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Effects of dry bioslurry and chemical fertilizers on tomato growth performance, fruit yield and soil properties under irrigated condition in Southern Ethiopian

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Poor soil fertility and low level of fertilizer application results in low productivity of irrigated tomatoes (*Lycopersicon esculentum* Mill.) in Arba Minch Zuria District, Southern Ethiopia. Therefore, this experiment was conducted to evaluate the role of integrated application of dry bioslurry and chemical fertilizers on growth performance and fruit yield of tomato, and on soil properties. A factorial combination of six levels of fertilizers and two tomato varieties (Gelilea and Roma VF) were laid out in randomized complete block design with three replications. The six fertilizer treatments included were: (1) control, (2) nitrogen and phosphorus fertilizer (NP), (3) blended fertilizer (NPSZnB), (4) NP + bioslurry, and (5) blended fertilizer +bioslurry and (6) bioslurry without any fertilizer. Gelila variety was superior to Roma VF in marketable and total fruit yields. All growth parameters of tomato such as (plant height, branches, etc) were significantly (P<0.05) enhanced by fertilizer application. Fertilizer and variety interaction significantly (P<0.05) influenced number of primary and secondary branches, fruit clusters per plant, and average fruit weight. The results showed that dry bioslurry and chemical fertilizers application significantly (P<0.05) increased total and marketable fruit yields. The highest total and marketable fruit yields occurred when NP and blended fertilizer were applied in integrated forms with dry bioslurry to soils. The integrated bioslurry application with NP and blended fertilizer also increased total N, organic carbon and pH of the study soil after harvest. Therefore, regular application of dry bioslurry and chemical fertilizer recommended for improved and sustainable irrigated tomato production and soil fertility improvement in Arba Minch Zura District, southern Ethiopia.

Key words: Bioslurry, chemical fertilizer, tomato fruit yield, integrated soil fertility management.

INTRODUCTION

Given the poor economic capacity of smallholder farmers, the chemical fertilizers used for crop production are still at inadequate rates in Ethiopia in particular and in Sub-Saharan Africa in general (Girma, 2017). Therefore,

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alternative and/or integrated options should be sought to improve crop production in smallholder production systems.

Tomato (*Lycopersicon esculentum* Mill.) is one of the most widely grown vegetable crops in the world. It is largely cultivated under irrigated conditions in the Rift Valley area of Ethiopia (Lemma, 2002). It is a profitable cash crop for smallholder farmers in Ethiopia. Nevertheless, the national average tomato fruit yield is often low (19.8 t ha^{-1}) compared even to the neighboring country, Kenya (23.2 t ha^{-1}) (FAO, 2013). Current productivity of tomato under farmers' condition in Arba Minch Zuria District is even low (11t ha^{-1}, personal communication with smallholder farmers), whereas fruit yield of up to 40 t ha^{-1} was recorded on research plots in Ethiopia (Tesfaye, 2008). Poor soil fertility, lack of well adapted improved varieties, lack of adequate nutrient supply and poor agronomic management practices (spacing, planting time, irrigation, etc) are the main constraints to agricultural production systems in Ethiopia (Dandena et al., 2011) and particularly in the study area.

Soil degradation in the form of nutrient depletion is an important cause for the decline of agricultural production in Ethiopia (Bekele and Holden, 1998). The rate of soil degradation is related to the management system, soil properties, vegetation, topography of the area, and the prevailing climatic condition. Indeed, soil degradation in traditional irrigation system would be lower to rain fed system. Fertilizer use is the core strategy to overcome soil fertility depletion (Rahman and Tetteh, 2014). In view of this, chemical fertilizers, specifically Diammonium Phosphate (DAP) and urea are used for major crops production over several decades in Ethiopia. Fertilizers, one of the major agricultural inputs are imported into Ethiopia in large extent every year. This causes significant outflow of national currency. In general, an increasing trend of chemical fertilizer use is observed along with improvement in the agriculture production system in Ethiopia over the last few decades. Due to the increase in population pressure on the one hand and the decrease in land availability on the other hand, fertilizer use has become the leading resource to increase crop productivity per unit land area. Nevertheless, alternative options should be sought to improve smallholder farmers' access for soil fertility management, hence bioslurry can be one of the resources that can be tested as integrated soil fertility management component under irrigation.

