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Evaluation and Demonstration of Different Organic Matter for Soil Fertility Improvement in Shashemene and Kofele Districts of West Arsi Zone, Ethiopia

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Abstract

The experiment was conducted in, Shashemene and Kofele districts of West Arsi Zone, Ethiopia, during 2013 - 2016 main cropping seasons. The aim was to select best organic matter for soil fertility improvement, to determine organic matter application cycle and to improve farmers' understanding on use of organic matter for soil fertility management. Four treatments namely compost, farm yard manure, green manure and control were used to evaluate their performance on crop yield and soil fertility dynamics. The treatments were arranged in RCBD replicated three times having an area of 3x4m for each plot at both experimental sites. Compost and Animal manure were applied at the rate of 10ton/ha. For green manure, haricot bean was sown and incorporated to the soil before flowering. Bread wheat variety (*Tritium aestivum L.*) was sown at Halache FTC, in Shashemene district. On the other hand, food Barley (*Hordeum vulgare L.*) was sown at Garmama FTC, in Kofele district. It was identified that both wheat and barley yield showed an increasing trend from 2013-2014 but decreased gradually in 2015 and 2016. Use of compost also showed a better yield response in the second year at both sites. This result showed that mineralization or nutrient availability from the Organic matter is higher in the second year (2014th) and the contents reduced gradually in the 3rd and 4th years. Both Barley and Wheat yield were highly significantly different ($p < 0.05$) in the first year, second and third year but yield was not significantly different in the fourth cropping time (2016). Therefore, Compost is more preferred to get more yields as compared with Animal manure and Green manure. In the absence of compost, it is advisable to use animal manure for soil fertility management. Both compost and animal manure should be applied again at the third cropping season.

Keywords: *Organic Fertilizer; Yield; Nutrient Dynamics*

Background and Justification

The agriculture sector in Ethiopia is the most important sector for sustaining growth and reducing poverty. However, lack of adequate nutrient supply, the depletion of soil organic matter, and soil erosion are major obstacles to sustained agricultural production [1]. Very low or low soil fertility status of agricultural land of smallholders are mentioned as one of the main constraints of crop yields in Ethiopia [2-4]. They have documented the problem of low soil nutrient reserves and negative nutrient balances in croplands with few or no external nutrient inputs compared to the nutrient status of forest areas, grazing or well managed lands. The problem is more serious in the highlands where most of the human and livestock population is found [3]. This is mainly due to the complete removal of crop residues from farm lands for household energy and livestock feed, use of manure as a source of fuel instead of using it for soil fertility maintenance and lack of appropriate *in-situ* SWC practices [5,6].

Continuous uses of inorganic fertilizers lead to deterioration of soil chemical and physical properties, biological activities and thus in general it affects soil health [7]. Nutrients supplied exclusively through chemical sources lead to unsustainable land productivity over the years [7,8]. Furthermore, the price of inorganic fertilizers is increasing and becoming unaffordable for resource-poor smallholder farmers. The negative impacts of chemical fertilizers and their high prices have prompted the interest in the use of organic fertilizers as source of nutrients.

Thus, the mitigation of soil fertility depletion is currently a pressing issue and major national concern. Organic fertilizer application has been reported to improve crop growth by supplying plant nutrients including macro and micro-nutrients as well as improving soil physical, chemical, and biological properties thereby provide a better environment for root development by improving the soil structure [9]. Nutrients contained in organic fertilizers are released more slowly and are stored for a longer time in the soil ensuring longer residual effects, improved root development and higher crop yields [10].

Organic fertilizers are usually applied at higher rates, relative to inorganic fertilizers. When applied at higher rates, they give residual effects on the growth and yield of succeeding crops [11]. Improvements of environmental conditions as well as the need to reduce cost of fertilizing crops are reasons for advocating use of organic materials [12].

