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Integrated Application of Compost and Inorganic Fertilizers for Production of Potato (Solanum tuberosum l.) at Angacha and Kokate in Southern Ethiopia

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Abstract

Declining soil fertility is one of the major problems causing yield reduction in Ethiopia. Farmers at Angacha and Kokate apply both organic and inorganic fertilizers to overcome the problem and increase yield. However, application of manure is restricted only to homestead areas due to shortage of manure to cover the out field and chemical fertilizers are costly to apply the recommended rate. This experiment was conducted during 2005 and 2006 growing seasons at Angacha and Kokate. The objective of the experiment was to determine the optimum compost and NP fertilizers rate for potato production in the respective locations. Compost was prepared at each location with available materials in respective locations, and incorporated in to the soil 30 days before planting. Improved potato variety 'Tolcha' was used as a test crop. Four levels of N/P (0/0, 36.7/13, 55/19.6, and 73.4/26 kg ha^{-1}) and four levels of compost (2.5, 5, 7.5, and 10 t ha^{-1}) were arranged in RCBD with factorial experiment with three replications. Nationally recommended NP rate (111 kg N and 39 kg P ha^{-1}) was used for comparison. Surface soil samples (0-30 cm) were analyzed for total N, available P, pH and organic matter (organic carbon). Application of compost increased tuber yield at both locations although not significantly. Application of NP increased tuber yield highly significantly ($P<0.01$) at both locations. The highest yield (34 t ha^{-1} at Angacha and 30.54 t ha^{-1} at Kokate) was obtained with application of 111 kg N and 39 kg P ha^{-1} without compost at both locations with yield advantages of 11.06 t ha^{-1} and 13.95 t ha^{-1} at Angacha and Kokate, respectively, and this is economically significant. Application of 10 t ha^{-1} compost and 73.4 kg N + 26 kg P ha^{-1} gave yield advantages of 6 and 10.8 t ha^{-1} at Angacha and Kokate, respectively. In conclusion, combined or sole application of compost and NP fertilizers could increase tuber yield. However, large amount of compost should be applied to significantly increase yield. Farmers in the area can apply choosing either 111 kg N + 39 kg P ha^{-1} or 10 t + 73.4 kg N + 26 kg P ha^{-1} depending on their interest, the availability of compost material, labor and money to purchase more fertilizers.

Key words: Compost, NP fertilizers, Combined application

1. Introduction

Potato *(Solanum tuberosum L.)* is one of the most widely grown tuber crops in the high and mid altitude areas of southern region. A survey by the Bureau of agriculture of the region indicated that in 1997/98 growing season a total of 181,189.6 tones of potato was produced from 26,151.5 hectares of land (SNNPR BoA, 1999). Potato is widely grown in Angacha and Kokate areas. As a high yielding crop, it can greatly contribute in securing food in these highly populated areas. According to CACC

(2003 part II B), the production of potato at Angacha is 30,265.32 t yr^{-1} out of which 47.47 % goes to house hold consumption, whereas 15.61 % is used to make cash at local market. However, the yield is very low (below 10 t ha^{-1}) as compared to the yield in developed countries (30 to 40 t ha^{-1}) where sufficient amount of fertilizers are applied (FAO, 1991).

Declining soil fertility is one of the most significant constraints to increased food production in Ethiopia (Mwangi, 1995). Farmers in the areas apply organic fertilizers particularly animal manure and also chemical fertilizers. But the manure is restricted only to homestead areas due to shortage of the material to cover the out field, and the chemical fertilizers are applied far below the recommendation due to the high price (Gruhn, 1995) of fertilizers. The use of compost can overcome the problem of shortage of farmyard manure as compost can be made from locally available materials such as grass, clippings, leaves, weeds, vegetable peels, animal manure etc. For small holder farmers, compost is important source of nutrients, and necessary to manage soil fertility (Giller, 2006). Compost contains 1 -3 % N, 1 – 2 % P, 1 – 2 % K (Koenig and Johnson, 1999) and micronutrients which are absent in DAP and Urea, which are commonly used in Ethiopia. A research conducted in Taiwan indicated that application of compost increased the availability of N and P (Chen et al., 2001). In addition to providing essential nutrients, compost also improves soil structure and benefit soil organisms (Pretty, 1995).

