Integrated Use of Compost and Nitrogen Fertilizer and its Effects on Yield and Yield Components of Wheat: A Pot Experiment

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Abstract

There is a research gap and no investigation on combined effects of compost produced from coffee husk and inorganic nitrogen fertilizer (Urea). The objective of this study was to evaluate the yield and yield components of wheat (*Triticumaestivum L.*) under integrated application of compost and nitrogen fertilizer (Urea). A pot experiment in lath house was conducted to determine the effects of integrated uses of compost produced from coffee husk and nitrogen fertilizer (urea) on yield and yield components of wheat. The experiment consisted nine treatments: (T1) control(untreated), (T2) 5t ha^{-1} (8.12g pot^{-1}) compost, (T3) 10t ha^{-1} (16.24g pot^{-1}) compost, (T4) 0t ha^{-1} compost + 50kg ha^{-1} nitrogen fertilizer(NF) (0.09g pot^{-1}), (T5) 5t ha^{-1} compost + 50kg ha^{-1} NF, (T6) 10t ha^{-1} compost + 50kg ha^{-1} NF, (T7) 0t ha^{-1} compost + 100kg ha^{-1} (0.18g pot^{-1}) NF, (T8) 5t ha^{-1} compost + 100kg ha^{-1} NF, (T9) 10t ha^{-1} compost + 100kg ha^{-1} NF and arranged in a complete randomized design (CRD) with three replications. The compost was prepared from coffee husk and applied in wet based. The findings showed that compost addition had little effect on wheat yield and yield components in the absence of nitrogen fertilizer (Urea). But, at the highest nitrogen fertilizer(urea) dosage rate which is the recommended field rate(100kg ha^{-1}) (equivalent to 0.18g pot^{-1}) and the addition of compost (5t ha^{-1}) (equivalent to 8.12g pot^{-1}) led to increase in grain yield significantly ($P \leq 0.05$) which is 26 g pot^{-1} (equivalent to 14.741t ha^{-1}) which is increased the grain yield by 66.29% compared with control 8.9g pot^{-1}(4.969t ha^{-1}) and use of the recommended rate of nitrogen fertilizer alone 21.98g pot^{-1}(12.273t ha^{-1}) increased by 16.74%. Spike length and dry matter yield is also significantly ($P \leq 0.05$) increased under the application integrated compost and nitrogen fertilizer(urea).The results of the experiment revealed that compost based soil management strategies can enhance wheat production thereby contribute positively to the viability and benefits of agricultural production systems. However, the nutrient-compost interactions should receive special attention due to the great variability in the properties of compost which may depend on the type of organic materials used for compost.

Key words: Compost application, coffee husk, crop production, yield, biomass, nitrogen fertilizer

INTRODUCTION

In many Sub-Saharan Africa countries, increasing wheat production to encounter higher demands in growing populations is still a challenge [1, 2]. Ethiopia is one of the largest wheat producers in Sub-Saharan Africa and has a favourable wheat growing climatic environment. However, over the past decade, there has been a consistent deficit in wheat production. The fragmented nature of land holdings and low use of agricultural inputs particularly, fertilizers contribute to low levels of wheat productivity in Ethiopia [3]. The country doesn't produce its own fertilizer supply, and farmers use a common fertilizer diammonium phosphate (DAP) and urea applied at a field recommended rate of 100 kg ha^{-1} each regardless of soil type. Several studies have reported that inorganic fertilizer applications resulted in increased crop productivity worldwide. However, the supplementation of the crop area using only two sources of inorganic fertilizers (DAP and urea) for many years and complete removal of crop residues from the production land has led to sever nutrient mining in Ethiopia. On the other hand, the use of compost alone as a substitute to inorganic fertilizer will not be enough to maintain the present levels of crop productivity of high yielding varieties [4]. Therefore, integrated nutrient management in which both compost and inorganic fertilizers are used simultaneously is the most effective method particularly in developing countries where the mineral fertilizers are expensive and difficult to afford the costs. Few previous studies by [5, 6, 7] showed that, wheat productivity could be enhanced through organic and inorganic fertilizer combinations. Though there are some trials conducted on the agronomic response of wheat to organic (i.e. farmyard and green manure) and mineral fertilizer integrations. But, there is no investigation on combined effects of compost produced from coffee husk and inorganic fertilizer (Urea) on the yield and yield components of wheat. In Ethiopia 192,000 metric ton of coffee husk is produced and disposed per year and the study area(Jimma) is commonly known by coffee production and 134,400 metric ton of coffee husk per year is simply disposed to the environment [8]. Thus, it is very important to use for agricultural input by composting and integrating with inorganic fertilizers. Therefore, the objective of this study was to evaluate the yield and yield components of wheat (*Triticumaestivum L.*) under integrated application of compost produced from coffee husk and nitrogen fertilizer (Urea).

