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Evaluation of compost with chemical fertilizers for Irish potato (*Solanum tuberosum* L.) production in Debub Ari Woreda, Southern Ethiopia

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ABSTRACT

Soil fertility reduction is the main problem for sustainable crop production and productivity in southern parts of Ethiopia. Integrated soil fertility management is the best choice to improve soil fertility constraints using accessible organic and chemical fertilizers. The aim of the experiment was to examine the effect of organic and chemical fertilizers on crop yield and soil fertility improvement. This experiment was conducted from 2017 to 2018 in Debub Ari district, southwestern Ethiopia. The treatments contain Control (no fertilizers), Recommended NP (69/30), 250 kg NPSB + 161 kg ha^{-1} Urea, 10 t ha^{-1} compost, and 5 t ha^{-1} compost + 125 kg NPSB + 80 kg Urea top dress. Potato variety 'Belete' became used for the experiment and was planted early in the 'Belg' season. The treatments were arranged in randomized complete block design with three replications. Soil sample was randomly collected before treatment application with a depth of (0-20cm) and composited into one kg of a sample. The analysis results of the initial soil sample revealed that it was sandy clay in texture, moderately acidic, low in total N, OC, CEC, and very low in available P. The analysis of variances showed significant differences among the treatments on potato tuber yield when compared to untreated plots. Potato tuber yield is increased by 32, 22, and 35% of sole use of inorganic fertilizer, compost alone, and 50% of compost + 50% of NPSB treatment, respectively, than control. The maximum tuber yield 18.7 t ha^{-1} was obtained from treatment 5 t ha^{-1} compost + 125 kg NPSB + 80 kg Urea top dress, whereas the minimum tuber yields 13.85 t ha^{-1} were obtained by untreated plot (without any fertilizer application). Farmers in the study area can use by selecting either recommended NP (69 N and 30 P) ha^{-1} or 5t + 125 kg NPSB + 80 kg urea ha^{-1} depending on the accessibility of labor, composting material, and cash to purchase an adequate amount of fertilizers.

Keywords: Compost, Fertilizer, Potato, Tuber

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Introduction

Irish potato is an important plant contributing to the world's food security (Karam *et al.*, 2009). Potato is the main field crop for domestic intake and enhances income through its exportation worldwide (Kandil *et al.*, 2011). Ethiopia, especially in the highland areas, is known as a food shortage relief crop at the end of the rainy season (Balemi, 2012). Through the German Botanist, Schemper, the crop was introduced to Ethiopia in 1858. Later, Potato became an essential crop in various parts of the region. In Ethiopia, approximately 70% of the suitable land is appropriate for potato production, situated at an elevation of 1500 to 3000 m.a.s.l with an annual rainfall ranging from 600 to 1200 mm (Gebremedhin *et al.*, 2008).

Nutrients are the foremost essential inputs for enhancing the crops' productivity (Ali *et al.*, 2009). Fertilizer trials have been accompanied for a couple of decays on numerous crops elsewhere in Ethiopia. Subsequently, yield and biomass production enhancements for many crop types have been reported by different scholars (Amsal *et al.*, 2000; Fanuel and Gifole, 2013; Okalebo *et al.*, 2003). In the same way, the application of fertilizer has a consequence in the Potato tuber quantity and quality (Leytem and Westermann, 2005). This crop is highly responsive to Nitrogen fertilizer, especially on sandy soils nitrogen is the limiting nutrient for potato production (Errebhi *et al.*, 1998). White *et al.*, (2007) discussed that nitrogen plays the major role in the complementary of both vegetative and reproductive growths for crop production.

To improve soil productivity and enhance crop productivity, plants such as potato must have a sufficient and well-adjusted supply of fertilizers by integrating management of nutrient practices through applying organic and synthetic sources (Gruhn *et al.*, 2000). In addition, Chen *et al.* (2001) showed that the integration of compost (either nutrient-rich trees/shrubs or legume sources and livestock manure) with chemical fertilizers allows the compost with ample nutrients, especially for strongly acidic soils. Similar findings are observed by Ayalew and Dejene (2011), who obtained the organic matter amount after harvesting the crop is high in the soil and improved through applying organic fertilizer, which the application of organic source could cause. This shows that organic fertilizer is a better organic matter source.