Although the balanced use of macro and micro nutrients in crops can play a significant role in increasing tomato yield, they may not be available from chemical fertilizer sources. Recently, there is a growing focus on Integrated Nutrient Management (INM) which encourages a more eco-friendly farming with reduced use of chemical fertilizers in agriculture sector (Amrit, 2006). Thus, Integrated Nutrient Management is the judicious use of organic and inorganic fertilizers and improved crop varieties to increase production and productivity of smallholder farmers. In Ethiopia, few crop residues are retained on farmer fields due to their competitive use for livestock feed, energy, cash sales and construction material (Girma, 2017). This further causes soil fertility depletion in Ethiopia. Biogas dregs and slurry are by-products of biogas generated during anaerobic digestion in biogas plants that could be used as organic fertilizer sources. Bioslurries similar to other organic amendments are known to have positive effects on soil structure, water-holding capacity, cation exchange capacity and microbial activity thus improving the physical, chemical and biological quality of soil by adding organic matter and plant nutrients to the soil (Garg et al., 2005; Goberna et al., 2011). However, the fertilizer value of bioslurry has not been well studied under different soil conditions in Ethiopia. If our agriculture is to progress in terms of productivity and quality it is imperative to use all available inputs judiciously.

With this respect, it is important to note that in Arba Minch area, a number of biogas structures were constructed for household energy generation and livelihood improvement. However, the bioslurry was not used as organic amendments for crop production in the study area. The proper use of locally available low cost bioslurry can reduce the dependency of many farmers on increasingly expensive chemical fertilizer. Hence, this study was conducted to evaluate the effects of sole and integrated application of bioslurry and chemical fertilizers on growth performance, yield of tomato and soil properties under irrigated condition at Kola Shele in Arba Minch Zuria District, Southern Ethiopia.

MATERIALS AND METHODS

Experimental location

The experiment was conducted at Kola Shele, Arba Minch Zuria District, Southern Ethiopia. The study site is located near Arba Minch town, at 05°42' N latitude and 37°18' E longitude with an altitude of1220 m above sea level. The mean minimum and maximum air temperature of the area is 26 and 30°C, respectively. The total annual rainfall amount of the study area is 830 mm which is characterized by a bimodal rainfall pattern (http://www.ethiomet.gov.et/). According to the soil map of Ethiopia, which was adapted from ETHIO-GIS Data Sets, the soil of the study area is Eutric Vertisols (Tuma et al., 2013). The major crops produced in the study area are maize (*Zea mays* L.), tef (Eragrotis tef L.), sorghum (*Sorghum bicolor* L.), haricot bean (*Phaseouls vulgaris* L.), banana (*Musa spp*.), mango (*Mangifera indica*), avocado (*Persea americana*) and vegetables (CSA, 2016).

Experimental design, treatments and procedures

The experiment was laid out in a randomized complete block design with three replications. The treatments were composed of the factorial combination of six fertilizers treatments and two tomato varieties. Fertilizer treatments and rates included were: (1) the control without any fertilizers (CT), (2) recommended N and P fertilizer (NP, 92 kg N and 30 kg P ha^{-1}), (3) blended fertilizer (BF,

Table 1. Description of nutrients applied in treatments.

Treatment code	Name of treatment	Nutrients applied (kg ha^{-1})						
		N	P	K	S	Zn	B	NPSZnB
CT	Control							
NP	Recommended N and P fertilizer	92	30					
BF	200 kg blended fertilizer + 124 kg ha^{-1} urea	158	29		14.6	4.46	1.34	200
NP+Biosl	Half recommended NP+ 7 t ha^{-1} dry bioslurry	137	23	78				
BF +Biosl	100 kg blended fertilizer +7 t ha^{-1} dry bioslurry + 62 kg ha^{-1} urea	136	23	78	7.3	2.23	0.67	100
Biosl	Bioslurry (14 t ha^{-1})	182	46	155				

Blended fertilizer employed is NPSZnB. 100 kg NPSZnB contains 16.9 kg N, 33.8 kg P_2O_5, 7.3 kg S + 2.23 kg Zn + 0.67B.

