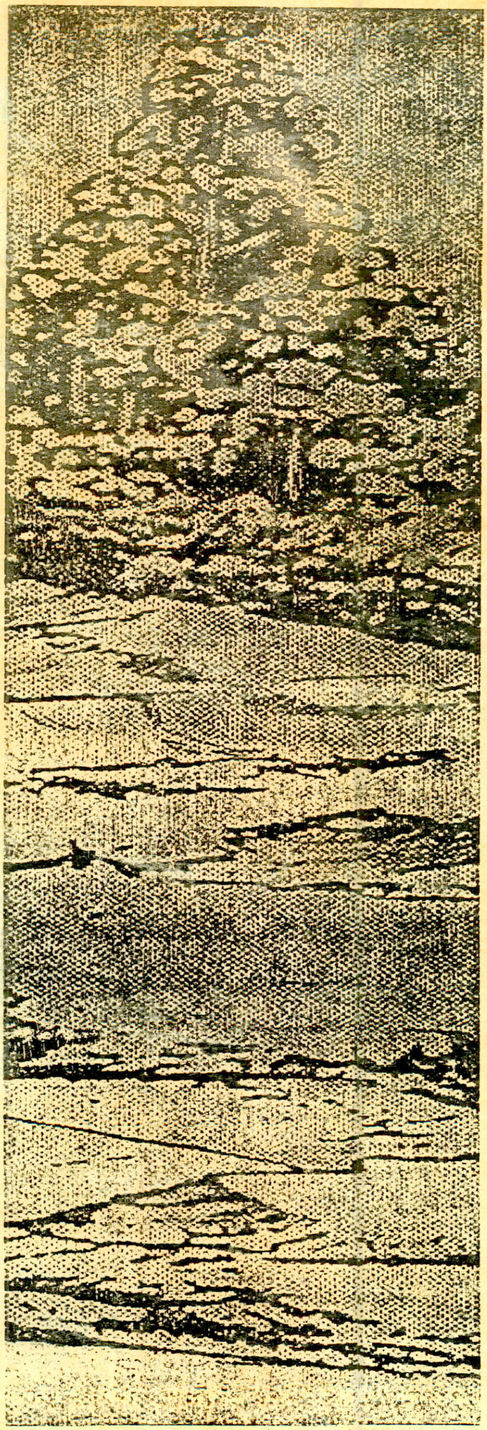

ETHIOPIAN JOURNAL OF NATURAL RESOURCES (EJNR)

VOLUME 10, Number 1; June 2008

ISSN: 1563-3705

Indexed by AGRIS

Research articles

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Ethiopian Journal of Natural Resources

Ethiopian Journal of Natural Resources. 2008. 10 (1): 85 –101

EFFECT OF INTEGRATED NUTRIENT MANAGEMENT ON YIELD OF POTATO AND SOIL NUTRIENT STATUS AT BAKO, WEST SHOA

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ABSTRACT

A field experiment was conducted on Nitisols of Bako during the 2005 cropping season with the objective of evaluating the effects of organic and inorganic nutrient sources on potato yield and soil nutrient status. A 3 x 4 factorial combination of three levels of inorganic fertilizers (25%, 50% and 75% of recommended chemical fertilizer) and four levels of organic manure (4 t/ha vermicompost, 5 t/ha farmyard manure, 8 t/ha vermicompost, and 10 t/ha farmyard manure) was evaluated along with four controls. The experiment was laid out in randomized complete block design with three replications. Analysis of variance revealed that the highest total tuber yield of 29.59 t/ha was obtained with integration of 10 t/ha farmyard manure along with 75% of recommended dose of chemical fertilizer compared to the three control treatments. Integrated use of 4 t/ha vermicompost along with 25 and 50% of recommended dose of fertilizer resulted in higher organic carbon, available P and K content of the soil over the control treatments. Economic analysis also revealed that integrated use of organic and inorganic fertilizer resulted in higher net return and benefit cost ratio over the control treatments. The study revealed that integrated use of 10 t/ha farmyard manure along with 75% recommended dose of fertilizer not only resulted in significantly higher tuber yield but also improved the nutrient status of the soil. It could also save 25% inorganic fertilizer for sustainable potato production in potato-growing areas.