MATERIALS AND METHODS

Description of the study area

This study was conducted in Jimma University College of Agriculture and Veterinary Medicine, South Western Ethiopia at lath house pot experiment. The study area is located at Latitude of 7°33′N and Longitude of 36°57′E. The altitude ranges from 1760 to 1920 m above sea level. The mean annual maximum and minimum temperatures are 26.8 and 11.4°C and the relative humidity are 91.4 and 39.92%, respectively. The mean annual rainfall is 1500 mm and soil is mainly dominated by Nitisols[9].

Soil sampling and Compost preparation

The top 0-30cm composite soil samples were collected. The collected soil samples were air-dried, crushed by using mortar and pestle and then passed through a 2 mm square-mesh sieve. Compost derived from coffee husk was prepared in Jimma University College of Agriculture and Veterinary Medicine (JUCAVM) using pit composting method.

Soil and compost analysis

pH and electrical conductivity (EC) were measured in distilled water at 1:5(w/v) [10]. OC content was determined by the Walkley-Black method and, OM percent was obtained by multiplying the percent of soil OC by a factor of 1.724 following the assumptions that OM is composed of 58% carbon, total N was analyzed using the Kjeldahl[11]. Available phosphorus (P) was determined by Mehlich 3 method [12]. CEC and exchangeable bases (Ca, Mg, K and Na) were determined after extracting the samples by (1N NH_4OAc) at pH 7. Fe was determined by the atomic absorption spectrometer (AAS) after extracting by the DTPA solution. Ca and Mg in the extracts were analyzed using AAS, while Na and K were analyzed by flame photometer [11]. Exchangeable acidity of soil was determined by the titration method after the 1N KCl solution at pH 7 used to leach exchangeable H^+ and Al^{3+} from soil sample [13]. The particle size distribution (texture), of the soil sample, was determined by the Boycouos hydrometric method [11]. Soil bulk density was determined by the undisturbed core sampling method after drying the soil samples in an oven at 105°C to constant weights.

Pot experimental set up

A pot experiment was carried out at controlled lath house. Plastic pots (33cm top and 20cm bottom diameter) with 30cm height were filled with air-dried soil. The experiment consisted the following nine treatments:(T1) control ,(T2) 5t ha^{-1} (8.12g pot^{-1}) compost,(T3) 10t ha^{-1} (16.24g pot^{-1}) compost, (T4) 0t ha^{-1} compost + 50kg ha^{-1}(0.09g pot^{-1}) nitrogen fertilizer(NF), (T5) 5t ha^{-1} compost + 50kg ha^{-1} NF, (T6) 10t ha^{-1} compost + 50kg ha^{-1} NF, (T7) 0t ha^{-1} compost + 100kg ha^{-1}(0.18g pot^{-1}) NF, (T8) 5t ha^{-1} compost + 100kg ha^{-} NF and (T9) 10t ha^{-1} compost + 100kg ha^{-1} NF. The treatments were arranged in a complete randomized design (CRD) with three replications. Ten wheat (*Triticumaestivum L.*) seeds were sown in each pot and thinned to keep five plants per pot after germination. After emergence, four plants were maintained in each pot until harvesting. Throughout the experiment, plants were regularly watered by distilled water to maintain field capacity moisture content until the end of the maturity. Plant height was recorded just before harvesting. The aboveground parts of plants were harvested at soil level from each pot. Fresh shoots were dried separately at 70°C for 72hrs.