Compost and animal manure had been used as a source of local fertilizer in the many developing countries across the globe for many centuries. Proper use of organic fertilizer is essential for both a production and environmental issues. However, best type of organic fertilizer, its application rate and frequency of application are not identified. As a result, too low applications can lead to nutrient deficiency and low yields. On the other hand, too high a rate can lead to nitrate leaching, phosphorus runoff, accelerated eutrophication of lakes, and excessive vegetative growth of some crops. Selection of Economically and environmentally sound organic fertilizer is also equally important in the implementation and management of organic agriculture. Thus, understanding how to manage and use of organic fertilizer is important to improve agricultural production and productivity of the land. One of the contributing factors to low yield generally in Ethiopia and particularly in the study areas was the inadequate agronomic management practices specifically, inadequate and inappropriate application of fertilizer and organic matter by farmers. Therefore, this project was designed to achieve the following objectives:

Objectives of the project:

- To select best organic matter for soil fertility improvement
- To determine organic matter application cycle
- To improve farmers' understanding on use of organic matter for soil fertility management

Materials and Methods

Description of study area

The experiment was conducted in two districts namely, Shashemene and Kofele of West Arsi Zone, Ethiopia, during 2013-2016 main cropping seasons. Shashemene and Kofele districts are located at 38° 56′ N, 7° 23′ E, 2002 m.a.s.l. and 39° 05′ N, 7° 15′ E, 2350 m.a.s.l., respectively. The rainfall pattern of these areas is characterized by bimodal distribution with small rainy season belg (March-June) and main rainy seasons Meher (July-November). The annual total rainfall was 1520 mm at Shashemene and 1767 mm at Kofele with respective mean annual temperature of 19.7 and 14.7°C respectively.

This activity was conducted at Halache FTC sites in Shashemene. As far as soil type is concerned, the dominant soil unit of Shashemene district is andisol. Texturally, the soils of the area are classified as sandy loam. Wheat, Barley, potato, maize and teff are the major crops produced in this district.

In Kofele district, the experiment was conducted at Garmama FTC. Texturally, the soils of the area is classified as clay loam. Barley, wheat, potato, and cabbage are the major crops produced in this district.

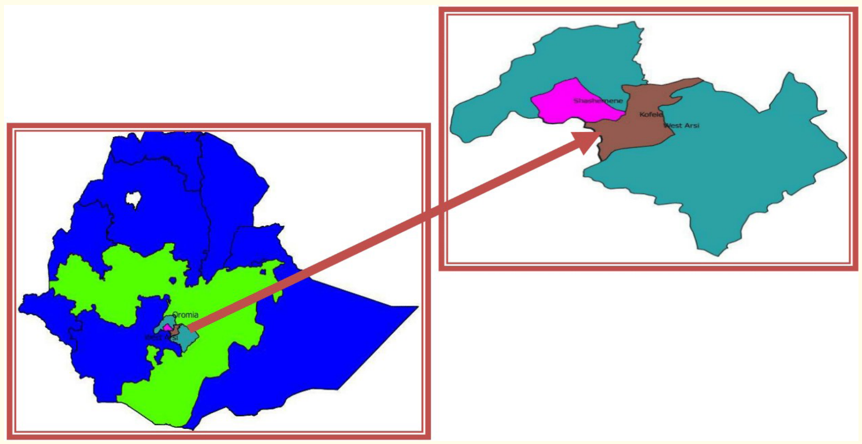

Figure 1: *Geographical location of Kofele and Shashemene district in West Arsi Zone, Oromia, Ethiopia.*

Treatments and Experimental Design

The experiment was restricted on the application of organic matter (compost, Animal manure, green manure) and control (with no organic matter application) to evaluate their effect on soil fertility status and crop production. The experiment was laid out in Randomized Complete Block Design (RCBD) having 3 replications. The net plot size was 3 x 4 m (12 m^2) with 50 cm row spacing and a total of 12 plots at each experimental site.

Both compost and Animal manure are applied to the maximum rate of 10ton/ha based on the recommendation given by FAO, 1998 which is 5 - 10 ton/ha for most of tropical soil. For green manure, haricot bean was sown on plots and incorporated to the soil at its flowering stage.

Bread wheat variety (*Tritium aestivum L.*) was sown at Halache FTC, in Shashemene district, to evaluate the treatments. This crop is selected due to its dominance crop in this district. On the other hand, food Barley (*Hordeum vulgare L.*) was sown at Garmama FTC, in Kofele district to evaluate the same treatment.