Key words: farmyard manure, inorganic fertilizer, vermicompost

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* Part of MSc thesis in Horticulture, Haramaya University (2006)

INTRODUCTION

Integrated use of various soil fertility enhancing inputs could alleviate the problem of soil nutrient deficiencies and improve their availability to the crop from soil reserves (Muriithi and Irungu, 2004). There are several options for restoring and maintaining soil fertility. The integrated nutrient management paradigm emphasizes the need for both organic and inorganic mineral inputs to sustain soil health and crop production due to positive interactions and complementarities between them (Place et al., 2003). This approach helps to attain higher crop productivity, prevent soil degradation and thereby meet the goals of food security (Sanchez and Jama, 2000; Vanlauwe et al., 2000).

It has been reported that organic and inorganic mineral inputs cannot be substituted entirely by one another as they are both required for sustainable crop production (Vanlauwe et al., 2000; Place et al., 2003). The excessive use of mineral fertilizers has been reported to cause adverse effects on soil nutrient balance thereby reducing plant growth performance and justifying the need for the use organic fertilizers. Farmyard manure is commonly applied to high value commodities such as potato, coffee and vegetables (Freeman and Coe, 2002; Shapiro and Sanders, 2002).

Ethiopia is endowed with suitable climatic and edaphic conditions for potato production. However, the national average yield is estimated at 10.5 t/ha, which is very low by any standard compared to the world average of 16.4 tons/ha (FAOSTAT data, 2004). One of the contributing factors to this low productivity is the inadequate application of proper agronomic management practices, particularly fertilizer and manurial use by potato growers. Potatoes are gross feeders, requiring large quantities of fertilizers, which could partly be attributed to their limited and shallow root system and high level of productivity (Beukema and Van der Zaag, 1990 The use of chemical fertilizers alone in large quantities without organic sources has resulted in a significant negative effect on soil fertility and potato productivity (Shalini et al., 2002).

According to Beukema and Van der Zaag (1990), a potato crop of average yield may remove 50 to 80 kg N, 9–13 kg P and 66–83 K per ha from the soil. Organic manure could play a significant role in the uptake of these nutrients by the crop. These authors have also confirmed that potato benefits from the application of organic manure. It benefits not only from the amounts of nitrogen, phosphate and potash it contains but also from its positive effects on the tilth and moisture-retaining properties of the soil. This suggests that the combined use of mineral fertilizers and farmyard manure plays a crucial role in sustaining higher yields, thus achieving better quality and gaining higher profit.

In Bako area, response to chemical fertilizer is getting lower and lower due to soil acidity. Moreover, the soil is fragile and easily affected by intensive cultivation and continuous use of mineral fertilizers (Wakene Negassa et al., 2005). In general, soil fertility decline claimed as the principal cause for reduction in crop yield in the study area. This situation is perhaps becoming a serious issue in the productivity of root and tuber crops, particularly potato, as the crop is heavy feeder of nutrients, because of its potential to give higher yield in a relatively short period of time (Girma Abera, 2001). There is, therefore, an urgent need to develop alternate low-cost technologies to get higher yield through intensive cropping apart from maintaining soil fertility and ameliorating soil acidity. Hence, the combined use of different nutrient sources, both organic and inorganic, could be considered as one of the strategic solutions for replenishing and maintaining soil fertility. This study is based on the assumption that farmyard manure and vermicompost integrated with inorganic fertilizers could serve as one of the promising techniques for improving soil fertility and increasing potato yield as suggested by Kachapur et al., (2001 and Muriithi and Irungu (2004). The objective of this study was, therefore, to investigate the effect of combined use of organic and inorganic nutrient sources on tuber yield of potato and soil nutrient status.