Postharvest soil and nutrient uptake analysis

NO_3-N in plant tissue was determined using 2% acetic acid [14]. Plant K content was determined by flame photometer after wet digestion with sulphuric acid. Plant P content was determined photometrically with the molybdenum blue method. At the end of the experiments (after crop harvest), soil samples were collected from each pot, air-dried and sieved (<2mm) and selected chemical properties were analzsed by followed standard procedures [11]. pH and EC of the soil were determined in water suspension at 1:5 soil: liquid ratio (w/v). Total carbon content was determined by the Walkley-Black method and, total N was analyzed using the Kjeldahl method [11].

Statistical data analysis

Data were subjected to statistical analyses. One-way analysis of variance (ANOVA) was performed to compare variations in soil properties and plant growth characteristics for each treatment. For all the analyses, treatment means were separated using the least significant difference (LSD), and treatment effects were declared significant at the 5%

level of probability (P≤0.05). All analyses were performed using the version 9.3 SAS package.

Table 1. Selected physicochemical properties of experimental soils and compost

Parameters	Experimental soil Mean±SD	Compost(Mean±SD)
Bulk density (gmcm3)	1.04 ± 0.01	-
pH-H_2O (1:5)	5.2 ± 0.02	7.6±0.03
Exch. Acidity(me/100g)	4.9± 0.1	-
EC (dS/cm) (1:5)	0.02 ± 0.00	4.32 ± 0.21
Exch. Ca (me/100g)	8.08 ± 1.32	58.35 ± 0.52
Exch. Mg (me/100g)	1.20 ± 0.2	6.45 ± 0.02
Exch. K (me/100g)	0.8 ± 0.02	1.98 ± 0.21
Exch. Na (me/100g)	0.02 ± 0.00	3.05 ± 0..21
Exch. Fe(me/100g)	35.54± 1.12	-
Exch. Al(me/100g)	795.00± 0.23	-
CEC (me/100g)	24.36 ± 1.7	68.12 ± 0.21
Organic Carbon (%)	3.97 ± 0.23	30.80 ± 6.12
Organic Matter (%)	6.85 ± 0.39	53.10 ± 1.50
Total Nitrogen (%)	0.34 ± 0.02	1.62 ± 0.62
Total P(mg/kg)	19.2± 0.14	130.01±2.25
Available P (mg /kg)	4.52 ± 0.09	14.45 ± 1.23

RESULTS AND DISCUSSION

Soil and compost properties

Physicochemical properties of the experimental soil and compost are shown in (Table 1). The soil had lower available P, total P, and higher exchangeable Fe and Al. The high pH values of compost may be due to basic cations such as Ca, Mg, Na, and K, which were present in compost materials. The CEC of compost was also high which may be due to high negative charge potential of surface functional groups. OC concentrations were high in compost. The compost contained high levels of both macro and micro-nutrient elements. Compost was especially high in basic cations (Ca, Mg, K, Na) and total P containing concentrations. This results supported by the findings of [15] reported that compost derived from coffee husk contained high levels of organic matters, micro and macro nutrients.