Organic material is used to prevent or enhance crop production by improving nutrient and water retention, soil structure, and microbial activities on a sustainable basis; this, in turn, is explained by attaining considerable yield and biomass production. Moreover, it has played appreciable contributions to decreasing soil salinity. Consequently, it is one of the most used fertilizer types (Hassanpanah and Azimi, 2012). The merits of organic fertilizer include improving the soil pH, raising the water holding capacity, and increasing hydraulic conductivity has been reported by several authors (Asiegbu and Oikeh, 1995; Tirol-Padre *et al*., 2007). Hence, (Najm *et al*., 2013) stated that organic sources has a potential influence for good tuber yield and vegetative growth.

In Ethiopia, soil fertility reduction is the major significant restriction that limits potato production. Soil fertility has already deteriorated because of abandoning fallowing, continuous cropping, minimum use of crop rotation, and manure in southern parts of the country. Tamirie (1989) reported that national variety trials and yield data over numerous sites on diverse crops show that plant nutrient limitation is an important issue affecting crop yield. Even though its significance as a food source, potato production is as lower as 10 t ha-1, mainly because of less or no application of fertilizers. For that reason, the aim of this research was to examine the effect of the combined use of compost with chemical fertilizers on tuber of potato production.

Materials and Methods

Description of the study area

The experiment was conducted for two years, in 2017 and 2018, at Debub Ari woreda, Southern Ethiopia. The experimental field is geographically situated with an altitude of 1940 m.a.s.l, latitude of 05°50' N, and longitude of 36°40' E. Trial was carried out in rain-fed areas of the study site and planted in the long rainy months of the area. The experimental area has a bi-modal rainfall pattern with an extended rainy season from August to November and a shorter rainy season from March to May. During the major cropping season in which the field experiment was conducted, the annual rainfall in the experimental site was 1273 ± 251 mm, and mean annual minimum and maximum temperatures were 22.65, 16.8 ± 0.9 and 27.8 ± 1.5 °C, respectively.

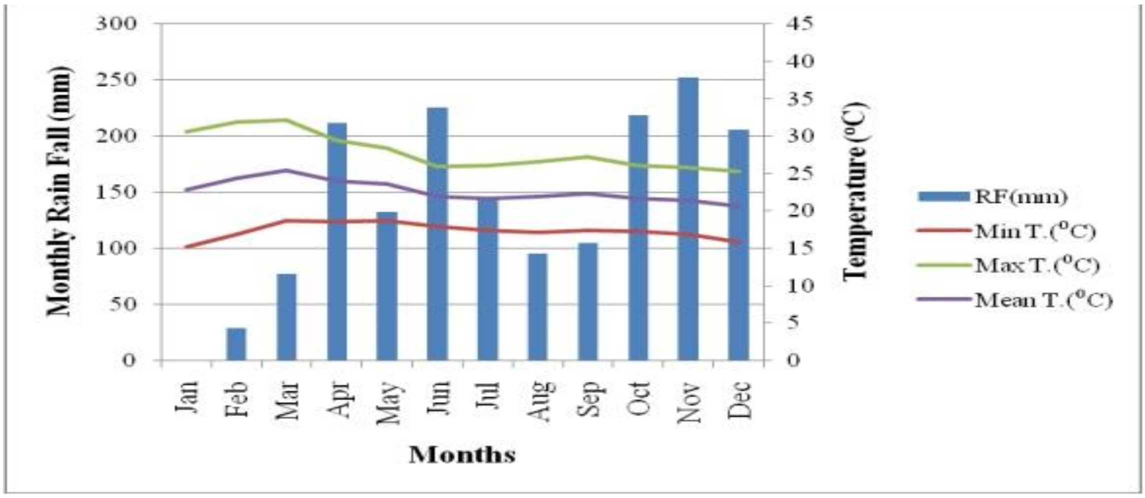

Fig. 1. Monthly rainfall, minimum, maximum, and average temperature of the study site during 2017 and 2018.

