.80) was obtained when Hundaol planted following Senate variety. On the other hand the minimum number of pod per plant of fenugreek varieties was obtained if fenugreek grows continually on the same land over years.

3.7. Spike Length

The spike length of bread wheat was affected by rotation of bread wheat varieties with fenugreek varieties. The maximum spike length (6.50 cm) was recorded when Galan variety was planted after Hundaol varieties of fenugreek while the lowest spike length was recorded when wheat grow followed wheat.

3.8. Number of Seed Per Pod

The number of seed per pod of fenugreek was influenced by rotation of fenugreek with bread wheat. As fenugreek grow as mono cropping the number of seed per pod show decreasing trend whereas the fenugreek grow following bread wheat the higher number of seed per pod of fenugreek was obtained. Thus the highest number of seed per pod (12.87) was obtained from Burqa variety of fenugreek when grew followed Senate variety of bread wheat (Table 3).

3.9. Number Seed per Spike

Bread wheat followed by fenugreek showed the number of seed per spike of bread wheat than bread wheat followed by bread wheat. The highest number of seed per spike (53.70) was obtained when wheat grow after wheat-fenugreek-wheat rotation. The lowest number seed per spike was obtained when wheat grow continuously on its own plot.

3.10. Seed and Grain Yield

The results of the study indicated that crop rotation affected seed yield of fenugreek, and grain yield of wheat was affected by rotating wheat with fenugreek. The maximum seed yield of fenugreek (1647 kg ha^{-1}) was obtained when the fenugreek (Buqa) variety grew after wheat. On the other hand, the maximum grain yield of bread wheat (6232 kg ha^{-1}) was observed when Senate grew after fenugreek. The minimum yield of fenugreek and wheat was obtained from continuous cropping. This is probably due to the improvement in soil fertility with different crops compared to continuous wheat cropping.

This indicates continuous wheat cropping in small-scale farms reduces bread wheat yield due to no host break for soil-borne disease and different pests. The higher yield of wheat in crop rotation with fenugreek is due to nitrogen fixation, and variation in root structure and depth is another benefit of crop rotation for change in soil fertility and can influence yield of crops by altering the physical and morphological properties of the soil. This result is similar to the findings of [17].

Rotation with pulse crop species, particularly the fenugreek crop, increased wheat grain yield in succeeding crops. This experiment revealed that the first wheat following a fenugreek precursor crop in rotation resulted in superior grain yields of bread wheat.

Table 4. *Mean Performance of agronomic parameters and yield of Fenugreek and Bread Wheat varieties at sinana on-station during 2021, 2022 and 2023.*

Treatment	PH (cm)			NPB/TPP			N Pod $plant^{-1}$ / SL (cm)			N seed Pod^{-1}/ N seed $spike^{-1}$			Seed/Grain yield (kg ha^{-1})		
	2021	2022	2023	2021	2022	2023	2021	2022	2023	2021	2022	2023	2021	2022	2023
F1F1F1	48.73	48.07	48.67	3.60	3.55	3.50	20.20	20.10	20.00	12.40	12.20	12.00	1569	1556	1550
F2F2F2	48.27	47.40	48.20	3.60	3.40	3.00	20.30	20.20	20.10	12.67	12.53	11.47	1594	1550	1538
F1W1F2	48.00	102.60	48.48	3.87	3.93	3.90	20.40	5.93	20.60	12.00	49.73	12.67	1592	6170	1663
F1W2F2	48.67	105.80	49.04	3.47	3.73	3.60	20.93	5.93	21.80	11.93	45.93	12.77	1545	6232	1585
F2W2F1	48.13	98.73	50.67	3.53	3.73	4.30	20.07	5.80	20.30	11.93	42.00	12.87	1588	6124	1638
F2W1F1	47.67	101.93	49.56	4.00	3.67	3.80	20.80	6.40	21.20	11.67	46.60	11.80	1560	6158	1647
W1W1W1	98.13	98.00	97.56	3.40	3.20	3.10	4.27	4.20	4.10	50.80	47.87	44.87	5600	5558	5354
W2W2W2	100.80	98.33	98.23	3.83	3.60	3.30	5.60	5.33	5.20	45.80	43.80	40.87	6015	5880	5697
W1F2W2	98.60	46.40	108.00	3.00	3.07	3.20	5.60	20.27	5.80	50.67	12.73	45.07	5948	1590	6014
W1F1W2	98.40	46.33	107.00	3.23	3.80	3.60	5.67	20.80	6.40	45.80	12.67	47.27	6015	1553	6190
W2F1W1	99.13	43.93	104.00	3.60	3.40	3.76	5.53	20.80	5.60	50.80	12.33	53.70	5962	1533	6109
W2F2W1	99.27	48.60	105.00	3.13	3.20	3.80	5.75	21.67	6.50	50.47	12.27	53.40	5984	1564	6193

