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EFFECT OF ORGANIC AND INORGANIC FERTILIZER APPLICATION AND SEEDBED PREPARATION ON POTATO YIELD AND SOIL PROPERTIES ON ALISOLS OF CHENCHA

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ABSTRACT

A field experiment was conducted for two years (2006 and 2007) during the belg seasons on strongly acid clay loam (Haplic Alisols) soils at Chencha research substation, Southern Ethiopia. The objective was to examine the effect of seedbed preparation methods and organic-inorganic fertilizers on potato tuber yield and soil properties. The experiment was arranged in split-plot design with seed bed preparation methods: hoe plough once (M1), hoe plough twice (M2) and hoe plough thrice (M3) as main plots, and fertilization levels, namely, a control without fertilizer, NP, NPK, NP+FYM, NPK+FYM and FYM as sub plots with three replicates. Results indicated that there were significant (P< 0.05) potato tuber yield differences among sub-treatments. The impact of main treatments showed no yield difference. Application of FYM and NPK significantly increased the yield of potato both years. NP application alone did not influence potato yield but significantly increased when combined with FYM. Exclusion of K from either inorganic or combined inorganic-organic fertilizer treatments significantly decreased tuber yield, suggesting K as a major limiting factor on potato production. Combined application of FYM and NPK gave the highest potato yield (41.28 t/ha). The highest net benefit (birr 23982) and maximum marginal rate of return (1060.8) were also achieved with the combined application of FYM and NPK. This result suggests that combined application of FYM and NPK is suitable for better potato production in the Alisols of Chencha.

Keywords: Farmyard manure, Hoe plough, Potato tuber yield, Seedbed, Strongly acid soils.

1. INTRODUCTION

Potato (*Solanum tubersum* L) is one of the most important food and cash crop and the first among root crops in area coverage in Chencha. The production of potato under farmers' condition is achieved mainly through application of farmyard manure (FYM) but due to the shortage of animal manure the level most farmers use is much lower (2-5 t ha^{-1}). Production of potato with low and imbalanced NP application to acid soils reduced potato yield. Low level and imbalanced use of fertilizers also pose accelerated mining of soil nutrients stocks [1-3].

Average tuber yields are too low (less 7 t ha^{-1}) on soils under research with recommended NP fertilizers (unpublished data) which is much lower than average commercial yields of many developing countries. However, average potato yield on soils where farmers have applied organic manures for many times are medium to good, 10 t ha^{-1}[4]. Fresh potato tubers yields can reach at least 100 t ha^{-1} [5], commercial yields are much lower, but can be as high as 42 t ha^{-1} in the Netherlands or 10-15 t ha^{-1} in many developing countries [6].

Potato has strict requirement for a balanced fertilizer management and is the most responsive crop [7-9]. Nutrients removal by tubers increased at very high yields [10, 11] and combined with high manure content [12-16].

Nutrition of crops in Ethiopia is limited to N and P, with very limited or no attention being given to K fertilizer. Amendments of larger amount of FYM can provide enough various plant nutrients and may temporary reduce acidity constraints [17-20]. Several researchers reported higher crop yield due to application of organic manure along with inorganic fertilizers as compared to isolate application of either sources [21].

Seedbed preparation method and other soil management practices have effects on the yield of crops. Tapela and Colvin [22] reported that excessive tillage can cause the soil to be vulnerable to erosion and increase the operational cost without concomitant yield increment. On the other hand, minimum tillage or no tillage results in minimal soil disturbance and maintain soil organic matter and nutrients [23-25].

Adequate information on the use of organic or balanced inorganic fertilizers alone or in combination for potato production in acid soil of Chencha is lacking. Furthermore, there is no information on effect of seed bed preparation methods. The present study was, therefore, undertaken to investigate the influences of organic and inorganic fertilizers on potato yield and soil properties. This paper also presents results on seed bed preparation methods effect on potato yield.

2. MATERIALS AND METHODS

2.1. Study Site Description

The experiment was conducted for two years (2006 and 2007) during the belg season at Chencha research substation of Hawassa Research Center, Southern Ethiopia between 06^{0} 17' 55" N latitude and 37^{0} 33' 04" E longitude at an altitude of 2900 m above sea level. Six-years mean annual rainfall is 1269.5 mm. The six-years and growing season monthly rainfall of the experimental site (highlighted) is presented in Table 1. Prior to this experiment the field was fallow for more than two years. The soil of the experimental site is Haplic Alisols [26] with clay loam texture, very strong reaction, and low available P and high total N contents. Some selected physical and chemical properties of the soil before the start of the experiment are presented in Table 2. Chemical composition of the FYM was low in total N and available K (Table 3).