However, since compost contains less nutrient concentration as compared to chemical fertilizers and it releases nutrients slowly, unless applied in very large amounts it doesn't provide all the NPK nutrients which are highly required by crops (Emiru, 2004).

Therefore, the integrated use of both compost and chemical (inorganic) fertilizers is the best alternative to provide balanced and efficient use of plant nutrients (Gruhn et al., 2000) and increase productivity of soil (Menon, 1992). Researches also witnessed that the integrated application of organic and inorganic fertilizers increased yields. An experiment conducted at Bako indicated that yield of maize increased due to application of compost and NP in combination (Tadesse and Abidissa, 1996). Consequently, this study was conducted to determine an optimum compost and NP fertilizers rate for potato at Angacha and Kokate.

2. Materials and Methods

2.1. Description of the study sites

The study was conducted at Angacha and Kokate which are located in Kembata Tembaro and Wolaita Zones, respectively, of Southern Nations Nationalities and Peoples' regional State (SNNPRS). Angacha is found at $7^o 0^'$ N and $38^o 29^'$ E at altitude of 2381 m- asl. Its mean annual rainfall is 1656 mm with a bimodal pattern that extend from February to September. The mean annual maximum and minimum temperature is 24 and 14 ^oC, respectively. The type of the soil is Alfisol (Soil Taxonomy) or Luvisol (FAO/Unesco classification). The soil is clay loam in texture and moderately acidic with pH around 6.5. Its organic matter (OM) and total nitrogen contents were medium with low P content. Kokate is found at $6^o 52^'$ 42" N and $37^o 48^'$ 25.2" E and altitude of 2162 m- asl. The type of the soil is Nitosol (FAO/Unesco classification). The soil is clay loam in texture and strongly acidic with pH around 5.1. It had medium OM content with low total nitrogen and available P.

2.2. Compost making

A compost heap of 1.2 m x 1.2 m size was made using available compost materials at each location. Except the materials, the same processes of compost making were applied to both locations. Materials used at Angacha were enset trashes, wheat and barley stover, different weed species, cattle manure and ash, whereas at Kokate ash, elephant grass, enset trashes, Croton macrostacheys, Erithyrina abyssinica, and different weed species were used.

The materials were arranged in layers with each layer about 30 cm thick. To facilitate decomposition, the materials were chopped in to smaller sizes. To assist aeration 30 cm thick of rough vegetation was put at the bottom of the heap in close contact with the loose soil. The second 10 cm thick layer was fresh manure from cattle. The third, forth and fifth layers were top soil to generally cover the material, 20 cm thick green vegetation (available plant biomass and weed species) and some wood ashes, respectively. Then the whole pile was watered. The compost pile process was completed repeating the above process and covering all over with 10 cm top soil to prevent gasses from escaping the compost pile. Lastly, the whole pile was covered with dry grasses (harvested before seed setting) to prevent loss of moisture through evaporation. A long sharp pointed stick was driven in to the pile at an angle to check the condition of the pile from time to time for the control of fungus development, water and turn the pile. The pile was turned after three weeks (to facilitate decomposition) making sure that the bottom part of the pile became the top of the pile. After three more weeks, the pile was turned a second time. Three weeks after the second turning, the compost became ready for use.

2.3. Treatments and Experimental design

Potato variety 'Tolcha' was used as a test crop to evaluate its response to increasing levels of compost and NP. Four levels of N/P (0/0, 36.7/13, 55/19.6 and 73.4/26 kg ha^{-1}) and four levels of compost (2.5, 5, 7.5, and 10 t ha^{-1}) were arranged in RCBD with factorial experiment with three replications. Nationally recommended NP rate (111 kg N and 39 kg P ha^{-1}) was used for comparison. A plot size of 3 m x 4 m and spacing of 75 cm between rows and 30 cm between plants were used. A distance of 1 m and 2 m were left between plots and blocks, respectively. Compost was applied to the field 30 days before planting. Urea and DAP were used as sources of N and P. The whole dose of DAP and half dose of Urea were applied at planting time and the rest half dose of Urea was applied one month after planting (at tuber initiation stage).