Statistical analysis

One-way ANOVA was carried out to determine the differences among treatment groups. Microsoft Excel was used to produce graphs particularly to show the changes in trends of yield over years.

Result and Discussion

Effect of organic fertilizer on crop yield

Effect of Organic fertilizer on Bread Wheat yield (*Tritium aestivum L.*) and food Barley (*Hordeum vulgare L.*)

The result revealed that wheat yield was increased from 21-30kun/ha, 15-25kun/ha, and 17-20kun/ha by using compost, Animal manure, and green manure respectively from 2013 - 2014 but showed a decreasing trend from 2015 - 2016 cropping season (Figure 2). On the other hand, yield of barley was increased from 41-58kun/ha, 36-51kun/ha, and 26-40kun/ha by using compost, Animal manure, and green manure respectively from 2013 - 2014 but showed a decreasing trend from 2015-2016 cropping season (Figure 3). This is due to the fact that mineralization or nutrient availability from the Organic matter is higher in the second year and reduced gradually in the 3rd and 4th years (keeping other yield factors control). Use of compost showed better yield response in both crops as compared with the rest of treatments.

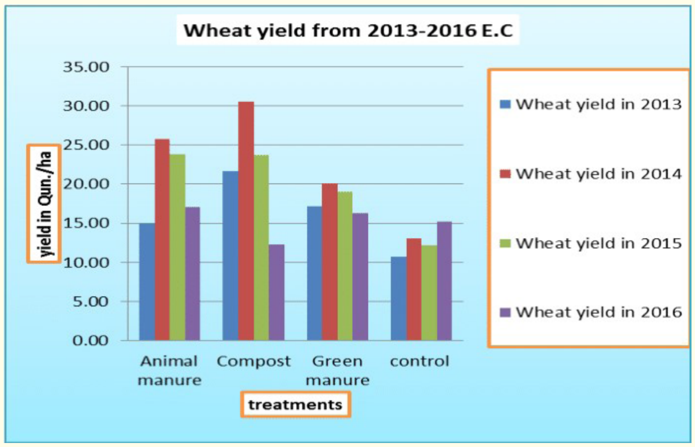

Figure 2: *Trends of wheat yield from 2013-2016.*

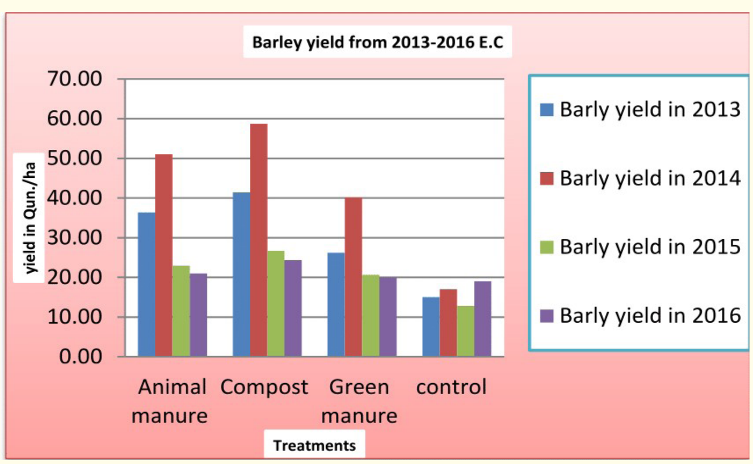

Figure 3: *Trends of barley yield from 2013-2016.*

On the other hand, Maximum wheat and barley yield was obtained in 2014. Crop yield was decreased gradually to the level of control in 2015th and 2016th cropping season. In using compost, both wheat and barley yield increased by 17kun/ha and 30kunt/ha respectively over the control in 2014 (at the second cropping season). This also indicated that nutrient availability for crop reached the maximum in the second year (2014). This result is also strongly agreed with the study by other authors indicating that nutrients contained in compost and FYM are released more slowly and are stored for a longer time in the soil, thereby ensuring a long residual effect, supporting better root development, leading to higher crop yields even better than the yield of inorganic fertilizer [13]. The study also added, only a fraction of the N and other nutrients becomes available in the first year after compost application. A large part of the compost N needs to be mineralized, because more than 90% is bound to the organic N pool and 30 to 60% is present in humic acids. The characteristics of the compost influence this mineralization process including the C/N, the biodegradability of the compost, contents of cellulose, and lignin and environmental factors like soil texture, pH, and climate. Therefore, 30 to 35% of the total N content can be plant available in the first year of application and most of the N release will occur in the first two years after application [14,15].