MATERIALS AND METHODS

Description of the study area

The study area is located 260 km away from Addis Ababa in western Ethiopia at $9^{0}6'$ N latitude, $37^{0}9'$E longitude and altitude of 1650 m asl. It has a warm humid climate with mean minimum and maximum temperatures of 13.5 and 29.7°C, respectively. It is a mid-altitude area with average annual rainfall of 1237 mm. The rainy season extends from May to October and maximum rain is received in the months of June to August. Soils in the study area are Nitosol with clayey, acidic reaction, low, organic carbon and available P (Wakene Negassa, 2001). The area is known by its mixed crop–livestock farming system where maize (*Zea mays*), noug (*Guizotia abyssinica*), potato (*Solanum tuberosum* L.), sweet potato (*Ipomoea batatas L*), hot pepper (*Capsicum* sp), mango (*Mangifera indica*), banana (*Musa* spp.), sugarcane (*Saccharum officinarum* L.) and haricot bean (*Phaseolus vulgaris* L) are the major crops grown.

Treatment description and procedure

The study was conducted at Bako Agricultural Research Center during the 2005 main cropping season. There were 12 treatment combinations of four levels of organic manure (4 t/ha vermicompost, 5 t/ha farmyard manure, 8 t/ha vermicompost and 10 t/ha farmyard manure) and three levels of inorganic fertilizers (25%, 50% and 75%) of recommended rate of N and P fertilizers (111 kg N and 40 kg P), which were compared with four control treatments consisting of unfertilized plot (absolute control), 100% recommended rate of fertilizer, 10 t/ha farmyard manure and 8 t/ha vermicompost. The experiment was laid out in randomized complete block design in factorial arrangement of treatments in three replications.

Well-sprouted potato tubers of 40-100 g were planted on prepared ridges on June 30, 2005 in rows of four per plot at a spacing of 75 cm row to row and 30 cm plant to plant within the row. The gross and net plot size of experimental plots was 3 x 3 m and 3 x 1.5 m, respectively. A distance of 1.5 m between block and 0.75 m between plots was employed. The potato variety named 'Menagesha' was used for the experiment. At the time of planting, all fertilizers were applied on the prepared ridges in a band form and incorporated manually into the soil to facilitate efficient nutrient uptake by the roots. N was applied in the form of urea and P in the form of DAP for each plot as per treatments.

The farmyard manure was cow dung collected from the animal farm of Bako Agricultural Research Center. The fresh manure was piled and allowed to decompose for at least four months before application (Arakeri et al, 1962). Vermicompost was prepared using locally isolated earthworms at 1000 earthworms per square meter compost pile and allowed to decompose for 2.5 months. Application of earthing up, weeding and different intercultural operations were done as per agronomic research recommendation. Data on five randomly selected plants per plot were recorded during the crop-growing period and also at harvesting time (October 10, 2005).

Soil sampling and analysis

Representative soil samples were taken using an auger at 0-30 cm depth from different places in the experimental field before planting to form one composite sample. Further, after crop harvest, soil samples were also collected from each treatment plot with three replications. The collected soil samples were air-dried in wooden tray ground and sieved to pass through a2-mm sieve. The samples were analyzed for pH, organic carbon, total nitrogen, CEC, available P and K following the standard procedures at National Soil Research Laboratory.

Statistical analysis

The data were analyzed by general linear model (GLM) analysis of variance (ANOVA) for randomized complete block design (RCBD) using SPSS computer software (SPSS, 1996). The means were separated by Duncan's Multiple Range Test (DMRT).

Economic analysis

To consolidate the statistical analysis of the agronomic data, economic analysis was carried out for each treatment. For economic evaluation of cost and return, the benefit to cost ratio was calculated following the CIMMYT procedure (CIMMYT, 1998). Benefit: cost ratio was calculated as the ratio of net return to total cost. To estimate economic parameters, potato was valued at an average open market price of 1.00 birr per kg, 10 workdays per ha for collection and transportation of both farmyard manure and vermicompost were used and wage rate of 10 birr/ workdays was used. Sixteen workdays/ha were used for frequent watering of farmyard manure and vermicompost.

RESULTS AND DISCUSSION

Selected physico-chemical properties of the study site

The results of the laboratory analysis of some selected physiochemical properties of the soil of the experimental site are presented in Table 1. The result of soil analysis showed the soil to be clay in texture (49% clay) and strongly acidic in reaction with a pH of 4.96. Furthermore, according to Landon (1991), the soil at the experimental site had medium CEC, total N and K and low organic carbon. These findings explicitly justify the need for external application of nutrients based on the rate recommended for the different crops grown in the area. According to the classification limit set by Marx et al. (1996), the soil is low in plant available P that could probably be attributed to high P-fixing capacity of the soils at Bako (Girma Abera, 2001; Wakene Negassa et al., 2002).