2.2. Field Experimental Design

The experiment was arranged in split-plot design with three replicates. Main treatments were seed bed preparation methods: hoe plough once (M1), hoe plough twice (M2) and hoe plough thrice (M3). Sub-treatments were six fertilization combinations namely, control (no fertilizers), NP, NPK, NP+FYM, NPK+FYM and FYM. The dose of N: P: K fertilizers were 100:100:100 kg ha^{-1} and that of FYM was 15 tons ha^{-1} (fresh weight). Urea, triple supper phosphate (TSP) and potassium chloride (KCl) were used as sources of N, P, and K, respectively. FYM was spread by hand after soil leveling just before planting and incorporated using hoe. Whole amount of TSP, KCl and half of urea were drilled in rows and covered before planting potato and the remaining half of urea was side dressed at hilling. The test crop was potato CIP variety 392650-516. The potato tuber was planted at a spacing of 75 cm between rows and 30 cm within the rows. The gross experimental plot size was 4 x 4 m and net plot size was 4 x 2.25 m.

The seedbed was manually tilled with hoe which was common land preparation method by the farmers around the study area. The first inversion plough in M2 and M3 was made in mid January and second plough in M3 was made 20 days after first plough. The Seedbed preparation in M1, second plow in M2 and the third plough in M3 were made at planting (20 days after 2^{nd} plough of M3).

2.3. Soil Sampling

Soil samples were collected from 0-30 cm to evaluate different soil chemical and physical properties. At the beginning of the experiment, 15 samples were randomly collected and composited. Then after soil samples were taken at planting and harvesting from each treatment. The samples were air dried, crushed with mortar and sieved to pass through 2 mm mesh. Soil pH was determined using soils: solution ratio of 1:2.5 (w/v). Soil organic carbon was determined by the wet oxidation method as described by Walkley and Black [27]. Determination of total nitrogen of the soil samples was performed by the Kjeldahl method [28] where available P content was determined after Bray II [29]. Exchangeable K^+ was determined from 1 M ammonium acetate extract at pH 7.0 using flame photometer. The samples were analyzed at Hawassa Research Center Soil Testing Laboratory

2.4. Statistical Analysis

Fresh tuber yield data were subject to analysis of variance (ANOVA) to evaluate statistical significance of organic and inorganic fertilizers and seedbed preparation. Simple correlation and multiple regression analysis were performed to see the relationship between and effects of soil properties on total fresh yield of potato.

Partial budget analysis was performed to evaluate economic feasibility of using organic and inorganic fertilizers. The cost for inputs was calculate from 2007 belg season market price and for potato was calculated from farm get price of local market at Chencha at harvesting. Price of fertilizers was Ethiopian Birr 7.06, 25.72, and 6.00 kg^{-1} for N, P and K, respectively as of 2007.

3. RESULTS AND DISCUSSION

The results of variance analysis of fresh potato tuber yield from Chencha experimental site over two years, 2006 and 2007, are depicted in Table 4 and 5. There were consistent and statistically significant difference ($p<0.05$) among fertilization treatments (Table 4). No yield difference was achieved due to main treatment effect (Table 5). All fertilizer treatments significantly increased potato tuber yield over untreated control and NP application. Over two years, the highest mean potato tuber yield (41.88 t ha^{-1}) was achieved by NPK (100-100-100 kg ha^{-1}) plus 15 t ha^{-1} FYM application followed by NP plus 15 t/ha FYM (30.96 t/ha), NPK (30.28 t/ha) and FYM (17.73 t/ha) application. Application of NP alone had low and no significant effect on yield increase; it increased potato tuber yield from 6.27 to only 8.09 t ha^{-1}.