In addition, crop yield response of the treatments are highly significantly different ($p < 0.05$) in the first, second and third year but they are not significantly different at the fourth cropping season (Table 1 and 2). Other similar studies also showed that grain yield of wheat increased significantly with the use of organic material in the form of compost and FYM [16]. Their results indicated that plots which received 7ton/ha FYM and compost had significantly increased crop yield by 15ton/ha as compared with the control (with no organic matter application).

Duration (2013-2016)	Treatments	Mean yield in Ku/ha	Std. Dev.	Minimum yield in Ku/ha	Maximum yield in Ku/ha
1st Year (2013)	Animal manure	15.00^{efg}	2.00	13.00	17.00
	Compost	21.67^{bcd}	1.53	20.00	23.00
	Green manure	17.17^{def}	0.76	16.50	18.00
	Control	10.67^{g}	1.53	9.00	12.00
2nd Year (2014)	Animal manure	25.78^{efg}	1.54	24.40	27.45
	Compost	30.50^{a}	0.50	30.00	31.00
	Green manure	20.10^{cde}	1.39	18.50	21.00
	Control	13.00^{fg}	1.00	12.00	14.00
3rd Year (2015)	Animal manure	23.74^{bc}	1.41	22.22	25.00
	Compost	23.70^{bc}	11.40	11.11	33.33
	Green manure	19.00^{cde}	1.00	18.00	20.00
	Control	12.17^{fg}	0.76	11.50	13.00
4th Year (2016)	Animal manure	17.03^{def}	5.01	12.22	22.22
	Compost	12.22^{fg}	1.11	11.11	13.33
	Green manure	16.29^{def}	1.70	14.44	17.77
	Control	15.18^{efg}	1.70	13.33	16.66
CV (%)		18.32			
$LSD_{0.05}$		5.58			
P-value		0.0001			

Table 1: *Mean Comparison Wheat yield among the treatments across the experimental period.*

In using compost, both wheat and barley yield increased by 17kun/ha (76%) and 30kunt/ha (50%) respectively over the control in 2014 (at the second cropping season). The result of this experiment also agreed with the finding of Amanuliah and Maimoona [17] who reported that the use of FYM and Compost increased wheat yield and the lowest crop yield was recorded from the control treatment.

Duration (2013-2016)	Treatments	Mean yield in Ku/ha	Std. Dev.	Minimum yield in Ku/ha	Maximum yield in Ku/ha
1st Year (2013)	Animal manure	36.38c	2.95	33.50	39.40
	Compost	41.40c	3.52	38.50	45.33
	Green manure	26.22d	4.22	21.66	30.00
	Control	15.00fg	2.00	13.00	17.00
2nd Year (2014)	Animal manure	51.00b	6.90	43.75	57.50
	Compost	58.75a	7.60	50.00	63.75
	Green manure	40.11c	6.22	33.75	46.20
	Control	17.00efg	1.73	15.00	18.00
3rd Year (2015)	Animal manure	22.94ed	2.08	20.83	25.00
	Compost	26.66d	4.72	23.00	32.00
	Green manure	20.66edf	1.15	20.00	22.00
	Control	12.83g	1.25	11.50	14.00
4th Year (2016)	Animal manure	19.66ef	0.57	19.00	20.00
	Compost	20.66edf	0.57	20.00	21.00
	Green manure	20.00ef	1.00	19.00	21.00
	Control	19.00efg	1.00	18.00	20.00
CV (%)		13.31			
$LSD_{0.05}$		6.20			
P-value		0.001			

Table 2: *Mean Comparison Barley yield among the treatments across the experimental period.*

This study also showed that application of compost and FYM increase crop yield to 65.63% over the control treatment. This might be due to the increased rate of FYM which might have attributed to the increased availability of NPK, improvement of soil water holding capacity. Also in agreement with this result, Ofosu and Leitch [18] reported that crop yield of spring barley increased with organic manure application as compared to inorganic fertilizer alone.