Table 1. Selected physico-chemical characteristics of Nitisols of the experimental site before the start of the experiment

pH	Sand (%)	Silt (%)	Clay (%)	Textural class	TN (%)	OC (%)	Av.P (ppm)	Av.K (ppm)	CEC (cmol(+)/kg)	BS (%)
4.96	23.00	28.00	49.00	Clay	0.154	2.42	8.70	89.70	34.00	40.00

pH=pH soil, TN=total nitrogen, OC=organic carbon, Av.P=available phosphorus, Av.K=available potassium, CEC=cation exchange capacity, BS=base saturation

Chemical composition of vermicompost and farmyard manure

The chemical composition of vermicompost and farmyard manure used in the experiment was characterized through laboratory analysis (Table 2). The vermicompost contained 19.5% organic matter, 0.99% total nitrogen, 170.19 ppm available P and 20.55 meq/100P exchangeable potassium. Similarly, farmyard manure contained 64.70% organic matter, 3.17% Nitrogen, 0.97% phosphorus and 3.23% potassium. This implies that organic manures are a source of plant nutrients and, thus, a complete fertilizer to be used for sustainable potato production and productivity.

Table 2. Nutrient composition of the vermicompost and farmyard manure in the experiment

A, Nutrient element composition of vermicompost			
OM (%)	TN (%)	Av. P(ppm)	Exchangeable K(meq/100g)
19.5	0.99	170.19	20.55
B, Nutrient element composition of farmyard manure			
OM (%)	N (%)	P (%)	K (%)
64.70	3.17	0.97	3.23

OM=organic matter, TN=total nitrogen, Av. P= available phosphorus, K=potassium, N=nitrogen, P=phosphorus

Potato tuber yield

The results of the analysis of variance for marketable and total tuber yield of potato are given in Tables 3 and 4. The analysis of variance showed that significant difference existed among treatments both for main effects of organic manure and inorganic fertilizers. Significant difference also existed among the combined use of organic manure and inorganic fertilizer on both marketable and total tuber yields. The marketable and total tuber yield (26.19 and 27.25 t/ha) achieved by using 75% recommended dose of chemical fertilizer was significantly higher than the one achieved by 25 and 50% recommended dose of chemical fertilizer. The marketable tuber yield advantage achieved at 75, 50 and 25% of recommended dose of chemical fertilizer was higher by 84.47, 94.08 and 154%, respectively, when compared with absolute control. Similarly, more marketable yield advantage was recorded at both levels of farmyard manure and vermicompost (Table 3).

Table 3. Yield of potato (t/ha) as influenced by the main effects of organic and inorganic fertilizers at Bako

Variable	Marketable tuber yield	% over absolute control	Total tuber yield	% over absolute control
norganic fertilizer				
25%RDF	19.00b	84.47	19.94b	80.27
50%RDF	19.99b	94.08	21.18b	90.64
75%RDF	26.19a	154.27	27.25a	145.27
sem(±)	1.28		1.29	
Organic manure				
4 t/ha VC	19.97b	93.88	20.97b	88.75
5 t/ha FYM	21.58ab	109.51	22.71ab	104.41
8 t/ha VC	21.86ab	112.23	22.90ab	106.12
10 t/ha FYM	23.49a	128.06	24.57a	121.15
sem(±)	1.53		1.55	

Means within the same column followed by the same letter do not differ significantly at the 5% level of the DMRT test, RDF=recommended dose of fertilizer, VC=vermicompost, FYM =farmyard manure, sem = standard error of mean; The yield values achieved for the absolute control was 10.30 and 11.11 t/ha for marketable and total tuber yield, respectively.

The marketable yield increased significantly with increasing rates of farmyard manure from 5 to 10 t/ha. Increasing vermicompost from 4 to 8 t/ha increased total tuber yield but did not affect marketable yield. This indicates that there is an increasing requirement of farmyard manure and vermicompost for potato production. The present finding is in agreement with the reports of various researchers who reported that higher crop yield due to application of farmyard manure and vermicompost is attributed to significantly higher tuber yield components (Seyed et al., 1998; Jayaprakash, 2001; Kang, 2004).

