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Determination of the Application Rate of Conventional Compost Integrated with Chemical Fertilizer on Maize (Zia Maize) Yield in Dugda District of East Shoa Zone, Oromia

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Abstract: Integrated soil fertility management is the application of inorganic in combination with organic fertilizer to maintain soil fertility and improve crop yield. A study was conducted in East Shoa Zone, Dugda District on farmers' fields to determine the combined effects of conventional compost as organic fertilizer and NPS as inorganic fertilizer on soil chemical properties and maize production. There were five treatments: Recommended rate of inorganic fertilizer, 100, 75, 50 and 25% equivalent level of compost for nitrogen fertilizer. Recommended level of 69 P_2O_5/ha were equally applied at all treatments. The experiment was laid out in RCBD design with three replications. The analysis of variance showed no significant differences ($P > 0.05$) in maize grain yield response. However, the highest maize grain yield (8728.20 kg ha^{-1}) was obtained from treatment two that received 100% equivalent compost for nitrogen fertilizer and the lowest (8325 kg ha^{-1}) was obtained from treatment one where recommended chemical fertilizer alone was applied. Composite Soil samples were also collected before compost application and after harvesting to evaluate the residual effect of compost on soil physiochemical properties. Accordingly, laboratory analysis showed no significance differences ($P > 0.05$) in total N, available P, soil organic carbon and CEC. However, analysis of variance of post-harvest composite soil samples indicated significant differences on soil available P, OC, TN and CEC as compared to initial soil sample. On the other hand, partial budget analysis was done to determine economically optimum rate of compost integrated with chemical fertilizer. Accordingly, the highest net benefit (126527 Eth. Birr ha^{-1}) was recorded for treatment two where 100% compost (4.6t/ha) plus 150kg/ha NPS fertilizers were applied. The highest marginal rate of return (146) was also obtained from the same treatment. Therefore, the present study showed that combined application of organic and NPS fertilizer enhanced maize productivity and soil fertility status in the study area. Hence combined fertilizer application of 4.6 t ha^{1} conventional compost integrated with 150 kg ha^{-1} NPS improved maize productivity and soil chemical properties, and recommended for the study area and similar agro-ecology.

Keywords: Soil Fertility, Soil Organic Carbon, Integrated Application, Organic and Inorganic Fertilizer

1. Introduction

Continuous uses of inorganic fertilizers lead to deterioration of soil chemical and physical properties and in general the total soil health [11]. Application of chemical fertilizers alone lead to unsustainable productivity over the years [11, 15]. However, Organic fertilizer application has been reported to improve crop growth by supplying plant nutrients including micro-nutrients as well as improving soil physical, chemical, and biological properties thereby provide a better environment for root development by improving the soil structure [4]. In addition, the price of inorganic fertilizers is currently increasing and becoming unaffordable for resource-poor small-holder farmers. Therefore, a combination of both inorganic and organic fertilizers, where the inorganic fertilizer provides readily available nutrients and the organic fertilizer mainly increases soil organic matter and improves soil structure and buffering capacity of the soil [2].

Due to the extensive and improper use of chemical fertilizers in the soil, soil is degrading to an alarming level, causing an imbalance in the ecosystem and environmental pollution as well. More recently, attention is being focused on the global environmental problems, utilization of organic wastes, farm yard manure, compost, compost and poultry manures as the most effective measure for the purpose. The use of bio-products for plant nutrition purposes is taken as a basic approach so that Food and Agriculture Organization (FAO) recently has taken some measure to implement the Integrated Plant Nutrition Management (IPNM) systems for the development of sustainable agriculture in developing countries. Adequate Input Sustainable Agriculture (AISA) is currently practiced based on the integrated use of chemical and organic fertilizers, especially bio-fertilizers as an approach to alternative agriculture for producing and maintaining yield at an acceptable level.

The ISFM paradigm acknowledges the need for integration of both organic (compost) and mineral inputs to sustain soil health and crop production due to positive interactions and complementarities between them. According to [8] the use of compost double the grain yield of cereal crops as compared to the chemical fertilizer, hence, Continuous usage of inorganic fertilizer affects soil structure and microbial biomass and their activities, whereas compost reduces production cost and it is an environmentally friendly method of agricultural in puts technology. However, successful use of either compost alone or its combination with chemical fertilizer relies on evaluating the soil to be amended followed an evaluation of available compost materials, and then determining the best materials and rate of compost and mineral fertilizer to meet the desired objective. So, this experiment is required with the objectives of assessing the effects of different levels of compost alone and its combination with mineral fertilizer as compared to the recommended inorganic fertilizer on the maize yield and yield components.