Experimental layout and design

The experimentation was carried out in a Randomized Complete Block Design (RCBD) with three replications. There were five treatments: T1: Control (no fertilizers), T2: Recommended NP (69 N and 30 P), T3: 250 kg NPSB + 161 kg Urea top dress, T4: 10 t ha^{-1} compost and T5: 5 t ha^{-1} compost + half (50%) of treatment-3. Phosphorus and Nitrogen fertilizers become applied as TSP and Urea, respectively. Full doses of phosphorus and half dose of nitrogen were applied at planting, while the remaining nitrogen was applied 40 days after planting. Compost was prepared from the locally available materials (maize stalk, green leaves (*Cordia africana*, Terminalia and other weed species), farm yard manure, Some wood ashes, Dry leaves (maize, coffee, and *Cordia africana*), and top soil following the standard procedure (Madeleine *et al*., 2005) before the experiment. The plot size used was 3.75 m in width and 3.9 m in length, with 1 m space between plots. The test crop used for the present study was the potato variety 'belete'. The variety was chosen based on the results of the adaptation evaluation trial conducted in the study area (unpublished package, 2017).

Soil sampling and laboratory procedures

After preparation of the land, soil samples were randomly collected before the treatment application with an auger at a 0-20 cm soil depth from ten spots and thoroughly mixed and composite sample was obtained and analyzed to determine the physicochemical properties like soil texture, pH, available P, CEC, total N, and total organic carbon (OC) (Table 1). The Bouyoucos hydrometer method was used to analyze the particle size distribution of the soil. Soil textural classes were determined by using the textural triangle of the USDA system. The pH of the soils was measured potentiometrically and measured in water suspension in a 1:2.5 (soil: water ratio). Bray method II was used to determine available soil P and was measured by spectrophotometer. Total nitrogen was determined by the Kjeldahl method and soil organic carbon (OC) content was used by the wet digestion method. Ammonium-saturated samples were used to determine CEC of the soil that were subsequently replaced by sodium (Na) from a percolating sodium chloride solution and reported as CEC [cmol(+)/kg].

Data collection

Yield and yield components data were collected from selected harvestable areas to avoid border effects. For the number of tubers per hill, counting the tubers of ten randomly selected hills from harvestable rows at harvesting, the mean value and time were figured and used for further analysis. Tuber yields were medium to large, free of disease, mechanical, and insect pest damages were measured as marketable yields. Alternatively, tubers that were small in size, and damaged were considered unmarketable, as described by (Tesfaye *et al.*, 2013). The tuber weights recorded from the harvestable area were measured using a scaled balance and expressed in kg ha^{-1}. Lastly, the sum of marketable and unmarketable yields was used for the total tuber yield.

Data analysis

From the experimental field, collected data for each variable were analyzed using the SAS statistical software (SAS, 2007). Whenever the mean separation was calculated, ANOVA checked for significant differences between treatments using the LSD at 5% probability level.

Partial budget analysis

For the economic analysis, partial budget and marginal analyses are used to examine the inputs' feasibility at planting and for outputs after the crop harvesting. The yield was adjusted downward by 10% to show the difference between the yield on the expected yield and experimental field at farms from the same treatments (CIMMYT, 1988). The collected data especially tuber, were economically evaluated using partial and marginal analysis for the feasibility of fertilizer application.

Results and Discussion

Initial soil physicochemical properties

The analyzed soil laboratory results, which were done before treatment application on the potato, are presented in Table 1. The initial soil laboratory test results before planting of potato indicated the soil is moderately acidic in soil pH, sandy clay in texture, very low available P, and low in total N, OC and CEC. These low contents of soil nutrients should be attributed to the effects of exhaustive and unceasing cultivation, which may aggravate OM oxidation and their consequent leaching/erosion. In the same way, Negassa and Heluf (2003) showed that farming of agricultural land continuously decreases OC and total N. The less contents of available phosphorous also because of its fixation problem with metallic cations.

Table 1. Selected physical and chemical properties of the study area.

Soil Properties	Values	Rating
Sand (%)	50.00	
Clay (%)	32.00	
Silt (%)	18.00	
Textural Class	Sandy clay	
Total Nitrogen (%)	0.04	low
Soil Reaction(pH)	5.80	moderately acidic
Organic Carbon (%)	1.95	low
Available Phosphorous (mg kg^{-1})	8.82	very low
CEC [cmol$^{(+)}$/kg]	11.50	low

Irish potato yield response for fertilizer

The tuber yield in the first cropping season was significantly ($P \leq 0.05$) influenced by differences between the applied treatments and control. Both the applied chemical fertilizers varied significantly with the control and compost alone. At the same time, the tuber yield recorded from the compost application alone and combined with chemical fertilizer are comparable with control (Table 2).