The study also revealed that application of 10 t/ha farmyard manure in conjunction with 75% of recommended dose of chemical fertilizer resulted in significantly higher marketable yield (28.67 t/ha) over the control treatments followed by 8 t/ha vermicompost plus 75% of recommended dose of fertilizer (26.81t/ha) and 5 t/ha farmyard manure plus 75% of recommended dose of fertilizer (25.96 t/ha) (Table 4).

Table 4. Tuber yield of potato (t/ha) as influenced by organic manure and inorganic fertilizer at Bako

No.	Treatment	Marketable tuber yield	Total tuber yield
1	4 t/ha VC +25% RDF	19.07defg	20.15def
2	4 t/ha VC +50% RDF	17.52fg	18.41ef
3	4 t/ha VC +75% RDF	23.33abcde	24.36abcde
4	8 t/ha VC +25%RDF	17.96efg	18.85ef
5	8 t/ha VC+ 50%RDF	20.82cdef	21.96bcde
6	8 t/ha VC+75%RDF	26.81ab	27.89ab
7	5 t/ha FYM+25%RDF	20.22def	21.04cdef
8	5 t/ha FYM+ 50%RDF	18.54def	19.95def
9	5 t/ha FYM+75%RDF	25.96abc	27.15abc
10	10t/ha FYM+25%RDF	18.74defg	19.71def
11	10t/haFYM+ 50%RDF	23.07bcdef	24.41abcde
12	10t/ha FYM+75%RDF	28.67a	29.59a
13	8 t/ha VC	11.74h	12.47g
14	10 t/ha FYM	13.78gh	14.40fg
15	100% RDF(111/40 Kg N and P)	24.04abcd	25.72abcd
16	Unfertilized plot (Absolute control)	10.30h	11.11g
	CV(%)	14.85	14.37
	sem(±)	2.99	3.61

Means within the same column followed by the same letter or by no letters do not differ significantly at the 5% level of the DMRT test, RDF=recommended dose of fertilizer, VC=vermicompost, FYM=farmyard manure

Total tuber yield also followed a similar trend. It was highest for those treatments with highest marketable yield. The result also revealed that application of farmyard manure and vermicompost alone did not significantly increase potato yield and was comparable to unfertilized plot. This shows that application of organic manure and vermicompost alone may not result in higher yields and this could be associated with the slow release of nutrients from these organic sources. The present result is supported by Teklu Erkossa et al. (2004) who reported the insufficiency of manure for optimum yield of the crop within a short period of time, regardless of its quantity.

The use of 100% recommended dose of chemical fertilizer alone and recommended dose of inorganic fertilizers (25%,50% and 75%) along with different levels of organic nutrient sources (farmyard manure and vermicompost) significantly increased marketable tuber yield and total tuber yield compared with plots that received 8 t/ha vermicompost, 10 t/ha farmyard manure or no fertilization (Table 4). On the other hand, increment in marketable and total tuber yield of potato with combined application of either farmyard manure or vermicompost along with recommended dose of fertilizer could possibly be attributed to their positive effects on growth and yield components, like average number of tuber per hill, plant height and total leaf area per hill as reported by Shanward et al. (2001). Similarly, substitution of inorganic fertilizer at 25 to 50% with vermicompost was also reported for sunflower and groundnut (Anon, 1994) to result in better yield.

Soil nutrient status after harvest

The main effects of different treatments and their interactions in relation to soil nutrient status are presented in Tables 5 and 6. The statistical analysis revealed that application of organic manure significantly increased the chemical properties of the soil at the study site (Table 5).