Recently, areas for maize cultivation and its consumption have been increased rapidly in all over the world and this may be because of its importance for consumption and raw material for producing different products. Maize is the largest and most productive crop in Ethiopia in general and mid rift valley in particular. According to the report by ministry of agriculture and Natural resource report, in 2015/16, maize production was 4.2 million tons, which was 40 percent higher than teff, 56 percent higher than sorghum, and 75 percent higher than wheat production. Maize needs different kinds of nourishment during its growth which can be obtained from the chemical fertilizers. Nitrogen is the one of the most important element which used for the maize cultivation and its deficiency can be limiting the nutritional elements of this crop. However, excessive or under use of chemical fertilizers decline soil fertility and grain quality [17, 10]. Considering the environmental pollution related to excess use of chemical fertilizer, and its cost needs of an alternative approach based on biological origin, which is safe for use and less expensive to generate adequate plant nutrient through ‘*’integrated soil fertility management’’* assuming that fully or partially replacements of chemical fertilizer in the soil through application of compost have both environmental and Economic benefit in maintaining crop production more sustainable.

Therefore, this project is designed to evaluate the effect of compost as organic source of fertilizer applied alone and in combination of chemical fertilizer on yield and yield components of Maize.

2. Objective

1. To evaluate the effect of compost integrated with chemical fertilizer on yield and yield components of Maize.
2. To recommend best compost and chemical fertilizer integration based on the yield response.

3. Materials and Methods

The study was conducted at two different PA in Dugda district where maize is the main crop for consumption. Conventional compost was prepared from Animal manure, Haricot bean straw and parthinium, forest soil, ash and other materials following conventional compost preparation standard at Adami Tulu Agricultural research center. Before conducting the experiment Compost Samples were taken to evaluate its quality in terms of total nitrogen content to compute the compost and chemical fertilizer equivalency.

4. Experimental Design and Treatments

The experiment has five treatments with three replications designed in RCBD. The area will be 3mx4m for each plot. BH546 maize variety, which is the most commonly, sown by the farmers in the area, was used to evaluate the treatments. Recommended chemical fertilizer was applied based on site specific crop response p-calibration study recommended by EIAR, Melkassa, for maize production in Dugda district. According to the report, P-critical, initial-p, optimum-N and P requirement factor for maize is 10, 3.2, 92kg and 3.04 respectively.

5. Treatments

T1= Recommended rate of chemical fertilizer (control)

T2 = 100% Equivalent level of compost + Recommended P_2O_5

T3= 50%N +50% Equivalent level of compost + Recommended P_2O_5

T4 = 75% N+25% Equivalent level of compost + Recommended P_2O_5

T5= 25%N +75% Equivalent level of compost + Recommended P_2O_5

6. Data Collection

Soil samples were collected to the depth of 20cm before planting and after harvesting to evaluate the effect of compost on soil chemical properties. Yield and yield components data were also collected after harvesting from all plots. Economic importance of integrated soil fertility management was also collected.

7. Data Analysis

The collected data was interred to the Microsoft excel and analyzed using SAS 9.0 software version. Soil and compost samples were analyzed for physical and chemical properties following analytical standards. The economic analysis was done using partial budget analysis model developed by CIMMYT to recommend the economically important combination of organic and inorganic fertilizer. In addition, the cost of compost was estimated based on its total nitrogen content. This technique was commonly used in different parts of the country like in UK.

8. Result and Discussion

8.1. Grain Yield and Yield Components

The effect of integrated soil fertility management on yield and yield component of maize was presented in table 1 below.

The result showed that there is no significant ($P<0.05$) differences among the treatments in grain yield response (Table 1). In the same table, mean of thousand seed weight and the number of cobs per plant also showed no significant difference ($P<0.05$) between the treatments. However, the maximum grain yield of 8728.20 kg/ha was obtained in treatment two (2) where compost substitute nitrogen fertilizer by 100% followed by the treatment 3 (three) where compost substitutes N-fertilizer by 75%. The minimum grain yield (8325kg/ha) was obtained from the control treatment where recommended rate of fertilizer was applied without compost (table 1). On the other hand, yield advantage (4.8%) was slightly greater for treatment two where compost substitutes N-fertilizer by 100% as compared with other treatments. This result was strongly in agreement with [19, 6] who were reported that sole compost with the substation of N fertilizer increased maize yield. In addition, [1] found higher maize grain yield from integrated use of organic and inorganic fertilizer application. This was mainly due to the compost applied which can supplement both macro and micro nutrients for better nutrient use efficiency and better grain development. Nutrient use efficiency can also increase as the soil is amend with organic and inorganic fertilizers [3]. Other similar studies also reported that maize grain yield was increased by 0.47t/ha in the first cropping season at the plots treated with organic and inorganic fertilizer in western Hararghe zone [7].

