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Response of potato (*Solanum tuberosum* L.) to the combined application of organic and inorganic fertilizers at Chena district, South Western Ethiopia

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ABSTRACT

Low level or no use of organic and inorganic fertilizers and serious imbalances soil nutrients, depressed potato yields and pose accelerated mining of native soil nutrients. Present on-farm studies was undertaken to observe the combined effects of FYM and compost along with inorganic fertilizers, particularly NPSB on potato production. The experiment comprised of seven treatments: No fertilizer, recommended NP (115 kg N and 92 kg ha⁻¹ P₂O₅), NPSB (115 kg N and 92 kg P₂O₅, 6.5 kg S. and 0.71 kg B ha⁻¹), 10 tone FYM ha⁻¹, 10 tone compost ha⁻¹, 5 tone FYM + 50% NPSB (57.5 kg N and 92 kg P₂O₅ ha⁻¹), and 5 tone compost + 50% NPSB ha⁻¹ were arranged in RCBD with three replications. The yield and yield components were collected and subjected to mean separation and economic analysis. The analysis of variance indicated that either applied organic and inorganic fertilizers combined or alone significantly ($p \leq 0.05$) improved potato yield at Chena. Full dose of each FYM and compost, recommended NP rate and NPSB gave similar potato yield. The highest average marketable and total fresh potato tuber yield (27.44, 27.92 t ha⁻¹, respectively) were recorded by combined application of 5 t FYM ha⁻¹ with 50% NPSB (115 kg N and 92 kg P₂O₅, 6.5 kg S. and 0.71 kg B ha⁻¹) which is economically acceptable with MRR (1239.7%), whereas the lowest tuber yield (14.45 t ha⁻¹) was obtained from unfertilized plot. Hence, combined application of 50% FYM and 50% NPSB proved best potato yield in the study area.

Keywords: Potato, Manure, NPSB, NP, Tuber yield

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Introduction

Potato (*Solanum tuberosum* L.) is world's third most important food crop after wheat and rice (Birch *et al.*, 2012). It is the most widely grown tuber crop in the high and mid altitude areas of Ethiopia (Berga *et al.*, 2009). Although the crop was mainly produced in Europe and North America, it has become an increasingly important food security crop in many developing countries (Birch *et al.*, 2012). For instance, the area under potato increased from 62,000 ha to 296,578 ha and production increased from 500,000 tons to 3.6 million tons from 2006 to 2016, respectively in Ethiopia (CSA, 2016). It regarded as a high-potential food security crop due to its ability to provide a high quality yield per unit input within a short cycle (Balemi, 2012). The major causes of low yields are unavailability and high prices of quality seed tubers, lack of improved varieties, poor soil fertility, and low market value at the time of harvesting, diseases, and postharvest losses (Tsegaw, 2006). Of this Low inherent soil, fertility associated with soil acidity coupled with inadequate use of organic and inorganic

fertilizers by smallholder farmers has caused low potato productivity in Africa (ATA, 2014). Thus, external supply of inorganic and organic fertilizer inputs is necessary to increase productivity of major food crops and enhance soil fertility in Ethiopia (Wakene *et al.*, 2005).

Judicious combination of organic and inorganic sources of nutrients might be helpful to obtain a good economic return with good soil health for the subsequent crop (Gruhn *et al.*, 2000). Several researchers reported higher crop yield due to the application of organic manure along with inorganic fertilizers as compared to sole application of either sources (Alam *et al.*, 2007; Daniel *et al.*, 2008; Yang *et al.*, 2015). Shiferaw (2014) observed that combined application of 5 tones FYM with NPK mineral fertilizer increased potato yield by 567% over control at chench acidic soil. Daniel *et al.* (2008) also evidenced that application of mineral fertilizers and FYM increased tuber yield by 43-45.3%.

Farmers in the Study areas use traditional soil fertility improvement practice such as intercropping, composting and sole inorganic fertilizer application in unmanageable way, and integrated application of organic and mineral fertilizers is not common. Therefore, this study was initiated to evaluate the effects of sole and integrated applications of mineral fertilizers and farmyard manure on yield, yield components and economic return of potato by smallholder farmers in acid soils of Chena district south west Ethiopia.