Improvement in the soil properties with application of organic manure might be associated with organic carbon, solubilization of different organic nitrogenous compounds into simple and available forms, acidifying action of farmyard manure on applied P at the time of decomposition making more P available, and causing a reduction of K fixation (Seyed et al, 1998). The extent of increase was, however, higher when organic manure was applied in combination with inorganic fertilizer. On the contrary, the use of inorganic fertilizer sources had no significant effect on the nutrient profile of the soil. This result is in conformity with the finding of Wakene Negassa et al. (2002) in maize crop in Bako area. Soil pH slightly increased from an initial level of 4.96 to 5.00 in 0-30 cm depth. However, the soil pH was higher in inorganic

Table 5 Soil nutrient status after harvest as influenced by the main effects of organic and inorganic fertilizers at Bako

Variable	OC (%)	% over control	Av. P (ppm)	% over control	Av. K (ppm)	% over control	TN (%)	% over control	CEC (Cmol(+/kg)	% over control	pH H_2O (1:2.5)	% over control
Inorganic fertilizer												
25%RDF	2.65	5.58	8.65	8.67	87.49	8.29	0.207	2.48	32.90	2.82	4.88	2.74
50%RDF	2.63	4.78	9.52	19.60	87.49	8.29	0.205	1.49	33.08	3.38	4.94	4.00
75%RDF	2.64	5.18	10.65	33.80	80.99	0.25	0.205	1.49	32.25	0.78	4.92	3.58
Absolute control	2.51		7.96		80.79		0.201		32.00		4.75	
sem(±)	0.39		1.49		82.79		0.17		0.33		0.81	
Organic manure												
4 t/ha VC	2.53c	0.80	6.13c	2.14	69.29c	0.25	0.202	0.50	32.37b	1.16	4.93c	3.79
5 t/ha FYM	2.60bc	3.58	8.25bc	3.64	81.86b	1.32	0.203	0.99	32.47ab	1.47	4.99c	5.05
8 t/ha VC	2.74a	9.16	12.27a	54.15	87.92b	8.83	0.207	2.99	32.53ab	1.66	5.38a	13.26
10 t/ha FYM	2.67ab	0.71	11.76ab	47.74	102.22a	26.52	0.212	5.47	33.60a	1.88	5.01b	5.47
Absolute control	2.51b		7.96c			80.79cd	0.201		32.00cd		4.75cd	
sem(±)	0.35		1.24			4.52	0.23		0.19		0.71	

Means within the same column followed by the same letter or by no letters do not differ significantly at the 5% level of the DMRT RDF=recommended dose of fertilizer, VC=vermicompost, FYM=Farmyard manure, OC=organic carbon, IOA=improvement over absolute control, P=phosphorus, K=potassium, CEC=Cation exchange capacity, pH=soil pH, sem=standard error of mean fertilizer plots as compared to plots that received organic and inorganic fertilizers. This increase in soil pH with combined use of organic and inorganic fertilizers could be attributed to addition of organic matter to the soil nutrient pool.

The results also clearly indicated that the N content of the soil was not significantly affected by organic and inorganic fertilizer application. However, the total N content increased as the level of vermicompost and farmyard manure increased. Organic carbon, cation exchange capacity, available P and K contents of the soil increased with incorporation of farmyard manure or vermicompost in conjunction with inorganic fertilizer (Table 6). Tolanur (2002) reported similar results in which cation exchange capacity, available P and K, and organic carbon were significantly increased with organic manure in conjunction with inorganic materials. Similarly, Shivanand (2002) also reported that application of organic materials like farmyard manure or vermicompost in combination with inorganic fertilizers improves soil chemical properties like CEC, available P and K.

Organic carbon content of the soil was higher in the plots to which 4 t/ha vermicompost plus 25 and 50% of recommended dose of fertilizer was applied. The increment in organic carbon content may be attributed to addition of organic matter and better root growth. These observations are in agreement with the findings of Omar et al (2000) and Singh et al (2001). Available K content of the soils differed significantly with addition of various levels of organic sources in combination with inorganic sources of nutrients. Application of 4 t/ha vermicompost in conjunction with 50% of recommended dose of fertilizer resulted in significantly higher available K (117.39 ppm) than the control treatments followed by 4 t/ha vermicompost plus 25% recommended dose of fertilizer (108.29 ppm) (Table 6).