Table 1. *Effect of treatments on yield and yield components.*

Treatments	Mean grain Yield in Kg/ha	000'kernal weight in kg	No. of cobs/plant	Yield advantage (%)
Recommended rate (46kg N+69 P_2O_5)	8325.30	0.42	1.16	-
100% Compost+69P_2O_5	8728.20	0.46	1.19	4.80
75% Compost+25%N+69P_2O_5	8602.30	0.44	1.17	3.32
50% Compost+50%N+69P_2O_5	8500.10	0.40	1.18	2.09
25% Compost+75%+69P_2O_5	8407.20	0.41	1.16	0.98
CV	9.12	11.33	7.11	
LSD0.05	717.99	0.08	0.04	
Significance	ns	ns	ns	

8.2. Residual Effect of Compost and Chemical Fertilizer on Soil Properties

The residual effect of applying compost integrated with chemical fertilizer was evaluated after comparing soil chemical properties before treatment application and after crop harvest. The result from soil sample analysis indicated that total nitrogen, organic carbon CEC and phosphorous content of the soil before treatment application was not significantly different ($p\geq0.05$) between the experimental plots. However, CEC, total N, available phosphorous, and soil organic carbon content of the soil after harvesting were highly significantly different ($p\leq0.05$) between the treatments (table 2). This result is strongly in agreement with the study by [8, 6] who were reported that after the first crop harvesting, total N, available phosphorous, potassium, CEC and soil organic carbon significantly higher for the plots treated with compost as compared with application of sole inorganic fertilizer. In addition, the residual effects of compost application can maintain crop yield level for two years after compost application since only a fraction of the N and other nutrients in compost become plant available in the first year after application [5].

Other similar studies also reported that, compost application have strong positive effect on the physicochemical and biological properties of the soil which often leads to higher crop growth and yield [1, 7]. This was mainly due to compost provides nutrients to the crop and improve land productivity.

Previous studies also indicated that the residual effect of compost and inorganic fertilizers gave positive yield benefits on rice, wheat [14, 1] and sorghum [13]. This indicates that farmers who cannot afford to apply compost every year could improve productivity by applying compost every other year. [12] reported 97% yield increase in wheat from residual effects of compost.

Table 2. *Soil chemical properties before application and after harvesting.*

Treatments	Soil chemical properties									
	Initial pH	Initial TN (%)	Initial OC (%)	Initial CEC me/100g	Initial P (ppm)	Final pH	Final TN (%)	Final OC (%)	Final CEC me/100g	Final P (ppm)
1	7.54	0.24	1.45	12.80	12.96	7.52	0.25^{b}	1.47c	12.31^{b}	13.59^{c}
2	7.46	0.26	1.47	11.98	14.39	7.65	0.33^{a}	2.21a	24.91^{a}	24.96^{a}
3	7.55	0.25	1.44	12.87	14.27	7.71	0.30^{a}	2.17a	23.34^{a}	24.52^{a}
4	7.60	0.24	1.43	11.99	14.10	7.43	0.27^{ab}	1.68b	21.98^{a}	22.84^{a}
5	7.47	0.23	1.39	12.97	13.67	7.46	0.26^{b}	1.57bc	15.26^{b}	17.11^{b}
CV (%)	5.89	17.75	20.28	13.78	13.28	6.31	19.50	9.74	14.04	11.47
LSD 0.05	0.39	0.06	0.38	2.37	2.43	0.44	0.05	0.27	3.62	3.05
Sign.	ns	ns	ns	ns	ns	ns	**	**	**	**

8.3. Integrated Soil Fertility Management as Climate Change Mitigation Strategy

Soil organic carbon significantly increased in a plot treated with compost and combination of compost and chemical fertilizers at different levels after the first crop harvest as compared with the plots treated only with inorganic fertilizer (table 2). Therefore, when managed properly, soils can play an important role in climate change mitigation by storing carbon or decreasing greenhouse gas emissions to the atmosphere [16]. On the other hand, if soils are cultivated through unsustainable agricultural practices, soil carbon can be released into the atmosphere in the form of carbon dioxide (CO_2), which can contribute to climate change (figure 1).

It was identified that, a substantial amount of global CO_2 comes from soil through decomposition, mineralization and soil respiration. However, integrated application of organic and inorganic fertilizers reduced decomposition rate of organic matters that consequently alter carbon dioxide emissions [6]. On the other hand, combined application inorganic fertilizers and organic have resulted in higher aboveground biomass yield than the application of 100% recommended rate of inorganic alone.