In addition, Getachew [19] reported that the use of organic manures in combination with mineral fertilizers maximized crop yield than the application of inorganic fertilizers alone. More specifically, Tittarelli., *et al*. [20] pointed out that the simplest method of examining the agronomic value of stabilized organic materials is the calculation both of organic matter supply and plant nutrients. The slow release of these nutrients is responsible for the increase in crop yields in the subsequent years.

Compost application significantly improved yield of wheat and Barley compared to other treatments. The observed increase in yield with application of compost compared to other treatments demonstrates that compost contributes to a better crop production. Farmers would therefore benefit of using compost as an alternative for the expensive inorganic fertilizers or the use of no inputs.

Effect of organic fertilizers on Soil nutrient dynamics

Soil Samples were collected to the depth of 20 cm every year starting from the first year of application (2013) to the last experimental period (2014) from both experimental sites and analyzed for major soil nutrient contents. Accordingly, soil samples were analyzed for total N, available P, K and soil organic matter content. It was identified that soil macro nutrient such as total nitrogen, available phosphorous and potassium are significantly different (at $p < 0.05$) among the treatments at all cropping season except in the fourth year where the there are no significance differences in soil nutrient contents among the treatments (Table 3 and 4).

Duration (2013-2016)	Treatments	Total N (%)	Avail. P in ppm	Avail. K in g/kg soil	EC in mmhos/ cm	pH	SOC (%)	C/N
1st Year (2013)	Animal manure	0.38^{b}	46.40^{b}	356.81^{b}	0.09^{c}	4.26^{d}	8.86^{a}	23.54^{ef}
	Compost	0.44^{a}	61.33^{a}	458.77^{a}	0.07^{c}	4.25^{de}	8.02^{ab}	18.54^{f}
	Green manure	0.31^{c}	37.00^{c}	259.25^{c}	0.13^{c}	3.99^{e}	7.48^{abc}	23.97^{ef}
	Control	0.15^{ghi}	15.67^{e}	130.55^{e}	0.39^{bc}	4.00^{ed}	7.87^{ab}	55.06^{ab}
2nd Year (2014)	Animal manure	0.29^{cd}	25.33^{d}	229.03^{cd}	0.43^{bc}	5.27^{a}	5.64^{def}	19.85^{ef}
	Compost	0.31^{c}	34.00^{c}	329.69^{b}	0.96^{a}	5.26^{a}	5.70^{def}	18.35^{f}
	Green manure	0.30^{c}	25.87^{d}	131.03^{e}	0.09^{c}	5.27^{a}	5.59^{def}	18.65^{f}
	Control	0.12^{hi}	14.00^{e}	125.02^{e}	0.69^{ab}	5.17^{abc}	4.42^{f}	46.19^{bc}
3rd Year (2015)	Animal manure	0.25^{ed}	17.23^{e}	198.67^{d}	0.05^{c}	4.99^{bc}	6.86^{bcd}	27.35^{def}
	Compost	0.23^{ef}	22.00^{d}	259.50^{c}	0.05^{c}	5.03^{abc}	6.98^{bcd}	30.48^{de}
	Green manure	0.18^{fg}	15.83^{e}	198.00^{d}	0.05^{c}	4.99^{bc}	6.14^{cde}	35.95^{cd}
	Control	0.11^{i}	19.33^{e}	111.00^{e}	0.06^{c}	4.95^{c}	6.59^{bcde}	59.26^{a}
4th Year (2016)	Animal manure	0.17^{gh}	13.67^{e}	131.58^{e}	0.06^{c}	5.10^{abc}	5.09^{ef}	31.03^{de}
	Compost	0.16^{ghi}	19.53^{e}	125.41^{e}	0.07^{c}	5.20^{a}	6.10^{def}	38.95^{cd}
	Green manure	0.13^{hi}	17.37^{e}	128.27^{e}	0.05^{c}	5.22^{ab}	6.71^{cdef}	31.68^{de}
	Control	0.13^{hi}	16.00^{e}	100.43^{e}	0.06^{c}	5.02^{abc}	4.81^{f}	37.32^{cd}
CV (%)		12.58	13.12	13.12	12.00	3.31	15.68	21.03
$LSD_{0.05}$		0.05	5.70	5.70	0.40	0.26	1.69	11.70
P-value		0.000	0.000	0.000	0.028	0.000	0.008	0.021