Table 2. Pre plant selected physicochemical properties of the study soil of Arba Minch Zuria District, southern Ethiopia.

Unit		%		ppm		meq 100 g^{-1} soil			Texture
Parameter	pH (H_2O)	OC	T.N	Av. P	Av. K	CEC	Ca	Mg	
Value	6.0	1.64	0.11	10.2	19.4	20.2	5.41	1.73	Loam

T.N= Total nitrogen, OC=: Organic carbon, Av. P= Available phosphorous, Av. K= Available Potassium, CEC= cation exchange capacity, Ca= Exchangeable Calcium; Mg= Exchangeable Magnesium.

200 kg NPSZnB+ 124 kg ha^{-1}urea), (4) integrated recommended NP plus dry bioslurry (NP+Biosl, 46/15 N/P kg ha^{-1} + 7 t ha^{-1}dry bioslurry), (5) integrated blended fertilizer plus dry bioslurry (BF +Biosl, 100 kg NPSZnB + 7 t ha^{-1}dry bioslurry + 62 kg ha^{-1}urea), and (6) dry bioslurry (Biosl, 14 t ha^{-1}) alone (Table 1). Urea and triplesuperphosphate (TSP, x %P) were used as sources of nitrogen and phosphorous, respectively. The TSP was band applied at planting while urea was applied in split, half at planting and half at first flowering stage. All of the bioslurry was band applied one month before planting and incorporated in to the soil at plow depth.

Tomato varieties, Gelilea and Roma VF obtained from LIVES Project and Woreda Agricultural Office, respectively were selected based on their adaptability and high yielding potential. Gelilea is an indeterminate type fresh market tomato with globular shape of fruits, whereas Roma VF is a determinate type with pear shaped fruit preferred by most farmers in the study area. Galilea is a tomato variety introduced from Israel by a private seed breeding and maintaining company called Hazera Genetics Limited and then recommended for production in Ethiopia in 2011.

The tomato varieties Gelilea and Roma VF were raised in a bed and then transplanted at recommended spacing (75 × 30 cm) to the field plot. The crop was furrow irrigated every three days. The plot size was 4*3 m and the spacing between blocks and between plots were 1.3 and 1.0 m, respectively. The plots were irrigated with equal amount of water at three days interval. All other cultural practices were conducted as per the national recommendation (Lemma, 2002).

Soil sampling and analysis

Surface soil (0-20 cm) samples were collected randomly by using auger from 10 spots of the experimental field before planting and application of the different treatments. These samples were composited for analysis of selected physicochemical properties (Table 2). In the same way, soil samples were collected from three replications for each treatment just after harvest. These samples were composited to yield one representative sample per treatment. The soil samples were air dried and ground to pass through 2.0 mm sieve before laboratory analyses. However, for total nitrogen and organic carbon content analyses, the soil samples were prepared using 0.5 mm sieve. Soil parameters mainly pH, organic carbon, total N, available P and K, CEC, exchangeable bases, and soil particle distribution (texture) were determined from the soil samples collected before planting and after harvesting. Organic carbon content of the soil was determined by wet combustion with $K_2Cr_2O_7$ (Walkley and Black, 1934). Total nitrogen was determined according to Micro-Kjeldahl method with sulphuric acid (Jackson, 1962). Determination of available phosphorous was carried out according to the methods of Olsen and Dean (1954). Exchangeable potassium was extracted using 1N ammonium acetate at pH 7 (Pratt, 1965) and determined by atomic absorption spectrophotometer. The pH of the soil was determined by glass electrode pH meter using a suspension of 1:2.5 soil to water ratio as described by Jackson (1973). Cation exchange capacity (CEC) was measured after saturating the soil with 1 N ammonium acetate (NHOAc) (Chapman, 1965). Particle size distribution was determined by the hydrometer method using particles less than 2 mm diameter (Hazelton and Murphy, 2007).