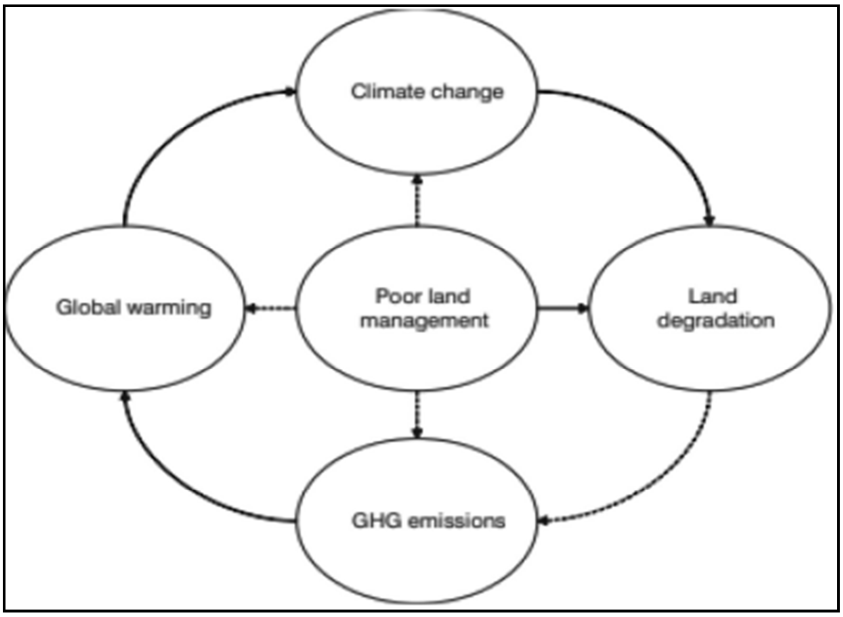

Figure 1. *The relationship between climate change and soil management (adapted from Bayu et. al, 2020).*

8.4. Partial Budget Analysis for Integrated Soil Fertility Management

Partial budget analysis and marginal rate of return were carried out for the integrated use of compost and NP fertilizers in maize production. The cost of compost was estimated based on its nutrient content particularly total nitrogen (table 3). As indicated in the Table 4, the highest net benefit (126527 Eth. Birr ha^{-1}) was recorded for treatment 2 (two) where 100% compost plus 100kg/ha NPS fertilizers were applied followed by treatment 3 (three) where 75% compost plus 25% UREA and 100kg NPS were applied. The highest marginal rate of return (146) was also obtained from the treatment that received 100% compost plus 100kg/ha NPS fertilizer.

Table 3. *Estimated cost of conventional compost based on its Total nitrogen content.*

Parameters	Treatments				
	1	2	3	4	5
Compost applied in kg/ha	0	4600	3450	2300	1150
TN/100kg compost	0	1	1	1	1
Cost of Urea/kg	0	15	15	15	15
Amount of Urea/kg N	0	2.17	2.17	2.17	2.17
Cost of 1kgN or 100 kg compost/kg	0	32.55	32.55	32.55	32.55
Total cost of compost/ha	0	1497.3	1122.975	748.65	374.325

Table 4. *Partial budget analysis using CIMMYT (1998).*

Treatments	Mean yield in kg/ha	Unit cost	NPS in kg/ha	Unit cost	UREA in kg/ha	Unit cost	Compost in kg/ha	Unit cost	TVC/ha	Gross income/ha	Net income / ha	MRR (%)
T1	8325.3	15	177	18.5	100	15	0	0	4774.5	124880	120105	0
T2	8728.2	15	177	18.5	0	15	4600	0.325	4395.75	130923	126527	146
T3	8602.3	15	177	18.5	25	15	3450	0.325	4770.75	129035	124264	87.17
T4	8500.1	15	177	18.5	50	15	3450	0.325	5145.75	127502	122356	43.74
T5	8407.2	15	177	18.5	75	15	3450	0.325	4399.5	126108	121709	36.45

9. Conclusion and Recommendations

For sustainable land management, implementation of Integrated Soil fertility management (SFI) is very important. Organic fertilizers maintains soil health, improves soil nutrient and increase crop yield. Maize grain yield was not statistically different between the treatments but higher for the treatments treated with compost as compared with the one treated with inorganic fertilizer alone. Laboratory analysis results of soil samples collected before sowing showed no significance differences in soil chemical properties. However, post-harvest analysis of soil samples indicated that significantly difference and positive increment on soil fertility status.

In conclusion, based on the data obtained from this study combined fertilization of 4.6 t ha^{1} conventional compost integrated with 150 kg NPS ha^{-1} fertilizer and 46 kg N ha^{-1} are recommended for maize production to the study area and similar agro-ecology.

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