Table 3: *Mean comparison of soil chemical properties at Garmama FTC, Kofele.*

Total nitrogen, available phosphorous and potassium in the soil is higher than control treatment in the first, second and third cropping but are in similar status with control in the fourth cropping season (Table 3 and 4). On the other hand, soil macronutrients (total nitrogen, available phosphorous and potassium) contents at the first cropping season is higher than the rest of the cropping season. Soil macro nutrient contents showed decreasing trend from the first through the fourth cropping season. This is mainly attributed to continuous nutrient utilization or available by the crop and losses through leaching. C/N showed an increasing trend from the first cropping time to the last cropping season (4th year). This is mainly due to decreased in total nitrogen over the experimental period. C/N ratio of organic material can be used as a good indicator of nutrient supply. Other similar studies by Weber., *et al*. [21], who found the C/N ratio clearly increased, from 10.7 up to 22.2, in the third year after municipal solid waste compost application. This behavior can be explained by a depletion of N reserve, probably because of plant N uptake.

As regards the P from organic amendments, Helk., *et al*. (2001) reported that compost applications can increase plant available P in the soil. The soil extractable P concentration increased on average from 7.2 to 86 mg kg^{-1} soil with enhanced application rates from 0 to 200 t ha^{-1} (Zhang., *et al*. 2006). Furthermore, Eghball (2002) suggested that 4-year beef cattle manure and composted manure application based on N needs of corn could eventually result in soil accumulation of P, since the manure or compost N/P ratio is usually smaller than the corn N/P uptake ratio. Overall literature analysis demonstrates that several organic amendments' long-lasting applications enhanced soil available potassium, extractable phosphorous and organic carbon content, and resulted in delayed N availability. When applied to soil, manure, compost, and other organic amendments undergo microbial transformations that release plant-available N over time. Volatilization, denitrification, and leaching result in N losses from the soil reduce the amount of N that can be used by crops.

Duration (2013-2016)	Treatments	Total N (%)	Avail. P in ppm	Avail. K in g/kg soil	EC in mmhos/ cm	pH	SOC (%)	C/N
1st Year (2013)	Animal manure	0.44^{a}	105.27^{ab}	226.73^{ab}	0.29^{ab}	5.45^{ed}	8.57^{a}	19.72^{efg}
	Compost	0.47^{a}	80.53^{abcd}	321.67^{a}	0.29^{ab}	5.33^{e}	8.52^{a}	18.03^{efg}
	Green manure	0.36^{b}	104.07^{ab}	128.79^{bcde}	0.32^{a}	5.47^{cde}	8.27^{ab}	22.94^{efg}
	Control	0.20^{fg}	48.33^{cde}	48.33^{e}	0.27^{abc}	5.44^{de}	8.29^{ab}	41.60^{a}
2nd Year (2014)	Animal manure	0.35^{bc}	88.07^{abcd}	112.24^{ed}	0.21^{cd}	6.00^{a}	5.64^{cd}	16.07^{fg}
	Compost	0.42^{a}	99.36^{abc}	209.00^{bcd}	0.23^{bc}	6.03^{a}	5.70^{cd}	13.50^{g}
	Green manure	0.29^{cd}	95.54^{abc}	101.43^{e}	0.21^{cd}	5.90^{abc}	5.60^{cd}	18.69^{efg}
	Control	0.19^{fg}	37.67^{de}	43.33^{e}	0.21cd	5.93^{ab}	5.42^{cd}	31.01^{bcd}
3rd Year (2015)	Animal manure	0.26^{de}	55.02^{bcde}	104.00^{e}	0.12^{f}	5.81^{abc}	6.86^{abc}	26.19^{cde}
	Compost	0.30^{cd}	55.55^{bcde}	123.00^{cde}	0.12^{f}	5.78^{abc}	6.99^{abc}	23.35^{efg}
	Green manure	0.23^{ef}	60.54^{bcde}	217.33^{bc}	0.11^{f}	5.74^{abcd}	6.14^{cd}	26.82^{cde}
	Control	0.18^{fg}	26.33^{e}	41.67^{e}	0.10^{f}	5.75^{abcd}	6.60^{bcd}	37.24^{ab}
4th Year (2016)	Animal manure	0.19^{fg}	30.12^{e}	73.33^{e}	0.10^{f}	5.83^{abcd}	5.09^{d}	26.31^{cde}
	Compost	0.21^{ef}	57.67^{cde}	60.13^{e}	0.13^{ef}	5.50^{bcd}	6.11^{cd}	30.36^{bcd}
	Green manure	0.20^{fg}	61.72^{cde}	48.63^{e}	0.12^{f}	5.63^{abcd}	6.71^{bcd}	33.77^{abc}
	Control	0.17^{g}	23.00^{e}	49.83^{e}	0.14^{def}	5.88^{abcd}	5.92^{cd}	33.90^{abc}
CV (%)		11.50	40.94	35.77	25.26	4.62	15.8	23.22
$LSD_{0.05}$		0.05	52.59	100.77	0.07	0.44	1.74	10.12
P-value		0.001	0.017	0.001	0.005	0.037	0.008	0.001