2.4. Soil sampling and Analysis

Thirty surface soil samples (0-30 cm) were randomly (following zig-zag way) collected and composited before planting. At harvest, eight surface soil samples were collected from every plot and composited for each plot. Soil analysis was done following the procedures in laboratory manual prepared by Sahlemedhin and Taye (2000). The soil samples were air dried and ground to pass 2 mm sieve and 0.5 mm sieve (for total N) before analysis. The pH of the soil was measured in 1:2.5 (soil: water ratio). Organic carbon content of the soil was determined following the wet combustion method of Walkley and Black. Total nitrogen content of the soil was determined by wet-oxidation (wet digestion) procedure of Kjeldahl method. The available phosphorus content of the soil was determined by Olsen method.

Potato yield data were statistically analyzed using the proc Glm function of SAS and means were compared using LSD at a probability level of 5 %.

3. Results and Discussion

Results indicated that application of compost did not significantly influence potato tuber yield at both locations (Tables 1 and 2). However, yield-increasing trend was observed with increasing application of compost (Table 3), which is in agreement with the findings of Assefa (1998) who obtained increased maize yield with increased application of farm yard manure. This implies that the application of higher rates of compost is required to get the highest tuber yield provided that the availability of composting material and other prevailing conditions occur.

On the other hand, application of N and P highly significantly influenced ($P<0.001$) potato tuber yield at both locations (Table 3 and 4). Increased yield was obtained with increasing application of N and P. The highest tuber yields (34 t ha^{-1} at Angacha and 30.54 t ha^{-1} at Kokate) were obtained with application of the highest N and P rates (111 kg N ha^{-1} and 39 kg P ha^{-1}) at which yield advantages of 11.06 and 13.95 t ha^{-1} over the control (0/0 N/P) treatment were obtained at Angacha and Kokate, respectively. Although this nationally recommended rate gave significantly the highest yield, still it is not the optimum rate at which maximum yield can be obtained, yield could be increased if more fertilizer was added. This indicates that site-specific fertilizer recommendation for each location is required. The value cost ratio (Table 7) also indicated that the increment of yield with increased application of NP is economical and it is necessary to apply fertilizer beyond the national recommendation to get the maximum yield and earn more. As it is clearly indicated in tables 7.1 and 7.2, each rate of fertilizer application is economical enabling to earn a net benefit of more than four times the cost.

There is no difference in tuber yield between growing seasons (2005 and 2006 growing years) at Angacha (Table 5). However, highly significant ($P<0.001$) yield difference was obtained at Kokate between 2005 and 2006 growing years (Table 4). Better yield was obtained in 2006 which might be attributed to the better climatic condition in the second year. In both years in both locations significant yield differences were obtained among the treatments.

The interaction between compost and NP fertilizers did not significantly affect tuber yield at both locations. This is again in agreement with the result obtained by Assefa (1998). However, as rate of compost and NP increased, yield also increased indicating the levels of fertilizers applied did not reach the amount at which the crop can give maximum yield (yield potential of about 40 t ha^{-1}). Yield advantages of 6 t ha^{-1} at Angacha and 10.8 t ha^{-1} at Kokate were obtained with application of 10 t ha^{-1} compost and 73.4 kg N ha^{-1} and 26 kg P ha^{-1} over the control (0/0 N/P) treatment. With application of the same 10 t ha^{-1} rate of compost and NP, 31.84 and 29.81 t ha^{-1} tuber yields were obtained at Angacha and Kokate, respectively. On the other hand, the control gave only 25.64 and 19.01 t ha^{-1} tuber yields at Angacha and Kokate, respectively.