The combined application of 10 t/ha farmyard manure in conjunction with 75% recommended dose of fertilizer improved the cation exchange capacity (CEC) of the soil. Similarly, available P of the soil was higher in treatments that received 5 t/ha farmyard manure plus 75% recommended dose of fertilizer (18.46 ppm) followed by 4 t/ha vermicompost plus 50% recommended dose of fertilizer (15.24 ppm) and 4 t/ha vermicompost plus 25% recommended dose of fertilizer (13.41ppm). The improvement in available P of the soil might be accounted to the organic sources that might have favored the release of higher amounts of P from the soil as reported by Tolanur and Badanur (2003).

Table 6. Soil nutrient status as influenced by organic manure and inorganic fertilizers at Bako

No	Treatment	OC (%)	Av.P (ppm)	Av.K (ppm)	TN (%)	CEC (Cmol(+/kg)	pH H_2O (1:2.5)
1	4 t/ha VC +25%RDF	2.77a	13.41abcd	108.29b	0.210	33.40abcd	5.25ab
2	4 t/ha VC +50%RDF	2.78a	15.24ab	117.39a	0.210	33.50abcd	5.40a
3	4 t/ha VC +75%RDF	2.68ab	8.16bcd	80.99cd	0.200	31.40d	4.90bcd
4	8 t/ha VC +25%RDF	2.50b	6.10cd	74.49cd	0.210	32.50abcd	5.10abcd
5	8 t/ha VC+ 50%RDF	2.52b	5.60d	74.49cd	0.195	32.60abcd	5.18abcd
6	8 t/ha VC+75%RDF	2.58ab	6.70cd	58.89d	0.200	32.00abcd	4.93bcd
7	5 t/ha FYM +25%RDF	2.67ab	7.19bcd	78.39cd	0.205	34.10abc	5.20abc
8	5 t/ha FYM+ 50%RDF	2.51b	9.64bcd	77.09cd	0.200	33.80abc	4.90bcd
9	5 t/ha FYM+75%RDF	2.62ab	18.46a	90.09bc	0.205	32.90abcd	5.15abcd
10	10 t/ha FYM +25%RDF	2.64ab	7.90bcd	88.71bc	0.205	32.00abcd	4.80bcd
11	10 t/ha FYM+ 50%RDF	2.70ab	7.47bcd	80.99d	0.215	32.70abcd	4.83bcd
12	10 t/ha FYM+75%RDF	2.68ab	9.27bcd	93.99bc	0.215	34.40a	4.85bcd
13	8 t/ha VC	2.54b	7.50bcd	100.49bc	0.210	31.70cd	4.95abcd
14	10 t/ha FYM	2.71ab	11.22abcd	112.19ab	0.205	33.20abcd	5.15abcd
15	100%RDF(111/40 Kg N and P)	2.50b	7.01bcd	80.99cd	0.201	32.40abcd	4.70d
16	Unfertilized plot(Absolute control)	2.51b	7.96bcd	80.79cd	0.202	32.00cd	4.75cd
	CV (%)	4.46	22.76	16.44	15.25	3.36	5.02
	sem(±)	0.56	4.22	9.48	0.27	0.93	0.60

Means within the same column followed by the same letter or by no letters do not differ significantly at the 5% level of the DMRT test. RDF=recommended dose of fertilizer VC=vermicompost, FYM=farmyard manure OC=organic carbon, P=phosphorus, K=potassium, TN=total nitrogen CEC=Cation exchange capacity, pH=soil pH., sem =standard error of mean

The clear implication that can be drawn from this study is that the nutrient status of soils could be improved and maintained by the combined application of farmyard manure in conjunction with recommended dose of chemical fertilizer. Improvement in the soil properties and yield increase resulting from the integrated use of organic and inorganic plots might be due to the impact of balanced fertilization as reviewed by Katyal et al. (1997). Rang-Xiang et al. (2001) also reported that application of organic manure with reduced rates of chemical fertilizer increased soil fertility. Palm et al. (1997) also suggested that well-decomposed farmyard manure could be used in combination with inorganic fertilizer to improve soil fertility and yield of potato.