Table 4: *Mean comparison of soil chemical properties at Halache FTC, Shashemene.*

Available levels of NPK after the second crop harvest were higher than those of the first crop cycle indicating that mineralization of NPK increased with time after the initial application of the organic amendments. Other similar studies also confirmed that irrespective of the manure type, soil available levels of N and P increased with increasing rates of application and experimental duration by Maerere., *et al*. [22]. Miller [23] also highlighted that organic material application to cropland could affect soil properties, but the effects generally may not be apparent over a short time period.

Availability of the nutrients for plant growth will depend on their breakdown and release from the organic components. Studies showed that about 70 to 80% of the phosphorus (P) and 80 to 90% of the potassium (K) will be available from manure in the first year after application (Zhang., *et al*. 2006). This study added, N availability is more complex than determining P and K availability. Most of the N in manure is in the organic form and essentially the entire N in compost is organic. Organic N is unavailable for uptake until microorganisms degrade the organic compounds that contain it. A smaller fraction of the N in manure is in the ammonium/ammonia or inorganic form. The ammonium-N form is a readily available fraction. Other inorganic forms such as nitrate and nitrite can also exist, but their quantities are usually very low [24].

Conclusion and Recommendations

The study showed that both wheat and barley yield were enhanced by the application of compost, Animal manure and green manure. Application of compost produces more crop yield than Animal manure and green manure. Maximum crop yield was attained at the second harvesting and reduced gradually in the third and fourth cropping season. Application of organic fertilizers improved the chemical properties of the soil when compared to the control. On the other hand, nutrient availability for the crop reached the maximum in the second year.

The residual effects of the manure and compost are important. Some benefit will be obtained in the second and third years following application. When manure and compost are used to fertilize crops, soil organic matter will increase over time and subsequent rates of application can generally be reduced because of increased nutrient cycling. Continuous use of manure or compost can lead to high levels of residual N, P, and other nutrients. Taking into account residual release of N in subsequent years should help to avoid excessive applications. Remember that some manures and composts contain high levels of P, so if organic nutrient sources are regularly applied at rates to meet crop N demands, the amount of P in the soil can build up to excessively high levels. Use of soil tests, plant tissue tests, and monitoring of crop growth will help in determining the amount of residual N and other nutrients in the soil and the need for further applications.

Recommendations

- Thus, it was recommended that the farmers can use organic fertilizers in their fields to full fill the deficiency of mineral nutrition in the soil. Because the synthetic fertilizers are now days become beyond the bought capacity of the farmers.
- Maximum crop yield was obtained in the second year while showing decreasing trend in the third and fourth years. Therefore, it is advisable farmers to reapply organic fertilizers starting from the third cropping season.
- Use of compost resulted in high yield for both crops followed by Animal manure and green manure. Therefore, it is advisable to use compost as strategy to improve soil fertility and increasing crop yield.

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