Bioslurry sampling and analysis

Bioslurry (cattle manure) was collected from biogas pit, dried and weighed to be used as fertilizer sources before the cropping season. Then it was analyzed in the laboratory for its pH, nitrogen, phosphorous, potassium, organic carbon content and CEC (Table 3). Total N in the bioslurry sample was estimated by Micro Kjeldahl method (Jackson, 1962). However, 0.1 g oven dried sample was digested instead of 1 g soil sample for manure analysis. The phosphorus, potassium, pH, OC content and CEC were determined by the procedures used for soil analyses (Table 3).

Data collection and measurements of yield and yield components

Plant height, number of primary and secondary branches, number

Table 3. Elemental composition and nutrient content of bioslurry applied for tomato field experiment, at Shele Arba Minch area, southern Ethiopia.

Unit		%			ppm	Av. K (g kg^{-1})	
Parameter	**pH (H_2O)**	**OC**	**TN**	**C:N**	**Av. P**	**Av. K**	**CEC**
Value	7.2	8.6	1.3	6.6	114.2	11.1	27.3

pH= Power of hydrogen; OC= Organic carbon; OM= organic matter; T.N= Total nitrogen; Av. P= Available phosphorous; Av. K= Available Potassium; CEC= cation exchange capacity.

of cluster per plant and fruit number per cluster were determined based on five randomly selected representative plants per plot. Data on fruit weight, fruit width and length, yield (marketable, unmarketable and total) and other agronomic characters of tomato were taken for each treatment at harvesting from three replications.

Statistical analysis

Analysis of variance for the measured crop parameters was performed using the GLM procedure of SAS version.9.0 (SAS Institute, 2002). Significant differences between and/or among treatment means were delineated using the least significance difference (LSD) when F test was significant (5%).

RESULTS AND DISCUSSION

Effect of bioslurry and chemical fertilizer on tomato growth parameters

The number of primary and secondary branches, and plant height were significantly ($P<0.05$) affected by fertilizer source (bioslurry, NP and blended fertilizers). Similarly, the interaction of fertilizer and variety had significant effect on primary and secondary branches. However, the main effect of variety as well as the interaction of fertilizer and variety had non-significant ($P>0.05$) effects on plant height. Soils treated with NP+Biosl and BF + Biosl resulted in greater number of primary and secondary branches and plant height than other treatments (Table 4). This might be due to the fact that the integrated application of chemical and organic fertilizers have enhanced the release of mineral nutrients and provided suitable environment for plant growth by improving soil moisture, pH and soil structure. Similar to the present findings, integrated nutrient management resulted in higher bell pepper performance than organic nutrient supply (Appireddy et al., 2008). The chemical fertilizer and soluble component of the bioslurry could have complemented the slowly available components from the bioslurry. This implies that sufficient amount of nutrients in soil near to the plant roots are available which is easily absorbed by the plant root to produce more vegetative growth. This result supports the findings of Alabi (2006) who found that number of branches and plant height were significantly increased in response to increasing the levels of both P_2O_5 and poultry manure as compared to the control. Similarly, these findings also agreed with that of Abdalla et al. (2001), Glala et al. (2010) and Glala et al. (2012) who reported similar results with pepper plants. Application of bioslurry alone also resulted in superior growth performance of tomato as compared to the control and the sole chemical fertilizer application (Table 4).

Effects of dry bioslurry and chemical fertilizer on tomato yield components

The analysis of variance revealed that the number of fruit clusters per plant and the number of fruits per cluster was significantly ($P \leq 0.05$) affected by bioslurry and chemical fertilizer application. However, variety and fertilizer interaction did significantly affect number of fruit clusters per plant, but did not affect the number of fruits per cluster. Similarly, the main effect of variety, did not affect number of fruit clusters per plant, but did affect number of fruit per clusters (Tables 4 and 5). Applications of NP + Biosl, BF + Biosl and Biosl alone resulted in higher number of fruit clusters per plant, which was 9.6% greater than the control. The application of BF + Biosl improved number of cluster per plant and number of fruit per cluster by 9.6 and 27.4%, respectively over the control.