Materials and Methods

Description of the experimental area

On-farm experiment was conducted for two years (2016-17 and 2017-18) during the Belg season at Kutashoray Kebele, Chena woreda, Kefa Zone, Southern Ethiopia. The study area lies between 7°16'03" N latitude and 36°55'91" E longitude. The experimental site is located at about 510 km away from Addis Ababa; the capital city of Ethiopia along the southwest and about 70 km from the Zonal town of Bonga at an elevation of 1913 meters above sea level. The area received average annual minimum and maximum rainfall 1379-1889 mm in a bimodal pattern. The mean monthly temperature ranges from 14-28°C (Belay and Yericho, 2015). The study area has predominantly Nitosols, with a textural class of clay loam (FAO, 1998). Major crops grown in the study area include enset (*Enset ventricosum*), potato (*Solanum tuberosum*), maize (*Zea mays*), wheat (*Triticum aestivum*), cabbage (*Brassica oleracea*), carrot (*Daucus carota*), and Ethiopian cabbage (*Brassica carinata*). Potato is extensively grown tuber in the study area. Topographically, the area consists of gently undulating plain with average slope gradient of 5%.

Experimental details and treatment set-ups

The field experiment was laid out in a Randomized Complete Block Design (RCBD) with seven treatments (Table 2). Each treatment was replicated three times and the experiment was conducted for two consecutive years 2016-17. The experiment had seven treatments including: Control (no inputs), RNP (115 N and 92 P₂O₅ kg ha⁻¹), NPSB (115N, 92 P₂O₅, 17 S, and 1.7 B), 10 tons FYM, 10 tons compost, 50% NPSB plus 5 tons FYM, and 50% NPSB plus 5 tons compost. Compost/FYM was prepared in pit three months before planting of test crop using standard compost preparation. Recommended NP rates were included as separate treatments for making comparisons with NPSB blend. Plot size used was 3 m x 3 m (9 m²) and the spacing between plants and rows was 30 and 75 cm, respectively. FYM and compost were distributed to experiment

plots one month before potato planting. TSP, NPSB and urea were used as fertilizer sources. Urea was applied in split: half at planting and the remaining half at about 35 days after planting. Potato variety "Gudane" was used as test crop which is released by Holeta Agricultural Research Centre in 2006 (MoANR, 2016). First earthing-up or hilling and weeding followed immediately after urea application. The second weeding and hilling were done 8 weeks after planting. The remaining all management practices were done as per the recommendation.

Data collection

Before the start of the field experiment, twenty surface soil samples (0-30 cm) were taken randomly (following zig-zag way) from the experimental field. The soil samples were composited, air-dried and ground to pass 2 mm sieve and 0.5 mm sieve (for total N) for analyses of the soil physico-chemical properties (Table 1). The analysis was done following the procedures in laboratory manual prepared by Sahlemedhin and Taye (2000). Agronomic data both yield and yield component related parameters on plot and plant bases were collected. Five randomly selected representative potato plant samples were used to take a measurement on plant height, number of plants hill⁻¹, number of tuber hill⁻¹, except marketable and total fresh tuber yield and then subjected to analysis of variance.

Partial budget analysis

Partial budget analysis was also carried out to evaluate the feasibility of fertilizer treatments for potato production. Potato tuber yield was valued at an average open market value of the local market price of Birr 600 per 100 kg whereas average price of urea, NPS and NPSB were Birr 10.00, 11.12 and 12.00 per kg, respectively. The costs of other production practices like, weeding were assumed to remain the same among the treatments. The tuber yield was down adjusted to reflect the situation in actual production by farmers (CIMMYT, 1988).

Statistical analysis

The collected data were subjected to statistical analysis. Analysis of variance (ANOVA) was carried out using the General Linear Model of the SAS Version 9.3 procedure using statistical software programs (SAS, 2011). Significant difference between and among treatment means were assessed using the least significant difference (LSD) at 0.05 level of probability (Gomez and Gomez, 1984).

Results and Discussion

Physico-chemical properties of soil before planting

The pre-planting soil analysis indicated that the soil of the study site was Clay loam in textural class with 25.83, 39.17 and 35% sand, silt and clay particles in proportion, respectively. It is very strongly acidic in reaction in accordance with [Tadese \(1991\)](#) rating, which indicates a negative impact on the availability of most essential nutrients. The organic matter content of the soil was 5.41%, which could be rated as very high according to [Hazelton and Murphy \(2007\)](#).

In highly acidic soils, microbial activity is low, slowing down the decomposition rate and results in accumulation of organic matter. On the other hand, the total N (0.26%) and available P (7.43 mg kg⁻¹) contents of the soil were high and low respectively in accordance with ratings by [Landon \(2014\)](#). The considerably low available P implies that P could be a limiting nutrient for crop production in the study area, and hence external application of P is required for optimum plant growth. The CEC of study soil was also rated as low in accordance with [Landon \(2014\)](#).

Table 1. Selected physico-chemical properties of the study area soil before planting.