F1=Burqa variety; F2=Hundaol variety; W1=Galan variety and W2= Sanate variety; PH= plat height; NPB= number of primary branch; NTPP= number of tiller per plant

Table 5. *Performance of agronomic parameters and yield of Fenugreek and Bread wheat varieties at Gololcha during 2021 and 2022.*

Treatment	PH (cm)		NPb/TPP		N Pod plant^{-1} / SL (cm)		N seed Pod^{-1}/ N Seed spike^{-1}		Seed yield (kg ha^{-1})	
	2021	2022	2021	2022	2021	2022	2021	2022	2021	2022
F1F1	35.53	40.87	3.93	3.73	13.33	10.73	11.87	12.73	1505	1533
F2F2	37.07	35.20	3.53	4.47	13.67	13.13	12.07	12.40	1580	1554
F1W1	34.33	80.27	3.27	1.80	12.33	6.73	12.60	30.60	1573	4524
F1W2	34.60	72.80	3.47	1.87	12.53	5.067	11.67	32.07	1527	5258
F2W2	35.07	73.20	3.20	1.93	13.80	5.00	11.93	33.53	1545	4978
F2W1	35.00	78.27	3.60	1.73	12.93	6.67	12.33	34.20	1569	4986
W1W1	87.13	79.13	3.40	2.00	5.40	7.73	43.53	33.07	5508	4876
W2W2	82.87	73.87	3.47	1.67	5.73	5.33	48.40	35.13	5521	4940
W1F2	88.27	40.33	2.87	4.60	5.40	14.53	43.27	13.00	5480	1654
W1F1	82.80	39.13	3.33	3.80	5.33	14.33	42.53	11.80	5445	1685
W2F1	82.80	40.40	3.00	3.80	5.40	12.93	44.00	12.27	5410	1584
W2F2	84.80	40.40	3.00	3.00	5.40	9.60	47.93	11.20	5584	1689

F1=Burqa variety; F2=Hundaol variety; W1=Galan variety and W2= Sanate variety; PH= plant height; NPB= number of primary branch; NTPP= number of tiller per plant

4. Conclusion and Recommendations

The growth parameters and yield of fenugreek and bread wheat was affected by rotations of fenugreek with bread wheat. Plant height, number of primary branches per plant, number of pod per plant, number of seed per pod and seed yield of fenugreek were influenced by rotation of fenugreek with bread wheat. On the other, plant height, numbers of tillers per plant, spike length, number of seed per spike and grain yield of bread wheat were affected by rotation of fenugreek and bread wheat.

The more number of primary branches of fenugreek per plant was observed from Burqa variety when planted after Senate variety of Bread wheat and more number of tillers per plant was obtained when wheat grow following fenugreek. The maximum number of pod per plant was obtained when Hundaol planted following Senate variety. On the other hand, the lowest number of pod per plant of fenugreek varieties was obtained if fenugreek grows continually on the same land over years.

The maximum spike length (6.50 cm) was recorded when Galan variety was planted after Hundaol varieties of fenugreek while the minimum spike length was recorded when wheat grow followed wheat. The highest number of seed per pod (12.87) was obtained from Burqa variety of fenugreek when grew Senate variety of bread wheat. The maximum spike length (6.50 cm) was recorded when Galan variety was planted after Hundaol variety of fenugreek while the lowest spike length was recorded when wheat grow followed wheat.

The highest number of seed per spike (53.70) was obtained when wheat grow after wheat-fenugreek-wheat rotation. The maximum seed yield of fenugreek (1647 kg ha^{-1}) was gained when fenugreek (Buqa) variety grow after wheat. On the other hand, the maximum grain yield of bread wheat (6232 kg ha^{-1}) was gained when Senate grow after fenugreek. The minimum seed yield of fenugreek and grain yield of wheat was obtained continuous cropping. This could be due to the improvement in soil fertility with different crops compared to continuous wheat cropping. This indicates continuous wheat cropping in small scale farmers reduce bread wheat yield due to no host break for soil born disease and different pests.

Rotation with pulse crop species, particularly the fenugreek crop, increased wheat grain yield in succeeding crops. This experiment revealed that the first wheat following a fenugreek precursor crop in rotation resulted in superior grain yields of bread wheat. The low yields obtained from the continuous wheat rotations at Bale. The result indicates the need to encourage the adoption of appropriate wheat rotations by peasant in the high lands of Bale zone and similar agro ecologies known by wheat production.