Wheat growth characteristics and yield components

Compost addition increased wheat grain production in the absence of the nitrogen fertilizer (NF), as compared to the control. These increases were clearly lower than those caused by the use of NF compared to the control soil for the NF without compost addition, respectively. These results are in agreement with several authors [16,17], who found little responses of crop yield and nutrient status from the application of compost alone which are likely due to its nature: a carbon- rich material. Therefore, most of the studies have shown that the beneficial effects of the addition of compost on crop production are most evident when compost is combined with NF. The detected increases in nutrient efficiency after amending the soil with compost have been mainly related to a greater nutrient retention, minimizing nutrient losses, improvements in soil properties like increase in WHC, decrease in soil compaction, and leading to immobilization of contaminants or nutrient mobilizations; and enhancement in soil biological properties such as more favorable root environment, microbial activities favoring nutrient availability. In this study, a significant compost*NF interaction was observed for wheat grain production (Table 3). Thus, the highest wheat grain productions were obtained by combining both the 5t ha^{-1} of compost and 100kg ha^{-1} NF application dosage rates. These represented an increase with respect to the control soil and with respect to the control soil plus the highest NF for the compost. These results demonstrated that the compost addition at the 5t ha^{-1} application rate increased grain yield with respect to the individual use of the NF under the presence of recommended NF. In this experiment conditions, nutrient losses were absent since irrigation was controlled to avoid leaching, and compost adsorption capacity might have limited nitrogen availability in the short term, especially after the NF addition. However, under field conditions, the fact that compost addition can avoid nutrient losses by leaching may favor an increase in the availability of nutrients in the soil in the long term. The substantial increase in total C and N contents from the compost treatments suggest that the compost may be useful for building C and N contents in soils, particularly the soils with low levels of inherent C and N.

Table 2. Effect of compost applied alone or mixed with NF on the shoot and root characteristics of wheat

		Shoot length(cm)		Shoot fresh weight(g/plant)		Shoot dry weight(g/plant)		Root length(cm)	
Comp t/ha	NF kg/ha	Vegetative stage	Heading stage	Vegetative stage	Heading stage	Vegetative stage	Heading stage	Vegetative stage	Heading stage
0	0	40.1^{e}	73.1^{d}	5.4^{e}	6.1^{f}	1.19d	3.1e	10.0e	12.1e
5	0	55.4^{cd}	89b^{c}	16.1^{d}	28.2^{e}	3.8b	16.2d	18.8a	20.0ab
10	0	54.6^{d}	81.3^{cd}	12^{d}	17.7^{e}	1.96d	7.1e	16.2bc	16.1d
0	50	53.2^{d}	82.1^{cd}	7.8^{c}	17.1^{d}	1.99c	6.8d	16.5bc	18.2bc
5	50	69.1^{a}	87.2^{bc}	13.8^{b}	21.0^{c}	2.10c	9.1c	14.0d	16.1cd
10	50	50.9^{d}	87.1^{bc}	13^{b}	21.2^{c}	2.3c	9.0c	14.1d	19.3b
0	100	61.4^{b}	92.2^{ab}	16.2^{a}	25.3^{b}	3.40ab	11.2b	15.0cd	22.0a
5	100	65.2^{bc}	97.8^{a}	17.3^{a}	30.1^{a}	3.81a	15.1a	17.2ab	18.3cd
10	100	61.6^{b}	85.4^{bc}	14.2^{b}	28.5^{ab}	3.78a	12.4b	16.1bc	16.8cd
Comp		ns	ns	ns	ns	ns	ns	*	ns
NF		ns	ns	**	ns	ns	ns	ns	*
comp* NF		**	**	**	**	*	**	ns	ns

ns= non-significant,**$P < 0.01$,*$P < 0.05$, Comp=compost, NF= nitrogen fertilizer

Result on growth parameters of wheat are influenced by different integrations of coffee husk compost and nitrogen fertilizer (urea) (Table 2) indicated that significantly highest shoot length at heading stage was recorded, when the nitrogen fertilizer (urea) application was applied at a recommended rate (100kg ha^{-1}) together with 5t ha^{-1} of compost and the lowest was recorded from the treatments with no nitrogen fertilizer applications. This implies that wheat growth might be retarded if wheat cultivation was not supplemented with mineral fertilizers regardless of the compost applications.

Table 3.Effect of compost alone and mixed with NF on yield and yield characteristics of wheat grown