Economic analysis

The economic analysis revealed that the highest net returns of birr 19,432.87/ha was recorded for the plot that received 10 t/ha farmyard manure in conjunction with 75% of recommended dose of fertilizer. The second highest net benefit of birr 17372.87 per hectare was obtained from plots that received 8 t/ha vermicompost together with 75% of the recommended dose of fertilizer. The third highest net benefit of birr 16, 2222.87 per hectare was obtained from plots that received 5 t/ha farmyard manure together with 75% recommended dose of fertilizer

On the other hand, the lowest net return was obtained with the control treatment (Table 7). The same treatments that resulted in the highest net return also resulted in the highest benefit: cost ratio of 2.10, 1.84 and 1.81, respectively. These observations are in agreement with those reported from central Kenya by Makokha et al. (2000) and from Bangladesh by Bhuiyan (2001). High net return from the foregoing treatments could be attributed to high yield while low net return would be attributed to low yield. From the economic point of view, it was apparent that 10 t/ha farmyard manure plus 75% of recommended dose of chemical fertilizer and the treatment consisting of 8 t/ha vermicompost plus 75% of the recommended dose of fertilizer were more profitable than the other combinations.

CONCLUSION

Integrated use of organic manure and inorganic fertilizer is required to supply and maintain better soil fertility for sustainable potato production on Nitosol of Bako. The results generally indicated that incorporation of organic manure alone or its combination with mineral fertilizer is beneficial for improving potato yield and maintaining soil fertility. Integration of 10 t/ha farmyard manure with 50–75% of recommended dose of fertilizer resulted in greater benefit compared to the recommend rate of inorganic fertilizer. A combination of 25–50% of recommended dose of fertilizer with 5 or 10 t/ha farmyard manure was superior to the control treatments.

Table.7. Benefit and cost ratio of potatoes as influenced by integrated nutrient management

No.	Treatment	Yield (t/ha)	Gross return (Birr/ha)	Total cost Birr/ha)	Net return (Birr/ha)	B: C
1	4 t/ha VC +25%RDF	19.07	19070	8812.38	10257.62	1.16
2	4 t/ha VC +50%RDF	17.52	17520	9124.50	8395.50	0.92
3	4 t/ha VC +75%RDF	23.30	23300	9437.13	13862.87	1.47
4	5 t/ha FYM +25%RDF	20.22	20220	8612.38	11607.62	1.35
5	5 t/ha FYM +50%RDF	18.54	18540	8924.75	9615.25	1.08
6	5 t/ha FYM +75%RDF	25.96	25960	9237.13	16222.87	1.77
7	8 t/ha VC +25%RDF	17.96	17960	8812.38	9147.62	1.04
8	8 t/ha VC+ 50%RDF	20.82	20820	9124.50	11695.50	1.28
9	8 t/ha VC+75%RDF	26.81	26810	9437.13	17372.87	1.84
10	10 t/ha FYM+25%RDF	18.74	18740	8612.38	10127.62	1.18
11	10t/ha FYM+ 50%RDF	23.07	23070	8924.75	14145.25	1.58
12	10 t/ha FYM+75%RDF	28.67	28670	9237.13	19432.87	2.10
13	8 t/ha VC	11.74	11740	8500.00	3240.00	0.38
14	10 t/ha FYM	13.78	13780	8250.00	5530.00	0.67
15	100%RDF(111/90 Kg N and P)	24.04	24040	8749.50	15290.50	1.75
16	Unfertilized plot(Absolute control)	10.30	10300	7500.00	2800.00	0.37

It was observed that application of 10 t/ha farmyard manure plus 75% of recommended dose of fertilizer, 8 t/ha vermicompost plus 75% of recommended dose of fertilizer, and 5 t/ha farmyard manure plus 75% recommended dose of fertilizer was more profitable than the other combinations. Hence, it would be reasonable to point out that these treatment combinations resulted in not only significantly higher tuber yield but also improved the nutrient status of the soil, and could save 25% chemical fertilizers. Therefore, it is advisable for users to choose various soil amendment options based on resource available for them.

ACKNOWLEDGEMENT

The authors acknowledge the assistance of Mr. Diriba Geleti who revised the draft manuscript and suggested comments for its improvement. They also express their gratitude and appreciation to the Canadian Bureau for International Education (CBIE) for providing financial support for this study. The authors' sincere thanks also go to the field workers and technical assistants of the Horticulture Research Division of Bako Agricultural Research Center for their technical support during data collection and field activities.

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