Abbreviations

RCBD	Randomized Complete Block Design
ANOVA	Analysis of Variance
LSD	Least Significant Difference

SNNPR	Southern Nations Nationalities and People Representatives
ISVCDOSP	Inclusive and Sustainable Value Chains Development in Oromia, Sidama and SNNPR Project
OC	Organic Carbon
OM	Organic Matter
Kg ha-1	Kilogram Per Hectare
m.a.s.l	Meter Above Sea Level
km	Kilometer
m	Meter
cm	Centimeter
%	Percentage

Acknowledgments

The authors would like to thank Inclusive and Sustainable Value Chains Development in Oromia, Sidama and SNNPR Project (ISVCDOSP) for funding this work and the Horticulture and Spices Research Team of Sinana Agricultural Research Centre for the successful implementation of the study.

Author Contributions

Chala Gutema: Conceptualization, Resources

Conflicts of Interest

The author declares no conflicts of interest.

References

[1] Engles, J. M., J. G. Hauwkes and MelakuWorede, 1991. Plant Genetic Resources of Ethiopia. Ethiopia. M. Sc. Thesis Presented to the School of Graduate Studies of Alemaya University.

[2] Khiriya, K. D., Singh, B. P. and Taneja, K. D. 2003. Effect of farm yard manure and phosphorus levels on yield, quality and nutrient uptake by fenugreek. *Forage Research*, 28(4): 210-214.

[3] Petropoulos G. A., Kouloumbis P. 2002 Botany, in: G. A. Petropoulos (Ed.), *Fenugreek - The genus Trigonella*, Taylor and Francis, London and New York. pp. 9-17.

[4] Myaka, F. M., W. D. Sakala, J. J. Adu-Gyamfi, D. Kamalongo, A. Ngwira, R. Odgaard, N. E. 2006.

[5] Rochester IJ, Peoples MB, Hulugalle NR, Gault RR, Constable GA. Using legumes to enhance nitrogen fertility and improve soil conditions in cotton cropping systems. Field Crops Research. 2001; 70: 27-41.

[6] McCallum MH, Kirkegaard JA, Green T, Cresswell HP, Davies SL, Angus JF. Improved subsoil macro-porosity following perennial pastures. Australian Journal of Experimental Agriculture, 2004, 44, 299-307.

[7] Kirkegaard JA, Christen O, Krupinsky J, Layzell DB. Break crop benefits in temperate wheat production. Field Crops Res., 2008; 107: 185-195.

[8] Osborne CA, Peoples MB, Janssen PH. Detection of a reproducible, single-member shift in soil bacterial communities exposed to low levels of hydrogen. Applied and Environmental Microbiology. 2010; 76: 1471-1479.

[9] Patrick, M. C., J. C. Gardner, B. G. Schatz, S. W. Zwinger and S. J. Guldan (1995). Grain yield and weed biomass of a wheat-lentil intercrop. Agron. J., 87(3): 574-579.

[10] GenStat. 2013. GenStat Procedure Library Release. 16th edition. VSN International Ltd.

[11] Cuvardic M., Tveitnes S., Krogstad T., Lombnæs P. 2004. Long-term effects of crop rotation and different fertilization systems on soil fertility and productivity. Acta Agr. Scand. B - S P, 54(4): 193-201. https://doi.org/10.1080/09064700410030258

[12] Blecharczyk A., Piechota T., Małecka I. 2005b. Changes of effect chemical soil properties under long term cropping systems and fertilization. Fragm. Agron., 2(86): 30-38. (in Polish) https://pta.up.poznan.pl/pdf/Fragm.%20Agron.%20vol.%2022%20(2005)/22(2)%202005.pdf

[13] Degu M., Melese A., Tena W. 2019. Effects of soil conservation practice and crop rotation on selected soil physicochemical properties: The case of Dembecha District, Northwestern Ethiopia. Appl. Environ. Soil Sci, 2019. https://doi.org/10.1155/2019/6910879

[14] Woźniak A., Kawecka-Radomska M. 2016. Crop management effect on chemical and biological properties of soil. Int. J. Plant Prod., 10(3): 391-402. https://doi.org/10.22069/ijpp.2016.2904

[15] Tekalign Tadesse. 1991. Soil, plant, water, fertilizer animal manure and compost anlysis. Working Document No. 13. International Livestock Research Center for Africa (ILCA), Addis Ababa.

[16] Roy. R. N., Finck, A., Blair, G. J. and Tandon, H. L. S. 2006. Plant nutrition for food security. A guide for integrated nutrient management. FAO. Fertilizer and Plant Nutrition Bulletin 16.

[17] Admasu, A., Shimels, F., Debela, D., Debele, T. (2020). Sustainable wheat based crop rotation system in tropical. Indian Journal of Agricultural Research, 5: 000253.