The greatest number of fruit clusters per plant might be due to the balanced nutrient supply and effects of P in promoting flower bud formation. The result supports the findings of Solaiman and Rabbani (2006) who found that number of clusters per plant ranged from 13.6 recorded in the control, to 23.5 recorded in treatment (200 kg N + 35 kg P_2O_5 + 80 kg K + 15 kg S ha^{-1}), which received the full dose of NPKS. In the present study, among the various treatment combinations, application of BF + Biosl recorded higher average fruit weight, higher number of fruits per cluster, higher fruit width and fruit length, more number of marketable fruits per plant and fruit yield per hectare followed by NP + Biosl while the lowest yield components were recorded at control plot.

The effects of fertilizer and variety significantly ($P \leq 0.01$) affected the average fruit weight of tomato. The interaction of fertilizer and variety also significantly ($P \leq 0.05$) influenced this parameter. Average fruit weight was significantly increased by 18.4% due to BF + Biosl application over the control. The result of this study is in agreement with the findings of Fandi et al. (2010) who reported that low amount of nutrients (particularly N) resulted in smaller fruit weight due to decline in rate of photosynthetic activity of the plant. The results showed

Table 4. Main effects of fertilizer, variety and their interaction on growth parameters of tomato at Shele Arba Minch Zuria District , southern Ethiopia.

Treatment	Plant height	No. of primary branches	No. of secondary branches	No. of clusters per plant
Variety (V)				
Gelilea	60.9	4.3	9.8	13.2
Roma VF	59.2	3.9	9.5	12.9
LSD (5%)	NS	NS	NS	NS
Fertilizer				
Control	56.0[c]	3.5[c]	8.5[b]	12.2[c]
NP	59.8[abc]	3.3[c]	8.5[b]	13.2[ab]
BF	60.3[abc]	4.0[bc]	9.5[b]	12.7[bc]
NP + Biosl	61.8[ab]	5.2[a]	11.3[a]	13.5[a]
BF + Biosl	64.0[a]	4.7[ab]	10.0[ab]	13.5[a]
Biosl	58.5[bc]	4.0[bc]	10.0[ab]	13.5[a]
LSD (0.05)	4.82*	1.15*	1.65*	0.68**
F*V	NS	*	**	*
CV (%)	6.69	23.35	14.29	18.51

NP= recommended N and P fertilizer (96 kg N 30 kg P ha^{-1}), BF = blended fertilizer (200 NPSZnB + 124 urea), NP + Biosl =46/15 N/P kg ha^{-1} plus 7 t ha^{-1} bioslurry, BF + Biosl = 100 kg NPSZnBplus 7 t ha^{-1} bioslurry and Biosl= 14 t ha^{-1} bioslurry alone. Means in the same column followed by the same letter are not significantly different (P ≤ 0.05) and NS- non significant; *significant at 0.05; **significant at 0.01.

Table 5. Main effects of fertilizer, variety and their interaction on yield parameters of tomato at Shele Arba Minch area, Southern Ethiopia.

Treatment	Fruit weight (g)	Fruit no. per cluster	Fruit width (cm)	Fruit length (cm)
Fertilizer				
Control	58.5[b]	8.5[c]	4.3[b]	4.1[c]
NP	59.2[b]	9.7[bc]	5.0[ab]	4.73[b]
BF	67.2[a]	9.2[c]	5.3[a]	4.9[ab]
NP + Biosl	67.7[a]	11.0[ab]	5.5[a]	5.2[a]
BF + Biosl	70.0[a]	11.7[a]	5.5[a]	5.3[a]
Biosl	58.3[b]	9.5[bc]	5.0[ab]	4.6[bc]
LSD (0.05)	4.47**	1.79*	0.734*	0.52*
Variety (V)				
Gelilea	65.8[a]	8.9[b]	5.7[a]	5.0[b]
Roma VF	61.1[b]	10.9[a]	4.6[b]	5.5[a]
LSD (0.05)	2.58**	1.033**	0.424**	0.352*
F*V	*	NS	NS	NS
CV %	5.87	15.07	12.0	3.10