Physico-chemical properties									
Material	pH-H ₂ O (1:2.5)	OM (%)	TN (%)	Ava. P (mg kg ⁻¹)	CEC (cmol (+) kg ⁻¹)	Clay (%)	Silt (%)	Sand (%)	Textural Class
Surface soil (0-30 cm)	4.72	5.41	0.26	7.43	5.81	35.00	39.17	25.83	Clay loam

Yield and yield components of potato as influenced by integrated application of organic and inorganic fertilizer

The two years combined analysis of variance indicated that statistically significant differences ($P < 0.05$) were observed between treatments of all tested parameters (Table 2) and there is no treatment difference between two growing

seasons. Application of either combined or sole sources of organic and inorganic fertilizers significantly improved marketable and total tuber yield compared to the control. However, there was no significant yield difference between the recommended NP and NPSB indicating that inclusion of S and B had no effect on potato in the study area.

Table 2. Combined mean tuber yield and yield components of potato as influenced by integrated and sole application of compost/FYM with inorganic fertilizer at Chena district.

Treatments	PH (cm)	PPH	TPH	MY (ton ha ⁻¹)	TY (ton ha ⁻¹)
1. Control (No fertilizer)	33.0d	3.5c	8.2b	14.13c	14.54c
2. Recommended NP (115 N, 92 P ₂ O ₅)	39.2bc	4.7ab	9.4ab	22.07b	22.57b
3. 115 N, 90kg P ₂ O ₅ , 17 kg S, 1.7 kg B	39.7bc	5.1ab	9.5ab	22.427b	22.81b
4. 10 t FYM ha ⁻¹	38.6c	4.1bc	9.5ab	23.99ab	24.47ab
5. 10 t compost ha ⁻¹	43.6a	5.3a	10.6a	23.62ab	23.95ab
6. 50% T3 + 5 t FYM ha ⁻¹	42.4ab	5.8a	9.7ab	27.44a	27.92a
7. 50% T3 + 5 t compost ha ⁻¹	38.16c	5.0ab	11.0a	22.19b	22.40b
Mean	39.2	4.8	9.7	22.27	22.67
CV %	7.6	20.2	18.0	18.30	17.30
LSD 0.05%)	3.5	1.1	2.0	4.59	4.61

N.B: LSD (0.05%): least significant difference at 5% level; CV: coefficient of Variation; PH: plant height; PPH: number of plant per hill; TPH: number of tuber per hill; MY: marketable yield; TY: total yield; Means in a column followed by the same letters are not significantly different at 5% level of Significance.

Sole applications of 10 t FYM and compost ha⁻¹ gave slightly higher tuber yield than sole inorganic fertilizer sources (NPSB) though not statistically significant. This result is in contrast with the reported results of [Alam *et al.* \(2007\)](#), who reported that inorganic fertilizers gave higher crop yields than organic sources. These increased yields in organic fertilizer could be attributed to provide different macro and micronutrients, and in part to improved soil

conditions and water holding capacity. The highest mean marketable (27.45 t ha⁻¹) and total fresh tuber (27.92 t ha⁻¹) potato yields were recorded by combined application of 5 t FYM and 50% recommended NPSB (57.25 N, 46 P₂O₅, 8.5 S and 0.85 B) though not significantly different from that of sole organic sources treatments.

The yield increment could be due to the supply of macro and micronutrients from the inorganic and organic fertilizer sources as well as improvement

of soil properties by FYM and compost application (Pervez *et al.*, 2000). The tuber yield in different treatment ranged from 14.54 to 27.92 t ha⁻¹. The maximum increase in tuber yield (94%) and highest mean marketable (27.45 t ha⁻¹) and total fresh tuber (27.92 t ha⁻¹) potato yields were recorded by combined application of 5 t FYM and 50% recommended NPSB (57.25 N, 46 P₂O₅%, 8.5 S and 0.85 B) though not significantly different from that treatments received 10 t ha⁻¹ sole FYM and compost. Several authors (Tsegaye *et al.*, 2020; Shiferaw, 2014; Eghball *et al.*, 2004) reported similar results. Pervez *et al.* (2000), proved increased potato yield by combined application of farmyard manure and higher doses of potassium in Pakistan and Shiferaw (2014), shown significantly higher potato yield by combined application of farmyard manure and NPK. Furthermore, an experiment was conducted at Arbegona district indicated yield of Potato increased due to the integrated application of FYM and Blended fertilizer in combination (Tsegaye *et al.*, 2020). FYM application either combined or alone gave greater marketable and total potato yield than compost. The control plot gave the lowest total fresh and marketable potato tuber yield. Plant height and plant per hill were different among most of treatments. Tubers per hill differ only between 10 t compost and control treatments. Again, combined application of FYM

with NPSB gave significantly higher marketable and total fresh potato tuber yield than that of combined application of compost with NPSB. Potato tuber yield increased by 56.2 to 94.2 percent by application of fertilizers, which suggests that all percent increments by application of fertilizers are appreciably high and the maximum increase in tuber yield (94%) was observed by application of 5 t FYM ha⁻¹ with 50% NPSB (Table 2).