Combined application of 15 t ha^{-1} FYM with NP (100/100 kg ha^{-1}) and NPK significantly increased the tuber yield as compared to the application of organic or inorganic fertilizers in isolation. Application of 15 t ha^{-1} FYM with mineral fertilizers NPK (100-100-100 kg ha^{-1}) and NP increased tuber yield over control by 567.9 and 393.9%, respectively. Yield advantage achieved by application of 15 t ha^{-1} FYM with NPK was higher by 136.2 and 38.3% over 15 t ha $^{-1}$ FYM and NPK (100-100-100 kg ha^{-1}) alone, respectively. The higher benefits from combined applications might be attributed, in part, to enhanced fertilizer recovery (increased uptake) due to increased soil physical and chemical properties as a result of increased soil organic matter. Besides increasing soil physical and chemical properties, by providing macro and micronutrient organic manure improve crop production. The results are in partial agreement with reports of Johnston [12], Nyiraneza and Snapp [13], Bereez, et al. [15], Alam, et al. [7], Gruhn, et al. [2], Daniel, et al. [21] who reported higher yields of potato from manure application along with inorganic fertilizers.

NP at rate of 100-100 kg ha^{-1} increased tuber yield over control by 29.02% but both are statistically similar. However, inclusion of K increased the potato tuber yield by about four times over NP. The yield limiting effect of K also was manifested on the tuber yield when K is included in NP + 15 t ha^{-1} FYM treatment. Exclusion of K from either inorganic or from combined inorganic-organic treatments significantly decreased the tuber yield, suggesting K as a major yield limiting factor for optimum production of potatoes on the Chencha Alisols. Yield advantage of 383, 274 and 71% over control, NP and FYM treatments, respectively, was achieved by application of NPK. These results are in line with reports of several workers [9-11] who suggested the balanced management of inorganic fertilizers in production of potato and other different crops. Significantly higher tuber yield by application of NP along with 15 t FYM over NP (100/100 kg ha^{-1}) alone was probably due to nutrients supply of manure and releasing of already bonded P from the soil due to acids release by decomposition of FYM.

FYM (15 t ha^{-}) alone gave 162 and 103 % higher yield over control and NP treatments. This higher yield could be, in part, due to balanced nutrient supply of FYM and, in part, to improved soil condition. This result also confirmed the observed differences of most crop yields at organically managed farmer's fields and experimental field in the study area. However, the relative effect of 15 t ha^{-1} FYM on the potato yield improvement was inferior to that of NPK.

This lower yield could be attributed to slow release of nutrients from organic manure This suggests that application of 15 t ha^{-1} FYM in the acid soil of Chencha research site is not adequate to optimize potato yield. This result is in agreement with reports of Daniel, et al. [21] who reported insufficiency of manure for optimum yield of crops in short period of time, regardless of the amount (low) they used. On the other hand, Rutunga and Neel [19] reported that application of high rate of nutrient rich farmyard manure (35 t/ha) alone was sufficient to increase potato yield and no supplemental P and lime were required up to four seasons after four regular seasonal applications in Alisols of Mata, Rwanda. From laboratory incubation results of 40 g animal manure kg^{-1} soil, Whalen, et al. [20] observed highly significant pH increase and high concentration of available P and K in labile forms.

Seedbed preparation methods (Table 5) had no significant effect ($p > 0.05$) on potato tuber yield. Current results show that at Chencha soil hoe plowing once gave similar yield with that of hoe plowing three times. Extending hoe plow more than one time for seed bed preparation incur labor cost and time without yield benefits but result in nutrient and soil organic matter degradation by increased soil disturbance. This suggests that plowing once using hoe at Chencha area is sufficient for production of potato without any yield reduction.

Field observations during growing season clearly showed that plant height and the biomass of potato were higher in NPK and integrated organic-inorganic fertilizers amended plots (data not shown). Maturity was delayed by more than two weeks by application of 15 t ha^{-1} FYM alone and by combining with NP or NPK (data not shown). Relatively low to medium vegetation coverage was observed in FYM amended treatments.

Partial budget analysis showed that balanced applications of NPK (100/100/100 kg ha^{-1}), 15 t ha -1FYM and combination of FYM with NP and NPK in production of potato at Chencha acid soil are feasible and highly profitable (Table 6). Negative net benefit was realized for NP (100/100) treatment which suggests that application NP alone for the study area is not feasible.

Application of combined NPK and 15 ton FYM gave highest net benefit (23982 ET birr) and marginal rate of return (1060.8) followed by organic amendment but the highest cost benefit ratio (5.59) was achieved by application of FYM alone (Table 4).