Although the interaction between compost and NP fertilizers showed that there is no significant difference among treatments, 6 and 10.8 t ha^{-1} yield advantages at Angacha and Kokate, respectively, is economically very much significant for the farmers. Here, the contribution of compost to the improvement of physical properties of soils in addition to chemical properties and yield should be underlined. On the other hand, yield advantage of 11.06 t ha^{-1} at Angacha and 13.95 t ha^{-1} at Kokate were obtained with application of only 111 kg N and 39 kg P ha^{-1}, respectively (national recommendation). The use of this recommendation is advantageous in that it is not bulky unlike compost and it gives higher yield as compared to the combination of compost and NP fertilizers. Providing options of technologies (recommendations) to farmers enables them to choose the best one in their situation. Those farmers who have access to compost materials and labor and who do not want (have low economic status) to incur much cost on chemical fertilizers can use 10 t ha^{-1} compost + 73.4 kg N and 26 kg P ha^{-1}.

Combined application of compost and NP fertilizers did not significantly influence the pH of the soil at Angacha (Table 5). Both before and after fertilizer application the soil remains moderately acidic (Herrera, 2005) with pH varying between 5.6 to 6.0. This pH value indicates that the condition of the soil is good enough for the availability of nutrients to the crop. Organic matter of the soil at Angacha increased in all treatments after compost was applied (Table 5), which has positive implication in improving both the physical and chemical properties of soils. The organic matter content of the compost (5.57 %), which is rated as high is by far greater than the content in the soil (2.45 %), which is rated as medium. The total nitrogen at Angacha was decreased in all treatments after application of fertilizers (compost and inorganic fertilizers). The decrease in total N might be attributed to leaching, uptake by the crop and the insufficient supply of N from the fertilizers to the crop. This is in agreement with the tuber yield obtained, which increased with increased application of compost and inorganic fertilizers. Because of insufficiency of N provided from the fertilizers, maximum yield was not achieved and the crop might have taken additional N from the soil. As a result N content of the soil in all treatments became lower than the N content before planting. The N content of the soil before fertilizer application (0.24 %) was medium, whereas the N content of the compost (0.356 %) is rated as high.

Available P content of the soil at Angacha increased after application of fertilizers. It was increased in all treatments after the fertilizers had been applied indicating sufficient amount of P was provided from the fertilizers to the crop. The available P content of the soil before fertilizer application was low (5.09 ppm) but after the application of fertilizers it increased up to 19.2 ppm (at application of recommended rate of NP). The compost was also very much rich in P (38.85 ppm), which, as a result, might contributed a lot of P to the soil.

Application of fertilizer influenced the contents of soil pH, total N and organic carbon (OC) or organic matter (OM) very slightly; however, there is no decreasing or increasing trend of the parameters at Kokate (Table 6). The pH of the soil indicated that the soil of Kokate research station is strongly acidic, which has negative impact on the availability of most of the essential nutrients. However, application of compost increased the pH, which indicates application of organic fertilizers (compost) is helpful in reducing soil acidity, which in turn has a positive impact on the availability of nutrients. The total nitrogen content of the soil is very low varying between 0.168 and 0.224 %. It was not increased after application of fertilizer, which is in agreement with tuber yield response of the crop (potato) to fertilizer application i.e. fertilizer application increased tuber yield but the maximum yield was not achieved as fertilizer rate did not reach the maximum level, because tuber yield continued to increase with increasing fertilizer. This low amount of N in the soil indicates the amounts applied were not enough to the crop to produce its potential yield. The N content at harvest was decreased when compared to the original content, which might be attributed to uptake by the crop, leaching, and insufficient supply from the fertilizers. Application of fertilizer increased available P content of the soil; however, the increment is not linear. The increment is higher with application of lower N fertilizer, but with increasing N fertilizer, the increment is lower which might be attributed to higher uptake of P to make it proportional with N uptake i.e. higher uptake of P with higher uptake of N. The P content of the soil, both before and after fertilizer application, is low indicating the need for P application for crop production.

The organic matter content of the soil at harvest is high and increased after fertilizer application, which could mostly be resulted from the applied compost. This indicates that compost is a good source of organic matter.

4. Conclusion and Recommendation

From the above analysis it can clearly be seen that Kokate is better responsive to application of fertilizers than Angacha indicating that nutrient depletion is higher at Kokate than Angacha. This strengthens the need of site-specific fertilizer recommendation.