Partial economic analysis

Partial budget analysis was carried out to determine the net benefit and marginal rate of return obtained from the application of different organic and inorganic fertilizer rates. Partial budget analysis results also indicated that application of 5 t FYM ha⁻¹ with 50% NPSB (57.25 N, 46 P₂O₅%, 8.5 S and 0.85 B) gave higher net benefit and acceptable %MRR compared to control and application of sole 10 t FYM ha⁻¹. Thus, it could be recommended that farmers at the study area and others with similar agro-ecology could apply 5 t FYM ha⁻¹ with 50% NPSB (125 NBSB+ 76 Kg urea top-dressed) for optimum potato production. Farmers can also use 10 t ha⁻¹ FYM as an option in the absence of NPSB to obtain modest potato yield if ample amount of cattle are available in the area.

Table 3. Partial budget and dominance analyses for organic-inorganic fertilizers effect on potato at Chena district.

No.	Treatments	AY (t ha ⁻¹)	Adj-Y t ha ⁻¹	Revenue (ETB ha ⁻¹)	IC (ETB ha ⁻¹)	AC (ETB ha ⁻¹)	TVC (ETB ha ⁻¹)	NB (ETB ha ⁻¹)	% MRR
1	No fertilizer	14.13	12.72	76302.0	0.0	0.0	0.0	76302.0	
4	10 t ha ⁻¹ FYM	23.99	21.59	129551.4	1200.0	1750.0	2950.0	126601.4	1705.1
6	5 t ha ⁻¹ FYM + 50% of NPSB	27.44	24.70	148197.6	3466.8	875.0	4341.8	143855.8	1239.7
2	115 N, 92 P ₂ O ₅	22.06	19.86	119151.0	5317.0	0.0	5317.0	113028.5	D
5	10 t ha ⁻¹ compost	23.62	21.26	127548.0	1200.0	4330.0	5530.0	122018.0	D
7	5 t ha ⁻¹ compost + 50% of NPSB	22.19	19.97	119842.2	3466.8	2165.0	5631.8	114210.4	D
3	250 kg NPSB + 152kg	22.42	20.18	121051.8	5733.6	0.0	5733.6	115318.2	D

Note: AY: Average yield; Adj-Y: Adjusted yield; IC: Input cost; AC: Application cost; TVC: Total variable cost; NB: Net benefit; MRR: Marginal rate of return; FYM: Farm yard manure.

Table 4. Analysis of net benefit and MRR % on application of organic and inorganic fertilizer on potato after removal of dominated treatments.

No.	Treatments	Average yield t ha ⁻¹	Adj-yield t ha ⁻¹	Gross benefit (ETB)	TVC	NB (ETB)	% MRR
1	No fertilizer	14.13	12.72	76302.0	0.0	76302.0	-
4	10 t ha ⁻¹ FYM	23.99	21.59	129551.4	2950.0	126601.4	1705.1
6	5 t FYM ha ⁻¹ + 50% of NPSB	27.44	24.70	148197.6	4341.8	143855.8	1239.7

Conclusion and Recommendation

An integrated approach that combines a sensitive appreciation of the properties of different soil types combined with the effective use of manures, compost, crop residues and fertilizers has the best chance of arresting and reversing soil fertility decline. Current study results show that significant increase in marketable and total fresh tuber potato yields increase from 100% organic (FYM and compost) and inorganic (NP and NPSB) fertilization alone. Potato tuber yield increased by 56.2 to 94.2 percent by application of fertilizers, the highest percent increments by combined application of 5 t FYM ha⁻¹ with 50% NPSB blend. This result suggests that all percent increments by application of fertilizers are appreciably high. Growth and development of tubers was affected with organic and inorganic fertilizers application either alone or in combination and the response was better by the application organic source alone than inorganic sources alone. The highest potato yield response was observed when 50% FYM (5 t ha⁻¹) along with 50% NPSB (125 Kg NPSB+ 76 Kg urea top-dressed) was applied. It is also economical beneficiary with the acceptable MRR (1239.7%). Hence, it is recommended that FYM along with NPSB should be applied to produce potato at Chena and similar agro-ecologies. More verification and demonstration studies are needed to establish reliable recommendations for wider use.

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Conflicts of Interest

The authors declare no conflict of interest. The funders had no role in data collection, analyses, interpretation and writing of the manuscript, or in the decision to publish the results.

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