Comp rate(t/ha)	NF rate (kg/ha)	Spike length(cm)	No.of grains/ spike	1000grains weight(gm)	DMY (g/pot)	Grain Yield(g/pot)
0	0	4.5^{c}	20^{e}	46.9^{d}	10.8^{e}	8.9^{g}
5	0	7.8^{b}	48^{a}	57.2^{abc}	31.6^{b}	21.5^{bc}
10	0	6.9^{bc}	29^{d}	60.1^{bc}	17.1^{d}	12.6^{f}
0	50	10.1^{a}	46^{ab}	53.8^{c}	18.6^{d}	13.9^{e}
5	50	9.8^{a}	42^{bc}	55.2^{abc}	28.3^{bc}	19.2^{cd}
10	50	10.4^{a}	40^{c}	58.6^{abc}	24.1^{c}	17.1^{d}
0	100	10.2^{a}	45^{ab}	61.4^{a}	25.9^{c}	21.98^{bc}
5	100	12.2^{a}	52^{a}	57.2^{abc}	38.4^{a}	26.4^{a}
10	100	12.3^{a}	46^{ab}	59.1^{ab}	26.8^{c}	22.4^{b}
comp		ns	*	ns	ns	ns
NF		*	ns	*	ns	ns
Comp * NF		*	*	*	*	*

ns=non-significant,*$P < 0.05$.comp=compost, DMY= Dry mass yield

The higher spike length (12.3 cm) was observed when wheat is cultivated under 100 kg ha^{-1} nitrogen fertilizer combined with 10t ha^{-1} compost with no significance difference with the treatments that receive 50 kg ha^{-1} of nitrogen fertilizer and 5 t ha^{-1} compost (12.2cm). Generally, 50-100 kg ha^{-1} nitrogen fertilizer and 5-10 t ha^{-1} compost combinations give significantly higher spike length and number of grain per spike. However, lower spike length was recorded when with no nitrogen fertilizer combination with compost. Similarly, dry matter yield was significantly influenced by the different combinations of nutrient sources and rates. Highest result (38.4g pot^{-1}) was observed with the combined application of 5t ha^{-1} compost and 100kg ha^{-1} nitrogen fertilizer and the lower result (10.8g $plot^{-1}$) was recorded from the control treatment (no compost and/or nitrogen fertilizer application). Fertilizer combinations significantly influence the other yield and yield components such as, thousand seed weight, grain yield and dry matter yield (Table 3). Thousand seed weight showed significant variation across treatments. The highest (61.4gm) was recorded when 100kg ha^{-1} nitrogen fertilizer alone was applied. Similar results were reported by different researchers, Kaur, Sarwar, Rasool and Brar[18- 21]. Lower results were observed alone with no nitrogen fertilizer integrations indicating that, unless it is integrated with inorganic fertilizers, the use of compost alone may not fully satisfy crop nutrient demand, especially in the year of application [22]. Grain yield was more than three times higher when wheat was cultivated under 100 kg ha^{-1} nitrogen fertilizer and 5t ha^{-1}

compost compared to wheat cultivated with no fertilizer application (control). This might be due to the soil from study area was poor in soil fertility.

Plant nutrient concentration

The compost application significantly increased the shoot concentrations of K and P, and significantly decreased the concentrations of N, Ca, Mg, Cu, Mn and Zn (Table 4). Sulfur concentration in the shoot was not affected by the compost application; however, there was a significant ($P \leq 0.05$) increase in its concentration with the NF application. The interactive effects of NF and compost treatments were non-significant in relation to the concentrations of all nutrient elements (Table 4).

Plant nutrient uptake

Shoot uptake data and associated statistical analyses for various nutrients are presented in Table 4. The shoot uptake of all nutrients, except Ca and Mg, increased significantly with the application of compost (Table 4). The uptake of Ca, and Mg remained similar or slightly increased in response to the compost treatments. Fertilizer's application had a significantly positive effect on the uptake of nutrients, except for Ca, Mg, Mn, and Fe, where the effect was not significant (Table 4). Plant uptake of almost all macro and micro-nutrients increased with increasing compost rating and the decrease of nutrient concentration in shoots was most directly related to the increased shoot dry matter yield of plants (dilution effect) in compost treated soil. Decreased concentration of some of the nutrients, however, could be due to their adsorption onto Fe and Al oxides present in the acidic soil. Iron and Al oxides are known to have high adsorption capacity for phosphate, and metallic cations like Cu, Zn, Mn, Mg and Ca.