Compost is a good source of N and P; however, large amount of compost should be applied to significantly increase tuber yield. In both cases, application of sole NP and combination of compost and NP, highly significant economic advantage was obtained. The experiment did not show the optimum fertilizer rate to produce the maximum potato yield. Hence, NP rate for the crop at each location should be carried out in order to get the optimum rate.

Farmers can use choosing one of the options (combined application of compost and NP or application of sole NP) but for improvement of the soil both in physical and chemical properties, using the combination of compost and NP is preferable. Since application of all rates of fertilizer is economical, farmers can apply any of the four NP rates (36.7 – 111 kg N ha^{-1} and 13– 39 kg P ha^{-1}). However, as higher rates gave higher economic benefit, application of 10 t ha^{-1} compost + 73.4 kg N + 26 kg P ha^{-1}, or 111 kg N + 39 kg P ha^{-1} is recommended for the time being.

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Table 1. Potato tuber yield (t ha^{-1}) as influenced by compost and NP fertilizers at Angacha

Compost rate (t ha^{-1})	N/P rate (kg ha^{-1})				
	0/0	36.7/13	55/19.6	73.4/26	Compost mean
2.5	25.64	25.74	29.90	28.89	28.17
5.0	20.55	25.83	24.17	29.07	26.16
7.5	22.03	26.11	29.16	28.69	28.37
10	23.52	28.42	27.49	**31.84**	30.32
N/P mean	22.94	26.53	27.68	29.62	
111/39	**34.01**				

	Compost	N/P	N/P x compost
LSD (5 %)	NS	4.033	NS
CV %	20		

Table 2. Potato tuber yield (t ha^{-1}) as influenced by compost and NP fertilizers at Kokate

Compost rate (t ha^{-1})	N/P rate (kg ha^{-1})				
	0/0	36.7/13	55/19.6	73.4/26	Compost mean
2.5	19.01	20.92	24.18	25.74	23.09
5.0	15.64	21.07	22.54	24.40	22.16
7.5	15.33	23.56	24.25	26.21	24.21
10	16.37	22.77	24.56	**29.81**	25.88
N/P mean	16.59	22.08	23.88	26.54	
111/39	**30.54**				

	Compost	N/P	N/P x compost
LSD 5 %	NS	3.23	NS
CV %	19.54		

Table 3. Potato tuber yields (t ha^{-1}) as influenced by application of compost and NP over years at Angacha

Compost rate (t ha^{-1})	N/P rate (kg ha^{-1})									
	2005					2006				
	0/0	36.7/13	55/19.6	73.4/26	Compost mean	0/0	36.7/13	55/19.6	73.4/26	Compost mean
2.5	28.15	28.70	30.74	26.30	29.1	23.14	22.78	29.05	31.48	26.61
5.0	21.48	28.15	22.04	25.93	25.65	19.62	23.52	26.29	32.22	25.41
7.5	24.44	25.93	29.26	28.15	28.82	22.59	26.28	29.06	29.23	26.79
10	21.67	25.74	27.04	**30.00**	28.61	22.39	31.10	27.93	**33.68**	28.78
N/P mean	23.94	27.13	27.27	27.6		21.94	25.92	28.08	31.65	
111/39	**32.96**					**35.60**				

	Compost	Year	N/P	N/P x compost	N/P x Year	Compost x Year	N/P x compost x year
LSD(5 %)	NS	NS	3.38	NS	NS	NS	NS
CV %	21.97						

Table 4. Potato tuber yields (t ha^{-1}) as influenced by application of compost and NP over years at Kokate

Compost rate (t ha^{-1})	N/P rate (kg ha^{-1}) 2005 0/0	36.7/13	55/19.6	73.4/26	Compost mean	2006 0/0	36.7/13	55/19.6	73.4/26	Compost mean
2.5	17.04	18.15	20.37	22.22	20.07	21.00	23.69	27.98	29.25	25.48
5.0	14.81	21.48	20.37	19.63	20.32	16.46	20.65	24.71	29.16	22.75
7.5	14.44	24.07	22.22	24.07	23.08	18.29	23.04	26.29	28.34	23.99
10	12.59	21.48	22.96	**25.56**	23.15	18.06	24.07	26.17	**34.07**	25.60
N/P mean	14.72	21.3	21.48	22.87		18.45	22.86	26.29	30.21	
111/39	**32.96**					**35.60**				