NP= recommended N and P fertilizer (96 kg N 30 kg P ha^{-1}), BF = blended fertilizer (200 NPSZnB + 124 urea), NP + Biosl = 46/15 N/P kg ha^{-1} plus 7 t ha^{-1} bioslurry, BF + Biosl = 100 kg NPSZnB plus 7 t ha^{-1} bioslurry and Biosl= 14 t ha^{-1} bioslurry alone. Means in the same column followed by the same letters are not significantly different (P≤ 0.05); NS= non-significant.

that integrated application of bioslurry and chemical fertilizers affected fruit yield components of tomato. The superiority could be attributed to the faster enhancement of vegetative growth and storing sufficient reserved food material for differentiation of buds into flower buds and fruits. This result is in agreement with the findings of Kuppuasmy et al. (1992), who reported that application of manures at 7 t ha^{-1} with full dose of NPK fertilizer recorded the highest number of fruits plant^{-1} (30.7), fruit yield (1.1 kg plant^{-1}) and seed yield (0.68 g plant^{-1}).

Effects of dry bioslurry and chemical fertilizer on tomato fruit number and yield

The main effect of fertilizer significantly (P ≤ 0.05)

Table 6. Main effects of fertilizer, variety and their interaction on marketable, unmarketable and total fruit number and yield of tomato at Shele Arba Minch Zuria District, southern Ethiopia.

Treatment	Fruit number per plant			Fruit yield (t ha^{-1})		
	Marketable	Unmarketable	Total	Marketable	Unmarketable	Total
Fertilizer						
Control	9.2^{c}	3.7^{b}	12.6d	21.11^{c}	4.44^{a}	25.55^{c}
NP	13.8^{ab}	6.0^{a}	20.0^{ab}	26.0^{b}	4.17^{a}	30.17^{b}
BF	12.5^{b}	5.8^{a}	18.7^{bc}	28.9^{ab}	4.18^{a}	33.07^{ab}
NP + Biosl	15.8^{a}	6.2^{a}	21.8^{a}	31.77^{a}	3.99^{ab}	35.76^{a}
BF + Biosl	16.0^{a}	6.2^{a}	21.8^{a}	32.44^{a}	2.93^{c}	35.37^{a}
Biosl	12.0^{b}	5.0^{a}	17.0^{c}	25.78^{b}	3.37^{bc}	29.15^{b}
LSD (0.05)	2.59**	1.19**	2.84**	4.06**	0.779**	4.24**
Variety (V)						
Gelilea	13.8	5.6	19.22	30.37^{a}	4.01	34.38^{a}
Roma VF	12.6	5.4	18.11	24.96^{b}	3.68	28.65^{b}
LSD (0.05)	NS	NS	NS	2.35**	NS	2.45**
F*V	NS	NS	NS	NS	NS	NS
CV %	16.38	18.11	12.72	12.26	16.9	11.23

NP= recommended N and P fertilizer (96 kg N 30 kg P ha-1), BF = blended fertilizer (200 NPSZnB + 124 urea), NP + Biosl = 46/15 N/P kg ha^{-1} plus 7 t ha^{-1} bioslurry, BF + Biosl = 100 kg NPSZnBplus 7 t ha^{-1} bioslurry and Biosl= 14 t ha^{-1} bioslurry alone. Means in the same column followed by the same letters are not significantly different ($P \leq 0.05$); NS=not significant.

influenced marketable, unmarketable and total fruit number and yield of tomato. However, there was no significant interaction effect between variety and fertilizer in terms of marketable, unmarketable and total fruit number and yield of tomato (Table 6). Similarly, the marketable, unmarketable and total fruit number of tomato was not significantly affected by variety. The applications of NP + Biosl and BF + Biosl treatments resulted in 40 to 73% increase in number and yield of marketable and total fruit of tomato. The lowest number and yield of marketable and total fruit was recorded from the control (Table 6). Soil treated with dry bioslurry and chemical fertilizers increased unmarketable fruit number over the control but they were not significantly different. The significant variation observed due to the application of balanced nutrients to the soil significantly improved the plant growth as well as the size and number of fruits perhaps through improving the nutrient status of the soil (Alabi, 2006). Similar to this, Ogwulumba et al. (2009) reported that tomato treated with organic amendments in the range of 10 to 20 t ha^{-1} integrated with chemical fertilizers produced higher number of fruit and higher average fruit weight than tomato plants not supplied with either organic manure or chemical fertilizers.