Table 4 Concentrations of macro- and micro-nutrients in wheat shoots grown as affected by different application rates of compost and NF

Comp	NF	N	P	K	S	Ca	Mg	Cu	Zn	Mn	Fe
rate(t/ha)	(kg/ha)	($g\ kg^{-1}$)						($mg\ kg^{-1}$)			
0	0	30.05	0.86	11.1	1.6	5.9	4.8	3.6	46	62	70
5	0	22.35	0.87	16.0	1.6	4.1	2.6	2.9	34	37	97
10	0	17.25	0.86	19.4	1.4	2.7	1.9	3.6	32	47	82
0	50	29.4	0.87	13.1	1.7	7.2	4.6	4.8	56	72	165
5	50	23.3	0.83	18.2	1.5	3.5	2.3	3.1	33	44	86
10	50	21.05	0.94	19.6	1.6	2.9	1.8	2.8	30	42	85
0	100	29.45	0.77	17.6	1.5	5.6	3.1	4.6	47	54	115
5	100	24.05	0.85	19.1	1.5	3.6	2.2	3.0	36	38	106
10	100	23.2	0.98	25.2	1.4	2.9	1.9	3.1	40	47	87
comp rate		***	*	**	ns	***	***	***	**	***	ns
NF rate		ns	ns	*	*	ns	*	ns	ns	ns	ns
Comp * NF		ns	ns	ns	ns	ns	ns	ns	ns	ns	ns

ns, non-significant. ***$P < 0.001$,**$P < 0.01$,*$P < 0.05$, TC, Total carbon, TN, Total nitrogen

Changes in post-harvest soil properties

At the end of the experiments (after crop harvest), composite soil samples were collected and analyzed. Compost had much influence on soil properties, which can explain its effects on plant growth and grain production. The application of compost at an increasing rate significantly increased the pH, EC, TC and TN (Table 5). Total C and N contents were increased significantly with the compost treatments, the increase in soil C was substantially greater (Table 5) and the fertilizer treatment significantly increased total N content. The application of compost has been reported to significantly increase soil total C relative to the control. Compost soil-interaction may enhance soil C storage via processes of organic matter sorption to compost [18]. The coffee husk compost offers greater potential as a soil amendment, which has potential supplies of nutrients. The increased soil pH with compost addition might have increased the adsorption capacity of metallic cations. Compost had much influence on soil properties, which can explain its effects on plant growth and grain production. The results of this study highlighted significant improvement in the soil amended with compost alone while the growth and yield components of both crops supplemented with compost and NF were higher than the highest N rate applied, displaying the fertilizer value of mixed treatments.

Table 5: Effects of compost and fertilizer treatments on pH, EC, total C and total N measured after the plant harvest

Comp rate(t/ha)	Fert rate (kg/ha)	(pH-1:5H_2O)	EC(1:5) dS/cm	TC(g kg^{-1})	TN (g kg^{-1})
0	0	5.20	0.164	316.12	34.25
5	0	5.46	0.336	319.20	34.15
10	0	5.96	0.626	436.40	35.30
0	50	5.11	0.188	316.21	34.23
5	50	5.45	0.409	439.15	35.26
10	50	5.83	0.996	468.10	38.60
0	100	5.24	0.250	429.30	35.17
5	100	5.42	0.389	430.22	35.28
10	100	6.15	1.052	462.14	38.70
comp rate		***	***	***	***
NF rate		*	***	**	*
Comp x NF		ns	***	ns	ns

ns, non-significant, ***P < 0.001.**P < 0.01.*P < 0.05, comp, compost, NF, Nitrogen fertilizer

While the lath house experiment is a good starting point for evaluating plant response under ideal conditions; the true agronomic potential of the coffee husk compost needs to be assessed by measuring crop responses to the coffee husk compost under field conditions. Therefore, use of integrated compost and nitrogen fertilizer is a feasible approach to overcome soil fertility constraints. Additionally, integrated use of nitrogen fertilizers along with compost may improve the efficiency of the mineral fertilizer.

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Data Availability Statement

All relevant data are within the paper.

Competing Interests

The authors have declared that no competing interests exist.

Author Contributions

Conceptualization: BD GB MM.

Formal analysis: BD MM.

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