Table 2. Effect of organic and chemical fertilizer on Potato tuber yield.

No.	Treatments	2017 Cropping season		2018 Cropping season		Average	
		Tuber yield (t ha^{-1})	Tuber per hill	Tuber yield (t ha^{-1})	Tuber per hill	Tuber yield (t ha^{-1})	Tuber per hill
T1	Control	14.90±3.55^{b}	7.04±2.62^{b}	12.8±5.80^{b}	6.3±2.08	13.85^{b}	6.67
T2	Recommended NP	22.90±2.84^{a}	11.48±0.70^{a}	13.7±2.08^{a}	6.0±4.58	18.30^{a}	8.74
T3	250 kg NPSB + 161 kg urea	21.70±6.42^{a}	12.72±1.40^{a}	14.5±3.50^{a}	7.0±2.00	18.10^{a}	9.86
T4	10 t ha^{-1} compost	15.40±3.68^{b}	7.88±2.19^{b}	18.4±2.80^{a}	5.0±0.00	16.90^{ab}	6.44
T5	5 t ha^{-1} compost + 50% of treatment-3	17.90±3.35^{ab}	8.40±2.58^{b}	19.5±3.10^{a}	6.0±2.00	18.70^{a}	7.20d
LSD (5%)		5.4	2.82	5.02	NS	5.21	NS
CV (%)		21.71	22.14	26.37	46.6	24.04	34.37

Mean with different letters within the column are statistically different at α ≤ 5%.

During the first cropping season, application of (N69 and P30 kg ha^{-1}) has enhanced the tuber yield by 53.7, 48.7, and 27.9% over the control, compost alone, and combined 50% of compost + 50% of NPSB treatment, respectively. Similarly, application of NPSB (150 kg NPSB + 161 kg urea) has increased the tuber yield of potato by 45.6, 40.9 and 21.2% over the control, compost alone, and combined application of 50% of compost + 50% of NPSB treatment, respectively. However, a non-significant difference was observed between the tuber yield obtained by RNP and NPSB treatments. Tuber yield of potato with compost alone and combined applications of (50% compost + 50% of NPSB) had comparable with that of the control. Unlike compost, this might be due to the rapid release of nutrients from chemical fertilizers. The first released nutrients, especially phosphorous, had a health influence on sprouting, root development, vegetative vigor and maturing of the potato; this is explained by the highest yield (Mbogo *et al.*, 2017). The present result (especially the first cropping season) is agreed with the findings of Powon *et al.* (2006). Instead, applying compost alone was not show a higher yield, but when combined with inorganic fertilizer, it tends to give higher yields. The average result indicated that the application of organic and chemical fertilizer significantly (P≤5%) influenced the tuber yield of potato as compared to control treatments, but among the applied treatments, there was a statistically non-significant difference was observed. The maximum tuber (18.7 t ha^{-1}) was recorded through the integrated application of (5.0 t ha^{-1} compost + 50% of treatment-3), whereas the minimum tuber (13.85 t ha^{-1}) was obtained by control plot (without any application of fertilizer).

Number of tubers per hill response for fertilizer

The first cropping season result indicated that there was a statistically significant (α≤0.05) difference in the means of tuber per hill within both inorganic fertilizers and that of a control (Table 2). Application of recommended NP and NPSB had gained a significantly higher number of tubers per hill compared with control and compost treatments. Application of 250 kg NPSB + 161 kg urea top dressing has enlarged the number of tuber per hill by 80.7, 61.4 and 51.4% over the control, compost alone and combined application of 50% compost + 50% of NPSB, respectively. Similarly, the application of recommended NP has enhanced the number of tuber per hill by 63.1, 45.7 and 36.7% over the control, compost alone, and combined application of (50% of compost + 50% of NPSB), respectively. Although there was statistically no significant difference was observed between RNP and NPSB treatments. Application of compost alone and combined application of (50% of compost + 50% of NPSB) did not significantly increase the number of tubers compared with the untreated plot. The maximum number of tuber per hill (12.72±1.38) and the lowest (7.04±2.62) was recorded by application of 250 Kg NPSB + 161 kg urea top dressing and control (no inputs), respectively. During the second cropping season, a non-significant (P≤5%) number of tubers per hill variation was shown between the treatments and control. However, the maximum number of tuber (7±2) and the lowest (5±0) were recorded by applying 250 kg NPSB + 161 kg urea top dressing and 10 t ha^{-1} compost, respectively.