Soil analysis results indicated that soil bulk density decreased (improved) and exchangeable K relatively increased by combined application of NPK and FYM (Table7). Application of NP significantly decreased available K content even compared to untreated control. Increased NP supply increase K uptake by potato and decreased K concentration in soil. Wilkerso and Grunes [30] reported that under high K availability, increasing N supply increase K concentration and uptake, whereas without K application K concentration decrease in high rates because of growth dilution. This suggested that continuous application of NP without K depletes soil K and may pose problem in crop production and demand consideration in crop and soil management in the Chencha case. All amended treatments increased TN and OC over untreated control. Seedbed preparation methods only significantly influenced soil organic carbon content; lower in M3 due to enhanced decomposition organic matter due to increased disturbance of by tillage operations. High organic carbon and moderate to high N content in this soil may be due to poor status of other nutrients in the soil and form strong organic matter complexes with oxides of Al and Fe, preventing microbiological degradation.

Correlation analysis indicated that potato tuber yield was positively and significantly correlated with soil available P (r = 0.613, p = 0.006) and available K (r = 0.652, p = 0.003). Multiple regression analysis, however, indicated that only soil available K significantly (Adjusted R^2 = 0.508, P = 0.009, b = 0.684) and directly influenced the potato yield. Available K alone accounted for 44.5% variation in potato yield in Chencha Alisols.

4. CONCLUSION AND RECOMMENDATION

Field observations have shown high crop performance and yield differences of different crops on organically managed farmer's field and research site. Our study results also revealed that 15 ton FYM application increased potato tuber yield approx by three and two fold over untreated control and NP treatments. Due to livestock number and manure production problem it may not be possible for most poor farmers, but from view point of agricultural sustainability farms should be encouraged to use sufficient amount of organic manure. It was observed that NPK fertilizers applied significantly influenced potato yield but combined application of 15 t ha^{-1} FYM and NPK is superior to all other treatments and profitable. Seed bed preparation method results showed that hoe plough once or reduced tillage practice is sufficient for potato production without yield reduction. Hence, the combined use of NPK and FYM and hoe plough once could be recommended as important nutrient management and sustainable potato production practice in Alisols of Chencha. But further research is needed to verify different combination of organic and inorganic fertilizers.

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Table-1. Six years total and growing season (highlighted) rainfall data of Chencha (Seven kilometer from the testing site)

						months							
year	**Sep**	**Oct**	**Nov**	**Dec**	**Jen**	**Feb**	**Mar**	**Apr**	**may**	**June**	**July**	**Aug**	**total**
2002	130.5	191.0	33.5	47.5	33.5	136.5	192.0	65.5	0.00	17.5	41.4	58.0	946.9
2003	85.0	112.5	26.4	264.0	45.0	49.0	88.5	253.1	82.0	57.0	164.0	192.0	1418.5
2004	51.5	95.5	273.9	0.00	4.9	0.70	91.5	244.5	51.0	25.0	116.0	105.0	1059.5
2005	172.0	52.6	58.5	52.0	34.5	28.6	151.1	106.4	135.9	58.5	120.0	167.2	1137.3
2006	313.7	61.0	65.0	66.6	12.5	0.00	322	231.0	105.6	83.2	114.0	0.00	1374.6
2007	100.2	186.1	107.5	93.3	146.5	25.0	97.3	210.6	162.4	246.2	137.1	167.7	1679.9
Average													1269.45

Table-2. Selected physic-chemical properties of Chencha Alisols before starting the experiment

pH	Sand %	Silt %	Clay %	Texture class	Db	OC %	TN %	Av P mg kg^{-1}	Ex K Cmol(+)	CEC Cmol(+)
4.89	36	38	26	Loam	1.03	4.60	0.347	2.62	3.63	25.73

*Db= Bulk density, OC = organic carbon, TN = total nitrogen, Av p = available phosphorus, Ex K = exchangeable potassium, CEC = cation exchange capacity

Table-3. Chemical composition of farmyard manure used for the study

TN %	**OC %**	**C:N**	**P %**	**K %**
0.97	23.4	24.12	2.0	0.95

Table-4. Mean Potato tuber yield (t ha^{-1}) as influenced by organic and inorganic fertilizers

Treatment	**Total Potato Tuber Yield (t ha^{-1})**		**Mean**
	2006	**2007**	
control	6.38d	6.16d	6.27d
N100P100	8.82d	7.36d	8.09d
N100P100K100	31.09b	29.48b	30.28b
N100P100+FYM	31.74b	30.18b	30.96 b
N100P100K100+FYM	42.59a	41.17a	41.88a
15 ton FYM	16.47c	18.99c	17.73c
LSD 5%	6.083	6.559	4.473
CV%	21.97	24.36	23.16

*Means within in the same column followed by the same letter do not differ significantly at the 5% level of LSD test

Table-5. Partial budget analysis for organic, inorganic fertilizers and their interaction.