Residual effects of bioslurry and chemical fertilizer on soil chemical properties

Among the analyzed parameters, soil pH, total nitrogen, organic carbon, available P and K, and CEC increased due to single and integrated application of dry bioslurry and chemical fertilizer after harvest (Table 7). Comparison of soil chemical characteristics of treated and control plots revealed that application of dry bioslurry with chemical fertilizers increased some chemical characteristics of soil, indicating improvement in soil fertility.

Indeed, residual soil pH varied among the soil treatments applied. It increased with bioslurry, integrated bioslurry and chemical fertilizers application, but decreased with only chemical fertilizer application. This result is supported by the findings of Taye (1998) who observed rise in soil pH with the increased rates of applied inorganic and organic sources including decomposed coffee husk and farmyard manure. Soil organic carbon increased significantly by integrated application of bioslurry and inorganic fertilizers. Thus, the greatest organic carbon was recorded with application of the highest rate of bioslurry alone while the lowest was recorded with control (Table 7). The result is supported by many workers (Pattanayak et al., 2001; Singh et al., 2001; Sarwar et al., 2003).

Availability of major plant nutrients like N, P and K were also affected by the application of bioslurry and chemical fertilizer sources (Table 7). In all cases, the nutrient availability increased in the soil and the highest availability of N, P and K was found from the application of bioslurry in combination with chemical fertilizers while the lowest availability of these nutrients recorded from the control plots. The increase in soil total N and available P and K might be attributed to bioslurry (organic manure),

Table 7. Soil chemical properties as influenced by fertilizer application after tomato harvest at Shele Arba Minch area, Southern Ethiopia.

Treatment	Unit	%		ppm	meq 100 g^{-1} soil	
	pH (H_2O)	OC	TN	Ava. P	Ava. K	CEC
Control	5.33	1.88	0.189	8.4	15.2	18.6
NP	5.38	2.11	0.211	9.8	18.4	21.8
BF	5.46	2.01	0.209	11.6	16.6	22.6
NP + Biosl	5.65	2.34	0.202	14.4	27.2	24.5
BF + Biosl	5.54	2.15	0.200	9.4	14.2	19.5
Biosl	6.12	2.45	0.195	9.8	17.8	18.4

NP= recommended N and P fertilizer (96 kg N 30 kg P ha^{-1}), BF = blended fertilizer (200 NPSZnB + 124 urea), NP + Biosl = 46/15 N/P kg ha^{-1} plus 7 t ha^{-1} bioslurry, BF + Biosl = 100 kg NPSZnB plus 7 t ha^{-1} bioslurry and Biosl= 14 t ha^{-1} bioslurry alone.

which helped in releasing the higher amount of N, P and K from the soil. Similar results were observed by Tolanur and Badanur (2003) in pigeon pea-treated plots. The organic carbon, CEC, and total N declined with application of chemical fertilizer alone and increased with conjunctive use of dry bioslurry and chemical fertilizers. This finding is corroborated with the findings of Wakene et al. (2002) and Tolanur and Badanur (2003).

Conclusion

The proper use of locally available low cost bioslurry can reduce the dependency of farmers on increasingly expensive chemical fertilizer. Integrated application of bioslurry with chemical fertilizers (NP or NPSZnB) significantly influenced most of the growth parameters, yield components and yield of tomato. Vegetative growth parameters of tomato showed increasing trend in response to increased application of integrated bioslurry and chemical fertilizers. The application of integrated bioslurry and chemical fertilizers resulted in significant increment in marketable, unmarketable and total fruit number and yield of tomato. It can be understood that the use of bioslurry and chemical fertilizer considerably improved fruit yield of tomato and chemical properties of soil. The application of 7 t ha^{-1} bioslurry in combination with 46/15 kg ha^{-1} N/P and/or 100 kg ha^{-1} NPSZnB blended fertilizer can be recommended for smallholder tomato producers of Arba Minch Zuria District, southern Ethiopia.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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