	Compost	Year	N/P	N/P x compost	N/P x Year	Compost x Year	N/P x compost x year
LSD (5%)	NS	NS	2.64	NS	NS	NS	NS
CV %		20.57					

Table 5. Soil organic matter, Total N, Available P (Olsen), and pH content before and after planting at Angacha

Compost (t ha^{-1}) + N/P (kg ha^{-1})	Organic matter (%)	Total N (%)	Available P(Olsen) (ppm)	pH (1:2.5soil:water)
2.5 + 0/0	2.795	0.203	8.74	5.9
2.5 + 36.7/13	2.725	0.174	6.87	5.9
2.5 + 55/19.6	2.858	0.159	7.24	5.9
2.5 + 73.4/26	2.579	0.174	7.27	5.7
5 + 0/0	2.934	0.189	6.82	6.0
5 + 36.7/13	2.87	0.189	6.41	6.0
5 + 55/19.6	2.57	0.203	7.10	5.8
5 + 73.4/26	2.72	0.174	10.57	6.0
7.5 + 0/0	2.795	0.189	7.44	5.8
7.5 + 36.7/13	2.72	0.174	5.85	5.9
7.5 + 55/19.6	2.23	0.239	6.48	5.7
7.5 + 73.4/26	2.72	2.17	6.85	5.9
10 + 0/0	2.596	0.189	6.62	6.0
10 + 36.7/13	2.71	0.203	6.86	5.8
10 + 55/19.6	2.60	0.185	6.28	5.7
10 + 73.4/26	2.94	0.189	7.96	5.6
0 + 111/39 (national recommendation)	2.87	0.184	19.2	5.7
Soil, Before fertilizer application	2.45	0.24	5.09	5.7
Compost	5.57	0.356	38.85	7.0

Table 6. Soil organic matter, Total N, Available P (Olsen), and pH content before and after planting at Kokate

Compost (t ha^{-1}) + N/P (kg ha^{-1})	Organic matter (%)	Total N (%)	Available P(Olsen) (ppm)	pH (1:2.5soil:water)
2.5 + 0/0	4.2	0.196	4.8	5.68
2.5 + 36.7/13	4.5	0.196	6.0	5.40
2.5 + 55/19.6	4.4	0.182	6.0	5.70
2.5 + 73.4/26	4.5	0.182	4.8	5.60
5 + 0/0	4.4	0.196	3.6	5.40
5 + 36.7/13	4.5	0.186	6.0	5.23
5 + 55/19.6	4.4	0.168	3.6	5.47
5 + 73.4/26	4.5	0.224	3.6	5.34
7.5 + 0/0	4.4	0.196	2.4	5.41
7.5 + 36.7/13	4.9	0.182	3.6	5.01
7.5 + 55/19.6	4.5	0.182	3.6	5.10
7.5 + 73.4/26	4.5	0.168	2.4	5.20
10 + 0/0	4.7	0.168	3.6	5.19
10 + 36.7/13	4.7	0.210	6.0	5.20
10 + 55/19.6	4.7	0.182	3.6	5.00
10 + 73.4/26	4.5	0.196	7.2	4.96
0 + 111/39 (national recommendation)	4.5	0.182	6.0	5.30
Before fertilizer application	3.5	0.23	2.3	5.1

Table 7.1. Economic analysis using value cost ratio (VCR) method for Angacha

N/P (kg ha^{-1})	Cost (Birr)	Gross benefit (Birr)	VCR
0/0	0	18352	
36.7/13	431	21216	6.65
55/19.6	648.32	22144	5.85
73.4/26	861.67	23696	6.20
111/39	1301.55	27200	6.80

Table 7.2. Economic analysis using value cost ratio (VCR) method for Kokate

N/P (kg ha^{-1})	Cost (Birr)	Gross benefit (Birr)	VCR
0/0	0	13272	
36.7/13	431	17664	10.19
55/19.6	648.32	19112	9.00
73.4/26	861.67	21232	9.24
111/39	1301.55	24432	8.57