Partial budget	**Treatments**					
	Control	**NP**	**FYM**	**NPK**	**NP+FYM**	**NPK+FYM**
Average yield ton/ha	6.27	8.09	17.73	30.88	30.96	41.88
Adjusted yield ton/ha	5.64	7.281	15.957	27.792	27.864	37.692
Gross benefit ET birr/ha	4232.25	5460.75	11967.75	20844	20898	28269
N kg ha^{-1}	0	706	0	706	706	706
P kg ha^{-1}	0	1866	0	1866	1866	1866
K kg ha^{-1}	0	0	0	600	0	600
FYM t ha^{-1}	0	0	750	0	750	750
Labor for input application (Et Birr)	0	70	260	105	330	365
TVC	0	2642	1010	3277	3652	4287
Net benefit birr/ha	4232.25	2818.75	10957.75	17567	17246	23982
MRR			665.9	291.5		1060.8

Table-6. Mean Potato tuber yield as influenced by seedbed preparation methods.

Treatment	Tuber yield		Mean
	2006	**2007**	
M1	23.07	21.86	22.46
M2	23.44	22.82	23.13
M3	22.04	21.99	22.02
LSD 5%	NS	NSNS	
CV%	21.97	24.36	23.16

*M1 =hoe plough once, M2 = hoe pough twice, and M3 = hoe plough three times

*N = Nitrogen, P = Phosphorus, K = Potassium, FYM = Farm yard manure, TVC = Total cost that vary, MRR = Marginal rate of return

*Adjusted yield equals Average yield minus 10% of average yield

* Gross benefit equals total potato yield ha^{-1} multiplied by unit price of potato

* Net benefit equals gross benefit minus TVC

* MRR equals increased net benefit divided by increased TVC and multiplied by 100

Table-7. Some of selected soil properties of the test site as influenced by seedbed preparation and fertilization at final harvest.

Seedbed Preparation methods	Fertilizers	pH 1:2.5 H_2O	Db	%OC	%TN	Available P (ppm)	Available K(ppm)	Average Tuber yield
M1	control	4.85	1.04	3.39	0.199	2.81	23.2	5.93
	N100P100	4.83	1.01	3.74	0.247	2.90	19.4	8.60
	N100P100K100	4.59	0.94	4.19	0.232	2.91	33.9	31.70
	N100P100+FYM	4.76	0.91	3.94	0.328	2.92	38.7	31.60
	N100P100K100+FYM	4.80	0.91	3.91	0.230	2.96	64.6	40.55
	15 ton FYM	4.69	0.97	4.40	0.220	2.95	58.1	16.38
M2	control	4.79	1.05	3.50	0.206	2.88	31.7	7.19
	N100P100	4.63	0.99	3.70	0.264	2.95	19.4	9.10
	N100P100K100	4.73	0.96	3.66	0.261	2.92	25.8	29.28
	N100P100+FYM	4.89	0.96	3.81	0.224	2.92	38.7	29.77
	N100P100K100+FYM	5.03	0.92	3.70	0.246	2.96	58.1	44.00
	15 ton FYM	4.82	0.84	4.27	0.251	2.93	46.3	18.43
M3	control	4.82	1.09	3.34	0.202	2.80	30.45	5.68
	N100P100	4.67	1.00	3.59	0.250	2.91	18.37	6.57
	N100P100K100	4.73	0.99	3.77	0.263	2.92	28.85	29.87
	N100P100+FYM	4.88	0.96	3.73	0.267	2.91	38.20	31.52
	N100P100K100+FYM	4.99	0.92	3.81	0.244	2.98	60.39	41.08
	15 ton FYM	4.79	0.94	4.14	0.246	2.95	50.21	17.38

* BD = Bulk density, OC = Organic carbon, TN = Total nitrogen, P = Phosphorus, K = Potassium