Table 3. Partial budget analysis of potato tuber yield under organic and inorganic fertilizer.

Trt	Av. Tuber yield/ha in ton	TR (ETB 7900/ t)	TVC (ETB)	TFC (ETB)	TCP (ETB)	GM (ETB)	Return/ invested	NR (ETB)	Benefit-cost ratio
T1	13.86	109478.2	22100	7458	29558	87378.2	11.72	79920.2	2.70
T2	18.29	144514.7	25115	7458	32573	119399.7	16.01	111941.7	3.44
T3	18.10	142978.2	25745	7458	33203	117233.2	15.72	109775.2	3.31
T4	16.89	133450.8	30850	7458	38308	102600.8	13.76	95142.8	2.48
T5	18.70	143543.0	28297	7458	35755	115246.0	15.45	107788.0	3.01

Trt: treatments, T1: control, T2: recommended NP, T3: 250 kg NPSB + 161 kg urea top dressing, T4: 10 t ha^{-1} compost, T5: 5 t ha^{-1} compost + 50% of treatment-3, TCP: Total cost of production (ETB ha^{-1}), TR: total revenue (ETB ha^{-1}), TFC: Total fixed cost (ETB ha^{-1}), TVC: Total variable cost (ETB ha^{-1}), GM: Gross margin (ETB ha^{-1}) and NR: Net return (ETB ha^{-1}).

The cost items include

For various agronomic practices, daily labor cost (ETB 35/day) become incurred such as; Compost preparation, including digging the hole, collecting plant materials etc., Land preparation, including ploughing, harrowing etc., Weeding, Fertilizer application, and Harvesting. The price of fertilizers, including Urea, NPSB and DAP was ETB 1500/quintal for each. The price of Seed tubers and Land rent were ETB 960/quintal and ETB 4800/year/ha, respectively.

Cost benefit analysis of Irish potato yield in response to fertilizer

Partial budget evaluation results showed the total cost of maximum (38308 ETB ha^{-1}) and minimum (29558 ETB ha^{-1}) was earned with 10 t ha^{-1} compost and control (without any application of fertilizer), respectively. The maximum gross margin (119399.7 ETB ha^{-1}) was obtained from recommended NP (69/30) application and the least (87378.2 ETB ha^{-1}) was also recorded from the untreated plot. Moreover, the highest net return (111941.7 ETB ha^{-1}), the marginal rate of return (10.6), and the benefit cost ratio (3.44) were recorded from the application of recommended NP (69/30). In contrast, the least net return (79920.2 ETB ha^{-1}) and benefit cost ratio (2.70) were obtained from no fertilizer applied. Akinpelu *et al.* (2011) reported that the maximum benefit cost ratio and net return indicates; it is cost-effective to cultivate potato with the NPK 15:15:15 application of fertilizer at the 200 kg ha^{-1} rate. 5 t ha^{-1} compost + 125 kg NPSB + 80 kg urea application would be economically comparable with recommended NP and viable while sustaining the soil fertility of the study area. Since crop production has the intent to maximize economic benefits through sustainable resource utilization such as soil. In this regard, fertilizers with organic sources are taken priority as long as providing comparable economic returns with inorganic sources.

Conclusion and Recommendation

The present study indicated the integrated application of chemical and organic fertilizer enhanced the considerable tuber yield of potato. The sole application of chemical fertilizers and integrated application of compost with chemical fertilizer gives a higher significant economic return. The potato tuber yield obtained from compost with chemical fertilizers and sole applications of inorganic fertilizer is comparable. Hence, the farmers can use choosing either of the options. However, the integrated approach has considerable long-term merits through improving important soil physicochemical properties for thriving sustainable crop production. It is suggested to apply the combined application of organic and chemical sources to accommodate both intermediate and long-term benefits from potato production. Therefore, farmers in the study area can use by selecting either recommended NP (69 N and 30 P) ha^{-1} or 5 t ha^{-1} compost + 125 kg NPSB + 80 kg urea ha^{-1} depending on the accessibility of labor, composting material, and cash to purchase more fertilizers.

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